sustainability

MDPI

Article

Choosing a Mode in Bangkok: Room for Shared Mobility?

Eva Ayaragarnchanakul [1,2,*], Felix Creutzig [1,3], Aneeque Javaid [3] and Nattapong Puttanapong [4]

[1] Technische Universität Berlin, Chair of Sustainability Economics of Human Settlements, Straße des 17, Juni 135, 10623 Berlin, Germany; creutzig@mcc-berlin.net
[2] Prince of Songkla University, Faculty of Economics, 15 Kanjanavanich, Songkhla 90110, Thailand
[3] Mercator Research Institute on Global Commons and Climate Change, Torgauer Str. 19, 10829 Berlin, Germany; javaid@mcc-berlin.net
[4] Thammasat University, Faculty of Economics, 2 Prachan Road, Bangkok 10200, Thailand; nattapong@econ.tu.ac.th
* Correspondence: eva.a@win.tu-berlin.de

Abstract: Individual motorized vehicles in urban environments are inefficiently oversupplied both from the perspective of transport system efficiency and from the perspective of local and global environmental externalities. Shared mobility offers the promise of more efficient use of four-wheeler vehicles, while maintaining flexible routing. Here, we aim to understand the travel mode choices of commuters in Bangkok and explore the potential demand for shared mobility through examining both revealed and stated choices, based on our survey (n = 1239) and a systematic comparison of mode choice situations. Our multinomial logistic regression analysis indicates that commuters value time in their vehicles and accept fuel costs, but that they dislike wasting time walking, waiting, and searching for parking or pay for road use and parking. Our model results imply that shared taxi has a higher chance of being used as a door-to-door mode rather than as a competitor to motorcycle taxis as a feeder to the metro stations. Ride sharing gains substantial potential when private motorized cars are charged with the social external costs they cause via congestion charges and parking fees. Replacing cars with shared taxis as the daily choice for those living in detached houses will result in a 24–36% reduction of car trips on Bangkok roads.

Keywords: shared mobility; sustainable transportation; revealed preference; stated choice experiment; discrete choice model; Bangkok

check for updates

Citation: Ayaragarnchanakul, E.; Creutzig, F.; Javaid, A.; Puttanapong, N. Choosing a Mode in Bangkok: Room for Shared Mobility? *Sustainability* **2022**, *14*, 9127. https://doi.org/10.3390/su14159127

Academic Editors: Junfeng Jiao, Amin Azimian and Haizhong Wang

Received: 28 June 2022
Accepted: 22 July 2022
Published: 25 July 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Private vehicles are a source of major social inefficiency and damage in cities. The use of cars is highly inefficiently, with only 1.1–1.4 passengers, on average, driving in vehicles that weigh 2–3 tons (UN Habitat III, 2016). Globally, urban motorized transport emits almost 3 Gt CO_2 in 2010, accounting for 40% of the transport sector's total emissions [1]. Climate change is not the only negative externality resulting from transportation, but air pollution, noise, road damage, accidents, and congestion are also generating social costs [2–6]. While the effect of climate change is global and mainly independent of the originating location, the other externalities are strongly dependent on location. In addition, these location-specific external costs in urban cities are much higher than in rural areas, mostly because of higher congestion costs and higher pollution costs from higher population receptor density [7]. In 2017, the external cost of mobility in Bangkok, one of the world's megacities, was approximately USD 15—22.9 billion or 7—10.8% of the Bangkok Metropolitan Region's GDP. Congestion cost is the major externality (42.4%), followed by traffic accidents (25.1%), air pollution (18.8%), climate change (7.9%), and noise pollution (5.9%) [8].

Buses were Bangkok's main transportation mode in the 1990s, but due to its old fleet and low service quality, private vehicle demands have been skyrocketing since 2000. In 2010, the number of cars exceeded motorcycles and dominated the roads [9], caused by both the increase in Bangkokian's purchasing power and by increasingly affordable ecocars. Traffic jams are dominating city life.

To remedy the gridlock, the Mass Rapid Transit Master Plan in the Bangkok Metropolitan Region (M-Map) aims to expand the urban metrosystem by 2029 from the first opening in 1999, which is a crucial and necessary measure. However, although public transportation is an effective way to move large number of people along the route and save cost, it does not provide the door-to-door service that people desire from private vehicles.

Shared mobility provides a service in combination between mass transit and private cars. It is used to decrease the overcrowded modes of public transportation in larger cities and improve accessibility and connectivity to public transportation in smaller ones. Shared mobility fits the characteristics of a sharing economy, as stated by Botsman and Rogers (2010) [10] because it is possible to (1) share underutilized vehicles (idle capacity); (2) support socially sustainable transport (belief in public or common goods); (3) be applied in the urban city with high demand not only from population density, but also from limited parking space and traffic jam (critical mass); and (4) be used with strangers when safety is ensured under the ICT tracking system and customer reviews (trust strangers). Shared mobility has become increasingly popular since there are important positive effects: (1) People become less dependent on their cars that can be substituted by healthier modes of transport such as on-foot or cycling that pollute less and become more interactive with each other along the way [11]. (2) People can save money by sharing rides from their underused cars that are sitting idle in the parking space [12] and simultaneously save time stuck in traffic that will lead to less congestion [13] and less frustration. (3) Finally, higher vehicle occupancy is one of the key measures to increase efficiency of vehicle use and decrease GHG emissions [14].

New transportation modes that emerge with innovative technology, for example, ride sourcing and automated vehicles (AVs), will become increasingly important in cities [15]. Apart from technological feasibility, AVs will be challenged by various issues such as safety, acceptability, ethics, and maintenance. AVs may reduce labor cost but simultaneously increase ownership costs. Shared AVs may seem like a good solution. However, this option may backfire because shared AVs will be driven all the time, increasing travel and energy demand from the low cost of sharing rides [16]. In addition, if in-vehicle time cost falls sharply, road pricing will be an important tool to alleviate congestion [17]. A series of simulations in European cities conducted by the ITF-OECD found that there are CO_2 emission reduction benefits and decreased total vehicle travel by motivating shared mobility usage, namely taxi buses, shared taxis, and carpooling services [18–22].

Earlier studies on determinants of shared mobility and mode choice show that the adoption of shared mobility options is based on individual monetary and time costs, social context, as well as infrastructure factors [23–25]. Additionally, travel attitudes and travel characteristics (such as travel distance), and the value placed on characteristics lead to differential mode choices, as relevant for shared-pooled mobility [26,27]. For example, shared mobility is more acceptable for young, well-educated, higher-income, working individuals residing in higher-density areas [28]. In effect, the economics of shared mobility, in the current price regime of subsidized private automobility, depend on high user density only found in metropolitan areas. However, while there is a growing number of studies using discrete choice models to understand the motivation for adoption of shared mobility options, they are relatively underdeveloped as compared with other travel modes.

Studies on shared mobility in Southeast Asia are scarce. A study in Ho Chi Minh City investigated the intention to use Uber/Grab and found that age, gender, distance, living cost, usefulness of Uber/Grab, subjective norms, environmental awareness, and privacy influence the use of Uber/Grab [29] (similarly [30] for Kuala Lumpur). Neither study, however, provided mode shifting potential of existing modes against shared mobility. Another paper demonstrated that motorcycle sharing in Jakarta increased mobility options for mostly young commuters, but failed to reduce GHG emissions [31].

Travel mode choice models performed in Thailand have mainly involved either urban school trips [32,33] or international travel destinations [34–36] that lacked focus on representing daily commuting pattern within a city, and hence were insufficient to identify suitable transport demand strategies for urban sustainability. In addition, the Bangkok mode choice studies are outdated [37,38] as the GDP has been growing, metro stations have been expanded, water transport modal share has been decreasing, and ride-hailing services have recently been legitimized. [37] explored household travel behavior and attitude towards existing modes and the proposed metrosystem. Their analysis showed that factors influencing vehicle ownership, mode choice, and trip sharing included age, gender, job status, household income, presence of children, trips in the CBD, and long-distance trips. [38] suggested that water transport was more reliable but less accessible in relative to road transport. Decreasing the total travel time, total travel cost, and maximum delay of boats would result in increasing demand elasticity of boat commute.

Here, we aim (1) to explain the influential factors determining the mode choice behavior of Bangkok commuters, (2) to identify potential commuters that are ready to make the shift to shared mobility, and (3) to estimate the sensitivity of trip attributes on mode choice probability. Our survey covers various districts of Bangkok that represent different income classes and areas of public transit coverage, including a unique private paratransit service in Thailand which is called the "motorcycle taxi" that is popularly used in narrow streets (called "soi"). Similar modes are available in most Southeast Asian cities. The survey consists of revealed preference (RP) and stated choice (SC) questions. In the stated choice experiment, we present respondents with nine choice situations. In each choice situation, respondents are asked to choose one mode from four modes: private vehicle (car or motorcycle), public transit (bus or metro), shared mobility (shared taxi or ride hailing), or multimodal (connections from motorcycle taxi or shared taxi to the metro). We use our analysis to provide a congestion alleviation policy to influence the shift away from private vehicles and into shared mobility.

The rest of this paper is organized as follows: in Section 2, we explain the survey design of the revealed preference and stated choice data; in Section 3, we clarify the discrete choice model methodology; in Section 4, we report the analysis results and discuss related strategies; and in Section 5, we conclude our findings.

2. Data Collection and Questionnaire Design

We use the socioeconomic characteristics and travel-related questions from the revealed preference (RP) survey and transport mode choice attributes from the stated choice (SC) survey, according to Figure 1. The calculation of 477 sample families for our survey is shown in Appendix A. Our selection comprises household members of at least 18 years old and above. A total of 1239 respondents participated.

2.1. Revealed Preference

The questionnaire is built on the initial input from the Household Travel Survey (HTS) conducted in 2017 provided by OTP, Thailand. The HTS asked Bangkok Metropolitan Region commuters to answer questions on the household and individual level. Household information included their current address, residential type, family size, vehicle ownership, and income. Then, household members were asked about their gender, occupation, income, main transport mode (all currently available transport modes were included in the questionnaire including car, motorcycle, walk, cycle, metro (MRT, BTS, and ARL), bus (conventional and with a/c), passenger van, Songthaew (converted pick-ups), boat (Saen Saeb canal, Padung Krung Kasem canal, and Chao Praya river express), ferry, taxi, ride-hailing (e.g., Grab), motorcycle taxi, Tuktuk (3-wheeler), and other), travel diary, and the reasons for choosing their main mode (respondents were asked to provide five main reasons by preference from the following options: travel time, waiting time, cost, convenience/accessibility, comfort, ability to multitask, privacy, reduce global warming, safety, reliability/punctuality, physical health, no sidewalk/bike lane, weather condition/pollution, indicate social status, meet new people/travel companion, and other.). In addition, we asked the respondents to provide information on their education and comfortable walking distance. All respondents' residential and employment locations were geocoded and used to calculate the Euclidean distances between the locations.

RP survey

Socio-economic characteristics:

Individual level:

- Gender
- Occupation
- Income
- Education

Household level:

- Residential type
- Family size
- Vehicle ownership
- Income

Travel-related:

- Main mode
- Reason for chosen main mode
- Distance from home to workplace
- Comfortable walking distance

SC survey

Choice situations:

- 4 modes
- 3 main attributes: travel time, travel cost, crowdedness
- 3 levels: low, medium, high

Post choice situations:

- Diagnostic questions
- Mode choice after presented with average emission per passenger by mode
- Mode choice after presented with average car ownership cost by engine

Figure 1. Survey data. Socioeconomic and travel-related variables that are likely to influence mode choices are included in the revealed preference survey. Questions about future mode choices that are traded-off by different levels of travel time, travel cost, and crowdedness are given in the stated choice survey.

2.2. Stated Choice

We gather travel information on the existing transport modes in Bangkok that are significant to commuters and their associated attribute levels according to the HTS (2017) and introduce shared mobility (SM) that could improve the continuity of commuting and are eco-friendlier. The SM modes that we choose to present are "ride hailing" and "shared taxi". Ride hailing is well recognized in Bangkok, but just became legalized in Thailand in May 2021. "Grab" has the largest market share among all ride hailing service providers in Thailand. Ride hailing is mainly used to replace the inefficiency of private cars, by specifically increasing the usage instead of parking for the majority of the time, but may not be able to decrease low-occupancy usage. Shared taxi is basically a ride hailing service in which the driver can pickup other passengers along the way within a proper detour time (up to 10 min). Passengers can split their cost with up to three other passengers that share the ride. The quality of shared taxi service falls in between public and private transportation. Commuters can save their travel cost and travel time (involves less transfer, waiting time, and time searching for parking), and also acquire a certain level of privacy. Shared taxi is not yet available in Bangkok, but can be seen in big cities worldwide such as Chicago, Berlin, and Beijing.

According to Walker et al. (2017) [39], a random design was more robust in a broader range of the value of time (VOT) which has been often estimated in transport studies. Hence, there is no benefit from using more complex models such as "efficient designs" that are conditional on the correctness of prior assumptions. In addition, the common full fractional "orthogonal designs" are efficient when employed in the original conjoint analysis, but have been called into question about their appropriateness for nonlinear models (The design usually begins with a full fractional design of $\Pi_j L_j^{M_j N_j}$ choice situations, where j represents alternative j, N is the number of alternatives or choices, M is the number of factors affecting the choices (attributes), and L is the number of levels of each attribute. The choice sets exponentially increase with the variables which make the design impracticable.). Therefore, we use the random fractional factorial design by using travel time as the factor linkage, eliminating the dominant choices, and ensuring utility balance while keeping the attributes level balanced to avoid biased effects [40]. Detailed literature on the experimental designs can be found from, among others, [23,41–46].

The SC questionnaire covers eight modes shown in Table 1. Commuters are required to perform a first preference choice task from nine choice situations (Table A1), each with four alternatives from each transport mode group (i.e., PV, PT, SM, and multimodal). In addition to the choice situations, we present car ownership costs by car type (Table A2) and emissions from vehicles (Figure A2). Then, we ask respondents to choose whether they will shift from their current modes or not. If so, to which mode. In case the respondents own a private vehicle, shifting means that they are willing to sell their vehicle(s).

Table 1. The alternatives, attributes, and attribute levels used in the stated choice experiments. All attributes have three levels, i.e., low, medium, and high. The levels are separated with commas for attributes: total travel time (min), fuel cost or fare (Baht), and parking fee (Baht), for example, total car travel time for low, medium, high choice situations are 13, 32, and 51 min from origin to destination. Tolls have three levels, i.r., 30, 45, and 60 Baht. Only the modes with check marks require commuters to pay for tolls and are assigned with crowdedness levels. The level of crowdedness is applied to the PT and SM modes, including multimodal. While shared taxis can accompany one to three people, buses and the metro may have plenty of seats left on board, few empty seats, or only standing room.

Attributes/ Alternatives	**Attribute Levels**							
	PV		**PT**		**SM**		**Multimodal (Transfer to Metro)**	
	Car	**Mtc**	**Metro**	**Bus, Van**	**Shared Taxi**	**Ride-Hailing**	**Mtc-Taxi**	**Shared Taxi**
Total travel time [1] (min)	13, 32, 51	6, 21, 36	11, 26, 42	15, 35, 57	12, 32, 45	9, 27, 42	7, 19, 37	12, 29, 46
Fuel cost, fare (Baht)	13, 33, 52	2, 8, 13	15, 44, 70	8, 19, 35	25, 66, 82	37, 99, 123	25, 60, 75	28, 63, 88
Toll (Baht)	√	-	-	-	√	√	-	√
Parking fee (Baht)	10, 30, 55	5, 10, 20	-	-	-	-	-	-
Crowdedness	-	-	√	√	√	-	√	√

[1] Total travel time includes in-vehicle time, walking, waiting, detour, and search for parking. PV, private vehicle; PT, public transit; SM, shared mobility; mtc, motorcycle. Source: Researcher's calculation from data provided by the HTS (2017), Bangkok Mass Transit System (BTS), Metropolitan Rapid Transit (MRT), Airport Rail Link (ARL), Bus Rapid Transit (BRT), and Bangkok Mass Transit Authority (BMTA).

3. Methodology

The discrete choice model (DCM) in the choice theory is an established method that is used to study and predict consumer satisfaction, willingness to pay, consumer behavior, including travel mode choice behavior. Since the dependent variable in this study is the travel mode choice from alternative options which is not a continuous variable, using DCM is suitable. Commuters' decisions on travel mode follow the random utility maximization (RUM) model because human behaviors cannot be forecasted under certainty [47]. We assume that the probability that an individual will choose a transport mode follows the multinomial logit (MNL) model. Methodological details are provided in Appendix C.

4. Results

4.1. Descriptive Statistics

In this section, we briefly describe the socioeconomic characteristics of the valid samples of 472 households and 785 individuals (Table 2.) from our survey. Gender is fairly balanced. Around half of the individuals graduated college or higher (52.3%) and 55.1% are private company employees. The majority of the individuals used private vehicles as their main transport mode (60.3%), similar to the proportion of families that own at least one car (62.1%). Commuters correspondingly gave importance to travel time (35%), convenience (27.4%), travel cost (13.6%), and privacy (7.1%) when they choose their transport modes. The average monthly income was approximately 20,909 Baht and the average age was about 39 years old. Due to the average number of household members (around four people), almost half of the respondents lived in detached houses (49.6%), followed by commercial buildings (22%), condos (14.4%), and townhouses (13.8%). The majority of trips from the travel diary in the revealed preference questionnaire were work based (82%).

Table 2. (**1**) Description of individual characteristics in the model; (**2**) description of household characteristics of variables in the model; (**3**) description of the list of continuous variables in the model.

(1)		
Variable	**Frequency**	**Proportion (%)**
Individual characteristics	N = 785	
Gender: male	385	49.0
Main mode		
Private vehicle	469	60.3
Public transit	219	28.1
Bus	122	15.7
Metro	13	1.7
Boat and ferry	7	0.9
Paratransit	77	9.9
Walk/cycle	72	9.3
Other	18	2.3
Most important factor of choosing main mode		
Time	275	35
Convenience/accessibility	215	27.4
Cost	107	13.6
Privacy	56	7.1
Reliability/punctuality/frustration	27	3.4
Social status	22	2.8
Physical exercise	19	2.4
Comfort	16	2.0
Waiting time	13	1.7
Safety	11	1.4
Others	24	3.2
Occupation		
Student	61	5.4
Government employee	81	7.1
Company employee	628	55.1
Freelancer	22	1.9
Business owner	134	11.8
Not working/stay at home	111	9.8
Other [1]	102	8.9
Education		
Lower than Pratom (middle school)	37	3.1
Middle school, high school	531	44.6
Bachelor's degree or similar	596	50.1
Higher than bachelor's degree	26	2.2

Table 2. *Cont.*

(2)		
Variable	**Frequency**	**Proportion (%)**
Household characteristics	N = 472	
Residential type		
Detached house	234	49.6
Townhouse/semi-detached house	65	13.8
Commercial building	104	22.0
Condo/apartment/dorm	68	14.4
Others	1	0.2
Income (Baht/month)		
≤10,000	8	1.7
10,001–50,000	222	47
50,001–100,000	203	43
100,001–200,000	25	5.3
>200,000	14	3.0
Car ownership, Yes	293	62.1
Motorcycle ownership, Yes	230	48.7

(3)					
Variable	**Obs**	**Mean**	**S.d.**	**Min**	**Max**
Household size (persons)	472	4	1.5	1	10
Individual income (Baht/month)	785	20,909	17,805	800	300,000
Age (years old)	785	39	11	18	79
Comfortable walking distance (meters)	785	770	909	20	15,000

[1] The majority of this category includes daily workers and taxi or motorcycle taxi drivers.

4.2. Influential Factors on Travel Mode Choice

The first result from our regression analyses (Table 3) is that the value of travel time (VOT) is high, around 240 Baht/hour. This value is larger than the extended Bangkok Urban Model (eBUM) [48] estimation of 78 Baht for motorcycle users and 132 Baht for car users. This could be because of modeling differences, for example, study year, sample size, explanatory variables, and transport modes. Nam et al. (2005) [38] showed that by selecting appropriate variables into the model, the VOT for car and taxi users were about 160 and 310 Baht/hour, respectively, in accordance with our results. In-vehicle time and fuel cost or service fare coefficients are positive, although insignificant for fuel cost or fare, which means that Bangkokians accept automobile commuting when it does not involve other travel time such as time search for parking, walking, and waiting, and other travel costs such as parking fees and road tolls [49]. The detour time and crowdedness coefficients for commuters choosing shared taxi as a full origin-to-destination trip are positive and statistically significant, while both coefficients are insignificant to those using shared taxi as a feeder to the metro. Commuters choosing shared taxis as a full ride are willing to share their rides to save costs.

Our regression analysis also shows that public transits are unfavorable when packed and less likely to be used as people age. It is surprising to see that income does not generally affect mode choice. The metro is the only mode that is less likely to be used when commuters' incomes increase, possibly because the metro provides less privacy from being the highest capacity mode and involves more walking to access. Men are less likely to use buses, shared mobility, and transits from motorcycle taxis to the metro. They are more likely to use motorcycles. College graduates avoid using motorcycles (for origin/destination trips) and public transits, especially buses, because they are perceived as low quality. Motorcycles, public transits, and motorcycle taxis as a feeder are convenient and reliable. The motorcycle mode is chosen by those that value travel time. Commuters that choose shared mobility services and motorcycle taxi as a feeder value travel cost. Commuters that care for the environment are more likely to avoid private motorized vehicles. Car and motorcycle ownership induce usage. Public transit, ride-hailing, and multimodal travelers intend to purchase a car in the future. This reflects that the price or quality of these modes are similar to cars. Using cars involve less walking as compared with motorcycles, the metro, ride-hailing, and connecting modes. Motorcycles are used for short-distance travel to work, while the metro and motorcycle taxis with the metro connection are used for longer distances. Members of larger households tend to use the metro, shared mobility, and connecting modes. Commuters that live in detached houses are less likely to use motorcycles and public transits, while those that live in condos are less likely to use buses.

Table 3. Estimated coefficients from the multinomial logit regression. The reference mode is car. See Appendix D for the estimated equation. Light-colored coefficient indicate the insignificance. * indicates significance level at 10%, ** indicates significance level at 5%, **bold coefficient** *** indicates significance level at 1%. T-statistics are in parentheses. MTC, motorcycle; ST, shared taxi; RH, ride-hailing; MTC-taxi+, motorcycle taxi and metro; ST+, shared taxi and metro.

Variable	Coefficient						
	MTC	Metro	Bus	ST	RH	MTC-taxi+	ST+
Total travel time				**−0.05** *** (−4.20)			
Total travel cost				**−0.01** *** (−8.84)			
In-vehicle time				**0.09** *** (6.12)			
Fare or fuel cost				0.004 (1.39)			
Detour time	-	-	-	0.04 ** (2.75)	-	-	−0.09 (−0.83)
High crowdedness	-	−0.22 ** (−2.85)	**−1.07** *** (−10.89)	**0.44** *** (4.72)	-	−0.08 (−0.72)	−0.37 (−0.84)
Income	−0.01 (−1.32)	−0.01 * (−2.15)	−0.007 (−1.57)	0.003 (1.12)	0.005 (1.51)	−0.001 (−0.32)	−0.01 (−1.42)
Male	0.25 * (2.17)	−0.13 (−1.23)	−0.29 * (−2.56)	**−0.4** *** (−3.78)	−0.44 ** (−2.76)	−0.31 * (−2.50)	−0.11 (−0.57)
Age	−0.009 (−1.77)	**−0.02** *** (−3.96)	−0.01 * (−2.53)	−0.001 (−0.30)	−0.01 (−1.54)	−0.003 (−0.51)	0.006 (0.66)
Graduated college or higher	−0.26 * (−2.13)	−0.26 * (−2.32)	**−0.43** *** (−3.46)	−0.13 (−1.17)	−0.22 (−1.30)	−0.19 (−1.46)	0.02 (0.11)
Employee [1]	0.07 (0.53)	0.19 (1.58)	0.15 (1.10)	0.008 (0.07)	−0.27 (−1.53)	−0.27 (−1.94)	−0.36 (−1.75)
Value privacy [2]	−0.2 (−1.63)	−0.26 * (−2.39)	−0.04 (−0.29)	−0.13 (−1.11)	−0.13 (−0.75)	−0.14 (−1.08)	0.06 (0.28)
Value convenience [2]	0.32 * (2.43)	**0.7** *** (5.83)	**0.91** *** (6.76)	0.06 (0.46)	0.18 (1.01)	0.42 ** (2.96)	0.3 (1.44)
Value reliability [2]	0.48 ** (2.67)	**0.81** *** (5.23)	**0.76** *** (4.40)	0.3 (1.60)	0.43 (1.47)	**0.8** *** (4.20)	0.52 (1.54)
Value travel time [2]	−0.36 ** (−2.92)	−0.21 (−1.94)	−0.13 (−1.10)	−0.07 (−0.58)	0.22 (1.27)	−0.15 (−1.16)	0.12 (0.60)
Value travel cost [2]	0.01 (0.09)	0.12 (0.90)	0.23 (1.77)	**0.57** *** (4.75)	0.36 * (2.06)	0.42 ** (3.03)	0.19 (0.90)
Environmental conscious [3]	0.32 (1.96)	**1.76** *** (12.98)	**1.98** *** (13.39)	**1.85** *** (13.59)	**1.99** *** (10.86)	**1.81** *** (11.89)	**1.78** *** (8.17)
Shift to car	0.55 (1.77)	**1.04** *** (3.85)	0.87 ** (2.83)	0.27 (0.80)	**1.36** *** (3.63)	**1.05** *** (3.38)	1.22 ** (2.91)
Max. walking distance	0.18 * (2.52)	0.2 ** (3.15)	−0.01 (−0.12)	0.11 (1.65)	**0.29** *** (3.84)	**0.33** *** (5.18)	**0.33** *** (4.27)
Distance from home to workplace	−0.03 ** (−2.64)	0.03 ** (2.58)	0.01 (0.96)	0.01 (1.13)	−0.01 (−0.76)	0.04 ** (3.25)	0.002 (0.12)

Table 3. *Cont.*

Variable	Coefficient						
	MTC	**Metro**	**Bus**	**ST**	**RH**	**MTC-taxi+**	**ST+**
Owns car	−0.28 *	**−1.3** ***	**−1.24** ***	**−0.83** ***	**−1.38** ***	**−1.63** ***	**−1.45** ***
	(−2.15)	(−11.44)	(−9.90)	(−6.80)	(−7.85)	(−11.96)	(−6.93)
Owns motorcycle	**0.58** ***	**−0.42** ***	**−0.71** ***	**−1.49** ***	**−1.34** ***	−0.33 *	**−0.997** ***
	(4.70)	(−3.79)	(−5.83)	(−12.49)	(−7.47)	(−2.43)	(−4.77)
Household size	0.03	**0.18** ***	0.04	**0.26** ***	**0.4** ***	**0.38** ***	**0.53** ***
	(0.73)	(4.45)	(0.84)	(6.23)	(6.68)	(8.01)	(7.67)
Detached home	−0.39 **	−0.37 **	**−0.5** ***	**0.5** ***	0.24	−0.05	0.01
	(−3.10)	(−3.27)	(−4.01)	(4.03)	(1.30)	(−0.38)	(0.04)
Condo	0.13	−0.29	**−0.59** ***	0.08	−0.11	−0.04	0.27
	(0.77)	(−1.54)	(−3.51)	(0.46)	(−0.40)	(−0.21)	(0.92)
ASC	−0.76 *	−0.98 **	−0.55	**−2.73** ***	**−2.78** ***	**−3.87** ***	**−4.32** ***
	(−2.06)	(−2.93)	(−1.49)	(−7.71)	(−5.46)	(−9.47)	(−5.12)
N				28,332			
Pseudo R^2				0.21			

[1] Employee is a proxy for individuals that are not working at home, i.e., commute to work. [2] Respondents that choose "privacy", "convenience", "reliability", "travel time", and "travel cost" as the top three out of five preferences as the reasons for choosing their mode throughout variables "value privacy", "value convenience", "value reliable", "value travel time", and "value travel cost", respectively. [3] Respondents that choose to (1) "reduce global warming" as one of the reasons for choosing their mode or (2) shift away from private vehicles to other modes when shown with the amount of CO_2 released from vehicles (Figure A2).

4.3. Policy Sensitivity Analysis

The choice probabilities of each mode group before any changes (baseline) in our model are similar to the mode group of the empirical modal share from the eBUM in 2017 (Table 4). Private vehicles and public transits share about 60% and 20% of all modes, respectively. But the share of metro and buses in the public transit category is different, possibly due to the metrosystem expansion in 2020. We analyze the sensitivity of the total travel cost and total travel time attributes of each transport mode group on the choice probabilities of each mode or the elasticities. The direct (indirect) elasticity of individual t choosing mode i with respect to the change in an attribute (x) of mode i (j) is represented in Equations (1) and (2) as:

$$\epsilon^{P(i)}_{x_{ik,t}} = \frac{\partial P(i)}{\partial x_{ik,t}} \times \frac{x_{ik,t}}{P(i)} \tag{1}$$

$$\epsilon^{P(i)}_{x_{jk,t}} = \frac{\partial P(i)}{\partial x_{jk,t}} \times \frac{x_{jk,t}}{P(i)} \tag{2}$$

We are interested to observe the aggregate elasticity change for the whole sample following Equation (3):

$$\widetilde{\epsilon}^{P(i)}_{x_{jk}} = \frac{\sum_{n=1}^{N} P(i)\epsilon^{P(i)}_{x_{jk,t}}}{\sum_{n=1}^{N} P(i)} \tag{3}$$

Elasticity is interpreted as the percentage change in choice probability from a 1% change in travel time or travel cost. The direct elasticities are negative and indirect elasticities are positive. The magnitude is interpreted in absolute values. The mode choice probabilities are inelastic to travel cost and travel time changes when $\left|\widetilde{\epsilon}^{P(i)}_{x_{jk}}\right| < 1$ and elastic when $\left|\widetilde{\epsilon}^{P(i)}_{x_{jk}}\right| > 1$. All of our calculated elasticities are inelastic which is expected in the short run, meaning that the changes of total travel cost and total travel time have small effects on the mode choice probabilities. For example, in Table 4, the direct elasticity of total travel time of private vehicles on the car choice probability is −0.011 or a 1% increase (decrease) in total travel time of private vehicles results in a 0.011% decrease (increase) in the car choice probability. The indirect elasticity of total travel time of private vehicles on the shared taxi choice probability is 0.044 or a 1% increase (decrease) in total travel time of private vehicles results in a 0.044% increase (decrease) in the shared taxi choice probability.

The "mode shift" variable in Table 4 does not directly tell us how many commuters will shift their modes, but it tells us how possible shifters are distributed to other modes when an attribute of the mode in consideration changes. For instance, if total travel time of private vehicles changes 1%, then 27%, 20.5%, 23.5%, 8.5%, 15.1%, and 5.4% of the possible shifters will use the metro, buses, shared taxis, ride-hailing services, motorcycle taxis to the metro, and shared taxis to the metro, respectively.

Table 4. The effect of travel cost and travel time sensitivity on aggregate choice probability elasticities. A combination of higher costs for private vehicle users, less on-street parking spaces (translating into increased time costs), and reduced time costs of shared mobility can initiate modal shifts from private vehicles towards shared mobility. MTC, motorcycle; ST, shared taxi; RH, ride-hailing; MTC-taxi+, motorcycle taxi and metro; ST+, shared taxi and metro; eBUM, extended Bangkok Urban Model (2017).

Variable Change		Car	MTC	Metro	Bus	ST	RH	MTC-taxi+	ST+
eBUM modal share		39.9	23.8	1.3	22.6	-	-	-	-
Baseline choice probability		40.71	19.06	9.73	9.34	10.86	2.81	5.23	2.26
PV cost	Elasticity (%)	−0.009	−0.0004	0.021	0.003	0.029	0.127	0.046	0.041
	mode shift (%)			29.7	23.3	17.7	9.0	14.4	6.0
PT cost	Elasticity (%)	0.001	0.0001	−0.013	−0.002	0.004	0.012	0.005	0.006
	Mode shift (%)	56.0	11.3			13.4	5.3	9.7	4.3
SM cost	Elasticity (%)	0.002	0.001	0.004	0.002	−0.045	−0.242	0.01	0.015
	Mode shift (%)	40.3	18.8	13.6	13.0			9.5	4.8
PV time	Elasticity (%)	−0.011	−0.001	0.031	0.008	0.044	0.17	0.071	0.077
	Mode shift (%)			27.0	20.5	23.5	8.5	15.1	5.4
PT time	Elasticity (%)	0.005	0.001	−0.033	−0.016	0.012	0.051	0.018	0.022
	Mode shift (%)	48.1	19.0			15.0	5.0	9.7	3.3
SM time	Elasticity (%)	0.002	0.001	0.004	0.003	−0.065	−0.201	0.013	0.026
	Mode shift (%)	30.9	30.4	11.8	12.8			9.1	4.9

The results reveal that a combination of higher costs for private vehicle users, less on-street parking spaces (translating into increased time costs), and reduced time costs of shared mobility can initiate modal shifts from private vehicles towards shared mobility.

Shared mobility users are sensitive to the mode's own travel cost and travel time change. Shared taxi users are slightly more sensitive to travel time than to travel cost. This means that they enjoy the service price decrease from the increase in the total cost's denominator, but are willing to wait for the driver to make a detour to pickup other riders along the way in a limited time frame. Ride-hailing users are more sensitive to travel cost than travel time because the service price is already the highest among other modes. In addition, they are sensitive to both changes in private vehicles, especially travel time. The sensitivity to travel time for public transit users is more than travel cost since they value reliability and punctuality. Car users are about as sensitive to total travel time of using their own vehicles as travel cost. This supports collecting road tolls and curbside parking fees to alleviate congestion, and thus, save travel time. Motorcycle users are the most insensitive among both changes throughout all modes, since motorcycles are faster and cheaper than other modes. In general, commuters are rather sensitive to travel time as compared with travel cost, which is in alignment with the descriptive statistics in Table 2 that they value travel time over travel cost.

There are various unexplained influential factors to mode choice from our model, total travel cost and total travel time adjustments alone may be insufficient to induce dramatical mode shifting. Descriptive statistics in Section 4.1 suggest convenience plays a dominant role in the travel mode decision for Bangkokians. It may be useful to further investigate transport mode choice modeling with latent variables such as the level of inconvenience.

4.4. Discussion

4.4.1. Traffic Problems: Congestion, Inefficiency, Commuter Behavior, and Attractiveness of Modes

Private vehicles are the main transport mode in Bangkok despite perpetual road congestion and related negative effects. The massive number of cars on the streets is the consequence of several reasons according to our findings. (1) Cars are affordable, especially ecocars—tempting public transit, ride-hailing, and multimodal commuters to shift to private motorized vehicles. (2) Cars are also convenient in minimizing walking (despite walking remaining a key measure to reduce the risk of cardiovascular diseases). (3) The marginal cost of other modes of transportation (other than the low-quality bus) in Bangkok is comparable to using private cars (though the latter's costs are much higher once ownership and maintenance are priced in). In addition, commuters are less likely to use the metro if they gain higher income and if they value privacy. (4) Public transits are jammed and the universal designs across age groups are deficiently constructed. (5) Men still insist on using private vehicles because of its important role as status symbol [50]. Similarly, it is also not status adequate for highly educated individuals to use motorcycles and public transits. Hence, as a result of these dynamics, Bangkok becomes increasingly gridlocked.

4.4.2. Proposed Solutions

(1) Pull Commuters toward Shared Mobility

Shared mobility promises to ameliorate the conflict between individual flexibility and systemic efficiency. The ITF-OECD modeled shared taxi bus and shared taxi services for Lisbon [19], Helsinki [18], Auckland [20], Lyon [21], and Dublin [22]. In the "full replacement of cars with shared mobility" scenario, shared taxis gained higher modal share as compared with taxi buses in Helsinki, Dublin, and Lyon. The changes in the modal shares for nonmotorized transport is small (1–3%, except for the 11% change for Dublin) and moderate (5–9%) for the existing public transit. Their results show a range of 28% (Helsinki) and 62% (Lisbon) CO_2 emissions reduction, and 23% (Helsinki) and 54% (Lyon) vehicle-kilometer reduction.

Our understanding of mode choice in Bangkok leads to insights on how to increase shared mobility. First, commuters are not too concerned about privacy. Hence, other modes can compete with private cars in this aspect, except for the overflowing metro lines. Second, shared pooled mobility (shared taxi) is appealing to women, bigger families, environmentalists, and those that reside in detached houses. Most of the detached houses in Bangkok are in gated communities, where commuters' demands are not served by public transits. Third, a key attraction of shared taxi is its flexibility and convenience, even trumping the private car; commuters can avoid searching for parking, walking, and transferring. Fourth, shared taxi has a high chance of being used as a full ride from origin to destination rather than to compete with motorcycle taxis as last mile connections to the metro stations, although multimodal commuters may shift to shared taxis instead of having to connect between modes. Shared taxis are used to substitute private cars rather than to complement public transits. It is true that shared taxis are stealing some public transport ridership by decreasing the overcrowded modes of mass transits. However, they attract individual car users more, increasing occupancy and decreasing GHG emission per person kilometer. Fifth, safety is not one of the main concerns for the respondents because they value travel time, cost, and convenience over safety, in spite of daily accidents occurring from motorcycles. Commuters will choose shared taxi as long as it saves their cost (the ride is fully occupied with three companions) and the detour time is, at most, 10 min.

Ride-hailing (which has much higher marginal GHG emissions than shared pooled mobility [14]) attracts similar individuals, i.e., women, bigger families, environmentalists, and those that are comfortable walking farther. However, there is a tendency for riders to buy their own cars in the future because of the expensiveness of the service matching or even higher than car ownership and usage costs. Environmental-concerned commuters are not choosing to travel by private vehicles (around 20%), yet the proportion of these individuals could be higher. Soft interventions such as creating positive social norms and building knowledge and awareness can reduce the modal share of cars [51]. Promoting green and sustainable transportation through education campaigns, study programs, and social ads should move commuters out of cars and navigate Bangkok towards systemic efficiency.

Shared pooled mobility has a major potential to replace private vehicles, and thus, reduce congestion and environmental externalities. According to the statistics generated from the HTS (2017), commuters living in detached houses own 62% of all private cars, account for about 50% of total travel distances, and share 48% of total car trips, in Bangkok. If an average of four people instead of one or two people occupied one car, then, the car trips on the streets of Bangkok would be reduced by 36% or 24%, respectively.

(2) Push Commuters out of Private Vehicles by Pricing car Usage and Ownership

Attracting commuters to shared mobility is appealing but alone inadequate. The mode choice elasticities of total travel time and total travel cost changes reveal that car users are inelastic to other modes' costs and time changes, but they are the most sensitive to their own travel time and usage cost changes. Ride-hailing users are the most sensitive to all changes of all modes, especially when its own travel cost and travel time changes and when there are changes in the travel time of cars. Charging for on-street parking or restricting on-street parking to off-street parking or controlling for on-street parking to be pricier than off-street parking can raise the time search for parking for cars and lessens the overall time stuck in traffic from cars cruising for on-street parking. Collecting road tolls will directly reduce travel time for all vehicles on the road and increase car usage cost. The Pigouvian toll is computed at 6.1 Baht/km in inner Bangkok [8].

Public transport commuters are the most sensitive to their modes' reliability and punctuality. When it takes longer to travel with public transits and it is more expensive to use cars, the choice probability of shared mobility and multimodal transport are sensitive. This implies that the quality of service of shared mobility is in between private and public transport and that commuters with metro connections are willing to use multiple modes from origin to destination as long as they can save time and cost. Ensuring that there are enough riders to split the travel cost and that the riders live along the same route to limit the detour time is essential for the successfulness of shared taxis. Advance booking and route planning will be important features to the shared taxi application. One important issue would be to keep the cost and service level of shared taxis closer to individual cars as compared with the metro, otherwise metro users instead of car users woulf shift to shared taxis. The cost of using shared taxis should be higher than using the metro, but traveling with the metro should be more reliable than traveling with shared taxis. We guaranteed that this is the situation in our choice experiments. Because car ownership induces usage, selling cars would result in using shared mobility and spilling over to public transits [11]. Public transits should also have greater integration of services [12] such as an integrated ticketing system and maybe collaborate with shared mobility modes.

4.4.3. Consistency and Limitations

Shared mobility has experienced increasing attention in the transport choice model literature in this decade, yet much more is needed to draw any conclusions. Respondents choosing shared taxis in Bangkok are time sensitive similar to those choosing automated car sharing in the Netherlands [52]. While Bangkokians look at shared mobility as an available mode in between private and public vehicle, only Dutch car users and not public transit users are charmed by shared mobility because of their cost averseness. This could be because the gap between private and public transport costs in Bangkok is lower than in the Netherlands.

To motivate the shift towards more sustainable transportation modes, we suggest (1) increasing private vehicle ownership and usage costs such as congestion charges and on-street parking fees, (2) lowering the prices of shared mobility options and ensuring sufficient demand and limited detour time of the shared taxi mode, (3) maintaining the reliability and punctuality and establishing universal designs for all ages for public transits, and (4) promoting transport emission reduction education campaigns and ending the men-drive and educated-own car culture. Since ride-hailing service obtained supporting regulation in May 2021 to become ”legal” in Thailand, there is also a bright future for shared taxi.

Our findings are subject to the experimental design. For instance, providing different transport modes as choices, modifying attributes, adjusting attribute levels, and adding various interventions may provide different results and implication. Similar most surveys, our samples may be under- or overrepresentative of some features of the population. Further research could be extended by including explanatory latent variables such as perception, attitude, social norm, and individual beliefs. In addition, future perception after commuters are familiar with new transport modes may change, so the results of our analysis should be carefully interpreted. Longitudinal data should be applied to assess the long-term effects of policies aiming to reduce car dependence [53]. Finally, transport trends after COVID-19 should be monitored.

5. Conclusions

Our paper highlights attitudes and factors of Bangkok inhabitants relevant to private car usage and the potential to shift to shared pooled mobility. We find that cars are favored by men, high-educated individuals, members of a small household, and those that dislike walking. Interestingly, income and privacy do not play a role in mode choices, except for metro patrons. Public transits are accessible and reliable, but lack universal design across ages and are unappreciated by highly educated individuals. While environmentalists avoid using private vehicles, owning vehicles induce theirusage.

There is potential demand for shared mobility as a convenient door-to-door transport service from gated communities, establishing a new hybrid public/private mode. However, it is important to ensure that shared taxis do not cannibalize metro ridership by setting the shared pooled mobility price higher than the public transit cost, by maintaining the reliability of the metro, and by integrating the services together, combined with reduced car ownership rates. By replacing cars with shared taxis as the everyday choice for gated community residences, car trips in Bangkok could be reduced by 24–36%. In addition, public campaigns should focus on making it cool for status-concerned male white collar workers to use shared mobility. Travel time and travel cost reduction in shared mobility modes alone are influential, but insufficient. Mode shifting is dominantly induced by changes in car usage cost and travel time. Commuters fancy traveling in their vehicles only if they are not required to pay for road tolls and parking fees and waste time walking and searching for parking. Policymakers should implement economic instruments to price out fossil-fueled individual motorized transport from the city center.

Author Contributions: Conceptualization, E.A., F.C. and N.P.; formal analysis, E.A.; methodology, E.A.; supervision, F.C. and N.P.; writing—original draft, E.A. and A.J.; writing—review and editing, F.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Program Management Unit for Human Resources & Institutional Development, Research and Innovation, Chulalongkorn University (CU), Thailand (grant number G_B16F630071_0102_01_14 (5-25)). We acknowledge support by the German Research Foundation and the Open Access Publication Fund of TU Berlin.

Institutional Review Board Statement: The survey questionnaire was approved by the social science committee of the Thammasat University’s institutional review board (IRB), project no. 042/2564, approval no. 034/2564.

Informed Consent Statement: Informed consent was obtained from all respondents involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restricted permission from the Thammasat University’s institutional review board.

Acknowledgments: We thank the Royal Thai Government for providing Eva Ayaragarnchanakul with a PhD scholarship; the Program Management Unit for Human Resources & Institutional Development, Research and Innovation—CU for funding the survey and project; the German Research Foundation and TU Berlin for their Open Access Publication Funding; and the Office of Transport and Traffic Policy Planning (OTP) Thailand for authorizing data usage. We are grateful to the anonymous reviewers for their valuable time in providing insightful comments and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Sample Size Calculation

The survey was proportionally distributed to households in seven districts of Bangkok (Figure A1) using the stratified random sampling technique. We ensured that every income subgroup was properly represented in the sample (as vehicle ownership is related to the purchasing power of respondents) by using land prices (where the value decrease as the district moves away from the central business district (CBD) in a concentric circle) as a proxy for income, for practicality. The sample zones also reflected different transport accessibility levels. Each respondent used approximately 40 min to finish the questionnaire. The survey was conducted during June–September, 2021 in which the coronavirus disease had spread in the area. Therefore, we highlighted that the questions were based on "normal conditions". The sample size calculation follows Equation (A1).

$$n = \frac{\sigma^2}{\frac{e^2}{z^2} + \frac{\sigma^2}{N}} = 477 \tag{A1}$$

where n is the sample size (households), N is the population (3,041,115 households (Department of Provincial Administration, 2019)), Z is the z-value corresponding to the statistical confidence level (Z = 1.96 at 95% confidence interval), σ is the standard deviation of the interested variable (σ = 39,005 Baht/month/household (National Statistics Office, 2019)), and e is the error term that the researchers can accept (set to 3500 Baht/month/household).

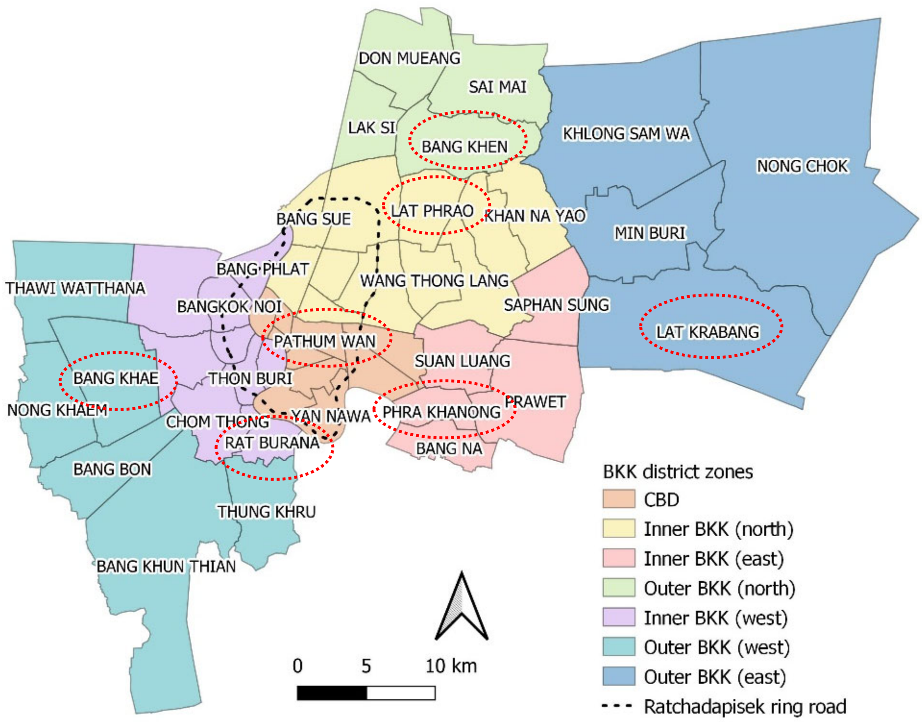

Figure A1. Sample size distribution in 7 districts of Bangkok (BKK). Sample districts are indicated by red dotted circles.

Appendix B. Stated Choice Experiments and Post Experiment Questions

Table A1 shows an example of one (out of nine) choice situation. Table A2 and Figure A2 are presented to respondents after stated choice experiments.

Table A1. Example of a choice situation.

Alternative #	1	2	3	4
Attribute	**Private car**	**Metro**	**Shared taxi**	**Motorcycle taxi + metro**
Travel time	On-board: 34 min Walk: 5 min Search for parking: 12 min Total 51 min	On-board: 21 min Walk: 12 min Wait: 9 min Total 42 min	On-board: 26 min Wait: 9 min Detour: 10 min Total 45 min	On-board: 26 min Walk: 2 min Wait: 9 min Total 37 min
Travel costs	Fuel: 52 Baht Toll fee: 30 Parking fee: 30 Baht	Fare: 70 Baht	Fare: 82 Baht Toll fee: 30	Fare: 75 Baht
Crowdedness	-	Crowded (a few empty seats and plenty of standing room)	No. of max. companion along the way: 1	[Metro]: crowded (a few empty seats and plenty of standing room)
You choose				

Table A2. Average vehicle ownership costs per year, month, and day. [1] Costs exclude the average fuel cost of 2.8 Baht/km, average parking fee of 40 Baht/hour, and toll fee of 35–115 Baht at entrance. Average monthly and daily car ownership costs are shown so that respondents can easily compare with their monthly salary and daily travel expenses. Source: Researcher's calculation from data provided by the Compulsory Motor Insurance (Department of Land and Transport) and Car insurance premium (2020).

#.	Car Type by Engine Size (Liters)	Average Purchase Price (Baht)	Depreciation (Baht/Year)	Annual Costs [1] (Baht)			Average Annual Cost of Ownership (Baht)	Average Monthly Cost (Baht)	Average Daily Cost (Baht)	
				Compulsory Insurance	Plate Registration	Maintenance			Excluding Voluntary Insurance	Including Voluntary Insurance
1	Ecocar (1.2 L)	569,000	35,800	645.21	1200–1500	3580	41,200	3432	158	193
2	Compact (1.4 L–1.6 L)	716,000	45,010	645.21	1500–1800	4500	51,800	4316	198	238
3	Medium (1.8 L–2.2 L)	1,055,000	66,300	645.21	2100–3700	6630	75,800	6315	290	331
4	Large (from 2.4 L)	1,495,000	94,000	645.21	from 4500	10,230	117,450	9787	450	506

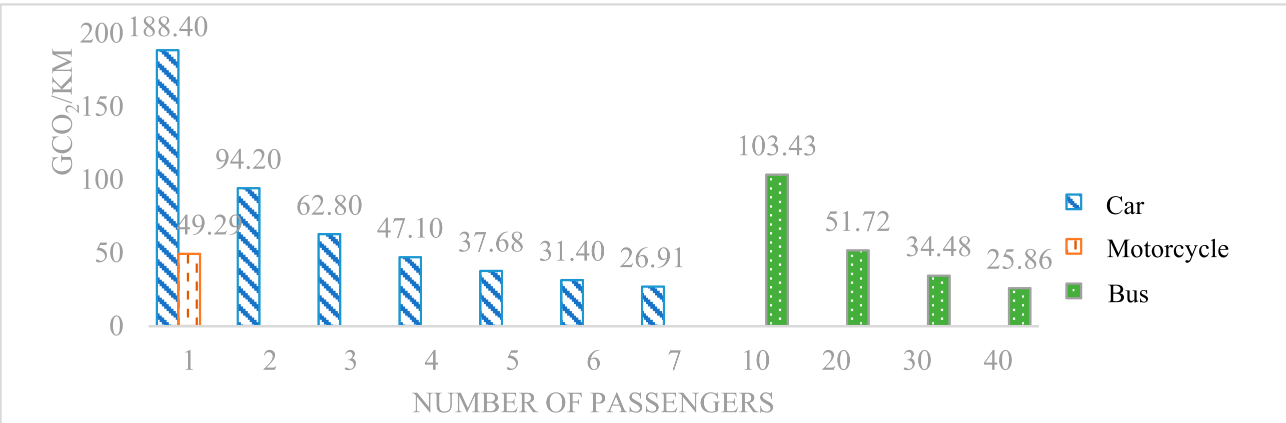

Figure A2. Average amount of CO_2 released per km per passenger by vehicle type. Source: Researcher's calculation from data provided by [8].

Appendix C. Discrete Choice Model

Consider J alternatives for an individual
Let the utility of alternative j be:

$$U_j = \beta' X_j + \varepsilon_j \quad \text{(A2)}$$

where U_j is the vector of attributes of alternative j, β is the vector of coefficients, and ε_j is the random error of the unobserved attributes of alternative j.

The errors could originate from various sources such as imperfect information, measurement errors, and omission of important variables to the model.

Hence, the probability that an individual will choose alternative i is:

$$P(i|X) = P(\beta' X_i + \varepsilon_i > \beta' X_j + \varepsilon_j \forall j = 1, \ldots, J; i \neq j) \quad \text{(A3)}$$

where $X = \left(X_1', \ldots, X_J'\right)'$.

For a special case that $P(i|X)$ has a simple analytic form which happens when the components $\varepsilon \equiv (\varepsilon_1, \ldots, \varepsilon_J)'$ are independently and identically distributed between the alternatives (i.i.a.).and have type 1 extreme value (Gumbel) distribution, then $P(i|X)$ will follow the multinomial logit (MNL) model which is the most common tool used:

$$P(i|X) = \frac{\exp(\beta' X_i)}{\sum_{j=1}^{J} \exp\left(\beta'^{X_j}\right)} \quad \text{(A4)}$$

Although, researchers argue that DCM neglects the explanatory latent variables such as perception, attitude, and individual beliefs, which is the benefit of using other prominent transport demand management (TDM) theories such as the attitude theory, self-regulation theory, and habit-formation theory, DCM has a strong theoretical background and clear assumptions for quantitative researches. Moreover, creating latent variables with statistical techniques such as factor analysis or Likert scaling to compile an index may overcome the disregarded problem, if necessary.

Appendix D. Model Estimation

We use the following equation for our survey data estimation:

$$\begin{aligned} U_{jt} = ASC_j &+ \beta_1 TTime_j + \beta_2 TCost_j + \beta_3 TInveh_j + \beta_4 TFare_j + \beta_{5,stm} Detour_j + \beta_{6,j\neq pv,rh} Crowd_j \\ &+ \beta_{7,j} Income_t + \beta_{8,j} Male_t + \beta_{9,j} Age_t + \beta_{10,j} Bachelor_t + \beta_{11,j} Employee_t \\ &+ \beta_{12,j} Privacy_t + \beta_{13,j} Convenience_t + \beta_{14,j} reliable_t + \beta_{15,j} Rtime_t + \beta_{16,j} Rcost_t \\ &+ \beta_{17,j} Green_t + \beta_{18,j\neq car} Tocar_t + \beta_{19,j} Maxwalk_t + \beta_{20,j} Dh2w_t + \beta_{21,j} Owncar_t \\ &+ \beta_{22,j} Ownmtc_t + \beta_{23,j} HHsize_t + \beta_{24,j} Singlehome_t + \beta_{25,j} Condo_t + \varepsilon_j \end{aligned} \quad \text{(A5)}$$

where U_{jt} is utility of alternative j (= car, motorcycle, metro, bus, shared taxi, ride-hailing, motorcycle taxi and metro, shared taxi and metro) for individual t $(= 1, \ldots, N)$,

β_k are the coefficients ($k = 1 - 25$),
TTime is total travel time (minutes),
TCost is total travel cost (Baht/trip),
TInveh is in-vehicle time (minutes),
TFare is fuel cost and service fare (Baht/trip),
Detour is detour time (minutes),
$\text{Crowd} = \begin{cases} 1 \text{ if alternative } j \text{ is crowded} \\ 0 \text{ otherwise} \end{cases}$,
Income is monthly income (thousand Baht),
$\text{Male} = \begin{cases} 1 \text{ if individual } t \text{ is male} \\ 0 \text{ otherwise} \end{cases}$,
Age is the age of individual t,

$$\text{Bachelor} = \begin{cases} 1 \text{ if individual } t \text{ graduated with a bachelor's degree or higher} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Employee} = \begin{cases} 1 \text{ if individual } t \text{ is a company or goverment employee} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Privacy} = \begin{cases} 1 \text{ if individual } t \text{ values privacy} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Convenience} = \begin{cases} 1 \text{ if individual } t \text{ values convenience} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Reliable} = \begin{cases} 1 \text{ if individual } t \text{ values reliability} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Rtime} = \begin{cases} 1 \text{ if individual } t \text{ values travel time} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Rcost} = \begin{cases} 1 \text{ if individual } t \text{ values travel cost} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Green} = \begin{cases} 1 \text{ if individual } t \text{ cares for the environment} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Tocar} = \begin{cases} 1 \text{ if individual } t \text{ shifts to car after presented with car ownership costs} \\ 0 \text{ otherwise} \end{cases},$$

Maxwalk is the maximum comfort walking distance (km),
Dh2w is the distance from home to workplace (km),

$$\text{Owncar} = \begin{cases} 1 \text{ if individual } t \text{ owns at least 1 car} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Ownmtc} = \begin{cases} 1 \text{ if individual } t \text{ owns at least 1 motorcycle} \\ 0 \text{ otherwise} \end{cases},$$

HHsize is the number of household members (people),

$$\text{Singlehome} = \begin{cases} 1 \text{ if individual } t \text{ lives in a detached house} \\ 0 \text{ otherwise} \end{cases},$$

$$\text{Condo} = \begin{cases} 1 \text{ if individual } t \text{ lives in a condo} \\ 0 \text{ otherwise} \end{cases},$$

ε_j is the i.i.a.random error.

References

1. Creutzig, F.; Agoston, P.; Minx, J.C.; Canadell, J.G.; Andrew, R.M.; Le Quéré, C.; Peters, G.P.; Sharifi, A.; Yamagata, Y.; Dhakal, S. Urban infrastructure choices structure climate solutions. *Nat. Clim. Chang.* **2016**, *6*, 1054–1056. [CrossRef]
2. Creutzig, F.; He, D. Climate change mitigation and co-benefits of feasible transport demand policies in Beijing. *Transp. Res. Part D Transp. Environ.* **2009**, *14*, 120–131. [CrossRef]
3. Parry, I.; Strand, J. International fuel tax assessment: An application to Chile. *Environ. Dev. Econ.* **2012**, *17*, 127–144. [CrossRef]
4. Parry, I.; Timilsina, G.R. How should passenger travel in Mexico City be priced? *J. Urban Econ.* **2010**, *68*, 167–182. [CrossRef]
5. Rizzi, L.I.; De La Maza, C. The external costs of private versus public road transport in the Metropolitan Area of Santiago, Chile. *Transp. Res. Part A Policy Pract.* **2017**, *98*, 123–140. [CrossRef]
6. Sen, A.K.; Tiwari, G.; Upadhyay, V. Estimating marginal external costs of transport in Delhi. *Transp. Policy* **2010**, *17*, 27–37. [CrossRef]
7. Creutzig, F.; Javaid, A.; Koch, N.; Knopf, B.; Mattioli, G.; Edenhofer, O. Adjust urban and rural road pricing for fair mobility. *Nat. Clim. Chang.* **2020**, *10*, 591–594. [CrossRef]
8. Ayaragarnchanakul, E.; Creutzig, F. Bangkok's locked-in traffic jam: Price congestion or regulate parking? *Case Stud. Transp. Policy* **2021**, *10*, 365–378. [CrossRef]
9. MRTA. *Mass Rapid Transit Authority of Thailand (MRTA) Annual Report*; MRTA: Bangkok, Thailand, 2020; pp. 18–19. Available online: https://www.mrta.co.th/media/896998/en_mrta_ar2020_7june.pdf (accessed on 23 September 2021).
10. Botsman, R.; Rogers, R. *What's Mine Is Yours: The Rise of Collaborative Consumption*; Harper Collins: New York, NY, USA, 2010.
11. Jonuschat, H.; Stephan, K.; Schelewsky, M. Understanding Multimodal and Intermodal Mobility. *Transp. Sustain.* **2015**, *7*, 149–176. [CrossRef]
12. Feigon, S.; Murphy, C. Transit Cooperative Research Program, Transportation Research Board & National Academies of Sciences, Engineering, and Medicine. In *Shared Mobility and the Transformation of Public Transit*; Transportation Research Board: Washington, DC, USA, 2016; p. 2378. [CrossRef]

13. Li, Z.; Hong, Y.; Zhang, Z. An Empirical Analysis of On-demand Ride-sharing and Traffic Congestion. In Proceedings of the International Conference on Information Systems 2016 (ICIS'16), Dublin, Ireland, 11–14 December 2017.
14. Creutzig, F. Making Smart Mobility Sustainable: How to Leverage the Potential of Smart and Shared Mobility to Mitigate Climate Change. Policy Paper Series: Shaping the Transition to a Low-Carbon Economy—Perspectives from Isreal and Germany. *Isreal Public Policy Inst. Heinrich Böll Found. Tel Aviv* **2021**, *18*.
15. Wu, L.; Wang, W.; Jing, P.; Chen, Y.; Zhan, F.; Shi, Y.; Li, T. Travel mode choice and their impacts on environment—a literature review based on bibliometric and content analysis, 2000–2018. *J. Clean. Prod.* **2019**, *249*, 119391. [CrossRef]
16. Martínez-Díaz, M.; Soriguera, F. Autonomous vehicles: Theoretical and practical challenges. *Transp. Res. Procedia* **2018**, *33*, 275–282. [CrossRef]
17. Wadud, Z.; MacKenzie, D.; Leiby, P. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transp. Res. Part A Policy Pract.* **2016**, *86*, 1–18. [CrossRef]
18. Furtado, F.; Martinez, L.; Petrik, O.; Kauppila, J.; Crist, P.; Gudmundson, L. Shared Mobility Simulations for Helsinki; International Transport Forum (ITF). 2017. Available online: https://www.itf-oecd.org/node/21473 (accessed on 6 June 2022).
19. Lopes, M.M.; Martinez, L.M.; Correia, G.H.D.A. Simulating Carsharing Operations through Agent-based Modelling: An Application to the City of Lisbon, Portugal. *Transp. Res. Procedia* **2014**, *3*, 828–837. [CrossRef]
20. Luis, M.; Petrik, O.; Furtado, F.; Kauppila, J.; Crist, P.; Gudmundson, L. Shared Mobility Simulations for Auckland; International Transport Forum (ITF). 2017, p. 116. Available online: https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwij4fzimpP5AhUSZ94KHbRyA2sQFnoECAIQAQ&url=https%3A%2F%2Fwww.itf-oecd.org%2Fsites%2Fdefault%2Ffiles%2Fdocs%2Fshared-mobility-simulations-auckland.pdf&usg=AOvVaw2UVKw0rb01W0nFYGJdihOp (accessed on 6 June 2022).
21. Martinez, L.; Petrik, O.; Wagner, N. *Shared Mobility Simulations for Lyon*; International Transport Forum (ITF), 2020; p. 93. Available online: https://www.itf-oecd.org/shared-mobility-simulations-lyon (accessed on 6 June 2022).
22. Petrik, O.; Martinez, L.; Kauppila, J. *Shared Mobility Simulations for Dublin*; International Transport Forum (ITF), 2018; p. 97. Available online: https://www.itf-oecd.org/sites/default/files/docs/shared-mobility-simulations-dublin.pdf (accessed on 6 June 2022).
23. Asgari, H.; Jin, X.; Corkery, T. A Stated Preference Survey Approach to Understanding Mobility Choices in Light of Shared Mobility Services and Automated Vehicle Technologies in the U.S. *Transp. Res. Rec. J. Transp. Res. Board* **2018**, *2672*, 12–22. [CrossRef]
24. Javaid, A.; Creutzig, F.; Bamberg, S. Determinants of low-carbon transport mode adoption: Systematic review of reviews. *Environ. Res. Lett.* **2020**, *15*, 103002. [CrossRef]
25. Shaheen, S.A.; Zhang, H.; Martin, E.; Guzman, S. China's Hangzhou Public Bicycle. *Transp. Res. Rec. J. Transp. Res. Board* **2011**, *2247*, 33–41. [CrossRef]
26. Abouelela, M.; Tirachini, A.; Chaniotakis, E.; Antoniou, C. Characterizing the adoption and frequency of use of a pooled rides service. *Transp. Res. Part C Emerg. Technol.* **2022**, *138*, 103632. [CrossRef]
27. König, A.; Grippenkoven, J. Modelling travelers' appraisal of ridepooling service characteristics with a discrete choice experiment. *Eur. Transp. Res. Rev.* **2019**, *12*, 1. [CrossRef]
28. Dias, F.F.; Lavieri, P.S.; Garikapati, V.; Astroza, S.; Pendyala, R.M.; Bhat, C.R. A behavioral choice model of the use of car-sharing and ride-sourcing services. *Transportation* **2017**, *44*, 1307–1323. [CrossRef]
29. Huynh, T.L.D.; Vo, A.K.H.; Nguyen, T.H.H.; Le Nguyen, V.B.; Ho, N.N.H.; Do, N.B. What makes us use the shared mobility model? Evidence from Vietnam. *Econ. Anal. Policy* **2020**, *66*, 1–13. [CrossRef]
30. Salim, S.; Sanik, E.; Osman, M.H.; Abdullah, M.I.S. Travel Behavior towards Shared Mobility Among Malaysian Users: Insights from a Preliminary Study. *Int. J. Eng. Trends Technol.—IJETT* **2020**, 1–5. Available online: https://ijettjournal.org/special-issues/ijett-aiic101 (accessed on 9 May 2022).
31. Suatmadi, A.Y.; Creutzig, F.; Otto, I.M. On-demand motorcycle taxis improve mobility, not sustainability. *Case Stud. Transp. Policy* **2019**, *7*, 218–229. [CrossRef]
32. Auttapibarn, N.; Sirikijpanichkul, A.; Vanichavetin, C.; Rujopakarn, W. Development of Hybrid Choice Models for Modal Shift Study: A Case Study of MRT Green Line Extension Kasetsart University Station. *SWU Eng. J.* **2018**, *13*, 1–17. Available online: http://research.ku.ac.th/forest/Publish.aspx?PublishID=23999 (accessed on 23 September 2021).
33. Lekawattana, N.; Sirithorn, S. Development of Travel Mode Choice Model between School Bus and Passenger Car. *Srinakharinwirot Eng. J.* **2014**, *9*, 1. Available online: http://ejournals.swu.ac.th/index.php/SwuENGj/article/view/4343 (accessed on 23 September 2021).
34. Lueangthitikanchana, K. Factors Affecting Thai Consumer Decisions to Travel to Taiwan. Master's Thesis, Thammasat University, Bangkok, Thailand, 2016.
35. Vithivoravee, P. Factors Influencing Thai Tourists' Decision to Travel to Internationtal Destinations: A Case Study of Thai Tourirsts Travelling to Scandinavian Countries. Master's Thesis, Dhurakij Pundit University, Bangkok, Thailand, 2016.
36. Waewkaew, T. Tourism Behavior of Thai Tourists Travelling to Korea or Japan. Master's Thesis, Rajamangala University of Technology Thanyaburi, Bangkok, Thailand, 2014.

37. Dissanayake, D.; Morikawa, T. Investigating household vehicle ownership, mode choice and trip sharing decisions using a combined revealed preference/stated preference Nested Logit model: Case study in Bangkok Metropolitan Region. *J. Transp. Geogr.* **2010**, *18*, 402–410. [CrossRef]
38. Nam, D.; Park, D.; Khamkongkhun, A. Estimation of value of travel time reliability. *J. Adv. Transp.* **2005**, *39*, 39–61. [CrossRef]
39. Walker, J.L.; Wang, Y.; Thorhauge, M.; Ben-Akiva, M. D-efficient or deficient? A robustness analysis of stated choice experimental designs. *Theory Decis.* **2017**, *84*, 215–238. [CrossRef]
40. Teye-Ali, C.; Davidson, P. New algorithms for generating balanced efficient stated preference designs. *HEART | Eur. Assoc. Res. Transp.* **2013**. Available online: https://transp-or.epfl.ch/heart/2013/ABS56_Teye-Ali_Davidson.pdf (accessed on 23 September 2021).
41. Bliemer, M.C.; Rose, J.M.; Hensher, D.A. Efficient stated choice experiments for estimating nested logit models. *Transp. Res. Part B Methodol.* **2009**, *43*, 19–35. [CrossRef]
42. Hensher, D.A. Stated preference analysis of travel choices: The state of practice. *Transportation* **1994**, *21*, 107–133. [CrossRef]
43. Hensher, D.A.; Greene, W.H. Specification and estimation of the nested logit model: Alternative normalisations. *Transp. Res. Part B Methodol.* **2002**, *36*, 1–17. [CrossRef]
44. Hole, A.R. Creating efficient designs for discrete choice experiments. In Proceedings of the Nordic and Baltic Stata Users Group Meeting, Oslo, Norway, 13 September 2016. Available online: https://www.stata.com/meeting/nordic-and-baltic16/slides/norway16_hole.pdf (accessed on 12 January 2021).
45. Rose, J.M.; Bliemer, M.C.J. Constructing Efficient Stated Choice Experimental Designs. *Transp. Rev.* **2009**, *29*, 587–617. [CrossRef]
46. Sanko, N. Guidelines for State Preference Experiment Design. 2002. Available online: https://b.kobe-u.ac.jp/~{}sanko/pub/Sanko2001_1.pdf (accessed on 23 September 2021).
47. McFadden, D. Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics*; Academic Press: New York, NY, USA, 1974.
48. Office of Transport and Traffic Policy Planning. *Travel Demand Freight Movement Survey For National Transport Planning*; OTP: Bangkok, Thailand, 2017. Available online: https://www.otp.go.th/index.php/edureport/view?id=147 (accessed on 15 August 2021).
49. Hess, S.; Bierlaire, M.; Polak, J.W. Estimation of value of travel-time savings using mixed logit models. *Transp. Res. Part A Policy Pract.* **2005**, *39*, 221–236. [CrossRef]
50. Ramakrishnan, A.; Creutzig, F. Status consciousness in energy consumption: A systematic review. *Environ. Res. Lett.* **2021**, *16*, 053010. [CrossRef]
51. Semenescu, A.; Gavreliuc, A.; Sârbescu, P. 30 Years of soft interventions to reduce car use—A systematic review and meta-analysis. *Transp. Res. Part D Transp. Environ.* **2020**, *85*, 102397. [CrossRef]
52. Winter, K.; Cats, O.; Martens, K.; van Arem, B. Identifying user classes for shared and automated mobility services. *Eur. Transp. Res. Rev.* **2020**, *12*, 36. [CrossRef]
53. Zhang, W.; Zhang, M.; Information, R. Short- and Long-Term Effects of Land Use on Reducing Personal Vehicle Miles of Travel. *Transp. Res. Rec. J. Transp. Res. Board* **2015**, *2500*, 102–109. [CrossRef]