Multiple shared mobility services under competition: Empirical evidence for public acceptance and policy insights to sustainable transport

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Abstract

Traffic congestion and roadside emissions are severe and common problems in metropolitans. As a promising and sustainable solution to mitigating these vehicle externalities, shared mobility reduces the required vehicle fleet size for serving a given level of demand by sharing a vehicle among travelers with similar schedules and itineraries. Public acceptance is the key to the success of shared mobility development. This study investigates the acceptance of drivers and passengers of two typical competing shared mobility modes, car-pooling and taxi ride sharing, taking Hong Kong as a case study. For an empirical evaluation, an on-street stated preference survey was conducted, and 829 respondents, including 257 private car owners and 572 non-private car owners were interviewed about their travel preferences in three given hypothetical scenarios. In total, 2,487 observations were collected for calibrating two proposed logit-based discrete choice models for drivers and passengers. The model results show that the out-of-pocket cost, in-vehicle travel time, and out-of-vehicle time are key factors influencing travelers' decisions towards car-pooling and taxi ride-sharing. An equilibrium model was proposed and an iteration solution procedure was applied to obtain a convergent solution to balance the demand and supply of drivers and passengers for car-pooling services. Furthermore, sensitivity analyses were carried out to examine the effects of variations in proportions of travel cost and taxi fare shared by passengers for car-pooling and taxi ride-sharing, and to assist in the formulation of relevant transport policies.

Keywords: sustainable transport, car-pooling, taxi ride-sharing, shared mobility, stated preference survey, equilibrium model

1. INTRODUCTION

Traffic congestion is a severe problem faced by many densely populated cities worldwide, and a source of enormous economic costs to individual travelers and society. Traffic congestion increases travel time and aggravates polluting gas emissions (Cai et al., 2019). The cause of traffic congestion is related to many components. Land-use planning, road planning, and traffic demand are some of the factors that can significantly affect traffic congestion patterns (Song et al., 2019). To ease congestion on the road, restricting the number of vehicles on the road network is an effective measure. However, vehicle ownership has rapidly growth in the past decades worldwide (Dargay et al., 2007). In an attempt to mitigate these vehicle externalities, the promotion of sustainable shared mobility, including car-pooling and taxi ride-sharing, should be actively considered as an alternative approach, which allows a private car or taxi to transport two or more travelers with similar schedules and itineraries (Daganzo and Ouyang, 2019; Barann et al., 2017; d'Orey and Ferreira, 2014; Meshkani and Farooq, 2022; Nourinejad and Roorda, 2016; Santos and Xavier, 2015; Wang et al., 2018a).

Car-pooling and taxi ride-sharing are two typical shared mobility modes, which have been widely implemented in recent years throughout the world. Car-pooling matches passengers with individual drivers who have their own trip plans. Drivers provide car-pooling rides to passengers with similar schedules and itineraries for sharing their travel costs (including the fuel cost and toll charge of their trips) with passengers. Unlike the intention of transportation network companies (such as Uber and Lyft) that provide ride-sourcing services, the intention of drivers offering car-pooling is not to earn money, but to share with a passenger the travel cost of the trips they would do anyway. In contrast, taxi ride-sharing assigns a taxi driver to serve two or more passengers in one ride, and the taxi driver does not have his/her own trip plan but offers ride services to make a living. Passengers who opt for taxi ride-sharing typically pay a lower taxi fare than those who use normal taxi services, but may experience additional waiting time, detour time, and uncomfortableness caused by sharing a ride with others. Taxi ride-sharing is similar to the ride-pooling service, such as Uber Pool and Lyft Shared, except that taxi ride-sharing is offered by taxi drivers instead of private car drivers. For both car-pooling and taxi ride-sharing services, two or more travelers (including the individual travelers in car-pooling and passengers) share a proportion of their rides, which improves the utilization rate of vehicles or saves the vehicle mileages required for servicing a given level of travel demand.

Many previous studies have suggested that practicing car-pooling and taxi ride-sharing benefits society as a whole. It helps suppress vehicle fleet size on the road by increasing the occupancy rate of a vehicle, and to bring other benefits such as reducing total vehicle-miles-travelled, reducing roadside emissions, and energy consumption (Lokhandwala and Cai, 2018; Minett and Pearce, 2011; Cai et al., 2019; Caufield, 2019; Zhu et al., 2018; Han et al., 2021). Cities around the world have been widely adopting car-pooling and taxi ride-sharing to ease traffic congestion. A study of New York revealed that the cumulative trip length can be reduced by more than 40% after the implementation of conventional taxi ride-sharing (Santi et al., 2014). A follow-up study conducted by Lokhandwala and Cai (2018) investigated the benefits and drawbacks of shared autonomous taxis instead of conventional taxis in New York by agent-based modeling. The findings showed that the required taxi fleet size can be reduced by 59% while maintaining a similar service level and waiting time for passengers, followed by other benefits such as an increase in the taxi occupancy rate from 1.2 to 3.0, a decrease in the total travel distance by up to 55% and a reduction in 866 metric tons of carbon emissions per day. A similar study of San Francisco also suggested that car-pooling was beneficial to reducing transportation energy consumption, with an estimation of 1.7 to 3.5 million liters of gasoline saved every year (Minett and Pearce, 2011). Moreover, a study was conducted in Paris using the integrated land-use transport model which captured the households' decisions related to transportation and their residential locations. The model predicted that carbon dioxide emissions would be saved by half or by a factor of three by 2030 through ride-sharing in the morning or evening peak period (Yin et al., 2018). In Beijing, a study indicated that the shared taxis saved 28.3 million gallons of gasoline and reduced 2,392 tons of carbon dioxide compared to the non-shared taxis per year (Cai et al., 2019). Besides, another study adopted an optimal assignment analysis and revealed that over 47% of total taxi trip mileage can be saved based on the taxi trip data collected in New York City, Wuhan, and Shenzhen (Qian et al., 2017). All the above results have suggested that effective operation of large-scale car-pooling and taxi ride-sharing in densely-populated cities can possibly bring positive externalities such as easing traffic congestion, saving the total travel distance, reducing roadside emissions, and practicing energy saving. In addition to the social and environmental concerns, the economic benefits are also the key to affecting the activeness of participation in car-pooling and taxi ride-sharing for both drivers and passengers (Yuana et al., 2019).

Drivers' and passengers' participation in car-pooling and taxi ride-sharing is critical to the success of these shared mobility programs and the realization of the societal benefit, due to the scaling effects of these programs. The more the drivers and passengers participating in the shared mobility programs, the higher the probability of matching two travelers with similar schedules and itineraries, the smaller the expected detour distance incurred by the sharing of two rides, and the higher the societal benefit. Wang et al. (2018b) established a model to characterize private car owners' and non-private car owners' mode choices among car-pooling programs, auto driving, and public transport. Their model developed a matching function to spell out how the probability of matching drivers and passengers with similar schedules and itineraries changes with the numbers of drivers and passengers participating in car-pooling programs. Ke et al. (2020a) investigated the extent to which the adoption of ride-pooling services (in place of normal ride-sourcing services) reduces traffic congestion and passengers' travel time. They also found that the mass of passenger demand is essential to the success of ride-pooling services and their effects on reducing traffic congestion. Ke et al. (2020b) developed a model to characterize a ride-pooling service market, and pointed out that an increase in the number of passengers opting for ride-pooling service can bring positive effects, including increasing the probability of pool-matching and reducing the detour time of drivers and passengers. By repeatedly solving an optimization model for the pool matching of passengers and conducting sensitivity analyses, Ke et al. (2021) quantitatively measured the changes in matching probability, drivers' routing distance, and passengers' detour distance with respect to passengers' participation in ride-pooling services. The previous studies for ride-pooling services can provide some insights into the characteristics of taxi ride-sharing, due to the similarity of these two services mentioned above.

To encourage both drivers' and passengers' participation in car-pooling and taxi ride-sharing, various forms of monetary incentives have been introduced and examined in previous studies. Drivers who provide car-pooling services mainly benefit from subsidizing their travel costs and saving operational expenditures (Shaheen et al., 2016; Shen et al., 2021). Passengers who opt for taxi ride-sharing services generally enjoy a taxi fare discount, which compensates for the detour cost, additional waiting time cost, and uncomfortable cost caused by sharing a ride with another passenger. The discount on the taxi fare is an essential factor influencing passengers' willingness to switch from normal taxi (or ride-sourcing) services to taxi ride-sharing (or ride-pooling) services, as indicated by some previous studies for ride-pooling services, such as Ke et al. (2020a) and Zhang and Nie (2021).

Despite the above monetary incentives to both drivers and passengers, there exist some limitations during execution that may hinder system effectiveness. According to previous studies, drivers and passengers expressed their travel concerns about extra detour distances, the uncertainty of travel time, personal safety, privacy issue, ride-sharing with strangers, personal hygiene, the possibility of transmission coronavirus, and other aspects (Bachmann et al., 2018; Ciasullo et al., 2018; Hong, 2017; Pratt et al., 2019; Shokouhyar et al., 2021; Wang et al., 2019; 2020) that may limit their willingness to participate in car-pooling and taxi ride-sharing (or ride-pooling). Although there are studies of a single shared mobility service, there has been a lack of empirical evidence to verify the effects of monetary incentives and travel concerns on the *modal split* of both drivers and passengers among multiple shared mobility services. This study is one of the pioneer studies; it provides empirical evidence and determines the travel decisions of both drivers and passengers towards two typical shared mobility modes, car-pooling and taxi ride-sharing, at the same time.

In fact, the decisions of drivers and passengers determine the demand and supply of car-pooling services respectively and influence each other. Without studying their decisions simultaneously, the demand and supply equilibrium of the car-pooling market cannot be determined. Moreover, the competition between car-pooling and taxi ride-sharing markets has not been widely discussed in the literature. We believe that offering both car-pooling and taxi ride-sharing services at the same time to drivers and passengers can boost the overall selection probability of shared mobility services and hence suppress vehicle fleet size on the road. However, the benefits of these services might not be simply additive. The competition and joint effect should be analyzed. To address the above concerns, this study investigates the acceptance of drivers and passengers of car-pooling and taxi ride-sharing, taking Hong Kong as a case study. For an empirical evaluation, an on-street stated preference survey was conducted to interview both private car owners (who can be drivers or passengers, depending on their travel decisions) and non-private car owners (passengers). Based on the survey results, two logit-based discrete choice models were developed to depict their travel decisions separately. An equilibrium model was proposed and an iterative solution procedure was applied to balance the demand and supply of car-pooling services between drivers and passengers and obtain a convergent solution. To demonstrate the model application, sensitivity analyses were further conducted to obtain the probabilities of selecting different transport options under the variations in proportions of travel cost and taxi fare shared by passengers for car-pooling and taxi ride-sharing. Policy insights are suggested based on the model results and the sensitivity analyses. The survey findings, models developed, sensitivity analyses, and discussion on legalization and price regulation in this paper provide some valuable insights into promoting sustainable shared mobility, and alleviating traffic congestion and roadside emissions in Hong Kong, as well as other international cities that have a similar transportation system.

The main contributions of this paper are as follows.
(1) It provides empirical evidence to verify the effects of monetary incentives and travel concerns on the modal split of both drivers and passengers among multiple shared mobility services, and proposes logit-based discrete choice models to determine the critical explanatory variables that simultaneously influence travelers' decisions in car-pooling and taxi ride-sharing;
(2) It offers an equilibrium model and an iterative solution procedure to predict the probabilities of selecting different transport options, including two competing shared mobility options; and
(3) It presents the anticipated overall selection probability of shared mobility services, and recommends transport policy in promoting sustainable shared mobility.

This paper comprises this introduction and four other sections. Section 2 describes the data collection methodology, the socio-demographic characteristics and concerns regarding shared mobility services of the interviewed private car owners and non-private car owners, and the settings of the stated preference survey. Section 3 presents the formulations of logit-based discrete choice models, and introduces the proposed equilibrium model, iterative solution procedure, and the procedure of sensitivity analyses. Section 4 discusses the results of models and the sensitivity analyses, and provides policy insights into promoting sustainable shared mobility. Section 5 summarizes the paper and recommends a future research direction.

2. DATA

2.1 Data collection

This study takes Hong Kong as a case study to investigate the acceptance of drivers and passengers of car-pooling and taxi ride-sharing. Hong Kong has a well-connected transport network, comprising both public and private transport. According to the most updated source in the public domain, most of the daily trips are made using public transport (e.g., trains and buses) accounting for 82.3% of the daily trips, while private cars and taxis take 11.3% and 6.4%, respectively (Transport Advisory Committee, 2014). Despite private cars and taxis carrying less than 20% of trips, they are often regarded as major contributors to traffic congestion and roadside emissions. Firstly, private cars correspond to nearly 70% of the total number of licensed vehicles, and we have experienced a high growth rate in recent years. The average annual growth rate of private cars rose by 4% between 2009 and 2018, resulting in about a 40% increase compared to 2008 (Research Office of Legislative Council Secretariat, 2019a). The estimated vehicle journey of private cars rose by 36% between 2010 and 2020 to 6,340 million vehicle-kilometers, which accounted for nearly half of all vehicle journeys (Research Office of Legislative Council Secretariat, 2022). Secondly, taxis offer 24-hour, personalized point-to-point services. Due to their unique operational characteristics, they occupy an average of 25% of road space thus reducing road capacity for other road-based transport modes (Szeto et al., 2019). Hong Kong has over 565,000 registered private cars, equivalent to 76.3 per 1,000 population (Research Office of Legislative Council Secretariat, 2019a), and 18,163 registered taxis, equivalent to 2.4 taxis per 1,000 population (Research Office of Legislative Council Secretariat, 2019b). On the other hand, their occupancy rates are much lower than other public transport modes. The average occupancy of private cars is about 1.4 (including the driver) in critical urban areas (all cross-harbour vehicular trips) (Transport Department, 2022). The average occupancy of urban taxis is approximately 1.4 (excluding the taxi driver) for occupied trips (Legislative Council Panel on Transport, 2015). This suggests that most private car drivers and taxi passengers tend to travel alone.

Although private cars and taxis are considered less efficient passenger carriers, they may be essential to certain travelers, particularly those traveling to locations with limited access to public transport, those with specific travel needs that require point-to-point service (e.g., the elderly and people with disability), or those who are not familiar with local public transport services (e.g., tourists). Instead of mandating a modal shift of the existing travelers from private cars and taxis to public transport, promoting car-pooling and taxi ride-sharing can serve as an alternative approach to managing fleet sizes on roads and increasing occupancy rates. This enhances the efficiency of road space usage while still accommodating the needs of those who rely on private cars and taxis.

To address these issues, a stated preference survey was conducted to examine the preference of private car owners and non-private car owners for car-pooling and taxi ride-sharing, and to obtain the model coefficients for model application and policy analysis. The survey was conducted on-street in various districts of Hong Kong by face-to-face interviews from 12 October 2020 to 1 March 2021, both in the daytime and at night. Respondents were approached by random sampling to prevent bias, and interviewed by our surveyors in around ten minutes. In total, 829 respondents, including 257 private car owners and 572 non-private car owners were successfully interviewed. The socio-demographic characteristics and concerns regarding shared mobility services of the respondents, and the decisions of selecting different transport options in three hypothetical scenarios (by assuming all the given options were legally operated) were asked. Hence, 2,487 observations were obtained in the survey for model development.

2.2 Socio-demographic characteristics and concerns regarding shared mobility services

Table 1 demonstrates the socio-demographic characteristics of the respondents in the stated preference survey. For the interviewed private car owners, it is noted that close to 90% of them were male. All interviewed private car owners aged above 18 years (i.e., the lowest driving age in Hong Kong) and the group between 30 and 49 years has the highest proportion. For the occupation, 90% of them had either a full-time or part-time job. They were highly educated up to the tertiary level in general, and about half of them had a high personal monthly income of more than HK$40,000. Among the interviewed non-private car owners, the gender was evenly distributed, while 54% were male and 46% were female. Most of them (40.2%) were in the age group of 18–29 years. 63% of the respondents had a full-time or part-time job, 22% of them were students, and the remaining 16% were either homemakers, retired, unemployed, tourist, or others. For the education level, slightly less than 70% of them reported that they were educated at the tertiary level or above. About 60% of them earned less than HK$20,000 a month. It is observed that the socio-demographic characteristics of these two groups were substantially different. Hence, two sets of model coefficients should be calibrated to explain their travel decisions.

Table 1. Socio-demographic characteristics of the interviewed private car owners and non-private car owners

Personal particulars	Group	Frequency (Percentage)	
		Private car owners (Sample size = 257)	Non-private car owners (Sample size = 572)
Gender	Male	228 (88.7%)	308 (53.8%)
	Female	29 (11.3%)	264 (46.2%)
Age	Below 18 years	0 (0.0%)	25 (4.4%)
	18–29 years	37 (14.4%)	230 (40.2%)
	30–49 years	157 (61.1%)	214 (37.4%)
	50–64 years	56 (21.8%)	79 (13.8%)
	65 years or above	7 (2.7%)	24 (4.2%)
Occupation	Full-time job	217 (84.4%)	323 (56.5%)
	Part-time job	14 (5.4%)	35 (6.1%)
	Student	8 (3.1%)	126 (22.0%)
	Homemaker	6 (2.3%)	47 (8.2%)
	Others (e.g., retired, unemployed, tourist, etc.)	12 (4.7%)	41 (7.2%)
Education	Primary or below	2 (0.8%)	11 (1.9%)
	Secondary	59 (23.0%)	176 (30.8%)
	Tertiary or above	196 (76.3%)	385 (67.3%)
Personal monthly income	HK$10,000 or below	26 (10.1%)	216 (37.8%)
	HK $10,001–20,000	22 (8.6%)	118 (20.6%)
	HK $20,000–30,000	44 (17.1%)	102 (17.8%)
	HK $30,000–40,000	43 (16.7%)	72 (12.6%)
	HK $40,001 or above	122 (47.5%)	64 (11.2%)

In our survey, the respondents were asked two questions about their concerns regarding shared mobility services. For car-pooling, the major concerns of the respondents were legality (46.7%), personal safety (e.g., the risk of robbery) (44.7%), and prefer not traveling with strangers (44.0%). Concerning taxi ride-sharing, the main reasons for not choosing this were hygiene concerns (50.2%), lack of privacy (41.4%), and additional time required to wait for another passenger (40.0%). Overall, the respondents valued their privacy and were hesitant to travel with strangers, and they preferred a direct mode of transport without spending additional time waiting for others.

2.3 Car-pooling and taxi ride-sharing options

A private car owner has five alternative transport modes related to car-pooling and taxi ride-sharing: Option I – Driving a private car alone, Option II – Driving a private car and carrying a passenger (as a car-pooling driver), Option III – Taking a private car (as a car-pooling passenger), Option IV – Taking a taxi alone, and Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger). In contrast, for a non-private car owner, the first two options are considered infeasible. He/she has only three possible alternatives: Options III to V.

Three potential attributes influence the transport decisions of travelers, namely, the out-of-pocket cost, in-vehicle travel time, and out-of-vehicle time. The out-of-pocket cost of the driving modes is calculated by adding the fuel cost and toll charge of the trip, and subtracting the out-of-pocket cost shared by a passenger (if any) from the sum. The out-of-pocket cost of the riding modes is simply regarded as the shared cost paid to the private car driver for car-pooling, the taxi fare to the taxi driver for traveling alone, or the shared taxi fare paid to the taxi driver for taxi ride-sharing. Fare reduction is found as a crucial factor to attract passengers to shift from their original transport mode to a car-pooling or taxi ride-sharing option (Amirkiaee and Evangelopoulos, 2018; Ke et al., 2020b). The in-vehicle travel time includes the normal journey time from origin to destination, plus the detouring and waiting time for taking a passenger (if any). The in-vehicle travel time for car-pooling or taxi ride-sharing trips is usually longer than that of original trips, unless car-pooling or taxi ride-sharing can effectively mitigate traffic congestion (Yin et al., 2018). The out-of-vehicle time is the sum of walking time (i.e., from the origin to the car park and from the car park to the destination for the driver, and from the origin to the pick-up point and from the drop-off point to the destination for the passenger) and waiting time for services (which equals zero for the driver). The out-of-vehicle time is an indispensable factor that affects car-pooling or taxi ride-sharing participation intention (Cetin and Deakin, 2019).

Table 2 shows the explanatory variables and their corresponding levels for the five travel options. All these quantitative attributes have three levels for capturing potential linear effects. The levels of each attribute were thoroughly carefully reviewed to ensure they accurately reflect the actual situation and tested in a pilot survey. For instance, we identified that the private car drivers generally had reservations about sharing their car with the car-pooling passengers. In the case where we attempted to set the out-of-pocket costs for Options I and II at similar levels, almost no driver selected Option I because of the limited incentive. Hence, we increased the shared cost contributed by the car-pooling passengers to make this car-pooling program more attractive. The arrangement of the taxi fare level setting is similar.

For the in-vehicle travel time, there is no detour for the car-pooling passengers (Option III), because it is expected that the car-pooling drivers take the shortest path from the origin of the car-pooling passengers to their destination. For Options I and II, the drivers have to additionally drive from/to car parks, which makes their in-vehicle travel times longer than those of the passengers (Option III). Additionally, to serve the car-pooling passengers, the trips of car-pooling drivers are detoured, which makes Option II have the longest in-vehicle travel time among these three options.

The orthogonal fractional factorial design method, which is a statistical method that only partially chooses the experiment sets among all possible combination sets, was adopted to generate 54 profiles (27 profiles for the private car owners and 27 profiles for the non-private car owners) for the stated preference survey. The choice set was randomly divided and distributed into 18 sets of questionnaires (nine sets of questionnaires for each group). Three hypothetical situations were given to each respondent for selecting their travel options.

Table 2. Explanatory variables and levels applied in the stated preference survey

Travel options	Explanatory variables	Levels
Option I – Driving a private car alone	Out-of-pocket cost (HK$)	90, 100, 110
	In-vehicle travel time (min)	21, 24, 27
	Out-of-vehicle time (min)	13, 15, 17
Option II – Driving a private car and carrying a passenger (as a car-pooling driver)	Out-of-pocket cost (HK$)	12, 15, 18
	In-vehicle travel time (min)	29, 32, 35
	Out-of-vehicle time (min)	13, 15, 17
Option III – Taking a private car (as a car-pooling passenger)	Out-of-pocket cost (HK$)	55, 65, 75
	In-vehicle travel time (min)	10, 15, 20
	Out-of-vehicle time (min)	2, 4, 6
Option IV – Taking a taxi alone	Out-of-pocket cost (HK$)	40, 50, 60
	In-vehicle travel time (min)	10, 15, 20
	Out-of-vehicle time (min)	1, 3, 5
Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger)	Out-of-pocket cost (HK$)	17, 20, 23
	In-vehicle travel time (min)	22, 25, 28
	Out-of-vehicle time (min)	7, 8, 9

3. METHODOLOGY

3.1 Formulation of discrete choice models

To predict the travel decisions of both private car owners and non-private car owners, a nested logit (NL) model and a multinomial logit (MNL) model are proposed respectively. Figure 1 shows the model structure. Option I – Driving a private car alone, and Option II – Driving a private car and carrying a passenger (as a car-pooling driver) are under the nest of driving. Option III – Taking a private car (as a car-pooling passenger), Option IV – Taking a taxi alone, and Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger) are under the nest of riding.

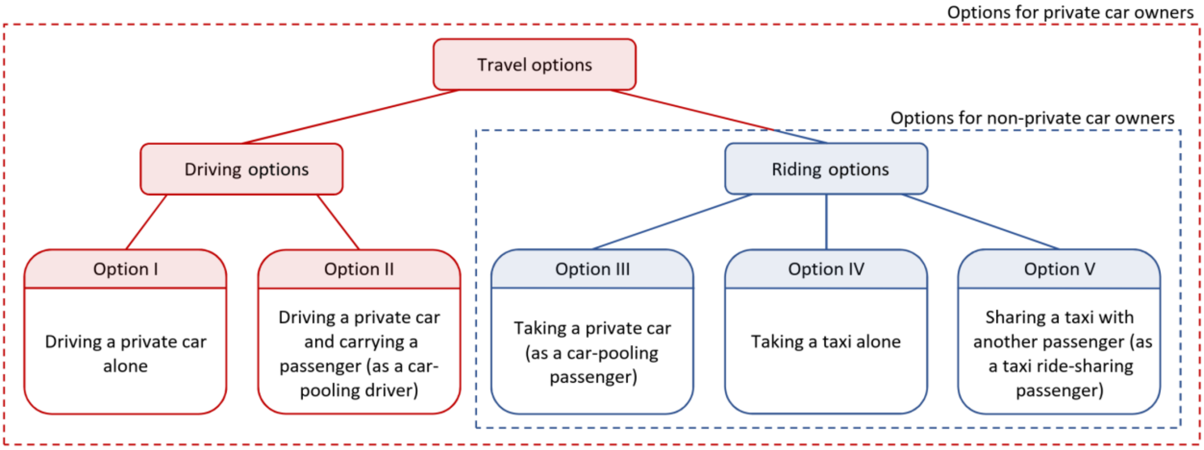


Figure 1. Discrete choice model structure

The NL model for private car owners

The NL model for transport options of private car owners consists of two levels of nests, which takes the following form (Williams, 1977; Daly and Zachary, 1978):

$$P_i^m = P_i(m \mid n) P_i(n), \quad (1)$$

where P_i^m is the probability that an individual private car owner i selects alternative transport option m, where $m \in M$. M is the set of possible transport options, and $M = \{\text{I, II, III, IV, V}\}$

for this case. It is calculated by the probability of choosing branch *n* in the upper nest, $P_i(n)$, multiplied by the conditional probability of choosing alternative *m* in the lower nest given the choice of branch *n*, $P_i(m \mid n)$.

The probability of choosing alternative *m* in the lower nest is

$$P_i(m \mid n) = \frac{\exp U_i^m}{\sum_{g \in A_n} \exp U_i^g} \text{, and} \tag{2}$$

$$U_i^m = \lambda_i^{\mathrm{C}} C^m + \lambda_i^{\mathrm{T}} T^m + \lambda_i^{\mathrm{O}} O^m + \lambda_i^{\mathrm{D}} D^m \text{,} \tag{3}$$

where U_i^m is the deterministic utility of alternative transport option *m* for an individual private car owner *i*, which is commonly used to describe the degree of satisfaction that travelers derive from their alternatives. A_n is the set of alternatives under branch *n* in the lower nest. C^m, T^m, and are the out-of-pocket cost, the in-vehicle travel time, and the out-of-vehicle time of transport option *m*, respectively. D^m is the dummy variable additionally introduced to reflect the disutility (unwillingness) of car-pooling or taxi ride-sharing to share a ride with a stranger, which equals one when a traveler selects Option II – Driving a private car and carrying a passenger (as a car-pooling driver), Option III – Taking a private car (as a car-pooling passenger), or Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger), and zero otherwise. λ_i^{C}, λ_i^{T}, λ_i^{O}, and λ_i^{D} are the corresponding model coefficients of the associated explanatory variables for an individual private car owner *i*. It is assumed that every private car owner has the same perception concerning each of the above attributes in this study. Therefore, the coefficient of each attribute is the same for all private car owners. Moreover, it is reasonable to expect that a private car driver prefers driving alone, and a taxi passenger prefers taking a taxi alone. The nature is very similar. We believe it is reasonable to use a single dummy variable to reflect the car-pooling/taxi-sharing behaviour.

The probability of selecting branch *n* in the upper nest is

$$P_i(n) = \frac{\exp\left[\theta_n S_i(n)\right]}{\sum_{h \in B} \exp\left[\theta_h S_i(h)\right]} \text{, and} \tag{4}$$

$$S_i(n) = \ln \sum_{g \in A_n} \exp\left[U_i(g \mid n)\right], \tag{5}$$

where $S_i(n)$ is the logsum variable for all alternatives of an individual private car owner *i* under branch *n*. *B* is the set of branches in the upper nest. θ_n is the corresponding parameter capturing the correlation between alternatives within branch *n*, where $0 < \theta_n \leq 1$. With a smaller value of θ_n, the alternatives are likely to be more correlated. In contrast, when $\theta_n = 1$, an NL model reduces to an equivalent MNL.

The MNL model for non-private car owners

Since the first two driving options are infeasible to non-private car owners, the MNL model has only three options, namely Option III – Taking a private car (as a car-pooling passenger), Option IV – Taking a taxi alone, and Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger). It takes the following form (Domencich and McFadden, 1975):

$$Q_j^m = \frac{\exp U_j^m}{\sum_{g \in A} \exp U_j^g}, \text{ and} \quad (6)$$

$$U_j^m = \lambda_j^{\mathrm{C}} C^m + \lambda_j^{\mathrm{T}} T^m + \lambda_j^{\mathrm{O}} O^m + \lambda_j^{\mathrm{D}} D^m, \quad (7)$$

where Q_j^m is the probability that an individual non-private car owner *j* selects alternative transport mode *m*. A is the set of alternatives for non-private car owners. Since Options I and II are excluded for non-private car owner *j*, $Q_j^{\mathrm{I}} = Q_j^{\mathrm{II}} = 0$. U_j^m is the deterministic utility, and λ_j^{C}, λ_j^{T}, λ_j^{O}, and λ_j^{D} are the corresponding model coefficients of the associated explanatory variables for an individual non-private car owner *j*. In this study, it is assumed that all non-private car owners have an identical perception concerning each of the above attributes. Hence, the coefficient of each attribute does not vary among non-private car owners.

Relationships between the explanatory variables in different options

There are relationships between the out-of-pocket costs among different options related to car-pooling and taxi ride-sharing. This study makes two assumptions to simplify and reflect the actual operations of shared mobility services. (1) The proposed car-pooling (or taxi ride-sharing) program is targeted at travelers with similar schedules and itineraries for sharing their travel costs (or taxi fares). As such, their journeys may be partially overlapped, but their origins and destinations may not be exactly the same. The car-pooling drivers additionally access and drive from/to car parks, resulting in longer in-vehicle travel and out-of-vehicle times compared to those of the car-pooling passengers. In contrast, taxi ride-sharing passengers have the same in-vehicle travel and out-of-vehicle times, and pay the same taxi fare. (2) Considering the operational complexity and capacities of a private car and a taxi, car-pooling (or taxi ride-sharing) can only accommodate two groups of people, including a car-pooling driver (with his/her co-rider, if any) plus a car-pooling passenger (with his/her co-rider, if any), or two taxi passengers (with their associated co-riders, if any, excluding the taxi driver). The travel cost (or taxi fare) is shared on a group basis. This group concept is not highlighted in the rest of this paper to keep the discussions simple.

Based on the above assumptions, the out-of-pocket cost paid by a car-pooling passenger for Option III, C^{III}, is calculated as a proportion of that of driving a private car alone (Option I), C^{I}. That is,

$$C^{\mathrm{III}} = \alpha C^{\mathrm{I}}, \quad (8)$$

where α is the percentage of the out-of-pocket cost contributed by a car-pooling passenger and is a parameter. The driver selects Option II – Driving a private car and carrying a passenger (as a car-pooling driver) will pay the out-of-pocket cost less by C^{III}. In addition, considering the potential financial incentive (ζ), such as a reduction in or exemption of toll charge, offered by the government to encourage car-pooling. The travel cost can then be expressed as

$$C^{\mathrm{II}} = C^{\mathrm{I}} - C^{\mathrm{III}} - \zeta. \quad (9)$$

Similar to car-pooling, a passenger selects Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger) has to share the taxi fare with another passenger, and can pay less. However, it may not be necessarily an equal split. The total taxi fare from two passengers could be higher than the regular taxi fare of a normal trip taking one passenger (Option IV), C^{IV}, to incentivize more taxi drivers to offer a taxi ride-sharing service. Let C^{V} be the taxi fare paid by each taxi ride-sharing passenger, and it can be calculated as

$$C^{\mathrm{V}} = \beta C^{\mathrm{IV}}, \tag{10}$$

where β is the percentage of the regular taxi fare paid by each taxi ride-sharing passenger and is a parameter.

The out-of-pocket cost for car-pooling depends on the fuel cost and toll charge, while the out-of-pocket cost for taxi ride-sharing depends on the taxi fare. Their factors are different. Therefore, there is no direct relationship between the shared mobility options.

The weighted probability of selecting different options

In order to find out the overall probabilities of all travelers (including both private and non-private car owners) selecting different travel options, the weighted probability of selecting travel option *m*, R^m , is expressed as

$$R^m = \mu P_i^m + (1-\mu) Q_j^m, \tag{11}$$

where μ is the percentage of private car owners of the personalized transport mode users. By adding the associated probabilities, the overall probability of selecting shared mobility (car-pooling and taxi ride-sharing) services, $\overline{R}$, can be determined by

$$\overline{R} = R^{\mathrm{II}} + R^{\mathrm{III}} + R^{\mathrm{V}}. \tag{12}$$

3.2 The equilibrium model

According to the model formulation, Options II and III are actually related to the supply and demand for car-pooling services between drivers and passengers. If the demand is much higher than the supply, the out-of-vehicle time (i.e., waiting time for services) of passengers for car-pooling, O^{III}, will be obviously prolonged, and hence the selection probability is reduced, and vice versa. In contrast, the out-of-pocket cost and in-vehicle travel time will not be changed, as they depend on the trip itinerary, but not the demand and supply. Accordingly, the car-pooling market is self-adjusted to strike a balance on the probabilities of choosing Option II – Driving a private car and carrying a passenger (as a car-pooling driver) and Option III – Taking a private car (as a car-pooling passenger). It reaches an equilibrium where the weighted probability of selecting Option II, R^{II}, equals that of selecting Option III, . R^{III} .:

$$R^{\mathrm{II}} = R^{\mathrm{III}}. \tag{13}$$

An equilibrium model is then constructed and consists of Equations (1) – (11) and (13). We aim to determine R^{II} to satisfy these equations.

3.3 The iterative solution procedure and sensitivity analyses

To obtain a solution for the proposed equilibrium model, an iterative solution procedure is applied. This approach has been widely adopted in some previous studies (Wong et al., 2015; Yang et al., 2018). An adjustment factor for the out-of-vehicle time is adopted in this procedure and expressed as follows:

$$\phi^{(k)} = \begin{cases} (1-\delta), & \text{if } R^{\mathrm{II}(k)} - R^{\mathrm{III}(k)} > \varepsilon \\ (1+\delta), & \text{if } R^{\mathrm{III}(k)} - R^{\mathrm{II}(k)} > \varepsilon \end{cases}, \text{ and} \tag{14}$$

$$O^{\mathrm{III}(k)} = \phi^{(k)} O^{\mathrm{III}(k-1)}, \tag{15}$$

where $0 < \delta < 1$, $\varepsilon > 0$. $\phi^{(k)}$ is the adjustment factor in iteration *k*. $R^{\mathrm{II}(k)}$ and $R^{\mathrm{III}(k)}$ are the weighted probabilities of choosing Option II – Driving a private car and carrying a passenger (as a car-pooling driver), and Option III – Taking a private car (as a car-pooling passenger), respectively. If the difference between these two probabilities is within the acceptable tolerance

ε, no adjustment is made to the out-of-vehicle time of passengers for car-pooling, O^{III}. Otherwise, either the reduction factor $(1-\delta)$ or the expansion factor $(1+\delta)$ is applied. Equations (14) and (15) are used to adjust the out-of-vehicle time for car-pooling in Equations (3) and (7) during the iterative solution procedure until a convergent solution is obtained. The procedure can be summarized as follows:

Step 1 – Initialization and parameter setting
Initialize C^m, T^m, and O^m. Set α, ζ, β, μ, δ, and ε. Set the iteration number $k=1$.
Step 2 – Compute the weighted probabilities of selecting different travel options
Apply the discrete choice models in Equations (1) to (11) based on the out-of-vehicle time of passengers for car-pooling $O^{\mathrm{III}(k-1)}$ in iteration $k-1$ to obtain $R^{m(k)}$ for all travel options *m*.
Step 3 – Convergence test
If the absolute difference of the weighted probabilities of selecting Options II and III is within an acceptable tolerance, $\left|R^{\mathrm{II}(k)}-R^{\mathrm{III}(k)}\right| \le \varepsilon$, then stop; otherwise, go to Step 4.
Step 4 – Adjust the out-of-vehicle time of passengers for car-pooling
Adjust the out-of-vehicle time of passengers for car-pooling $O^{\mathrm{III}(k)}$ according to Equations (14) and (15). Then set $k=k+1$, and go to Step 2.

Sensitivity analyses are carried out by repeatedly solving the proposed equilibrium model by the above iterative solution procedure for different combinations of the percentage of out-of-pocket cost shared by a car-pooling passenger, α, the percentage of taxi fare paid by a taxi ride-sharing passenger, β, and the percentage of private car ownership, μ, to examine their influences to the overall selection probabilities.

4. RESULTS AND DISCUSSION

4.1 Results of nested logit and multinomial logit models

NLOGIT, an extension of the econometric and statistical software package LIMDEP, was adopted to calibrate the coefficients of each explanatory variable using the maximum likelihood estimation method. The coefficients of explanatory variables of both NL and MNL models are presented in Table 3.

Table 3. Coefficients and t-statistics of NL and MNL models

Explanatory variables	Coefficients (t-statistics)	
	Nested logit model (for private car owners)	Multinomial logit model (for non-private car owners)
Out-of-pocket cost (HK$)	-0.004 [b] (-1.6)	-0.035 [a] (-12.1)
In-vehicle travel time (min)	-0.077 [a] (-3.6)	-0.069 [a] (-6.5)
Out-of-vehicle time (min)	-0.002 (-0.1)	-0.149 [a] (-6.9)
Dummy variable for car-pooling or taxi ride-sharing	-0.652 [a] (-5.1)	-0.487 [a] (-6.6)
Logsum of driving nest	0.269 [b] (1.9)	--
Logsum of riding nest	0.586 [b] (1.7)	--

Notes: [a] parameters are significant at the 1% level; [b] parameters are significant at the 10% level.

For the NL model for private car owners, all attributes show negative coefficients and most of them are significant at the 1% or 10% level, which are logical and meet our expectations. It implies that the private car owners prefer selecting a travel option with a lower out-of-pocket cost, in-vehicle travel time, and out-of-vehicle time. The absolute value of the coefficient of the dummy variable for car-pooling or taxi ride-sharing (0.652) is the largest among all attributes, which means that the private car owners have a rather strong reluctance to participate in car-pooling and taxi ride-sharing probably because of the travel concerns, including personal safety (e.g., the risk of robbery) and prefer not traveling with strangers due to hygiene and privacy concerns, as reported by the respondents.

The logsum parameters were additionally calibrated for the two nests of driving and riding, with the values at 0.269 and 0.586, respectively, and they are both significant at the 10% level. As both these values range from zero and one, it statistically confirms the correlations between Option I – Driving a private car alone, and Option II – Driving a private car and carrying a passenger (as a car-pooling driver) under the nest of driving, and between Option III – Taking a private car (as a car-pooling passenger), Option IV – Taking a taxi alone, and Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger) under the nest of riding.

The MNL model for non-private car owners demonstrates similar results, in which all the attributes have negative coefficients and are significant at the 1% level. It is worth mentioning that the coefficient of the dummy variable for car-pooling or taxi ride-sharing is -0.487. The findings show that the non-private car owners are less resisting car-pooling or taxi ride-sharing than their counterparts in general.

4.2 Results of sensitivity analyses

To demonstrate the equilibrium model application, the sensitivity analyses were carried out to obtain the probability of selecting different travel options when the percentage of the out-of-pocket cost shared by a car-pooling passenger, α, ranges from 25% to 75%, and the percentage of taxi fare shared by a taxi ride-sharing passenger, β, ranges from 50% to 100%. It is assumed that all the explanatory variables take the middle value of the levels as tabulated in Table 2, except the out-of-pocket costs of shared mobility options, C^{II}, C^{III}, and C^{V}, which are calculated by Equations (8) to (10). No financial incentive, ζ, is offered by the government, and the iterative solution procedure parameters, δ and ε, are 0.01 and 0.0001, respectively.

According to the statistics (Transport Advisory Committee, 2014), 11.3% of daily trips are made by private cars. Given that the occupancy rate is 1.4 (Transport Department, 2023), this breaks down to 8.1% as private car drivers and 3.2% as private car passengers. 6.4% of trips are made by taxis, with all travelers as taxi passengers. Based on these figures, it is estimated that out of all personalized transport users, approximately 45% are drivers (i.e., 8.1/17.7). In view of this percentage being highly fluctuated and varied by multiple components, two cases, namely a higher private car ownership percentage ($\mu = 60\%$) as well as a lower private car ownership percentage ($\mu = 30\%$), are considered in these sensitivity analyses. We believe that the anticipated overall selection probability of shared mobility services will be controlled with these upper and lower bounds under different private car ownership percentages.

Figure 2 presents the results of sensitivity analysis when different percentages of out-of-pocket cost shared by a car-pooling passenger, and different percentages of taxi fare paid by a taxi ride-sharing passenger are applied in the higher private car ownership case. Figure 2(a) portrays the probability of travelers selecting Option I – Driving a private car alone. The result shows that a lower taxi fare for taxi ride-sharing passengers and a higher monetary compensation (i.e., travel cost of the trip shared by the passengers) to car-pooling drivers lead to a smaller probability of travelers driving alone. It is noted that the probability decreases from 22.6% to

21.3% from bottom-right to top-left, or equivalently the probability has a 5.8% reduction. Both the car-pooling compensation and taxi ride-sharing discount are attractive to the drivers for car-pooling. From Figure 2(b), we can observe that the probability of travelers selecting Option II – Driving a private car and carrying a passenger (as a car-pooling driver), or Option III – Taking a private car (as a car-pooling passenger) gradually decreases from about 8.1% to 7.0% when the percentage of out-of-pocket cost shared by a car-pooling passenger decreases from 75% to 25%. It is because a lower out-of-pocket cost of the car-pooling passengers leads to a higher out-of-pocket cost of the car-pooling drivers. This makes the intention of drivers participating in the car-pooling program lower, and more drivers drive alone, and hence the supply of car-pooling is lower and the required out-of-vehicle time of passengers for car-pooling is higher. Besides, the contour lines are almost horizontal, which implies that the influence of shared taxi fare for car-pooling is minimal. Figure 2(c) illustrates the variation in the probability of travelers taking a taxi alone (Option IV), which shows that a higher shared taxi fare paid by a taxi ride-sharing passenger attracts more travelers taking a taxi alone. For instance, given that the out-of-pocket cost shared by a car-pooling passenger is fixed at 50% (i.e., the driver and passenger equally split the cost), the probability increases from 47.8% to 53.4%. It is interesting to find that lowering the compensation paid by a car-pooling passenger will also increase this probability. A possible reason is that the required waiting time for car-pooling will be dramatically boosted. Figure 2(d) presents the probability of travelers selecting Option V – Sharing a taxi with another passenger (as a taxi ride-sharing passenger). It is noted that when a lower percentage of the shared cost for car-pooling passengers and a lower percentage of shared taxi fare for taxi ride-sharing passengers, more travelers are willing to choose Option V, with the probability steadily increasing from 9.4% to 15.3%.

In view of the MNL model structure, the ratio of probabilities within the nest of riding for drivers (Figures 2(b), 2(c), and 2(d)) is exactly the same as that of passengers. The shape of contours in the figures for private car owners and non-private car owners for the same option is therefore the same and is not shown here for simplicity.

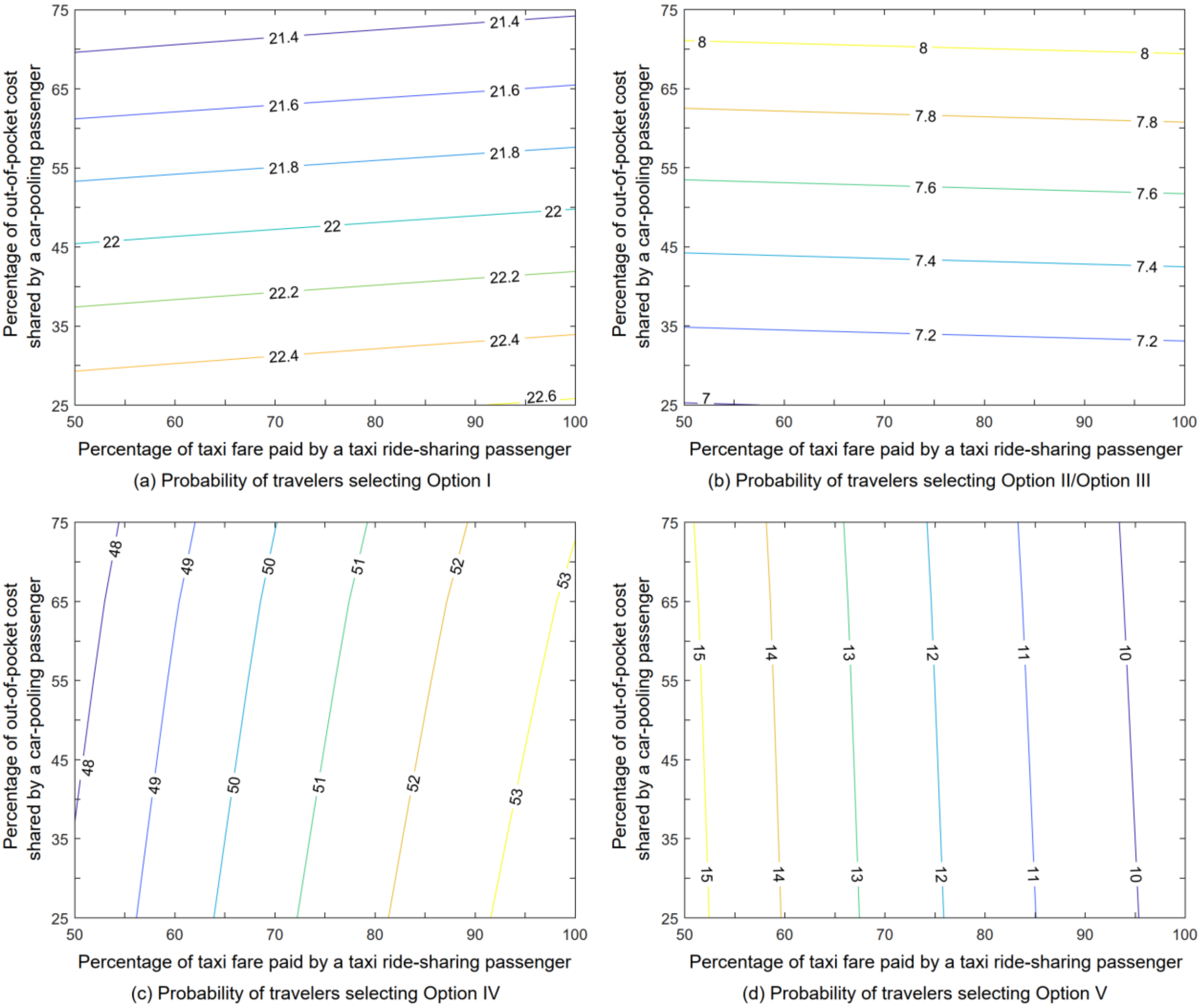


Figure 2. Sensitivity analysis of different percentages of out-of-pocket cost shared by a car-pooling passenger, and different percentages of taxi fare paid by a taxi ride-sharing passenger in the higher private car ownership case

Figure 3 stipulates the results of sensitivity analysis for the selection probabilities in the lower private car ownership case. From Figures 3(a) and 3(b), it is observed that the patterns of contour lines for selection probabilities of Option I – Driving a private car alone, and Option II – Driving a private car and carrying a passenger (as a car-pooling driver), or Option III – Taking a private car, are quite similar to those in Figure 2 but the probabilities are reduced by half. Only 11.3% of travelers will drive alone at most, and not more than 5% will select car-pooling as a driver or a passenger in all attempted scenarios. Figure 3(c) shows the probability of travelers choosing Option IV – Taking a taxi alone. If a taxi ride-sharing passenger has to pay the original taxi fare (i.e., no fare discount), about 70% of them will take a taxi alone. Figure 3(d) illustrates the probability of travelers sharing a taxi with another passenger (Option V). We can see that the contour lines are close to vertical, which means that the variation in the percentage of out-of-pocket cost shared by a car-pooling passenger has a limited effect on the decision of taxi ride-sharing. The probability reduces from about 20.7% to 11.1% when the percentage of taxi fare paid by a taxi ride-sharing passenger increases from 50% to 100%.

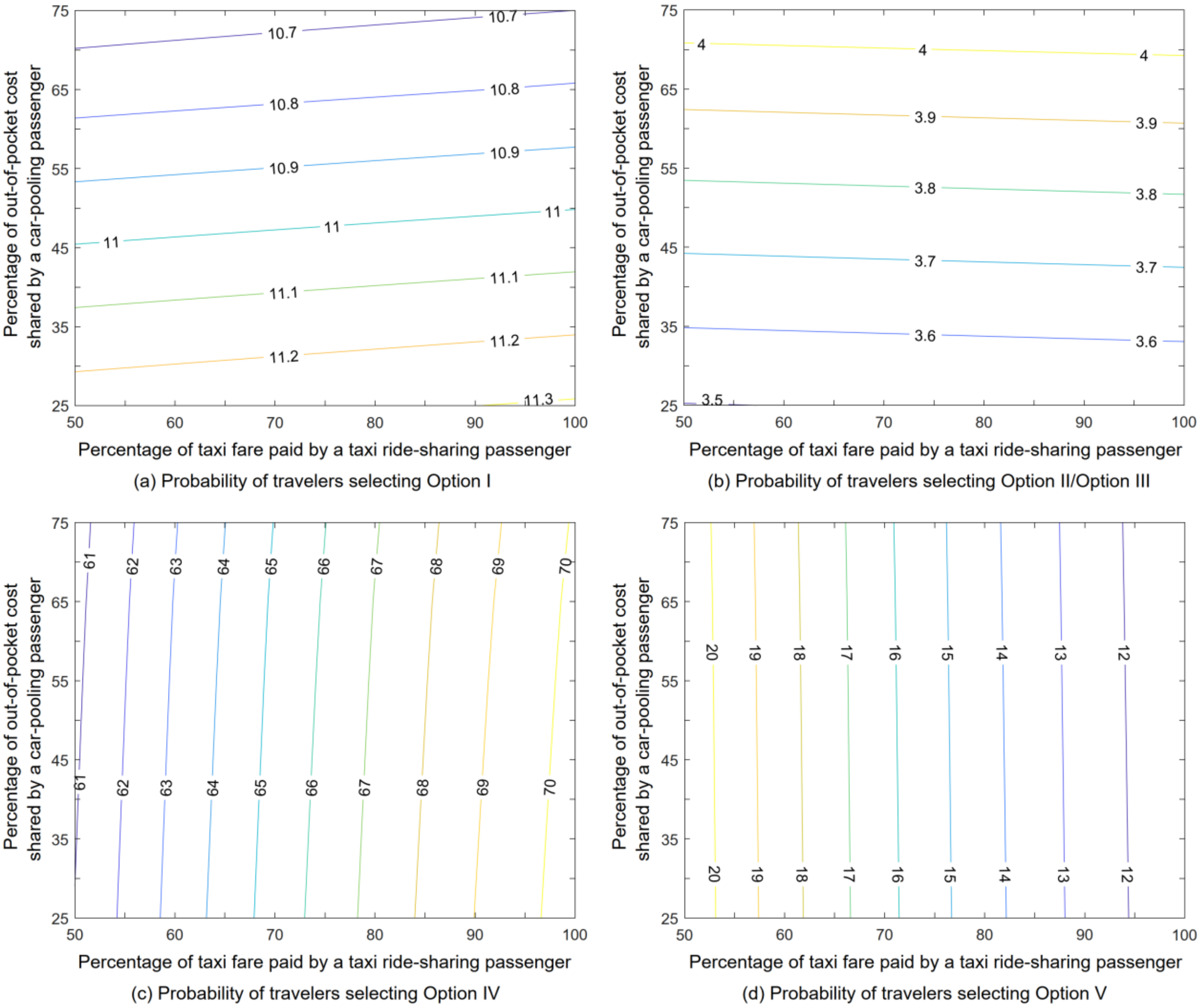
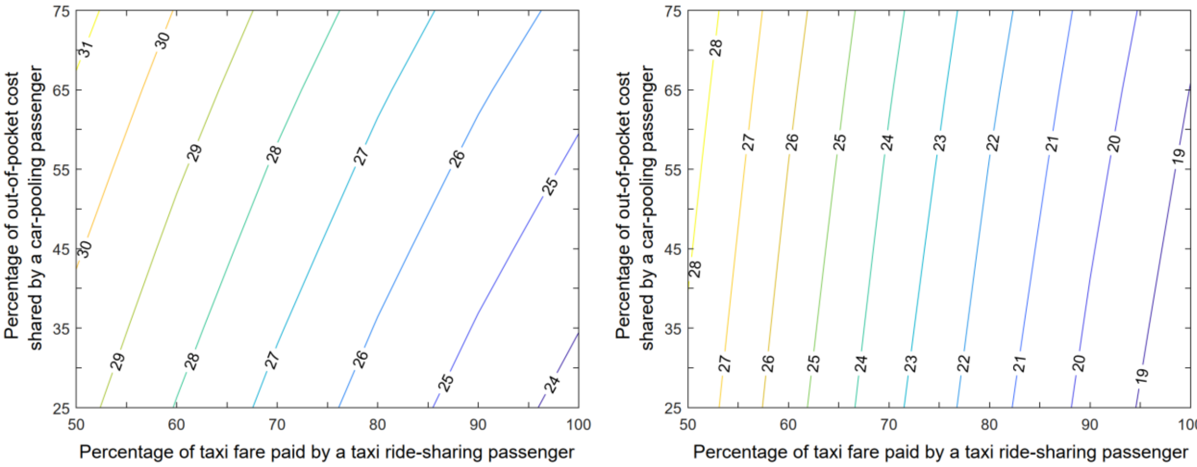


Figure 3. Sensitivity analysis of different percentages of out-of-pocket cost shared by a car-pooling passenger, and different percentages of taxi fare paid by a taxi ride-sharing passenger in the lower private car ownership case

Figure 4 shows the overall probabilities of selecting shared mobility services (for Options II, III, and V). It is noted that the probabilities in both cases reach their peaks when the percentage of out-of-pocket cost shared by a car-pooling passenger is 75%, and the percentage of taxi fare paid by a taxi ride-sharing passenger is 50%. The anticipated highest probabilities are 31.3% and 28.7%, respectively, for the higher and lower private car ownership cases, in which the difference is not substantial. The results demonstrate that this combination of percentages of shared cost and taxi fare effectively can attract private car owners offering car-pooling services and the taxi passengers sharing a taxi with another passenger, and suppresses vehicle fleet size on the road.



(a) Probability of travelers selecting shared mobility options in a higher private car ownership case

(b) Probability of travelers selecting shared mobility options in a lower private car ownership case

Figure 4. The overall weighted probability of selecting shared mobility options

4.3 Policy insights in promoting sustainable shared mobility services

The results of sensitivity analyses demonstrate that the percentage of the out-of-pocket cost shared by a car-pooling passenger and the percentage of taxi fare paid by a taxi ride-sharing passenger can effectively influence travelers' decisions towards shared mobility. The results also illustrate that different combinations of percentages of shared cost and taxi fare can effectively increase the probability of selecting shared mobility options up to around 20-30% in the given cases, which implies that promoting multiple shared mobility services can suppress vehicle fleet size on the road by increasing the occupancy rate of a vehicle, and can bring other benefits such as reducing total vehicle-miles-travelled, reducing roadside emissions, and energy consumption. However, shared mobility options are now illegal in Hong Kong and some other cities and countries. The legalization of shared mobility should be actively considered by governments and policy makers.

In Hong Kong, using a private car or a light good vehicle for the carriage of passengers for hire or reward is now illegal according to Section 52(3) of the Road Traffic Ordinance (Cap. 374), Moreover, the driver of a taxi shall not permit, any person other than the hirer without reasonable excuse to enter the taxi without the consent of the hirer when his taxi is hired according to Regulation 37(e) of the Road Traffic (Public Services Vehicles) Regulations (Cap. 374D). In other words, both car-pooling (paying part of the travel cost to drivers) and taxi ride-sharing (sharing the taxi fare between passengers) are illegal. In contrast, there have been many countries, including Australia, Mainland China, the United Kingdom, and the United States, allow operating car-pooling and/or taxi ride-sharing under regulations (Chassin and Msaid, 2016; Dudley et al., 2017; Santi et al, 2014; Sun and Ding, 2019). We believe that the government plays a major role in contributing to widely promoting car-pooling and taxi ride-sharing. Although the government might face hindrance due to the objection from the taxi industry to car-pooling (Chassin and Msaid, 2016; Dudley et al.; Yuana et al., 2019), other research has proved that car-pooling drivers in fact may not directly compete with conventional taxi drivers since car-pooling services mainly serve routine commuting purposes, such as home-to-work or work-to-home trips (Dong et al., 2018), while taxi services play the role in providing non-routine, fast, and direct personalized trips at the roadside.

The results of sensitivity analyses indicate that attracting private car owners to participate in car-pooling is crucial for the success of shared mobility programs, which can increase the supply of car-pooling and reduce the wait time of passengers. Instead of burdening the passengers with a higher proportion of travel costs, the government should offer financial incentives to drivers, such as a reduction in or exemption of toll charges, for carpooling, which has been found effective in enhancing the choice of carpooling in previous studies (Baldassare et al., 1998; Bulteau et al., 2023).

In addition to the aspects of legalization, price regulation, and financial incentives, the respondents raised concerns regarding the shared mobility options, specifically personal safety (e.g., the risk of robbery) and prefer not traveling with strangers due to hygiene and privacy concerns. To address these issues, the government should implement measures and regulations to ensure the personal safety of both car-pooling drivers and passengers. This could involve setting up authentication and registration systems within smartphone apps, as well as making insurance and licensing mandatory for car-pooling drivers. The government should initially launch shared mobility programs in smaller communities (e.g., schools or workplaces) first, where the privacy concern could be eased as people are more accepting of sharing a ride with friends or colleagues, which has been shown in a previous study (Al-Ayyash et al, 2016). Last but not least, the government should focus on educating the public, promoting the benefits of shared mobility, and emphasizing the positive externalities such as easing traffic congestion, saving the total travel distance, reducing roadside emissions, and practicing energy saving. The government should organize events and campaigns to encourage people to use shared mobility options, and share their experiences with their friends on social media (e.g., Instagram and Facebook) to arouse public interest in shared mobility.

5. CONCLUSION

Sustainable shared mobility has been widely implemented in different cities as a means to ease heavy traffic congestion, reduce roadside emissions, and promote energy saving. Public acceptance is the key to the wide implementation of car-pooling and taxi ride-sharing. In this study, a stated preference survey was conducted to interview 829 respondents, including 257 private car owners and 572 non-private car owners, for their travel preferences in three hypothetical scenarios considering mode competition. In total, 2,487 observations were received for developing an NL model and an MNL model. The model results show that the out-of-pocket cost, the in-vehicle travel time, and the out-of-vehicle are significant factors influencing the travel decisions of both private car owners and non-private car owners. Comparatively, the non-private car owners were less reluctant to use car-pooling or taxi ride-sharing than their counterparts, given the same level of monetary incentivization. An equilibrium model was introduced and an iteration solution procedure was applied to determine a convergent solution to balance the demand and supply of drivers and passengers for car-pooling services. Sensitivity analyses were carried out to obtain the probabilities of selecting different transport options given different percentages of out-of-pocket cost shared by a car-pooling passenger, and different percentages of taxi fare paid by a taxi ride-sharing passenger in both the higher and lower private car ownership cases. The results demonstrate that the percentages of shared cost and taxi fare for car-pooling and taxi ride-sharing can effectively affect the modal split.

Legalization, price regulation, and financial incentives of these services should be actively considered as they serve as a prerequisite to the wide implementation of both car-pooling and taxi ride-sharing. Besides, measures and regulations to ensure personal safety in shared mobility should be implemented. Launching shared mobility programs in smaller communities to ease privacy concerns, and focusing on educating the public about the associated benefits are recommended. This study provides some valuable insights into promoting sustainable shared mobility, and alleviating traffic congestion and roadside emissions in Hong Kong, as well as other international cities that have a similar transportation system.

The sensitivity analyses conducted in this study demonstrate the model application to understand the general effects of variations in proportions of travel cost and taxi fare shared by passengers for car-pooling and taxi ride-sharing. A follow-up study is suggested to conduct a simulation that considers a road network, travel time between locations, and the temporal and spatial demand and supply of the shared mobility market. This will enable the prediction of the probabilities of selecting shared mobility services in real-world scenarios.

DISCLOSURE STATEMENT

The authors report there are no competing interests to declare.

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