Car-Pooling Attractiveness Modeling in Greater Cairo Organizations – A Case Study

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Abstract. Car-pooling is one of the solutions for the traffic problems in Greater Cairo Region (GCR). It leads to increase the average occupancy of autos, and consequently reduce the traffic volumes on GCR roads. Car-pooling implementation within organizations is expected to be more effective compared to car-pooling with non-work colleagues. The main objective of this research is to understand the factors affecting car-pooling deployment more deeply and how to maximize its share. A Stated-Preference Survey (SPS) has been conducted within the Faculty of Engineering at AinShams University (FOE-ASU) with a sample size of 1071 commuters. SPS data were used in calibrating different binary discrete choice logit models in order to estimate the share of car-pooling mode compared with current transport mode (public transport/private cars). This paper concluded that applying car-pooling within organizations in GCR as FOE-ASU is expected to be successful, in case of considering the factors affecting car-pooling service.

Keywords: Car-pooling · Car-sharing · Stated Preference Survey
Binary logit model

1 Introduction

Car-pooling is considered a tool for the transport demand management [1] that describes a mode of transportation which consolidates individuals in fewer autos by sharing their commuting trips [2–4]. As an attempt to introduce car-pooling in GCR, it is thought that car-pooling during the commuting trips will be more efficient and successful especially within the same organization [5]. Faculty of Engineering at Ain Shams University (FOE-ASU) has been selected to be the case study in this research. The main reason of this selection is that it has various commuter types such as staff members, teaching assistants, employees, and students. The main objectives of this paper are to investigate the main attributes that affect car-pooling mode and to develop models that estimate car-pooling share.

Stated Preference Survey (SPS) has been conducted among the commuters of FOE-ASU. The survey aims at investigating the commuters' preferences about the

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car-pooling service by calibrating a binary discrete choice logit model predicting the car-pooling share. The users' preferences included the maximum accepted extra out-of-vehicle travel time due to carpooling, the maximum accepted extra detour time for drivers, car-pooling trip cost and others.

2 Research Objectives

The objectives of this research are to identify and calibrate the factors affecting car-pooling participation by developing discrete choice logit-models to predict the car-pooling tendency in our case study. This logit-model will help us determining the values of these factors.

3 Literature Review

The basic idea of car-pooling existed since more than 60 years, and it is still growing around the world [6]. A lot of studies were focusing on car-pooling systems in the recent decades. Here are some of these researches:

- Researchers in New-Zealand proposed study to examine the effectiveness of an initiative (Let's Carpool) [11],
- A researcher studied university students' commute and housing behaviors at university in California–Los Angeles by on-line survey conducting 769 questionnaires [12, 13],
- SP web survey was conducted in Lisbon with 996 individuals in order to evaluate the potential of the car-pooling club structure for managing car-pooling groups, and know the preferences of car-pooling systems [5],
- In Zurich-Switzerland, the Swiss Federal Roads Authority has funded a research project aiming at determining the potential of car-pooling by executing a survey via email/phone, and they conducted 881 questionnaires [10].
- In Italy, (PoliUniPool) was a project promoting a new car-pooling system among the students and administrative staff of "UniversitàStatale" and "Politecnico di Milano" universities [14].

The classical car-pooling system is not flexible enough, particularly in case of handling variant time schedules and destinations of car-poolers [7–9]. In theory, car-pooling system could lead to great reductions in the use of private vehicles; however, it has got limited success in practice. One of main reasons for this is the psychological barrier associated with riding with strangers and losing the trip time and route flexibility [1]. Gender variable is also significant in explaining the attitudes towards car-pooling occupant types; men show a tendency for having more acceptances of different car-pooling groups. Car-pooling is still limited to lower income strata where saving money is still an important reason for joining. Parking supply study has led generally to the conclusion that when parking is easy, car-pooling loses its attractiveness for the car owners [1]. It turns out that also in small companies, with less than 100 employees, a large potential for car-pooling exists. Also it is possible to

implement car-pooling on a small scale; therefore, the first targets in such a strategy must be the companies [10].

Car-pooling is already applied in Egypt in small scale. It is mainly limited only to the individuals who already know each other, and this is very small domain for the car-pooling process. As a solution to this problem, several platforms have tried to spread car-pooling; they exploit the increasing rate of using the World Wide Web and smart phones. These experiences started with designing and operating Egyptian car-pooling websites like: www.EgyptCarpoolers.com, www.Wadeeny.com, www.NerkabSawa.com and www.Tawseela.com in addition to smart phone apps. These experiences depended on presenting the idea of car-pooling to the public, and explaining its benefits and advantages for the environment and individuals so as to encourage people to register on the website and join the service. Actually all these websites and apps could be considered as limited car-pooling entities, because they are not widely spread. These websites only offer the connection among the participants based on their data and trip schedules without any legal responsibility on the websites operators. They obtain some fees in return of the car-pooling contact service.

4 Data Collection

Stated preference survey (SPS) form has been designed to investigate the factors affecting car-pooling in GCR. The questionnaire form consists of three parts. These parts are the socioeconomic characteristics of the respondents, trip attributes, and characteristics of the proposed car-pooling service.

The first part in the survey form contains questions about age, job, gender, number of autos owned by the respondent household, number of adults in household and residence district. The second part contains questions about the private car trip which are parking availability at FOE-ASU, fuel consumption rate and travel time in going/returning trip; in addition to the public transport trip which are level of service in public modes, number of modes, out-of vehicle time, total travel time, and total trip cost for both going and returning trip. The third part contains questions only for passengers which are action when drop at intermediate station, action when find only one way car-pooling trip, maximum extra out-of-vehicle time and maximum paid cost for a single trip; in addition to questions only for drivers which are maximum extra detour time and minimum accepted cost for a single trip. In the third part, there are also questions about car-pooling service for all respondents which are reasons for joining service, reasons for not joining service, type of car-pooling group, number of participants and probability of joining service.

Although the population in this survey is all commuters of FOE-ASU including academic staff members, teaching assistants, students and administrative staff, the staff members were excluded; because in the governmental universities there are no fixed schedules for them, which leads to relative little attendance. The survey was conducted using direct interviews and World Wide Web. The direct interview method was accomplished through random sampling. The web survey was designed using the

Google Drive Forms, with the link posted via Facebook on students' groups. The collected data was then processed and assessed. The incomplete and illogical records have been removed from the collected data. The collected data has been filtered to be ready for the modeling process. The total valid and reasonable data for analysis includes 1071 cases distributed as shown in Table 1.

Table 1. Population and sample size distributed by job.

Job	Population number	Sample size	Sample size percent
Academic staff	700	13	1.9%
Teaching assistants	300	46	15.3%
Administrative staff	1600	79	4.9%
Students	13000	933	7.2%
Total	15600	1071	(6.9%)

5 Data Preparation

The description and values of all variables are displayed and illustrated in Table 2. It is noticeable that the options of the continuous numerical attributes have been determined using the distribution patterns of these attributes. For example, most of respondents have chosen 5, 10, or 15 min for the extra CP_DETOUR and extra CP_OVTT. Concerning the carpooling kilometer cost, it was found by analyzing the data that the optimum car-pooling fee is 0.32 L.E./indv./km. Therefore, their options were set as 0.25, 0.3 and 0.35 L.E./indv./km. In order to make use of the stated preference data, and in the context of formatting the data for modeling, it is considered that the participants face 144 scenarios/cases during answering the part of the proposed car-pooling service attributes which are shown in Table 2. These scenarios are composed from values permutation of car-pooling attributes.

Table 2. Explanatory variables included in the model.

Type	Variables	Nature	Definition	Options
SE variables	AGE	Numeric	In years	Integer number
	GENDER	Dummy	Male/Female	1. Male, 0. Female
	CAPA	Numeric	Car ownership per adult in household	Float number >= 0
	JOB	Categorical		1. Academic staff, 2. Teaching assistant, 3. Administrative staff, 4. Student

(*continued*)

Table 2. (*continued*)

Type	Variables	Nature	Definition	Options
CurrentTrip Variables	TRIP_DISTANCE	Numeric	Distance from home to faculty	Float number in kilometers
	PARKING AVAILABILITY	Categorical	Availability of parking at FOE-ASU	1. Not available, 2. Rarely, 3. Sometimes, 4. Almost and 5. Always available
	AUTO_COST	Numeric	Cost of auto trip	Float number in (L.E.)
	AUTO_TT	Numeric	Travel time of autotrip	Integer in minutes
	PUBLIC_LOS	Categorical	Level of service in public modes	1. V. Bad, 2. Bad, 3. Accepted, 4. Good, 5. V. Good
	NO_MODES	Numeric	Num. of public modes	Integer >= 1
	PUBLIC_OVTT	Numeric	Out of vehicle time	Integer in minutes
	PUBLIC_IVTT	Numeric	In-vehicle travel time	Integer in minutes
	PUBLIC_COST	Numeric	Total paid cost in public modes	Float number in (L.E.)
Car-pooling Variables	CARPOOL_GROUP	Categorical	Type of partners in car-pooling group	1. Acquaintances of same gender, 2. Acquaintances of any gender, 3. Any persons of same gender, 4. Any persons
	FINAL_DESTINATION	Dummy	System guarantees taking passengers to destinations	1. To exact destination, 0. Close to destination
	ROUND_TRIP	Dummy	System has to be for round tripor not	1. Round trip, 0. Only one way trip
	CP_DETOUR	Numeric	Max. extra travel time due to detour	5, 10, or 15 min
	CP_OVTT	Numeric	Max. extra out of vehicle time	5, 10, or 15 min
	CP_KM_COST	Numeric	Cost of taking 1 person for 1 km	0.25, 0.30, or 0.35 L.E./ km/indv.

6 Data Analysis

It is noted that the academic staff members aren't involved in modeling process because they gave low tendency to join the car-pooling service. This refers to their dynamic time schedules, as well as they do not like to commit with others or do not like to share

with others of different cultures (61.5% of academic staff). The concluded characteristics of the proposed car-pooling service are as follows:

- The priority in forming the car-pooling groups is for acquaintances of the same gender.
- The preferred car-pooling group size is four partners.
- It is not necessary to give great attention to transport the passengers to their final destinations; however, transferring passengers to another intermediate location will be acceptable.
- Provision of the car-pooling service for only one-way trip is accepted for most of the users and not necessary to provide the service for both trip directions.
- The accepted time increase for the car-pooling trip are 6.6 min for the drivers EXTRA_CP_IVTT and 7.4 min for passengers EXTRA_CP_OVTT; these values should satisfy 85% of both drivers and passengers. Consequently, the maximum accepted distance between the car owner and passenger should be less than 15 min.
- The most likely accepted fee of transporting one individual is 0.32 L.E/km from the point of view of both the car owners and passengers. About 73% of all respondents (car owners and passengers) will be satisfied with this value.

7 Model Variables

The model calibration process is the process of estimating the variables coefficients. This process was accomplished using "SYSTAT" software by the maximum likelihood estimation method. Table 2 shows all variables used in the calibration process. It is mentioned that the staff members are not incorporated into the model calibration process, because they are considered to be captive users to their autos.

All next models are either related to the car drivers or the passengers. The utility functions of passengers' models compare between car-pooling and public transport modes. Consequently, these models include the attributes of the public transport modes not the attributes of private cars. While, the utility functions of the car drivers' models compare between car-pooling and solo-driving mode. So, these models include the attributes of private cars not the attributes of public transport modes. In the next topics, the calibration results will be discussed.

8 Modeling Stages

The proposed model will be a binary discrete choice logit model where the choice set includes the current mode and the proposed car-pooling mode. The modeling process was conducted using two stages. The first stage was to develop a logit model containing all available variables. The objective of this stage was to determine which of these variables are significant and logic. The second stage was to develop the final form of the models which contains the best significant variables. Based on the results of the second stage and in order to get more accurate results, the dataset was divided into

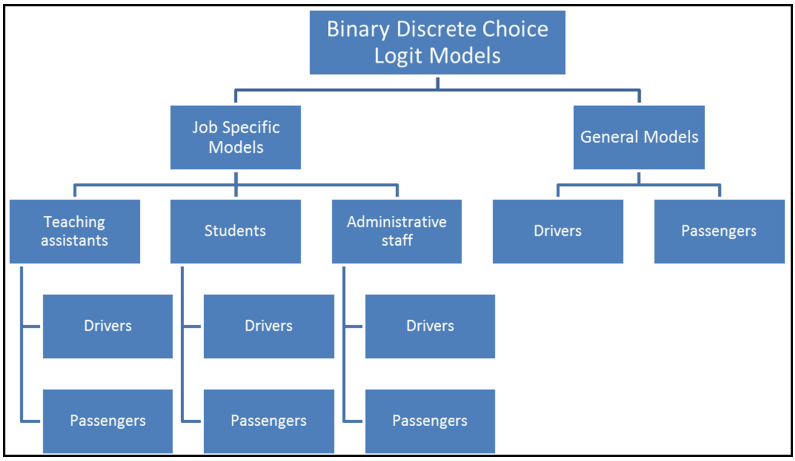

Fig. 1. Divisions of the dataset used in modeling.

subsets based on the car-pooler type (driver/passenger) and job (teaching assistants, students, or administrative staff). Figure 1 shows the divisions of the dataset used in modeling.

9 Models Calibration

In this stage, the final models are calibrated including the most significant variables based on the pre-mentioned subsets of data described in Fig. 1. It is mentioned that the incorporated variables have the largest values of t-ratio. Table 3 shows the estimated coefficients with their t-values. Based on the aforementioned scenarios/cases, the total number of data records is 84,096 as a total, including 19,296 records for all car drivers and 64,800 records for all passengers.

10 Model Evaluation

As for the t-ratio, except t-ratio of CP_KM_COST in the model of administrative staff passengers, all estimated coefficients are statistically significant at 5% level of significance as the t-ratio values for all parameters are greater than the tabulated t-test value (± 1.96). The signs of all variables whether positive or negative are making sense. As it was expected, CP_KM_COST is very important variable and it is necessary to be incorporated, even if its t-ratio (-1.322) is not satisfactory. The combination of McFadden's Rho squared ($\rho 2$), McFadden's Rho-bar squared, and percent correct estimate for the models are considered rather acceptable.

– For the passengers' models, the following can be noticed from the table: As expected, the cost and travel time of the public transport relative to the car-pooling are generally the most effective variables.

Table 3. The estimated coefficients for all logit models.

Variable	Passengers regardless job	Drivers regardless job	Passengers – Teaching assistants	Passengers – Students	Passengers – Admin. staff	Drivers – Teaching assistants	Drivers – Students	Drivers – Admin. staff
CONSTANT	4.280 (34)	−3.334 (−14.9)	−3.582 (−5.16)	2.519 (27.75)	0.907 (2.32)	−7.128 (−7.6)	3.106 (8.877)	−5.915 (−10.7)
AGE	–	–	0.431 (16.78)	–	–	0.12 (4.758)	−0.183 (−13.1)	–
GENDER	–	0.487 (10.09)	−3.083 (−19.2)	0.305 (13.57)	−0.391 (−3.99)	–	–	0.84 (6.21)
CAPA	–	–	–	–	–	–	−1.391 (−12.5)	3.207 (12.6)
TRIP_DISTANCE	−0.046 (−36.5)	0.031 (15.55)	−0.073 (−11.6)	−0.048 (−35.2)	−0.108 (−11.1)	−0.109 (−7.4)	–	–
JOB	−0.575 (−18.7)	0.492 (11.35)	–	–	–	–	–	–
AUTO_TT	–	0.018 (14.15)	–	–	–	–	0.034 (27.95)	0.044 (11.6)
AUTO_COST	–	–	–	–	–	0.96 (12.47)	–	–
PUBLIC_LOS	–	–	−0.958 (−13.7)	–	–	–	–	–
PUBLIC_OVTT	0.020 (18.7)	–	0.044 (5.03)	0.023 (19.39)	–	–	–	–
PUBLIC_IVTT	–	–	0.025 (7.75)	–	–	–	–	–
PUBLIC_COST	0.151 (35.9)	–	–	0.161 (35.79)	0.202 (6.29)	–	–	–
CARPOOL_GROUP	–	−0.461 (−25.4)	−0.447 (−9.86)	−0.519 (−53.4)	−0.622 (−14.3)	−0.618 (−9.5)	−0.486 (−23.2)	−0.395 (−7.27)
FINAL_DESTINATION	0.193 (9.85)	–	–	0.15 (7.24)	1.214 (12.73)	–	–	–
ROUND_TRIP	0.169 (8.65)	–	–	0.143 (6.85)	0.898 (9.67)	–	–	–
CP_OVTT	−0.152 (−60)	–	−0.237 (−17.7)	−0.156 (−58.3)	−0.08 (−7.15)	–	–	–
CP_DETOUR	–	−0.170 (−33.2)	–	–	–	−0.294 (−14)	−0.161 (−27.4)	−0.228 (−13.9)
CP_KM_COST	−4.772 (−20)	4.955 (10.33)	−2.599 (−2.16)	−5.19 (−20.3)	−1.457 (−1.32)	9.953 (5.84)	3.727 (6.773)	12.083 (8.07)
McFadden's Rho-bar Sq.	0.130	0.151	0.332	0.131	0.183	0.371	0.153	0.249
Percent correct estimate	67.8%	72.5%	72.8%	67.9%	75.6%	78.6%	73.5%	73.5%

- The negative sign of TRIP_DISTANCE reflects the fact when the trip distance is longer, the passenger will pay the car-owner more cost; and this reduces the passenger desire to car-pool.
- The positive sign of GENDER emphasizes that male students are eager to car-pool more than females because of higher security aspects at females. The negative sign of GENDER for both teaching assistants and administrative staff reflects that the previous strong relations between females and males in workplace build a wide trust level among them; so females of teaching assistants and administrative staff are eager to car-pool as passengers more than males.

For the drivers' models, the following can be noticed from the table:

- It is not recommended to let the car owner get away from his traditional route to transport his passengers.
- The positive sign of GENDER emphasizes that males are eager to car-pool as a driver more than females because of the higher security aspects at females.

11 Conclusions and Recommendations

Based on the modeling results, the main conclusions can be summarized as follows:

- Male drivers tend to join the car-pooling service more than female drivers. This refers to more conservative thoughts about females in Egypt.
- Based on the negative signs of CAPA which is a general indicator to the level of income, car-pooling service is expected to be more attractive for car owners with relative lower level of income, which is like in the previous researches.
- The kilometric cost of car-pooling is the most important and sensitive variable for the individuals' tendency towards car-pooling service.
- The preferred car-pooling group size for drivers is four partners, which is also accepted by passengers.
- Car-pooling passengers accept transportation to an intermediate location and not at their exact destinations.
- Provision of the car-pooling service for only one-way trip is accepted for most of the users and it's not necessary to provide the service for round trip.
- The accepted time increase for the car-pooling trip is about 7 min for both drivers and passengers.
- The most likely accepted cost of transportation is 0.32 L.E/passenger/km from the point of view of both the car owners and passengers.

The main recommendations of this research can be summarized as follows:

- Car-pooling is expected to be successful when be applied in the Egyptian organizations in case of considering the equilibrium between the benefits of drivers and passengers.
- The integration and cooperation among multiple neighboring organizations need to be studied in another research, because it may enlarge the users' base.

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