*European Transport \ Trasporti Europei n. 40 (2008): XX-XX*

# Car sharing demand estimation and urban transport demand modelling using stated preference techniques

**Mario Catalano [1], Barbara Lo Casto [1], Marco Migliore [1*]**

[1] *DITRA – Department of Transportation Engineering*
*University of Palermo, Italy*

---

**Abstract**

The research deals with the use of the stated preference technique (SP) and transport demand modelling to analyse travel mode choice behaviour for commuting urban trips in Palermo, Italy.

The principal aim of the study was the calibration of a demand model to forecast the modal split of the urban transport demand, allowing for the possibility of using innovative transport systems like car sharing and car pooling.

In order to estimate the demand model parameters a specific survey was carried out inside the urban area of Palermo. The survey focused on the morning rush hour and involved mainly employees, self-employed workers and students (about 500 respondents) whose final destination is located within the historical centre of the city. The questionnaires contained a stated preference experiment regarding the choice between four different transport alternatives: private car, car pooling, car sharing and public transport.

A random utility model was developed by using data resulting from the SP experiment. We found out that, for the specific case of Palermo, the multinomial logit proved to be the best urban transport demand model, even if the choice set contained three car alternatives. We identified as main attributes affecting mode choice behaviour the one-way trip travel time and cost, the parking time, the number of cars available to each household member, the alternative specific attributes for the car option and the car sharing one.

The model was applied to analyse the potential demand for car sharing and car pooling in Palermo, under a future scenario characterized by several policy actions for limiting private transport use. The analysis highlighted that the car club market share could increase up to the 10% level, while car pooling could slightly rise.

*Keywords:* Car sharing; Car pooling; Stated Preference; Random Utility Models; Sustainable transport systems.

---

* Corresponding author: Marco Migliore (migliore@ditra.unipa.it)

## 1. Introduction

In the last decades, the growth of mobility (passenger and freight transport demand) has produced a wild development of vehicles (car and trucks) moving inside urban Italian areas, with an alarming negative impact on the quality of life for citizens. The main effects of such a phenomenon are the following: critical travel times for urban trips during peak periods; high levels of air pollution and noise; damages to monuments and buildings with a cultural value, owing to the polluting traffic emissions.

In order to face such challenging problems, the Italian Government launched in 1998 the "Sustainable Mobility in Urban Areas" Decree (or Ronchi Decree) that resumed the engagements for the environment protection emerging from the Kyoto International Conference held in 1997. The strategies in favour of a sustainable urban transport system, which are contained in the Ronchi Decree, are listed below:

- the introduction of the mobility manager role for enterprises and institutions with many employees (more than 300 in the first case and more than 800 in the second one); the task of a mobility manager consists in planning commuting trips, so as to minimize the use of car;
- in relation to all the other enterprises and institutions, fostering the use of innovative transport modes, like car pooling and car sharing;
- favouring the diffusion of low polluting emission vehicles.

This paper considers car pooling and car sharing. Car pooling and car sharing (or car club) are demand optimization strategies that are widespread in Northern Europe. The former guarantees the reduction in vehicles moving on the urban road network by the formation of pools of colleagues using the same car for their journey-to-work trips. The application of such a solution is a typical task of a mobility manager, who can put workers, who need to get to the same destination within the same time-window, in contact with each other (Ferguson, 1997;Giuliano *et al.*, 1990; Teal, 1987). To gain this outcome, the technical board of mobility managers can use a software able to manage databases containing information about employees (personal data, trip origin and destination, journey date and time, constraints and preferences) and create "ideal crews" based on spatial and temporal proximity conditions.

Car sharing is a service that permits one to book a car for a short-term use (one hour or less), to take possession of it at a terminal close to one's house, to return it at a terminal close to one's destination, paying hourly and kilometric fees, so as to reduce the need for a personal vehicle (Bonsall *et al.*, 1981; Enoch, 2002; Litman, 2000; Prettenthaler and Steininger, 1999; Shaheen *et al.*, 2004; Shaheen *et al.*, 2005). The consequent main benefits are the following:

- reducing cars moving on the urban road network: a car sharing vehicle can replace several personal cars;
- customers pay per use, sharing the following vehicle costs: lease, maintenance, repair, taxes and insurance;
- reducing emissions by supplying a fleet of clean fuel vehicles;
- reducing the need of space for parking.

Only in the 1990s, interest in car sharing as an alternative mobility solution grew remarkably throughout Europe, North America and Asia. In Europe, the first organizations were created in Switzerland and in Germany: Mobility CarSharing Switzerland, StattAuto (Berlin), Stadtmobil (Bremen). Mobility CarSharing Switzerland (40 % of the European market at present) took place in 1987 with only 2 cars and 30 users; in 2001 it managed a fleet of 1700 cars located in 700 different places for 44000 users throughout Switzerland. In Germany different car sharing societies exist today: StattAuto operating in 200 cities for 8000 users with 300 cars located in parking areas for 2-10 vehicles each, Stadtmobil in Bremen with a fleet of 300 cars for 8.000 users, Cambio with 300 cars in 5 main cities and 7000 users. Today in Germany more than 60 organizations supply car sharing services with a global fleet of 2000 cars for 50000 customers; moreover, they tend to cooperate with local public transport companies to implement fare integration systems.

The principal aim of the study is the calibration and use of a random utility model to forecast the modal split of the urban transport demand in Palermo, allowing for the possibility of using innovative transport systems, more particularly, car sharing and car pooling. In particular, the research focuses on the role that can be played by car sharing in Palermo through the application of the calibrated model to estimate the potential demand for car sharing depending on the kilometric fare.

This research rests on the scientific literature about travel choice behaviour modelling, with particular reference to random utility models and stated preference methods (Ben-Akiva and Lerman, 1985; Daly and Rohr, 1998; Louviere *et al.*, 2000; Ortùzar and Willumsen, 1994; Permain *et al.*, 1991). In particular, this study is based on urban transport demand modelling background. Some relevant papers from previous research are described below.

O'Fallon *et al.* (2004) investigated the impact on mode switching of a wide range of policy tools (both measures discouraging car use and measures improving public transport services) through a stated preference experiment conducted in the three largest New Zealand urban areas. The observations deriving from the SP survey were employed to develop mode choice logit models. The policy actions increasing the cost of using a personal car proved to influence commuter's mode preferences much more than the others. In the authors' opinion, such a result should not induce policy makers to ignore the need to improve public transport services, since it is not acceptable to discourage car use without guaranteeing a convenient alternative mode of travel. Furthermore, the study revealed several constraints that make many car users "captive", like the need to transport children, the need to use the car for work-related trips.

Hunt and McMillan (1997) performed a stated preference experiment in Calgary to examine factors affecting the use of car pooling to work in the central business district. The observations thus obtained were used to estimate parameters of logit choice models. An interesting finding regards the time spent picking up other carpool participants that was valued at a premium rate of $4.00 (Canadian) per hour (about 45 percent) more than the automobile ride time for the direct trip. Moreover, the study revealed that each additional non-household member, who does not imply further benefit, does tend to reduce in a nonlinear manner the effect of parking costs for the respondent.

Washbrook *et al.* (2006) investigated commuter mode choice behaviour in response to road pricing and parking charges. They involved 548 commuters from a Greater Vancouver suburb, who at present drive alone to work, in a discrete choice experiment in which respondents could choose between driving alone, carpooling or taking a hypothetical express bus service. The resulting observations were employed to develop logit models that were applied to predict commuter response to various pricing strategies and single occupant vehicle travel time increases. Model estimation results suggested that increases in drive alone costs lead to greater reductions in single occupant vehicle demand than improvements in the times and costs of alternative modes (like carpooling).

In the research presented here, adopting discrete choice modelling techniques, we aimed at highlighting the role that could be played, in a great town like Palermo, by innovative transport systems such as car pooling and car sharing in supporting a transport policy for a sustainable urban mobility.

The rest of the paper describes the study area (Section 2), the sample used for the SP survey (Sections 3 and 6), the questionnaire employed for the interviews (Section 4), the SP experiment design (Section 5), the mode choice model estimation results (Section 7), the application of the mode choice model (Section 8), some conclusive remarks (Section 9).

## 2. Study Area

The study area is Palermo city that plays a leading role in Sicily: with a population of about 700 000 inhabitants, its territory holds all the regional level administrative offices.

Palermo is characterized by a "weak" public transport system. In particular, the urban rail network is not wide enough and its service capacity is limited by the single-track constraint. Moreover, in spite of covering the whole urban area, the road public transport suffers from the interference with the car traffic, with a negative impact on frequency and comfort, which can be ascribed to the insufficient development of the bus way network (Migliore and Catalano, 2007).

Other problems consist in the remarkable lack of suitable parking areas for private vehicles, especially within the centre, and the need of new parking facilities to favour intermodalism.

## 3. Features of the sample

The research focuses on the centre of Palermo (see Figure 1) where many important work sites are placed: regional and municipal level administrative units, the town hall, the head offices of the main banks, some departments of the University, the most important commercial area of Palermo.

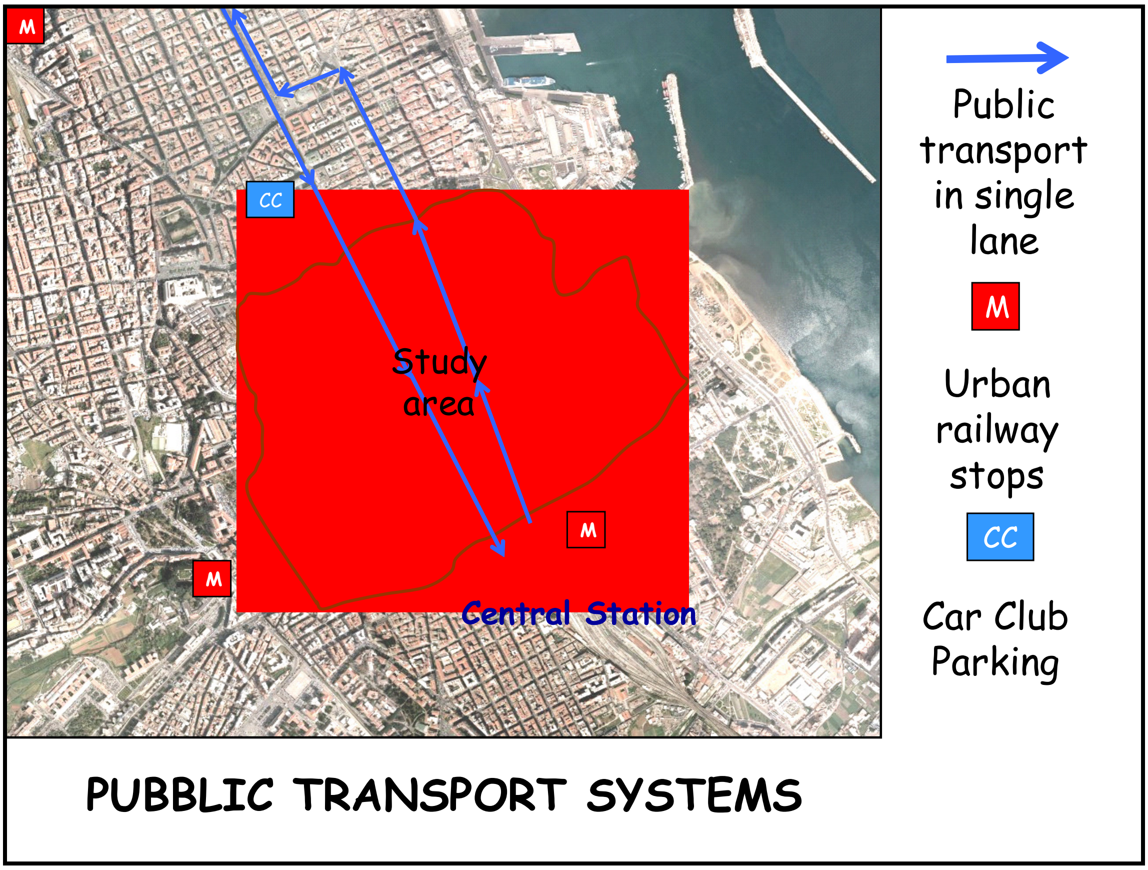



Figure 1: Study area.

So, we conducted a Stated Preference survey involving a random sample of employees, university students and self-employed workers daily moving towards the city centre. Table 1 and Figure 2 show the composition of the sample together with its size.

Table 1**:** The sample of commuters moving towards the city centre compared to the corresponding universe.

| *Category* | *Universe of Palermo* | *Percentage in relation to the whole population* | *Universe of Palermo city centre* | *Respondents* | *Percentage of respondents in relation to the city centre universe* |
|---|---|---|---|---|---|
| Employed | 135.803 | 19,40 % | 12.901 | 235 | 1,82 % |
| Self-employed | 12.268 | 1,75 % | 3.249 | 218 | 6,70 % |
| Student | 11.992 | 1,71 % | 480 | 42 | 8.75 % |
| Total | 160.063 | 22,86 % | 16.630 | 495 | |

Source: ISTAT (National Institute of Statistics) Census 2001

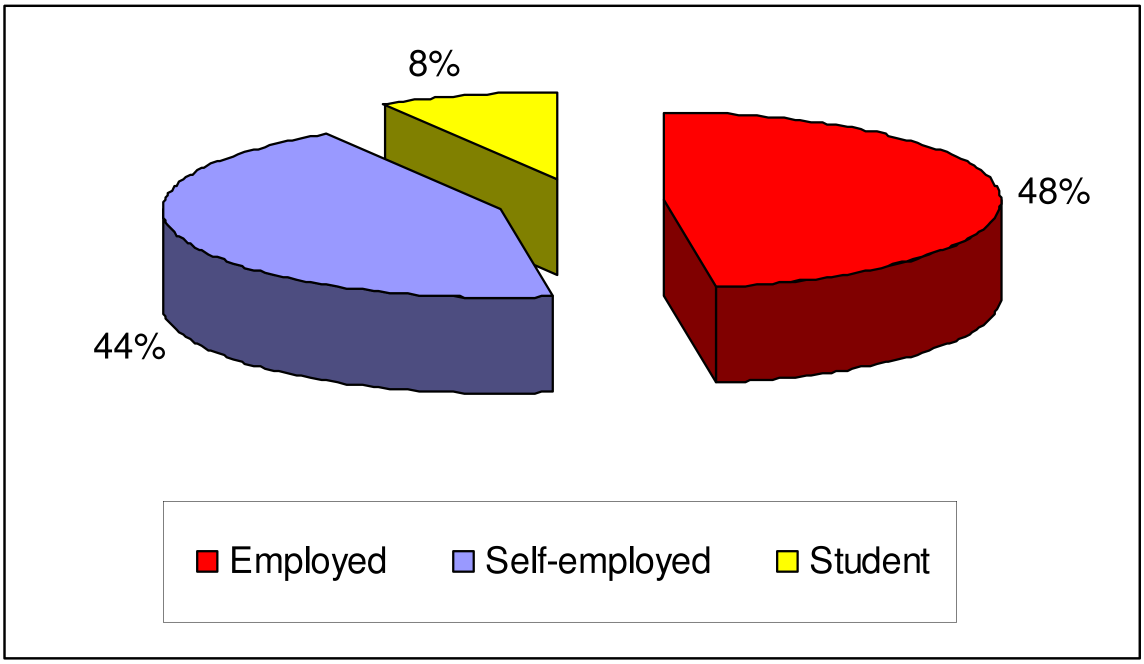



Figure 2: Composition of the sample.

## 4. Questionnaire structure

As stated before, this research aims at constructing a modelling tool to forecast choices between traditional modes of transport and innovative ones and consequently to identify the optimal strategy for developing car sharing and car pooling in Palermo. To calibrate such a demand model, a SP survey was carried out by a questionnaire consisting of three parts. The first section (Revealed Preference phase) deals with the following socioeconomic characteristics of the decision makers' households: composition, sex and age of members, number of available cars and mopeds, income, number of members daily travelling to work or to study; moreover, we submitted questions concerning only the single respondent on the following aspects: mode usually used, time spent, origin and distance covered for a journey-to-work (or study) trip.

The second section describes the car sharing option and asks the respondent to express his opinion about this alternative transport system compared with the traditional private car.

The third part contains the SP exercises submitted to the sample. They consist in choice games requiring the decision-maker to opt for one of four alternatives: private car; car pooling; car sharing; public transport.

The attributes selected to characterize the previously listed options are the following ones: the transport hourly cost (€/h), for car sharing; the transport kilometric cost (€/km), for private car, car pooling and car sharing; the transport cost per one-way trip (€/trip), for public transport; the parking cost per one-way trip (€/trip), for car, car pooling and car sharing; the time spent to move from the origin zone to the destination one (min.), for all the alternatives[1]; the parking time (min.), for car, car pooling and car

[1] For public transport, this time attribute includes the waiting time spent at the bus stop.

sharing; the access time (min.) for all the options, that is the time spent for moving from one's house to the starting point of the trip (parking lot, car sharing centre, bus stop).

The attributes vary according to a pre-specified set of levels in a way that is illustrated in Section 5.

## 5. Definition of attributes' levels

The levels of the above mentioned attributes or explanatory variables (see Table 3) were determined taking into account the need of limiting the number of choice exercises for the respondent and the need of constructing a database suitable for analysing the role that can be played by car sharing in Palermo, under a future scenario characterized by a better public transport level of service. Consequently, the car sharing option has the larger number of attributes at two levels. The following considerations apply:

- The car kilometric cost was set at the present value for each respondent. Under the random utility model calibration stage, this parameter was specified for every decision maker based on the yearly run covered by car, taking into account the following cost items referring to the car ownership case[2]: yearly equivalent value of the purchase cost, insurance, taxes, maintenance and fuel. The output of this estimation process consists in three cost parameters based on three different scenarios about the distance covered per annum (see Table 2).
- The car pooling kilometric cost was set at the present value for each respondent, considering an occupancy factor of two passengers per vehicle.
- The transport cost for car sharing consists of two components: the hourly cost and the kilometric one, each characterized by two levels: 1.00 € and 1.50 €, in the former case; 0.20 € and 0.30 €, in the latter one.
- The public transport cost per one-way trip has one level (1.00 €) that was computed on the basis of the season ticket price for a commuter using the bus service in Palermo: the monthly ticket price / 48 trips per month.
- The car parking cost has one level (1 €) based on the monthly parking pass price for the city centre: the monthly parking pass price / 48 trips per month. The car pooling parking cost was calculated dividing the car parking cost by the occupancy factor of two passengers per vehicle. In the case of car sharing, parking inside the study area was considered free, to allow a municipal policy action in favour of sustainable urban mobility systems.
- The time spent to move from the origin zone to the destination one, for car, car pooling and car sharing, was set at the present value for each respondent; under the model estimation phase, it was determined for the O/D pair declared by each respondent through a *deterministic user equilibrium* assignment (Cascetta, 2001; Ortuzar and Willumsen, 1994) of the origin-destination matrix representing the private transport demand of Palermo during the peak period of a working day (2003) to the corresponding graph.
- The time spent to move from the origin zone to the destination one for public transport[3] has two levels. In particular, one level is the 50% of the present value for each respondent; under the model estimation process, it was quantified for the O/D

[2] The decision of introducing a full monetary cost for car can be explained considering that a commuter using car sharing services does not need to own a personal vehicle.

[3] That is the sum of the in-vehicle time and the waiting time spent at the bus stop.

pair declared by each respondent through a *hyperpath* assignment of the origin-destination matrix representing the public transport demand of Palermo during the peak hour of a working day (2003) to the corresponding graph.

- The parking time presents two levels in the car sharing case (5 min. and 10 min.) and in the car pooling one (0 min. and 5 min.), while the car alternative is characterized by one parking time level (7 min.).
- As for the access time, one level was introduced for car (3 min.), car pooling (3 min.) and public transport (7 min.); while, for car sharing, two levels were identified (5 min. and 10 min.).

The choice scenarios that can be constructed by combining the shown levels with each other are 64: a choice set that can't be proposed to a decision maker; so, the full choice set was divided into 8 blocks of 8 choice games, to be presented to 8 different groups of respondents, through one of the most used *experimental design* techniques, that is the *block design*. This method is performed in the following way: a block variable (corresponding to an interaction[4] between two or more attributes) is selected and the scenarios are divided into as many clusters as the levels of the block variable; for example, if an interaction between any two attributes were used as block variable, this one would present a level referring to the concordance case (low/high level for both attributes) and another one relative to the discordance case (low level for an attribute and high level for the other one).

Table 2: The small-sized car kilometric cost under different scenarios on the distance covered per annum.

| *COSTS* | *1st Scenario 5000 km/annum* | *2nd Scenario 7500 km/annum* | *3rd Scenario 10000 km/annum* |
|---|---|---|---|
| Equivalent value* of car cost per annum (€) | 1371.11 | 1371.11 | 1371.11 |
| Surplus value (€) | 128.53 | 128.53 | 128.53 |
| Insurance per annum (€) | 1100.00 | 1100.00 | 1100.00 |
| Taxes per annum (€) | 144.87 | 144.87 | 144.87 |
| Park cost per annum (€) | 400.00 | 400.00 | 400.00 |
| **Fixed cost per annum (€)** | **3144.50** | **3144.50** | **3144.50** |
| | | | |
| Fuel cost per annum (€) | 472.00 | 708.00 | 944.00 |
| Maintenance per annum (€) | 245.11 | 380.69 | 429.68 |
| **Variable cost per annum (€)** | **717.11** | **1088.69** | **1373.68** |
| | | | |
| Total cost per annum (€) | 3861.62 | 4233.19 | 4518.18 |
| Cost per kilometre (€) | 0.77 | 0.56 | 0.45 |

Source: ISTAT (National Institute of Statistics) Census 2001.
*Assuming a life-cycle of ten years.

[4] An interaction can be defined as the effect of two or more factors which, when acting together, produce an influence different from the sum of the their individual impacts (Cascetta, 2001).

Table 3: Levels of the attributes.

| *Options* | *Levels of the attributes* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Transport cost per hour (€) | Transport cost per km (€) | Transport cost per trip (€) | Parking cost per trip (€) | O/D time (min.) [c] | Parking time (min.) | Access time (min.) |
| Car | - [a] | PV [b] | - | 1.00 | PV | 7 | 3 |
| Car Pooling | - | PV | - | 0.50 | PV | 0 5 | 3 |
| Car Sharing | 1.00 1.50 | 0.20 0.30 | - | 0.00 | PV | 5 10 | 5 10 |
| Public Transport | - | - | 1.00 | - | PV PV/2 | - | 7 |

Note: [a] -: no level, [b] PV: present value; it varies across the respondents, [c] time spent to move from the origin zone to destination.

## 6. Analysis of the SP survey output

This section presents statistical data deriving from the SP survey, which involved about 500 workers and students daily travelling towards Palermo city centre. In particular, the data concern the characteristics of the respondents and their households (see Figure 3), especially in terms of travel behaviour.

Most respondents belong to households owning at least two cars (see Figure 4). These households could give up owning a vehicle and use the car sharing service: in fact most respondents (about the 83% of the sample) cover by car less than 10 000 kilometres per annum (see Figure 5), which makes the car sharing option potentially competitive with the private car one.

Furthermore, the data reveal a high percentage of respondents that daily drive at least 7 km to reach work (or study) (see Figure 6), thus coming from suburban origins served by a public transport supply with a low level of service.

A final consideration regards the transport mode used by respondents for their journey-to-work (or study) trips (see Figure 7): in this case, it is interesting to observe the percentages of the car pooling[5] and public transport options indicating an urban mobility system which has to improve so much from the environmental impact point of view.

[5] Car pooling refers to the following choice possibilities: car as driver with passengers and car as passenger.

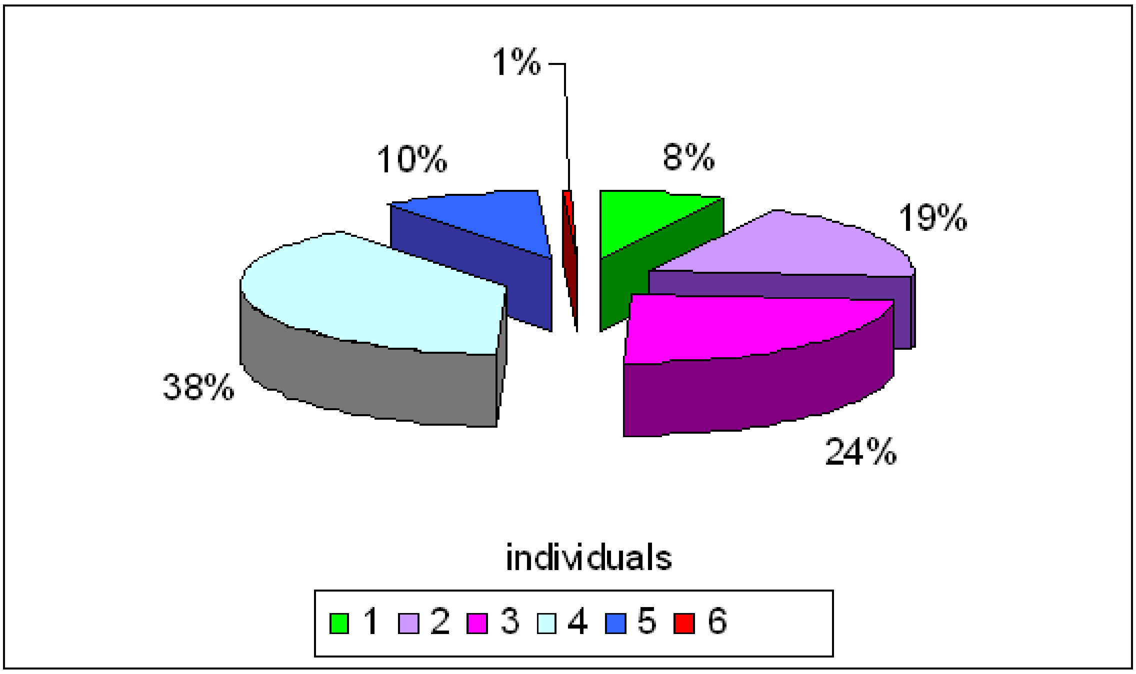



Figure 3: Composition of households.

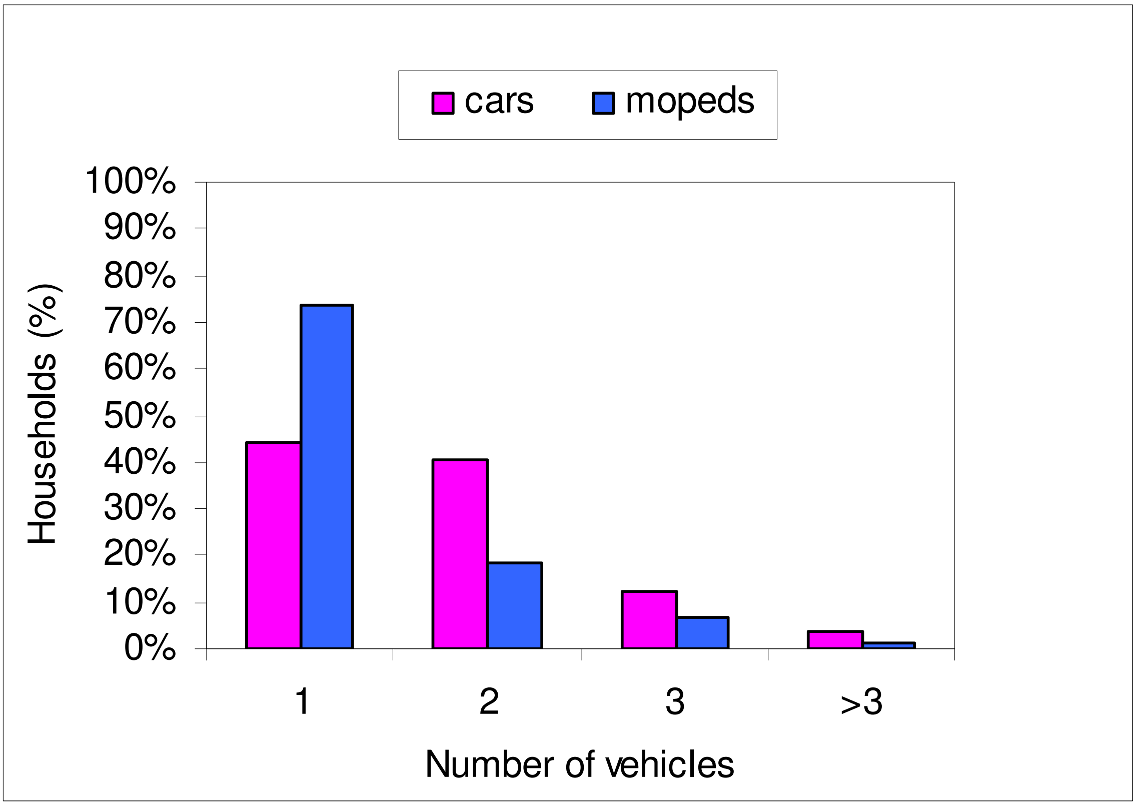



Figure 4: Number of cars and mopeds available to the households.

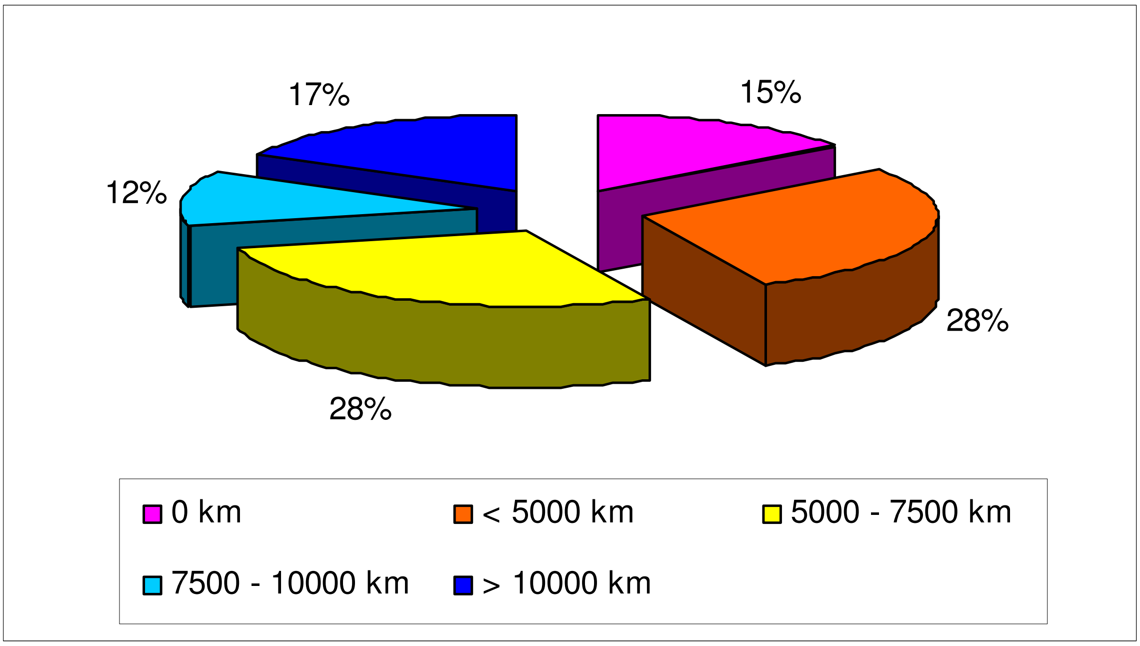



Figure 5: Kilometres covered by car per annum.

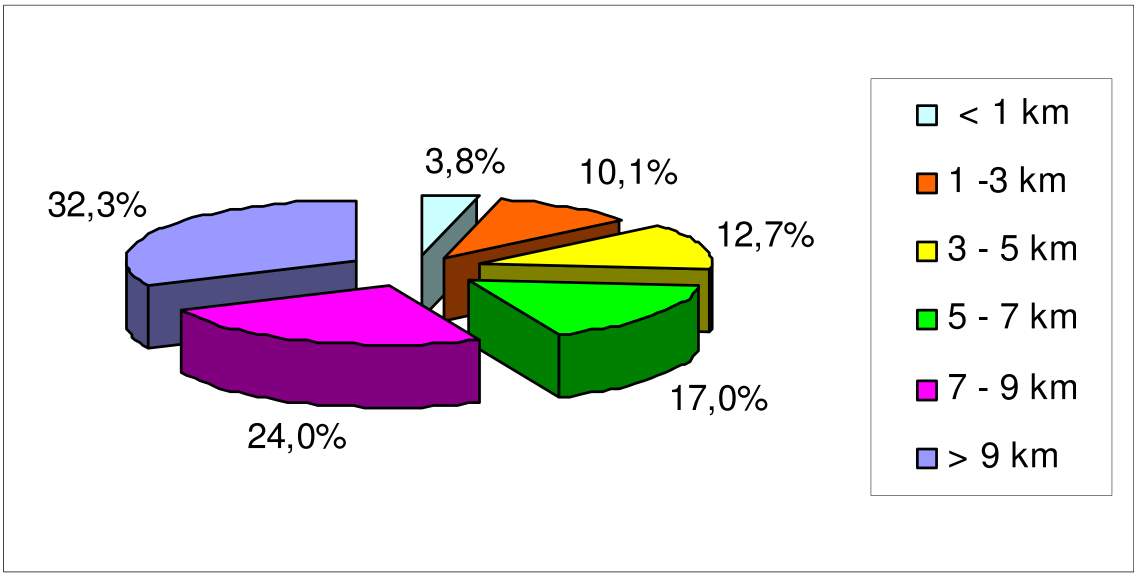



Figure 6: Length of the typical commuting one-way trip.

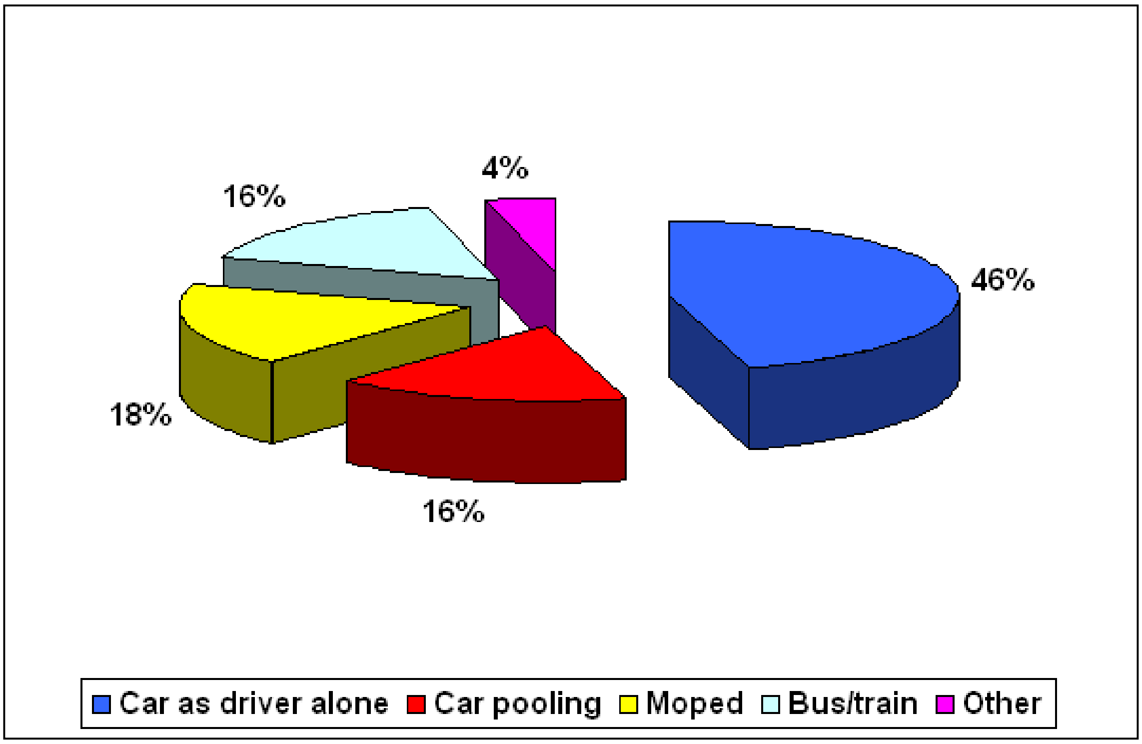


Figure 7: Transport modes used for the typical commuting one-way trip.

## 7. Mode choice model estimation

As stated before, to simulate transport mode choice behaviour for commuting trips within the urban area of Palermo, a multinomial logit model was employed. To estimate the model parameters, we adopted the Nlogit 3.0 software processing 3080 choice observations (several respondents haven't completed the SP experiment). The following formulations refer to one-way trip systematic utility functions, associated with the different transport modes, containing only the attributes that have proved to be statistically significant.

$$V_{CAR} = \beta_{T_{TRAVEL}} \cdot T_{TRAVEL} + \beta_{C_{TRAVEL}} \cdot C_{TRAVEL} + \beta_{T_{PARKING}} \cdot T_{PARKING} + \beta_{CAR} \cdot CAR$$

$$V_{CARPOOLING} = \beta_{T_{TRAVEL}} \cdot T_{TRAVEL} + \beta_{C_{TRAVEL}} \cdot C_{TRAVEL} + \beta_{T_{PARKING}} \cdot T_{PARKING}$$

$$V_{CARSHARING} = \beta_{T_{TRAVEL}} \cdot T_{TRAVEL} + \beta_{C_{TRAVEL}} \cdot C_{TRAVEL} + \beta_{T_{PARKING}} \cdot T_{PARKING} + \beta_{NCARS} \cdot NCARS + \beta_{CS} \cdot CS$$

$$V_{PUBLICTRANSPORT} = \beta_{T_{TRAVEL}} \cdot T_{TRAVEL} + \beta_{C_{TRAVEL}} \cdot C_{TRAVEL} + \beta_{PT} \cdot PT$$

Where:
$V_j$: systematic part of the utility function assigned to alternative $j$;
$T_{TRAVEL}$: one-way trip travel time (min.);
$C_{TRAVEL}$: one-way trip travel cost (€);
$T_{PARKING}$: parking time (min.);
$CAR$ (1/0), $CS$ (1/0), $PT$ (1/0): alternative specific constants;

*NCARS*: for a single family, it measures the number of cars available to each individual daily moving for working or studying;

$\beta_{T_{TRAVEL}}, \beta_{C_{TRAVEL}}, \beta_{T_{PARKING}}, \beta_{NCARS}, \beta_{CAR}, \beta_{CS}, \beta_{PT}$ : coefficients.

For private car, car pooling and car sharing, the one-way trip travel time attribute is the sum of the time spent for moving from the origin zone to destination and the access time; for public transport, travel time consists of the following elements: the in-vehicle time, the waiting time at the bus stop and the access time. For the access time, other specifications were tested as a distinct variable rather than a part of the trip travel time attribute, finding out worse estimation results.

As regards the one-way trip travel cost variable, in the car and car pooling case, it consists of the following components: a cost attribute obtained multiplying the kilometric cost by the distance covered (from the RP survey) and the parking cost. The specification introducing the parking cost as a distinct variable gave worse estimation results. In the car sharing case, the trip travel cost is based on the kilometric and hourly costs: (the kilometric cost x the distance covered) + the hourly cost. For public transport, the one-way trip travel cost is calculated on the basis of the season ticket price for a bus user in Palermo.

Table 4 shows the coefficients of the attributes that proved to be statistically significant, the model goodness-of-fit measures and the output of the *t*-test on individual parameters.

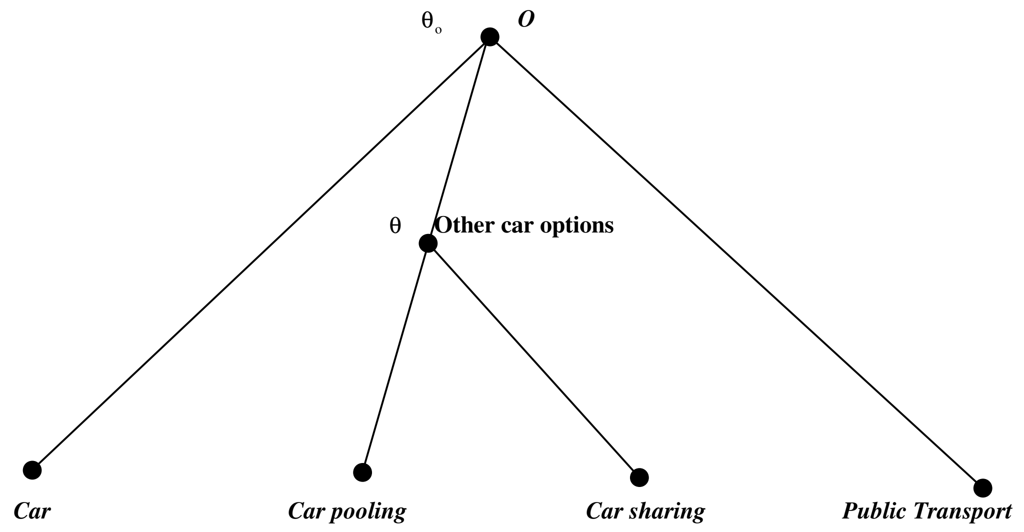
Table 4: Estimation results for the multinomial logit model.

| *Attribute* | *Coefficient* | *Standard Error* | *t-ratio* | *P[\|Z\|>z]* |
|---|---|---|---|---|
| $T_{TRAVEL}$ (min.) | -0.02605340 | 0.27924585E-02 | -9.330 | 0.0000 |
| $C_{TRAVEL}$ (€) | -0.28923442 | 0.27332091E-01 | -10.582 | 0.0000 |
| $T_{PARKING}$ (min.) | -0.10766113 | 0.13312674E-01 | -8.087 | 0.0000 |
| NCARS | -2.60542611 | 0.21059922 | -12.371 | 0.0000 |
| CAR (1/0) | 1.14893210 | 0.98749327E-01 | 11.635 | 0.0000 |
| CS (1/0) | 1.48328631 | 0.16045208 | 9.244 | 0.0000 |

*Summary statistics*
Number of choice observations = 3080
Log likelihood function = - 3892.192
$\rho^2$ (constants only) = 0.04
Value of time ($T_{travel}/C_{travel}$): 5.40 €/h

As the reader can observe in Table 4, the selected explanatory variables are highly significant and have the proper signs; furthermore, the resulting trade-off between travel time and travel cost which is consistent with the findings of previous studies on transport mode choice behaviour in Italy (see for example Cherchi, 2003).

Besides the multinomial logit, we also tested other model structures by using the Nlogit 3.0 software; in detail, some nested logit functional forms were examined. Among these, only one form resulted good enough as regards the *t*-test on coefficient estimates and the informal tests on coefficient signs and trade offs (like the rate of substitution between travel time and travel cost). This model is the one assuming a correlation between the two innovative transport systems, car pooling and car sharing. Figure 8 and Table 5 illustrates, respectively, the decision-making process and the estimation output under the aforesaid nested logit model.




*$\theta_o$: parameter determining the variance of the first decision-making step error term.*
*$\theta$: parameter determining the variance of the second choice level error term.*

Figure 8: The variation in modal split depending on the car sharing kilometric fare.

Table 5: Estimation results for the nested logit model.

| *Attribute* | *Coefficient* | *Standard Error* | *t-ratio* | *P[\|Z\|>z]* |
|---|---|---|---|---|
| $T_{TRAVEL}$ (min.) | -0.00453299 | 0.00245883 | -1.844 | 0.0652 |
| $C_{TRAVEL}$ (€) | -0.08562979 | 0.02325707 | -3.682 | 0.0002 |
| $T_{PARKING}$ (min.) | -0.03196440 | 0.01516793 | -2.107 | 0.0351 |
| NCARS | -2.82168303 | 0.41167262 | -6.854 | 0.0000 |
| CAR (1/0) | 0.60815977 | 0.12725500 | 4.779 | 0.0000 |
| CS (1/0) | 1.31656840 | 0.19183171 | 6.863 | 0.0000 |
| PT * (1/0) | 0.33456320 | 0.10599345 | 3.156 | 0.0016 |
| Inclusive value car | 1.00000000 | | (fixed parameter) | |
| Inclusive value other car options | 1.12921693 | 0.18949129 | 5.959 | 0.0000 |
| Inclusive value Public Transport | 1.00000000 | | (fixed parameter) | |
| Summary statistics<br>Number of choice observations = 3080<br>Log likelihood function = -3918.695<br>$\rho^2$ (constants only) = 0.03<br>Value of time ($T_{travel}/C_{travel}$): 3.22 €/h | | | | |

Note: * Alternative specific attribute for the public transport option.

The following observations on the nested logit model emerge from the analysis of Table 5:

- all the coefficient estimates have the expected signs;
- unlike the multinomial logit case, the public transport specific constant significantly differs from 0;
- in comparison with the multinomial logit case, the log likelihood function value and the rho squared index worsen; in addition, the statistical significance level of individual coefficients decreases, especially for the trip travel time attribute that can be considered different from 0 only at the 10% significance level;
- the inclusive value parameter for the "other car options" composite alternative is not significantly different from 1 (*t*-ratio with respect to 1 = 0,682), so multinomial logit appears an appropriate choice, since the hypothesis of correlation is rejected by the data.

## 8. The application of the mode choice model

The potential demand for car sharing and car pooling was estimated applying the calibrated multinomial logit model to a future scenario characterized by the following transport policy actions: a rise in parking fees and the implementation of closed-to-traffic zones for high emission vehicles, with reference to Palermo city centre; the development of the public transport system, in terms of frequency and capacity, thus reducing the in-vehicle time and the waiting one (due to a new light rail line and new three tram lines); the diffusion of reserved parking areas for car sharing and car pooling users. For a typical outskirts-city centre trip, Table 6 highlights the modal split under the present conditions of the urban mobility system in Palermo; while Figure 9 shows the variation in the modal split depending on some future pricing strategies fostering the car sharing competitiveness by the car sharing kilometric fare.

As the reader can notice in Figure 9, the car sharing or club market share grows from the present scenario level that is close to 0 to a value of about 10%, in the case of the lowest kilometric cost; furthermore, car pooling users increase slightly, with respect to the present situation. The low market share of car sharing can be explained considering it as a mode of transport particularly addressed to commuters moving from those suburban zones characterized by a weak travel demand, that consequently are not adequately served by the public transport system.

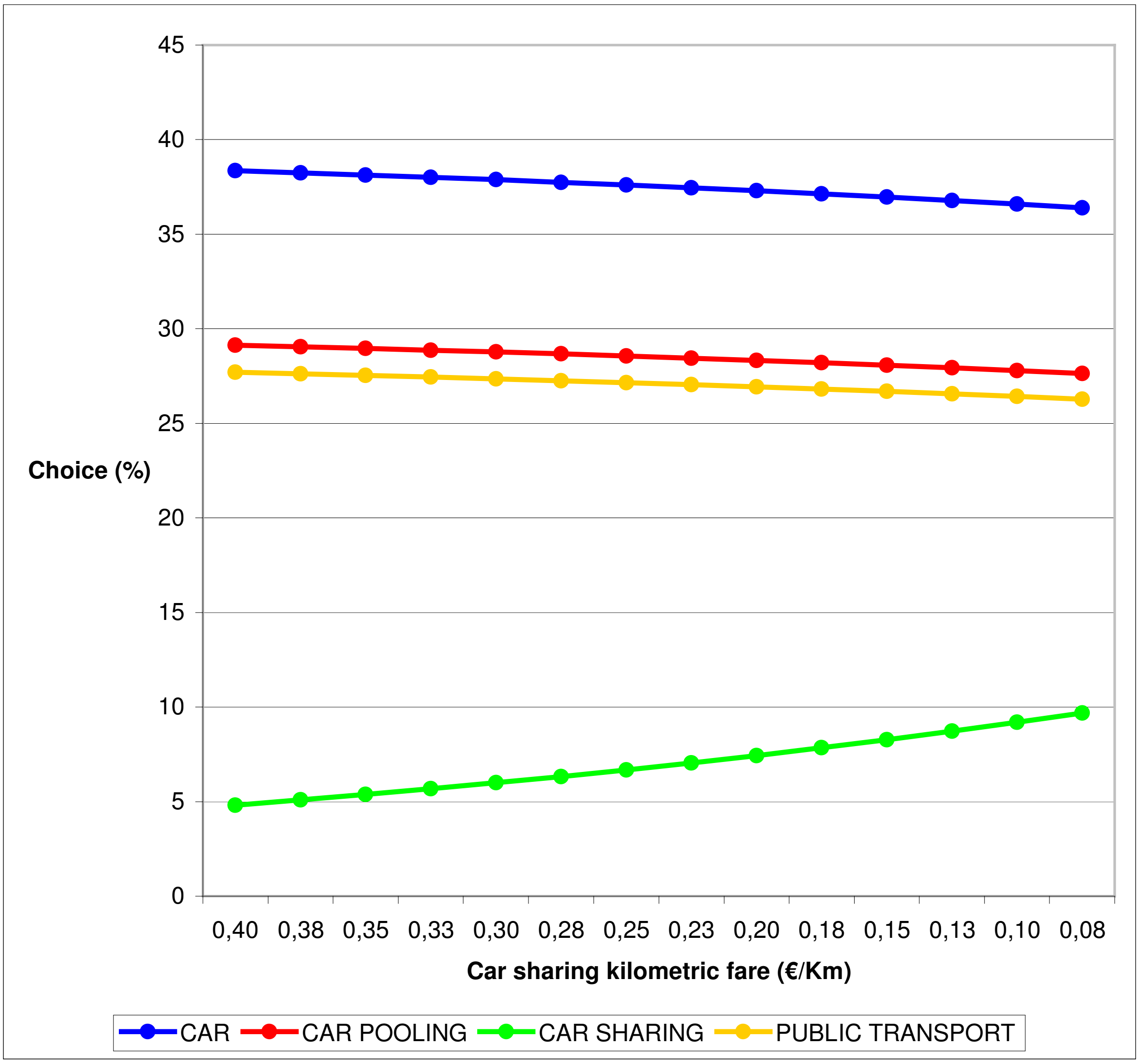



Figure 9: The variation in the modal split depending on the car sharing kilometric fare.

Table 6: The modal split under the present scenario.

| *Kilometric fare (€/Km)* | *Choice probability (%)* | | | |
|---|---|---|---|---|
| | Car | Car pooling | Car sharing | Public Transport |
| 0,20 | 68,02 | 21,06 | 0,02 | 11 |

## 9. Conclusions

The paper illustrates the development of a urban transport demand model to forecast commuter choice behaviour between car, public transport and innovative modes like car sharing and car pooling. In particular a multinomial logit model was calibrated by a SP survey involving workers and students (about 500 respondents) daily travelling towards the city centre of Palermo (Italy). Other functional forms were tested (some nested logit structures), but the hypothesis of correlation was rejected by the data. The model was applied to analyse the role of car pooling and car sharing in Palermo, under a future scenario in favour of a low environmental impact transport system (park pricing strategies, discounted or preferential parking for rideshare vehicles, improvement of the public transport service). As a result, car sharing, with its 10% market share, revealed its vocation for serving “weak” travel demand areas.

A future step of the research consists in employing the described random utility model to determine the optimal pricing strategy for car sharing service and to optimize location and size of parking areas for car club customers and car pooling users.

*Acknowledgements*

We wish to express our appreciation to the editors and the referees for the constructive comments that helped to clarify several methodological issues and improve the exposition.

## *References*

Ben-Akiva, M. and Lerman, S. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press, Cambridge, Massachusetts.

Bonsall, P.W. *et al*. (1981) *ITS YORKSHARE: Car-Sharing Schemes in West Yorkshire*, TEC.

Cascetta, E. (2001) *Transportation Systems Engineering: Theory and Methods*, Kluwer Academic Publishers, Dordrecht (The Netherlands).

Cherchi, E. (2003) *Il Valore del Tempo nella Valutazione dei Sistemi di Trasporto*, Franco Angeli, Milano.

Daly, A. J. and Rohr, C. (1998) “Forecasting Demand for New Travel Alternatives”, In: Gärling, T. Laitila, T. and Westin, K. (eds.) *Theoretical Foundations for Travel Choice Modelling*, Pergamon Press, Amsterdam, Netherlands.

Enoch, M. (2002) “Car Clubs – Lessons from the Netherlandsand San Francisco”, *Traffic Engineering and Control* 43 (4).

Ferguson, E. (1997) “The Rise and Fall of the American Carpool 1970-1990”, *Transportation* 24 (4).

Giuliano, G., Levine, D.W. and Teal, R.F. (1990) “The Impact of High Occupancy Vehicle Lanes on Car-Pooling Behaviour”, *Transportation* 17 (2).

Hunt, J. D. and McMillan, J. D. P. (1997) “Stated-Preference Examination of Attitudes Toward Carpooling to Work in Calgary”, *Transportation Research Record* 1598: 9-17.

Litman, T. (2000) “Evaluating Car Sharing Benefits”, *Transportation Research Record* 1702: 31-35.

Louviere, J., Hensher, D. and Swait, J. (2000) *Stated Choice Methods: Analysis and Application*, Cambridge: Cambridge University Press.

Migliore, M. and Catalano, M. (2007) “Urban public transport optimization by bus ways: a neural network-based methodology”, In: BREBBIA, C.A. and Wessex Institute of Technology, UK (eds.) *Urban Transport XIII: Urban Transport and the Environment in the 21st Century*.

O’Fallon, C., Sullivan, C. and Hensher, D.(2004) “Constraints Affecting Mode Choices by Morning Car Commuters”, *Trasport Policy* 11: 17-29.

Ortuzar, J. and Willumsen, L. (1994) *Modelling Trasport*, John Wiley & Son.

Permain, D., Swanson, J., Kroes, E. and Bradley, M. (1991), *Stated Preference Techniques: a Guide to Practice*, London: Steer Davies Gleave and Hague Consulting Group.

Prettenthaler, F. E. and Steininger, K. W. (1999) “From Ownership to Service Use Lifestyle: the Potential of Car Sharing”, *Ecological Economics* 28: 443-453.

Shaheen, S., Cohen, A. and Roberts, D. (2005) "Car Sharing in North America: Market Growth, Current Developments and Future Potential", *Working Paper*, Institute of Transportation Studies, University of California, Berkeley, NY.

Shaheen, S., Schwartz, A. and Wipyewski, K. (2004) “Policy Considerations for Car Sharing and Station Cars”, Transportation Research Record 1887: 128-136.

Teal, R.F. (1987) “Car Pooling: Who, How and Why?” *Transportation Research* 21A(3).

Washbrook, K., Haider, W. and Jaccard, M. (2006) “Estimating Commuter Mode Choice: a Discrete Choice Analysis of the Impact of Road Pricing and Parking Charges”, *Transportation* 33: 621-639.