EUROPEAN COMMISSION

DG RESEARCH

SIXTH FRAMEWORK PROGRAMME

THEMATIC PRIORITY 1.6

SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS

INTEGRATED PROJECT – CONTRACT N. 031315

A study on the effect of user transport demand

Deliverable no.	1.3.1.8
Dissemination level	Public
Work Package	WP 1.3
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Status (F: final, D: draft)	F_18.11.11
File Name	D1.3.1.8-Public-Giustiniani-Final.doc
Project Start Date and Duration	01 May 2006 – 31 December 2011

Abstract

This work describes the demand analysis carried out for the Demo of Rome, which should be installed in the P1 car park of the New Rome exhibition. The Rome Demo is planned to be Cybernetic Transport System, which takes users of the Exhibition from P1 car park to the entrances.

The analysis looked into the different factors which affect the demand, considering both the system transport attributes (such as: on-board time, waiting time at stops and on-board comfort) and technological aspects (such as: the absence of the driver on board), trying to understand which reaction users will have towards this innovative transport system. This aspect has been looked into both comparing the system proposed with a conventional transport system (with driver on board), and analysing the relation between the demand and users' socioeconomic attributes.

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Introduction

One of the main problems of big urban zones is the congestion due to the intensive use of private vehicles, which produces negative effects on increasing travel times, on environment – with regard to air and noise pollution, and soil consumption. Not always public transport provides an effective solution for the individual's and masses' mobility demands.

The European CityMobil project aims to provide possible solutions to this problem, contributing to a more effective urban transport organization, a more rational use of motorized traffic, a congestion and pollution reduction, a safer driving, a higher quality of living and, finally, an enhanced integration with spacial development. To succeed these objectives, advanced concepts have been elaborated for the implementation of advanced vehicles and for passengers. Furthermore, new instruments for urban traffic management are introduced and the barriers obstructing the introduction of automated systems are removed.

Within the project CityMobil the subproject 1 deals with implementation and demonstration of innovative transport systems. In particular, three permanent demos have been developed or in progress, with the aim to be opened to the public permanently in the following sites:

- Heathrow airport (UK), where a Personal Rapid Transit (PRT) has been implemented to connect the business car park to the new airport terminal 5.
- Castellón (Spain), where an Advanced Bus Rapid Transit (ABRT) has been installed.
- The New Exhibition of Rome (Rome Demo), where a Cybernetic Transport System (CTS) is planned be installed in P1 car park to take the users from and to the Exhibition entrances.

This study is part of Rome Demo and its objective is *to estimate the demand level as the different operating conditions of the Rome Demo change.*

This objective raises several issues, because the demand is connected to the quality of service offered, but the innovative character of the system can affect the demand itself and the effect caused can vary according the users' socioeconomic attributes.

According to the objective of this work and for the above-stated reasons, the research questions having answer in this work are:

- How does the demand vary as the quality of service changes?
- Which system do users prefer most? A CTS or a conventional system?
- Are there relations between users' different socioeconomic attributes and the demand?

In light of these research questions, the state of the art reached in the field of innovative transport systems has been analyzed and the results from the analysis of the few studies in this field are favourable to these innovative transport systems, revealing an attractive power of these systems on users.

A common feature of the majority of these studies is the use of the *Stated Preferences* (SP), since there is a lack of data about the real demand of working systems. SP is a method used for estimating the demand model and submits hypothetical choice scenarios to the potential users.

Since the Rome CTS has not been implemented and the SP method has been used in such conditions, it has been used in this work too. After this, the alternatives and the related experimental design are defined.

The alternatives proposed to the users of P1 car park are used by the CTS to reach the entrances of the Rome Exhibition from P1 car park or to reach the entrances on foot. These alternatives have been chosen because they will be at P1 users' disposal when CTS will have been installed.

As for features, three categories have been identified: (i) one related to scenario attributes (the presence or the absence of light and weather situation); (ii) one related to the CTS alternative, considering the following factors: distance from the stops, bus waiting times, on-board time and on-board comfort (meaning the presence or the absence of seats on board); (iii) one related to the alternative of going on foot (considering only the distance to reach the entrances).

Once defined the choice scenarios and the attributes, the times and the ways to submit questionnaires and the very questionnaires are defined. In this stage, to highlight possible preferences by users towards innovative or conventional transport systems, two choice scenarios, i.e. two questionnaires are submitted to two separate and random samples of P1 car park users. One of these questionnaires asked which way users prefer to reach the entrance: by CTS or foot?, and the other one proposed an electric Minibus (those working in the centre of Rome) or foot? The two choice scenarios had identical experimental designs, and so the probable preference for CTS instead of Minibus by users would have been clear in the demand models through the Alternative Specific Attribute (*ASA*), different in the cases of CTS or Minibus.

The questionnaires are divided into three sections: the first one (different for the pair-choice CTS vs foot and Minibus vs foot) concerning the description of the alternative and the proposed systems; a second one - common to both questionnaires – concerning the respondents' socioeconomic attributes; finally, in the third one (identical, in terms of experimental design, to both pairs-choice), all users were asked to choose between CTS and foot or Minibus and foot in different scenarios.

To reduce the number of scenarios to submit to all respondents, the techniques of fractional factorial plan and block decomposition have been sequentially used. So, from 288 possible choice scenarios (considering the attributes and related levels), only 24 have been selected, all of them divided into 6 blocks. Each block has been delivered to an equal number of interviewees.

The face-to-face interviews were held in the P1 car park to two separate and random samples of users in November and December of 2009. In all, 476 valid interviews were delivered and are equally distributed between the two samples: 238 interviews for CTS vs foot, 238 interviews for Minibus vs foot.

The interviews results have been used to calibrate Multinomial Logit demand models, using jointly the data from the two delivered questionnaires. In the first calibrated demand model – defined full model -, not all attributes are statistically significant. In detail, the attributes related to on-board time, the walking distance to reach the stops and the waiting time at stops are not statistically significant, while on-board comfort is statistically significant and relevant. Furthermore, both scenario attributes related to illumination and weather, distance to walk to reach the entrances and Alternative-Specific Attributes of CTS and Minibus are statistically significant and relevant, too.

Considering these results and in order to analyse the trend of the demand as the walking distance to reach the entrances changes in the different operating conditions, a final

Multinomial Logit model has been defined, in which the non significant attributes of the complete model have been removed.

Once estimated, the final Multinomial Logit model has highlighted that all attributes were statistically significant; in detail:

- The scenario attributes related to illumination and weather were the most relevant, affecting considerably the demand;
- The attribute related to on-board comfort affects the demand and the presence of seats on board favours transport systems;
- As for the attribute related to the walking distance, as it increases the modal split of "foot" alternative decreases for transport system alternative;
- As for *ASA*, ASA_{CTS} is three times higher than ASAMINI. This means that innovative transport systems are looked favoured by users, who probably consider them more reliable.

Once calibrated the model, the demand was analysed in 8 scenarios, where attributes change: weather, illumination and on-board.

After having completed the analysis of demand with the final Multinomial Logit model, the presence of significant correlations between the socioeconomic attributes of the sample and the demand, with particular reference to the following attributes: gender, education and age.

To carry out this analysis Mixed Logit (ML) demand models are used. Excluding some restrictive hypothesis present in Multinomial Logit models, they permit investigating the presence of heterogeneity - as regards to a given attribute like *ASA* in this case – in the population. Essentially, one or more model parameters are considered as stochastic instead of deterministic and, supposing a distribution (in this case, uniform, triangular and normal), are represented through an average, a variance and a prospective correlation with underlying parameters (in this case, the socioeconomic attributes).

A first ML model has been estimated to investigate the possibility that *ASA* show heterogeneity and so could be treated as stochastic instead of deterministic parameters. The analysis has highlighted that ASA_{CTS} is represented as stochastic parameter, while ASA_{MINI} are not.

After having reached this result, the presence of a statistically significant relationship between ASA_{CTS} and socioeconomic attributes of the sample has been investigated. The analysis has highlighted that this relation is significant only in the case of the age represented as a continuous variable. This relation has been positive and so as the age increases the demand for CTS increases (while the demand for Minibus is age invariant). Furthermore, for all age ranges, ASA_{CTS} is always higher than ASA_{MINI}.

Once calibrated ML model, how modal split changes as age between 20 and 65 changes is analysed. The same 8 scenarios of the final Multinomial Logit model have been analysed, imposing a 400 metre walking distance.

The last analysis concerns the comparison of scenarios from the final Multinomial Logit with ML. The comparison was made in two scenarios: Scenario 4 (day, dry, NOT guaranteed seat on board) is the most favourable for "foot" alternative both in CTS and Minibus cases, while Scenario 6 (artificial light, rain and guaranteed seat on board) is the most favourable for CTS and Minibus alternatives.

This work is divided into 6 chapters. In Chapter 1 a brief description of CityMobil project is reported, highlighting the Rome Demo and the activities done within it. The Chapter ends reporting the objective of this research work and research questions related to it.

In Chapter 2 the description of the state of the art in the innovative transport systems field is reported, both describing briefly innovative transport systems and reporting the demand studies carried out on this kind of systems and present in literature.

In Chapter 3 the experimental design, the methodology used for questionnaires and in which way questionnaires are delivered to P1 car park users are described. The Chapter ends with an analysis on what emerged from administered questionnaires.

In chapter 4, after a brief description of theoretical background underlying Multinomial Logit demand models, models are defined and results from their estimate with the aid of NLOGIT 3.0 software are reported. After having estimated the models, the way the modal split of different alternatives in P1 car park changes as attributes related to weather, illumination and on-board comfort at different walking distances to reach the entrance change is analysed.

In Chapter 5, the presence of correlations between demand and socioeconomic attributes of the sample is analysed. This correlation is investigated through Mixed Logit demand models, on which a brief description of theoretical background is reported. In the Chapter the results from models estimate and the analysis of demand change as users'age changes – the only socioeconomic attribute that has showed statistically significant correlations with the demand – are reported. For Mixed Logit models, too, NLOGIT 3.0 has been used for the estimate.

Finally, in Chapter 6 the final analyses, in which results from final Multinomial Logit model are compared and analysed, are reported. Then, the conclusions are reported and, after a brief description of the methodology used in this work, the results reached and coherent with the objective of this work are summed up. Furthermore, possible future developments of research in the field of innovative transport systems demand are shown.

1 The innovative transport systems and the CityMobil project

1.1 The research questions

In view of the possible opening to public of this system it was necessary to estimate the users demand for CTS in the different operating conditions. From this point of view the objective of this work is *to estimate the demand level as the different operating system conditions change*.

However simple it may seem, this objective raises a series of issues to deal with, because the expected demand for CTS is connected to the quality of service offered. This last one could be briefly expressed in service access times and on-board times or on-board comfort of the different alternatives. However, it is also true that, as the state of the art analysis will highlight, the very innovation of the system can have an impact to be estimated on the expected demand and this impact can change according to the users' socioeconomic attributes. These remarks broaden the horizon of the simple demand study of the Rome Demo and allow analysing certain aspects. These aspects will be useful in the valuation of innovative transport systems implementation in other sites, making the results of this work more generalizable and useful to the scientific community. For example, the possible presence of a correlation between users' age and the demand of the CTS will provide useful information on the opportunity to implement this system in areas with elderly population (or vice versa very young).

According to the objective of this work and in the light of above-stated remarks, the research questions which have answer in this work are:

- How does the demand change as the quality of service changes (distance from the stops, waiting time, on-board time and on-board comfort)?
- Which system do users prefer most? A CTS or a conventional system?
- Are there relations between users' different socioeconomic attributes (age, gender, education) and the demand?

The research questions are briefly reported in Figure 1. They have answer in this work thanks to demand models which allow connecting the level of the demand with CTS presence, with its transport features and with socioeconomic attributes of P1 car park users.

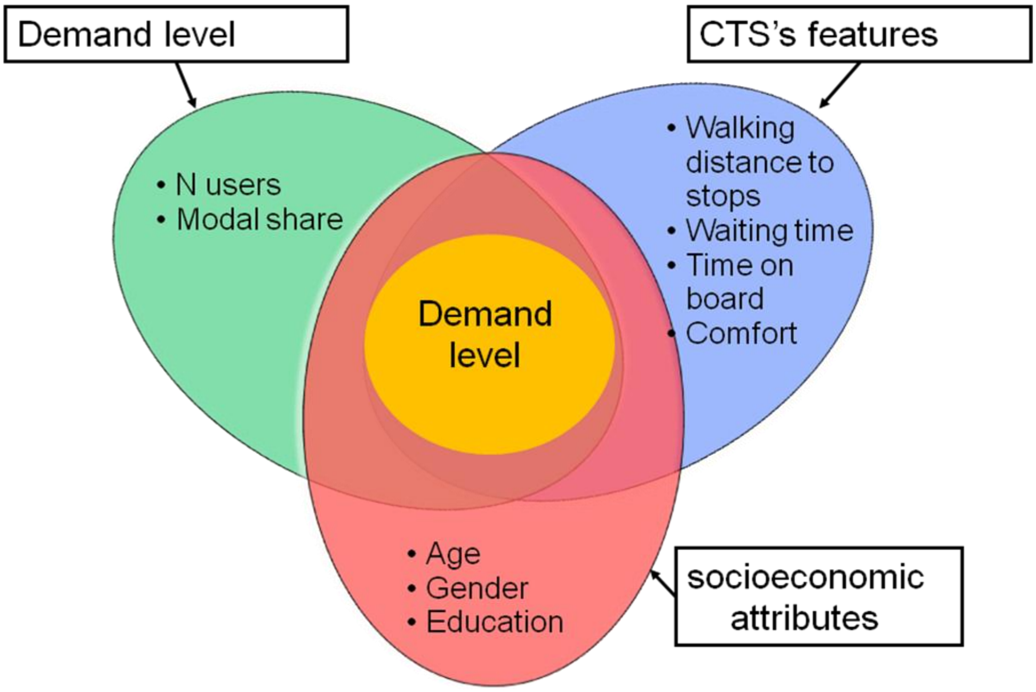


Figure 1 – Relation between the demand level of CTS, CTS's features and users' socioeconomic features.

2 The state of art in the field of automatic transport systems

2.1 Case studies and demand studies for innovative transport systems

Case studies and demand studies for innovative and automatic transport systems such as CTS and PRT have been carried out within some European research projects, and in detail CyberMove and EDICT, both co-funded by European Commission within 5th Framework Programme.

CyberMove focused on the CTS, while EDICT focused on PRT. Within these projects feasibility studies have been carried out and small demos have been made to value different aspects such as: financial sustainability, technical feasibility, users acceptance of these systems and demand analysis. After these two European projects, the European Commission financed the NETMOBIL project to revise the results of the researches carried out in the field of innovative transports. So, NETMOBIL has revised, analysed and summarized the results and the demand studies carried out within CyberMove and EDICT.

The main information sources on demand analysis for these transport systems are mostly present in the Deliverables of the projects (CyberMove Consortium, 2004a and 2004b; EDICT Consortium 2004a, 2004b and 2004c; NETMOBIL Consortium, 2005). As for demand studies on innovative transport systems, they are few and practically all published in conference proceedings (Alessandrini and Filippi, 2004; Bekhor and Zvirin, 2004; Minderhoud and Van Zuylen, 2005).

CyberMove has estimated the impact made by the implementation of CTS in 11 different European sites. The project results have been highlighted general remarks and first recommendations for the implementation in the city (CyberMove Consortium, 2004b), which can be summed up as follows:

- Critical factors for the success of a CTS are the localization and the care interface with other transport systems;
- The CTS have the potential to provide an innovative public transport system with a strong attraction to the users, but they do not solve themselves mobility problems.
- Users and their perception of CTS and its quality service are key factors for the success of every CTS. Users and their needs have to be considered right from the start also with actions for consensus building such as: information campaigns, focus groups and local meetings. This approach is recommended for all new transport infrastructures, but in the case of innovative transports such as CTS is compulsory.
- The role of local governments as for the implementation of CTS is fundamental and can decide the success or the failure of the project, and the failure of a CTS project can affect negatively the CTS concept and the related future diffusion.

In one of the CyberMove project sites placed near the “Technion University Campus” (Haifa, Israel) a demand study on a hypothetical CTS connecting the main buildings of the university to the car park and to the main bus stops has been carried out. It’s important to underline that the campus is placed in a hilly area and both car parks and the main bus stops are placed outside the campus. The demand model has been calibrated thanks to the administration of SP questionnaires to 150 students (1% of total population of the campus). On the whole, results show that 75% of respondents would use the CTS proposed, both after have parked near the campus entrance, and as a last-mile solution after having used the public transport system. It is important to highlight that the CTS, as it is described by respondents, has been proposed as a complement of public transport systems (Bekhor e Zvirin, 2004).

Another study, carried out within CyberMove project, concerns the city of Antibes, in France, one of main French Riviera sites, and the realization of a CTS which connects the car parks placed far and outside the old town with this one. At the moment the car parks are connected to the old town with a shuttle service, but the majority of the tourists prefer parking near the old town centre, causing traffic and congestion instead of using the car parks and the shuttle service. The demand study of Antibes has highlighted that the implementation of a CTS that connects the outside car parks with old town centre would triple the number of users of car parks and shuttle service (CyberMove Consortium, 2004b; NETMOBIL Consortium, 2005).

As for the PRT, a demand study has been carried out in the city of Almelo (Netherlands). The main aim of the study was to investigate the “willingness to pay” for a PRT that connects different crucial points of the city, such as the railway station or the hospital. The study was based on interviews with 300 potential users of the system. The majority of the respondents express their own willingness to use a PRT if it was implemented, but, anyway, about 25% of respondents said they would not use the PRT. The average “willingness to pay” for a PRT service emerged from the study has been in the range of 1 € (Minderhoud and Van Zuylen, 2005).

Another study was carried out in Cardiff (United Kingdom). Its aim was to estimate the impact of a supposed PRT in the area of Cardiff Bay, which in 2005 was deeply urbanistically modernized and reorganized for residential and commercial functions. The study has highlighted that the PRT would attract about 61% of actual users of TPL and about 9% of pedestrians, but it also would attract about 8% of car commuters who would use the combination of rail or bus into the centre and then onward by PRT. The study also shows that the average “willingness to pay” is in the range of 1£ (EDICT Consortium 2004a e 2004b; NETMOBIL Consortium, 2005).

Kungens Kurva is one of expanding areas in Huddinge (Sweden). In 2004, when the study was carried out within EDICT project, about 5 million of people Kungens Kurva visited this commercial area every year and the opening of “Hereon City entertainment” centre, according to estimates, would attract 3.5 million additional visitors. The majority of the visitors and of the employees, when study was carried out, reached the site by car, while only 5.5% of them reached it by PT. The demand study has highlighted that the implementation of PRT in 2015, when the trade centre will have reached its maximum extension, might allow a visitor out of 5 to reach the area by PT and so 17.3% of visitors would use PRT. This modal split is about four times larger than one of 2004 (EDICT Consortium 2004a; NETMOBIL Consortium, 2005).

3 The design and implementation of surveys

3.1 Definition of experimental design

The analysis of the state of the art has highlighted that there are not working CTS or PRT systems, on which demand studies were carried out as regards the system features with questionnaires based on *Revealed Preferences* (*RP*) method. Users are asked to describe their movements through structured questionnaires. These data, once properly elaborated, are then used to estimate the demand model.

As for CTS or PRT, on which demand studies were carried out to estimate demand models, *Stated Preferences* (*SP*) method was used. This method consists in submitting different scenarios to the respondent – hypothetical future user of the transport system. Scenarios are different from each other for value of different attributes related to: different alternatives of transport systems and the level-of-service of the different systems proposed, weather situation, the presence or less of tolls and other aspects. Through SP method, users can be asked to:

- Choose one of the different alternatives proposed. The alternatives are generally proposed in pairs and users are asked to choose one of the two alternatives;
- Rank the alternatives proposed. In this case, users are asked to rank the alternatives proposed from the best one to the worst one, creating a classification of different alternatives.
- To poll the different alternatives proposed. In this case, users are asked to poll the different alternatives proposed.

In the field of the transport models estimation, the two most widespread methods are the alternative choice and the alternative ranking. The use of the two methods is appreciable, each one has pros and cons. However, the analysis of the state of the art has highlighted that in the field of transports the choice between two or more alternatives is preferred for different reasons, such as:

- The ranking method is more difficult for the respondents and so the results can be less reliable than the method of choice, even if it provides more information for the same number of respondents;
- In the real world, users choose between different alternatives and rarely are asked to make a ranking in order of preference. In this case too, this aspect can make raking results less reliable than ones achieved by users' choice between different alternatives, since users are not used to ranking alternatives;
- If the objective is to predict user behaviour rather than to estimate the value of every single parameter or attribute, and since the behaviour is usually the result of a choice between different alternatives, the method of choice describes best the real behaviour of users.

For these reasons and for the fact that the method of choice is used to estimate demand models observed in literature, the choice between different hypothetical alternatives has been submitted to the respondents, using SP method.

Then, the alternatives between which respondents have to choose and the attributes used to describe each alternative are defined. As for alternatives, since the CTS will be implemented in the P1 car park of Rome New Exhibition, the two possible alternatives will be: (i) using the CTS to reach the entrance; (ii) reaching the entrance on foot.

Defining the attributes and the intervals in which they change, two different aspects are considered: (i) similar examples in literature; (ii) the conditions in which CTS will operate, considering both the different attributes used and the intervals in which attributes change. For example, since the system will be free, the attribute related to the travel cost has not been considered, or an interval of distance ranging from 200 to 800 metres has been used to consider the walking distances to go out from the car park.

The analysis of the state of the art has highlighted that the attributes often used are related to: (i) the quality of service in terms of: spread of the system often considered as the walking distance to reach the stops, waiting time at the stops, on-board time but also the cost of service and comfort; (ii) scenario attributes such as weather situation or illumination; (iii) attributes related to the other alternatives, such as the distance to reach the destination.

According to this information, attributes and intervals in which attributes change are defined. As for the CTS, the following attributes are defined: the walking distance to reach the stops, waiting time at stops, on-board time, on-board comfort, which has only two values: guaranteed seat on board – not guaranteed seat on board. As for the “foot” alternative, the only attribute considered is the walking distance. In conclusion, two scenario attributes are considered: weather situation, which could have rain and dry values, and illumination which could be artificial or day light. A synthesis of the different attributes and levels is reported in Table 1.

Table 1 - Attributes and levels for the different alternatives.

	Attributes	**Numbers of level**	**Levels**
Scenario	illumination	2	Day light – artificial light
	weather	2	Dry - rain
CTS/Minibus	distance from stop	3	20 – 75 - 150 (m.)
	waiting time at stop	2	2 – 5 (min.)
	on-board time	2	3 – 10 (min.)
	on-board comfort	2	Car – Bus
Foot	Distance	3	200 – 400 - 800 (m.)
Tot scenarios		**288**	

After having defined the attributes and the levels of the alternatives, the last thing to do is to investigate the presence or the absence of preferences towards innovative transport systems in comparison with classical systems. A possible approach could be to add the presence or absence of the driver on board among the attributes of the CTS. However, this approach has the drawback to make the presence or absence of the driver explicit and to turn it into a variable, creating the possibility of choice between three alternatives: the CTS, a conventional transport system with the same attributes of the CTS and the “foot” alternative. In this work, the choice between automatic system and system with driver has not been made explicit and another approach has been preferred: submitting two questionnaires to two separate and random samples of users. The questionnaires have the following features:

- CTS vs foot;

- Electric Minibus vs foot.

The two questionnaires submitted have the same experimental design, and so both Minibus and CTS have the same service level and operate in the same way (on-demand service, the same walking distances to reach the stops, the same waiting and on-board times) in the same scenarios. This approach permits understanding the implicit preference of the users towards automation.

3.2 Questionnaire design and delivery

The definition of questionnaire needs a reduction of the full Factorial Plan. In this case, considering the number of attributes and levels related, there are 288 choice scenarios. To submit these scenarios to respondents and to have a representative sample of answers for each of them, it would be necessary to deliver several thousand interviews, causing a significant increase in costs. For this reason, under similar conditions the number of scenarios to submit to every single respondent is reduced in two different ways:

- The “block decomposition technique”. Through this technique the possibility to decompose the scenarios in blocks is guaranteed. Each block will be submitted to a sample of users, avoiding that every single user answers to 288 scenarios. This technique provides some key aspects. The first one is that the “comparison” is provided for every single attribute in the block, i.e. in the same block there are the same number of scenarios of the attribute J, which has a high value and a low value. The second aspect is the “orthogonality”, i.e. given two attributes J and H, in the same block the number of cases in which these attributes have concordant values is equal to the number of cases in which attributes have discordant values.
- The technique of “fractional factorial plan”. This technique allows reducing the number of scenarios, though maintaining the “orthogonal” comparison among the remaining scenarios and so allowing estimating the main effects. Essentially, the fractional factorial plan is obtained with a full factorial plan through the definition of “defining relations”, which connects a value of an attribute with one of other attributes. If on the one hand this method allows reducing, even considerably, the number of scenarios, on the other hand it leads to loss of chances to estimate side effects of interaction between the attributes confused with kept effects.

In this work the technique of the fractional factorial plan have been used reducing the number of scenarios from 288 to 24, and the technique of block decomposition, which decomposed the remaining scenarios in six blocks, each having four scenarios. During the interviews, a block was submitted to each user, so four scenarios of choice were submitted to each user. According to what has been observed in literature and trying on the one hand to avoid submitting too many interviews with the aim to contain costs and the other hand to avoid submitting too many scenarios to a single user, four scenarios for each block have been considered adequate.

After having defined the blocks of the scenarios, it was possible to define the questionnaire. The questionnaire submitted is divided into three sections, which are:

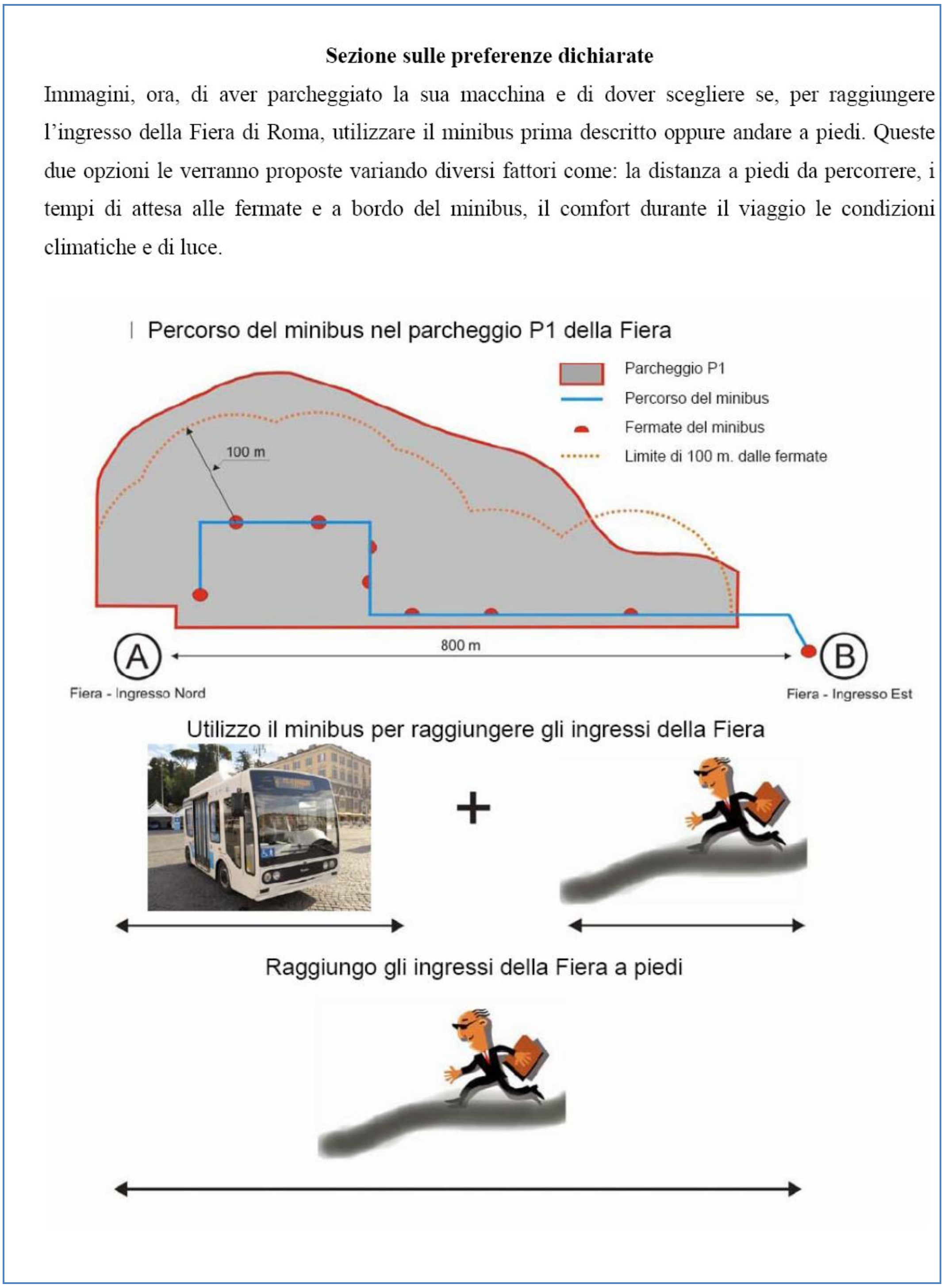
- Description of the alternatives. In this section, a CTS operating in P1 car park, providing an on-demand service is described in the most neutral way possible. In the other questionnaire, a system of electric Minibus operating in P1 car park and providing an on-demand service is described. The two texts are very similar and much attention has been paid to make them the most neutral possible, trying to avoid distortions. In short the systems are showed as operating along a route, providing an on-demand service between the stops;

- Respondent's data, the same for Minibus and CTS, related to: age, gender, education, profession, point of departure to reach the Exhibition and time spent to reach it;
- The part related to SP, the same for CTS and Minibus.

The face-to-face interviews have been delivered in the car park P1 to two different and random samples of users in November and December of 2009. 476 valid interviews have been delivered and they are distributed between the two samples as follows:

- CTS vs "foot" alternative (238 interviews – DB0);
- Minibus vs "foot" alternative (238 interviews – DB1).

The users who parked in P1 car park and then went to the entrance of the Exhibition were interviewed. Users, who were stopped by operators near the exit of car park, were informed of the objective of the interview and, if they agreed to be interviewed, they were asked to sit in a gazebo specially-set up. At the beginning of the interview the hypothetical system and the two possible alternatives are described: using the system or reaching the entrance on foot. In order to fix ideas and contextualize the choice, a sheet with the route scheme of the system implemented in P1 car park and the graphical display of the two alternatives was given to every user: using the system or reaching the entrance on foot (in Figure 2 the sheet used for Minibus). After having described the system, the respondent's data were collected and finally the SP scenarios were submitted.



Sezione sulle preferenze dichiarate

Immagini, ora, di aver parcheggiato la sua macchina e di dover scegliere se, per raggiungere l'ingresso della Fiera di Roma, utilizzare il minibus prima descritto oppure andare a piedi. Queste due opzioni le verranno proposte variando diversi fattori come: la distanza a piedi da percorrere, i tempi di attesa alle fermate e a bordo del minibus, il comfort durante il viaggio le condizioni climatiche e di luce.

Figure 2 – The sheet shown to respondent to see the two alternatives proposed.

3.3 First analyses on the collected sample

After the interviews, an analysis on the sample composition was carried out. Below the gender distribution between the two samples is reported (see Figure 4). As it is possible to see, the two samples as for gender representation have similar compositions with a strong male presence (at least 67% of respondents).

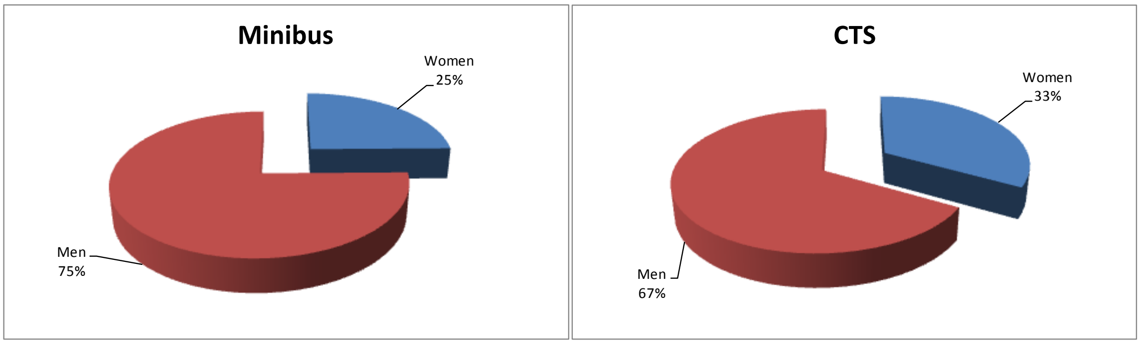


Figure 3 – Gender composition of the two samples interviewed.

In Figure 4 percentage breakdown about level of education in the two samples is reported. As it is possible to see, in the two samples there is a strong component of people with secondary school qualifications. The interviewees with a junior secondary school qualification is equal to about 7% for the sample Minibus vs “foot” and about 10% for the other sample. A more marked difference is observed as for people with three-year degree: in the case of Minibus vs “foot” they are about 13% of interviewees against 23% of sample CTS vs “foot”.

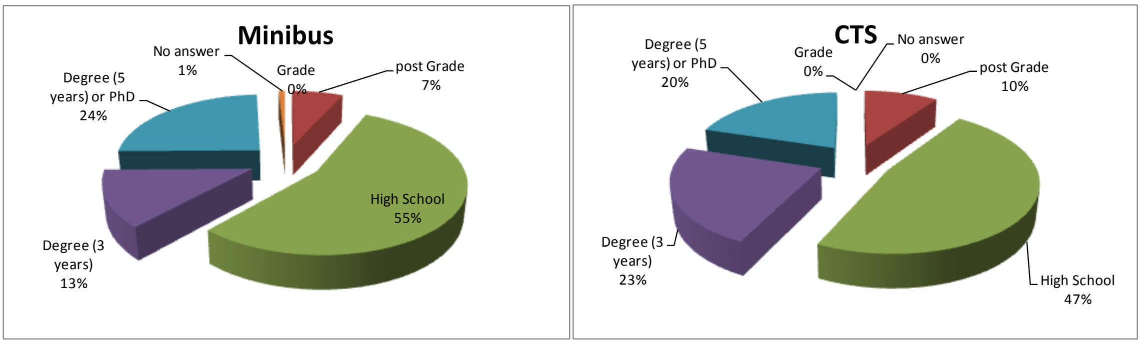


Figure 4 – Percentage breakdown in the two samples for educational qualification.

In Figure 5 the percentage break down between the two sample of different age ranges is reported. The two samples have not marked differences as for the age and, in both cases, the most represented age group is the 30-39 range.

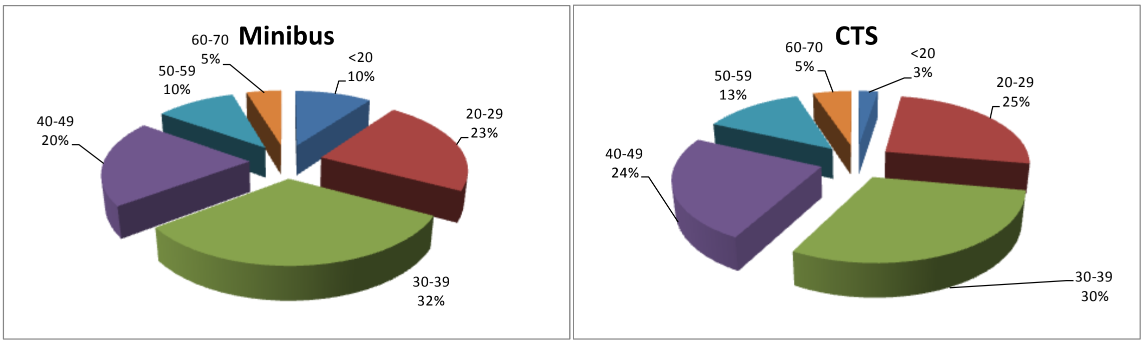


Figure 5 – Age breakdown of the two samples for age range.

In conclusion in Figure 6 the choices, made by the two samples in the different scenarios are reported in terms of modal split. This split has been done adding up the choices made by respondents in each scenario. As it is possible to see, apart from the scenario submitted, in the case of Minibus vs “foot”, in 56% of scenarios the interviewees chose to use the Minibus to reach the entrance of the Exhibition. In the case of the sample CTS vs "foot", the percentage of scenarios in which the interviewees chose to use the CTS to reach the entrance of the Exhibition is equal to 66% of the answers. These results, since the scenarios used are the same for both samples, highlighted how the CTS has a competitive advantage in comparison with the Minibus under the same operating conditions.

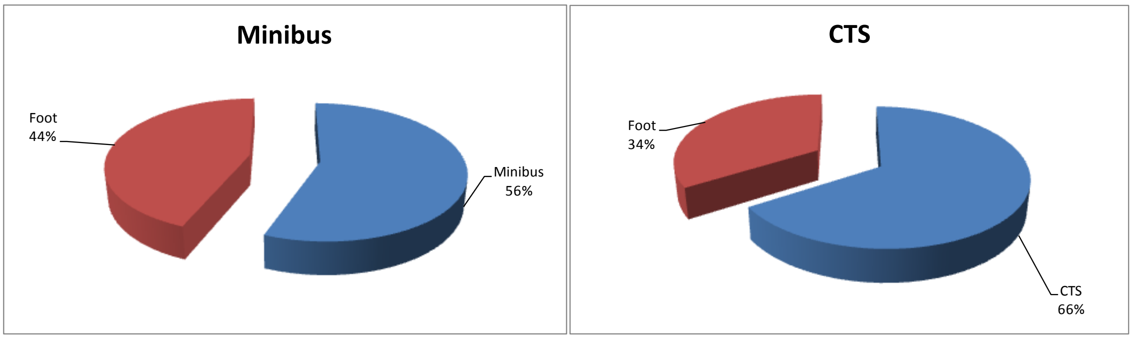


Figure 6 – Percentage breakdown of the choices, in terms of transport mode, calculated in both samples.

4 Calibration of Logit Multionomial demand models

4.1 Methodology

After having collected and properly organized interviews data, the methodology to estimate demand models, or more precisely modal split models was defined. In this first stage, Multinomial Logit models have been used.

Multinomial Logit models belong to the broader category of random utility models, which is a very widespread category in the simulation of users' choice behaviour.

The random utility models are based on the assumption that the user, possibly belonging to a homogeneous class of users in terms of behaviour, is a *rational decision maker* who maximizes the utility related to his own choices. In particular, the random utility models are based on the following hypotheses:

- While making his choices, the generic user *i* considers mi alternatives which are his choice set I_i.
- The decision maker *i* associates each alternative *j* of his choice set with perceived U_{ij} and choose the alternative which maximizes this utility.
- The utility associated with each alternative of choice depends on a series of attributes of the alternative and the decision maker and takes the form $U_{ij}= U_i(X_{ij})$, where X_{ij} is the vector of the attributes related to the alternative *j* and the decision maker *i*.
- The utility related to alternative j and to decision maker i for different reasons is not known with certainty by the outside observer (the analyst) and therefore it should be represented as a random variable.

So, random utility models do not allow determining the choice of user *i*, but allow defining the probability that, given a set of choice I^i, a certain alternative *j* is chosen.

According to these preliminary remarks, the perceived utility U^i_j can be expressed as the sum of the systematic utility V^i_j, which represents the average or the expected value of the perceived utility among all users with the same context of choice of the decision maker *i* and of a *random residuals* ε^i_j, which represents the deviation of the utility perceived by the user *i* from this value.

$$U^i_j = V^i_j + \varepsilon^i_j \qquad \forall j \qquad [1]$$

Among random utility models, Multinomial Logit model is the most widespread and "simple". This model is based on the hypothesis that ε_j related to the different alternatives are Indipendent and Identically Distributed (IID hypothesis) according to a Gumbel random variable with zero mean and parameter θ .

In particular, the mean and variance of the Gumbel variable apply:

$$E[\varepsilon_j] = 0 \qquad \forall j$$
$$Var[\varepsilon_j] = \frac{\pi}{6}\theta^2 \qquad \forall j \qquad [2]$$

Furthermore, the indipendence of random residuals implies that the covariance between any pair of random residuals is nothing:

$$Cov(\varepsilon_j, \varepsilon_h) = 0 \qquad \forall j, h \in I \qquad [3]$$

Using a Multinomial Logit model, two different demand models were calibrated: the first complete model and the final model. In the different calibrations made with the full model, the statistical representativeness and significance of the different attributes are analysed, supposing linear, algorithmic and square root trends. The calibration of the models was made using both DB and the utility functions took the form:

$$\begin{aligned}
&\underline{V}_1^0 = \beta_1^T * \underline{X}^0 && foot\ (CTS) \\
&\underline{V}_2^0 = \beta_2^T * \underline{X}^0 + ASA_2^0 && CTS \\
&\underline{V}_2^1 = \beta_1 * X^1 && foot\ (Minibus) \\
&\underline{V}_2^1 = \beta_2^T * \underline{X}^1 + ASA_2^1 && Minibus
\end{aligned} \qquad [4]$$

Where:

DB0=CTS vs foot

DB1=Minibus vs foot

The joint calibration allowed imposing the equality of β to common attributes and so making explicit the different users' perceptions of CTS and Minibus through the two values of *ASA* (Alternative-Specific Attribute), which are included both in the CTS and Minibus utility. In detail, the joint likelihood function to maximize for models calibration took the form:

$$L = \prod_{i \in DB0} P_i^0 \cdot \prod_{j \in DB1} P_j^1 \qquad [5]$$

Where P_i^x is the probability that the user *i-th* chooses the alternative belonging to the set of alternatives *X*. In the application of this calibration method, it was assumed that both DB were homoskedastic (equal variance of the random residual). This hypothesis is based on the fact that the two samples are separately and randomly extracted from the same population and both questionnaires are SP.

4.2 Calibration of the "full" model.

The full model includes all attributes considered in the SP questionnaires and in detail the demand models take the form:

$$\begin{aligned}
&V_{piedi}^0 = \beta_1 * X_{Dfoot}^0 \\
&V_{CTS}^0 = \beta_2 * X_{il}^0 + \beta_3 * X_{Weather}^0 + \beta_4 * X_{Twait}^0 + \beta_5 * X_{Dstop}^0 + \beta_6 * X_{Tonboard}^0 + \beta_7 * X_{Com}^0 + ASA_{CTS} \\
&V_{piedi}^1 = \beta_1 * X_{Dpiedi}^1 \\
&V_{Mini}^1 = \beta_2 * X_{il}^1 + \beta_3 * X_{Weather}^1 + \beta_4 * X_{Twait}^1 + \beta_5 * X_{Dstop}^1 + \beta_6 * X_{Tonboard}^1 + \beta_7 * X_{Com}^1 + ASA_{Mini}
\end{aligned} \qquad [6]$$

Where:

β_1 is the parameter related to the "Walking Distance"attribute

β_2 is the parameter related to "Illumination"attribute

β_3 is the parameter related to "Weather" attribute

β_4 is the parameter related to "Waiting Time at stops" attribute

β_5 is the parameter related to "Walking Distance to reach the stop" attribute

β_6 is the parameter related to "On-board Time" attribute

β_7 is the parameter related to "On-board Comfort" attribute

SAA_{CTS} is the specific attribute of the CTS alternative

SAA_{MINI} is the specific attribute of the Minibus alternative

The model has been calibrated supposing different kinds of relationships between the attributes and the collected data, and in detail: linear, logarithmic and square root. The calibration results have highlighted very interesting aspects (see Table 2).

Table 2 – Parameters value of the different attributes in the full model – linear relationship between the data and the attributes.

	CTS	Minibus	Significance
β_1	-0,00148		-7,141 (si)
β_2	-0,4366		-4,316 (si)
β_3	-1,2195		-11,892 (si)
β_4	0,0217		0,640 (no)
β_5	0,0006		0,645 (no)
β_6	-0,0190		-0,131 (no)
β_7	0,2672		2,642 (si)
ASA	0,6971 - 0,1599		CTS 2,937 (si) Mini 0,676 (no)
ρ^2=0,56671		ρ^2adj=0,56465	

The first aspect is that the scenario attributes related to Weather and Illumination are statistically significant and relevant and in particular Weather, which has a very high value of the parameter. The attributes related to the Walking distance to reach the stop, Waiting Time at stop and On-board Time are, however, not statistically significant and so did not affect the hypothetical choice of the respondents. This result has to be put into the context of choice, where distances and time are limited and the differences in terms of time spent to reach the entrance with the system or on foot do not differ substantially. In the light of these remarks, the walking distance to reach the Exhibition is statistically representative and relevant, considering that it is related not to binary sizes like Illumination or Weather (which can take 0 or 1), but to the Walking Distance, which is shown in hundreds of metres in the questionnaire. As for the system attributes, On-board Comfort is statistically significant and quite relevant, even if scenario attributes related to Weather and Illumination are more relevant than it. In conclusion, it is important to note that *ASA* values are different from each other and in particular ASA_{CTS} is much higher than ASA_{MINI}, even if this last one is statistically little significant.

4.3 Calibration of the "final" model

In the light of the full model calibrations results, the attributes to consider and ones to exclude in the final model are defined, in order to represent the users' choices of P1 car park. The results highlighted that, regardless of hypothesized relationship (linear, logarithmic and with square root) between the data and the attributes, those related to the Walking Distance to reach the stop, Waiting Time at the stop and On-Board Time were not statistically significant. For these reasons, these attributes were removed from the final model. As for ASA_{MINI}, which was statistically little significant, it was maintained because *ASA* usually include all those effects not made explicit, and so in this case it would have partially included the effects of the attributes removed. For these reasons, these attributes have been removed from the final model.

According to these remarks, the demand models have taken the following form:

$$
\begin{aligned}
V^0_{piedi} &= \beta_1 * X^0_{Dfoot} \\
V^0_{CTS} &= \beta_2 * X^0_{il} + \beta_3 * X^0_{weather} + \beta_7 * X^0_{Com} + ASA_{CTS} \\
V^1_{piedi} &= \beta_1 * X^1_{Dpiedi} \\
V^1_{Mini} &= \beta_2 * X^1_{il} + \beta_3 * X^1_{weather} + \beta_7 * X^1_{Com} + ASA_{Mini}
\end{aligned}
\qquad [7]
$$

Where:

β_1 *is the parameter related to the "Walking Distance"*

β_2 *is the parameter related to "Illumination"attribute*

β_3 *is the parameter related to "Weather" attribute*

β_7 *is the parameter related to "On-board Comfort " attribute*

SAA_{CTS} *is the specific attribute of CTS alternative*

SAA_{MINI} *is the specific attribute of Minibus alternative*

The demand model has been calibrated using data from both DB0 and DB1, as shown in previous paragraphs, and supposing a linear relationship between data and attributes considered. In Table 3 the results of the final model calibration are reported.

In detail, β_1 is negative and so the "foot" alternative decreases as the Walking Distance increases. As for β_2, it is negative and this means that, since it is included in the utility function of CTS/Minibus, in the case of "day light" the modal share decreases, while in the case of "artificial light" it increases. Also β_3, which is related to weather, is negative and has high value: so, a substantial increase in CTS/Minibus modal share is observed in case of rain, while in case of "dry" the "foot" alternative has many advantages. As for the only attribute related to the quality of the service, i.e. the on-board comfort, the related parameter β_7 is positive, even if has lower value than one of the attributes Climate and Light (anyway, all attributes which can take the value 1 or 0), and therefore in case of guaranteed seat on board the demand for CTS/Minibus increases.

In conclusion, both *ASA* increase substantially because they probably include the effects of the attributes removed from the model. It is important to underline that ASA_{CTS} has a value which is three times higher than the value of ASA_{MINI} and therefore the CTS attracts more users than Minibus under the same conditions.

Table 3 – Value of the parameters of the different attributes in the final model – linear relationship between data and attributes.

	CTS	Minibus	Significance
β_1	-0,00145		-7,141
β_2	-0,4373		-4,316
β_3	-1,2196		-11,892
β_7	0,2685		2,642
ASA	0,8111	0,2740	CTS 5,522 Mini 1,885
ρ^2=0,56655		ρ^2adj=0,56518	

4.4 The demand analysis through the final Multinomial Logit model

According to the results of the final model calibration, it is possible to analyse the variation in demand as the attributes change. The analysis was carried out supposing different operating conditions in which the system might operate in the future. In particular, the way the modal split of the system vs foot changes as the walking distance to reach the entrance changes in different conditions of Illumination, Weather and On-board Comfort is analysed, for a total of 8 scenarios reported in Table 4. The walking distance varies from 50 meters to 800 meters. The over 800 metres distances weren't considered, because the above-stated distance is the real longest distance to walk in the car park.

Table 4 – The scenarios considered as the walking distance to reach the entrance changes.

	Illumination*	Weather**	Comfort***
Scenario 1	1	1	1
Scenario 2	0	1	1
Scenario 3	1	0	1
Scenario 4	1	1	0
Scenario 5	0	1	0
Scenario 6	0	0	1
Scenario 7	1	0	0
Scenario 8	0	0	0

* 1= Day; 0=artificial m light

** 1= Dry; 0=Rain

*** 1= Car; 0=Bus

Below the trend of demand as the walking distance changes in the 8 simulated scenarios. As prelimary remark common to all scenarios, it is possible to note that:

- The modal share of the system increases as the walking distances to reach the entrance increase;

- As shown above, the SAACTS is much higher than SAAMINI (almost three times) and this leads to a modal split of CTS which is about 10% higher than one of the Minibus under the same conditions in all scenarios.

In Figure 7, the modal split as the walking distance to reach the entrances in the Scenario 1 (daylight, dry weather and guaranteed seat on board) is reported. It is possible to note that near the entrance more than 60% of users choose to reach it by walking in the case of CTS (percentage rising to 70% for the Minibus), while 800 metres from the entrance the situation is reversed and about 65% of users decide to reach the entrance using the CTS.

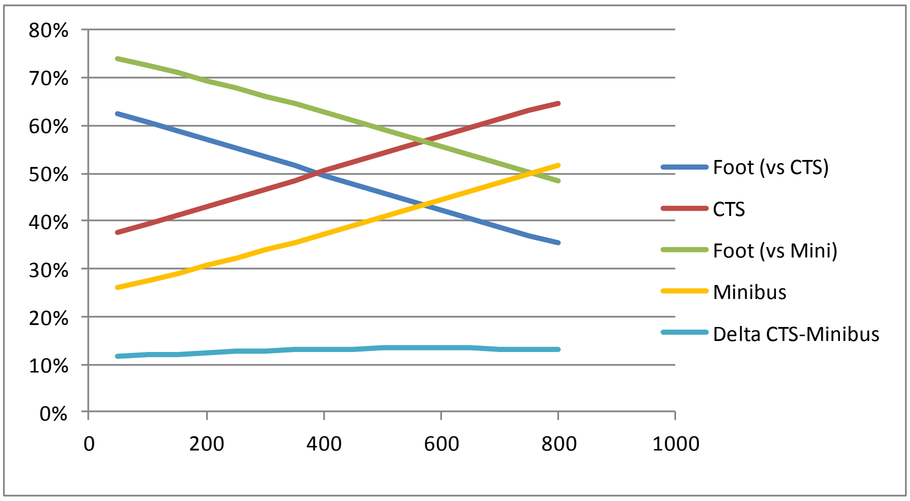


Figure 7 – Modal split in P1 as the walking distance changes in presence of: daylight, dry weather and guaranteed seat on board (Scenario 1).

In Figure 8 the trend of the demand as walking distance changes in Scenario 2 (dark, artificial light, dry weather and guaranteed seat on board) is reported. In comparison with Scenario 1, the only difference is related to Illumination and in this scenario dark and artificial light was supposed. As it is possible to observe in Scenario 2, the CTS/Minibus has a 10% higher modal split regardless of the walking distance in comparison with Scenario 1, showing that, in the presence of dark and artificial light, users prefer using transport systems rather than walking.

In Figure 9 the trend of the modal split as the walking distance to reach the entrance changes in Scenario 3 (daylight, rain, guaranteed seat on board) is reported. In comparison with Scenario 1, the only difference is the presence of rain (instead of dry weather as in Scenario 1). This difference makes a significant impact on the demand for CTS/Minibus, raising on the average the modal split of both CTS and Minibus by about 30% regardless of the walking distance.

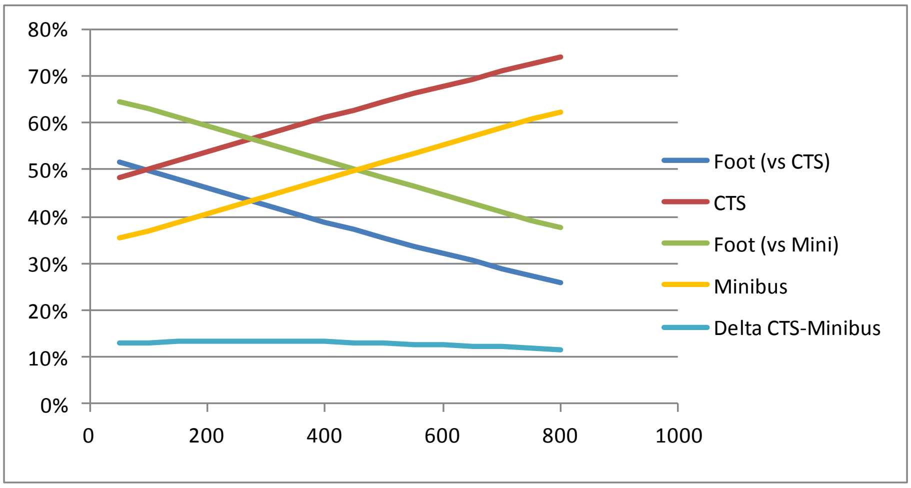


Figure 8 – Modal split in P1 as the walking distance changes in the presence of: dark, artificial light, dry weather and guaranteed seat on board (Scenario 2).

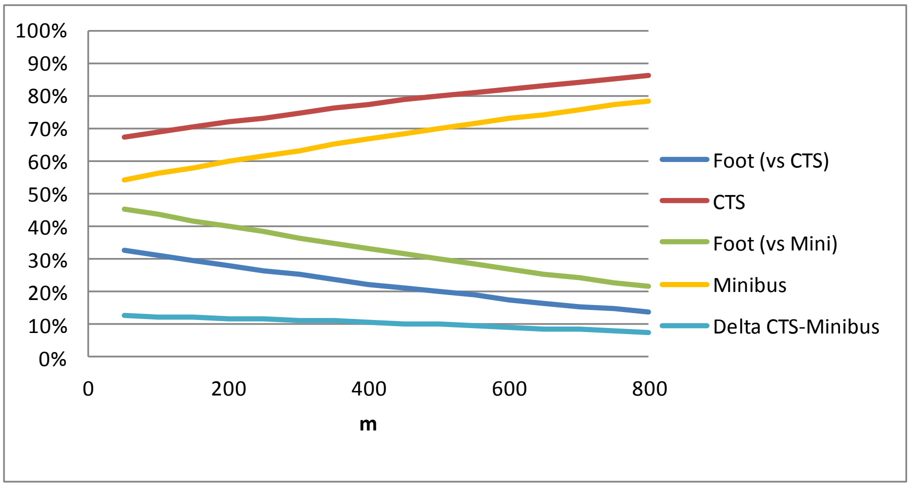


Figure 9 – Modal split in P1 as the walking distance changes in presence of: daylight, rain and guaranteed seat on board.

In Figure 10 the trend of the modal split as the walking distance to reach the entrance changes in Scenario 4 (daylight, dry weather, NOT guaranteed seat on board) is reported. In comparison with Scenario 1, where the seat was guaranteed, the seat is NOT guaranteed in Scenario 4. This attribute affects the demand of CTS/Minibus which, even if it increases as the walking distance increases, is anyway about 5% lower than one of Scenario 1. This data is also relevant from a planner's point of view, because it confirms the significance of the comfort on board in the user's choice process, even if it is not so important as the other attributes of scenario.

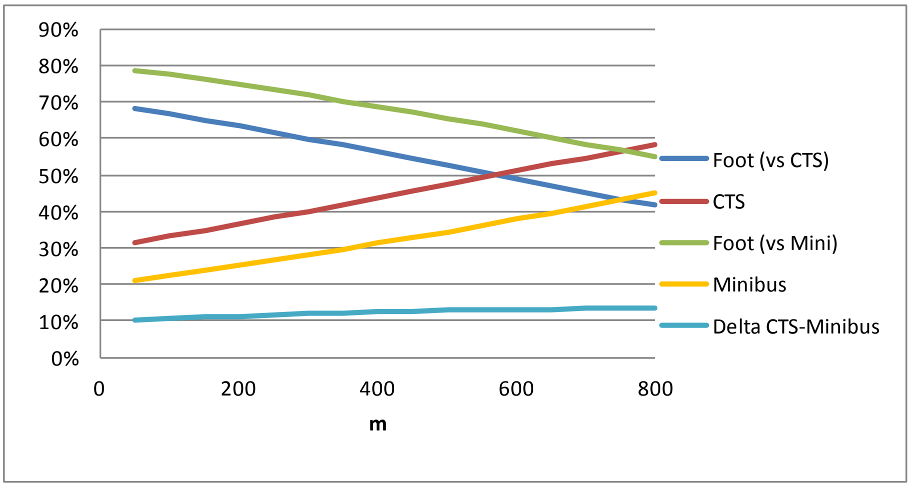


Figure 10 – Modal split in P1 as the walking distance changes in the presence of: daylight, dry weather and NOT guaranteed seat on board (Scenario 4).

In Figure 11 the trend of the modal split as walking distance to reach the entrance changes in Scenario 5 (dark, artificial light, dry weather, NOT guaranteed seat on board) is reported. In comparison with Scenario 4, a modal split increase of 10% for CTS/Minibus is observed in the presence of dark and artificial light in Scenario 5.

In Figure 12 the trend of the modal split as the walking distance to reach the entrance changes in Scenario 6 (dark, artificial light, rain and guaranteed seat on board) is reported. In Scenario 6 there are the more favorable conditions for CTS/Minibus, which both have modal shares higher than 60% 50 metres from the entrance.

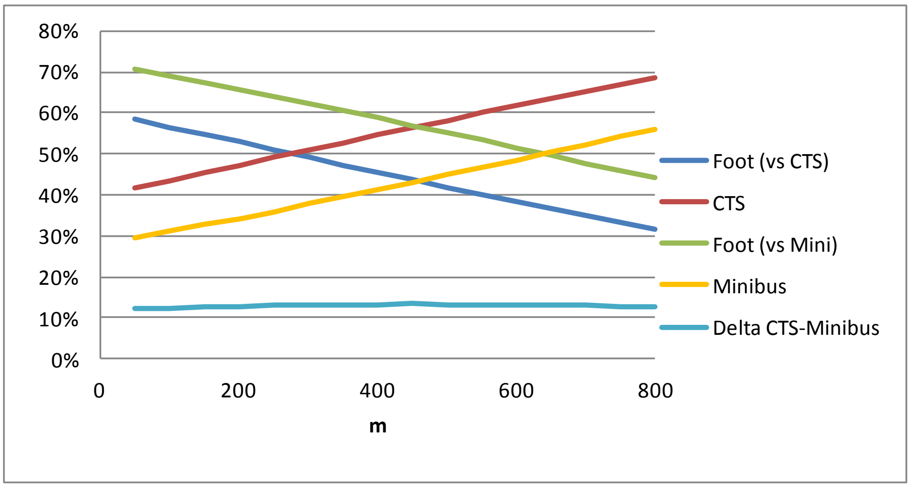


Figure 11 – Modal split in P1 as the walking distance changes in the presence of: dark, artificial light, dry weather and NOT guaranteed seat on board (Scenario 5).

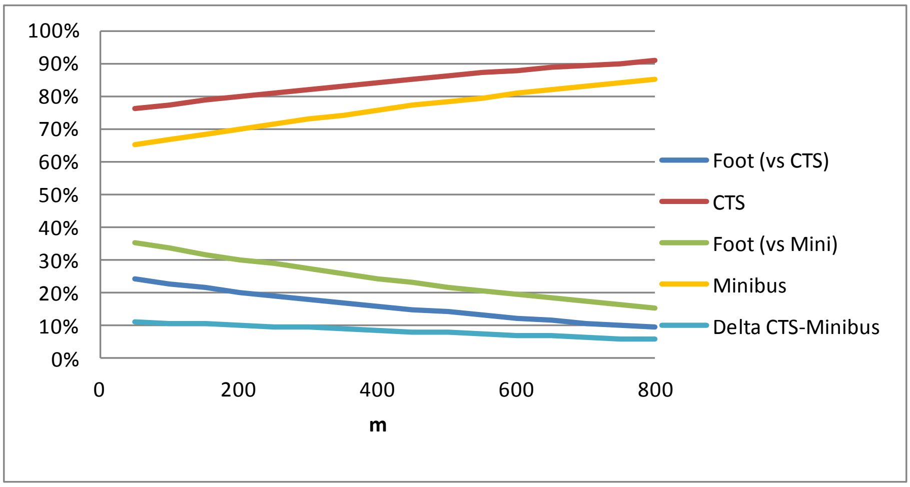


Figure 12 – Modal split in P1 as the walking distance changes in the presence of: dark, artificial light, rain and guaranteed seat on board (Scenario 6).

In Figure 13 the trend of the modal split as the walking distance to reach the entrance changes in Scenario 7 (daylight, rain and NOT guaranteed seat on board) is reported. In comparison with Scenario 6, in the presence of "day light" factor the modal share for CTS/Minibus is at least 50% 50 metres from the entrance.

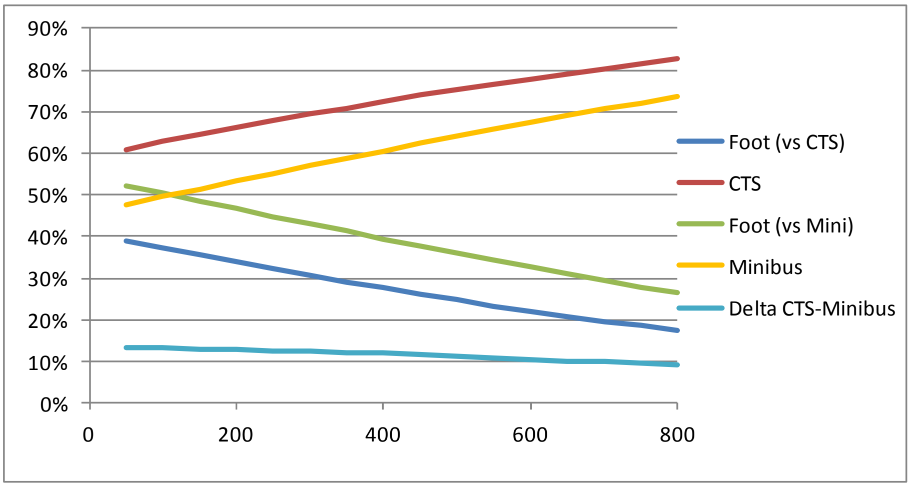


Figure 13 – Modal split in P1 as the walking distance changes in the presence of: daylight, rain and guaranteed seat on board (Scenario 7).

In Figure 14 the trend of the demand as the walking distance to reach the entrance changes in Scenario 8 (dark, artificial light, rain and NOT guaranteed seat on board) is reported. In comparison with Scenario 7, in presence of dark and artificial light the modal share for CTS/Minibus is at least 60% 50 metres from entrance and then it further increases.

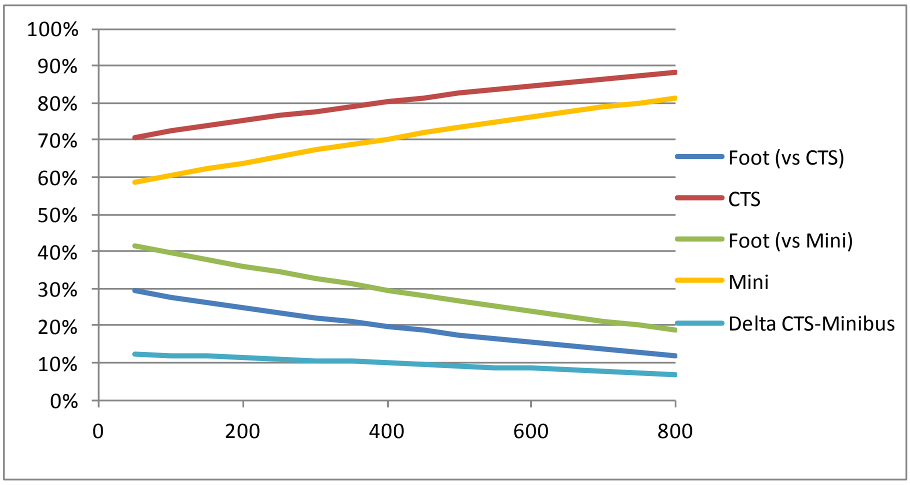


Figure 14 – Transport demand in P1 as the walking distance changes in the presence of: dark, artificial light, rain and NOT guaranteed seat on board (Scenario 8).

As the overall analysis shows, Scenario 4 is the most favourable to the “on foot” option in the case of both CTS and Minibus. This scenario has the following features: daylight, dry weather and NOT guaranteed seat on board. Under these conditions it is understandable that, even considered short walking distances 800 metres from entrance, 40% of users prefer walking in the case of CTS (50% in the presence of a Minibus).

However, more favourable conditions for CTS/Minibus are observed in Scenario 6 (dark, artificial light, rain and guaranteed seat on board). Under these conditions 65% of users decide to use the Minibus 50 metres from the entrance (about 75% of them prefer to use the CTS).

Apart from these two extreme cases, the walking distance has affected substantially the modal split and, in the other 6 scenarios, a percentage variation of 25% in the modal split in favour of CTS/Minibus is observed, when the distance is 800 metres from the entrance.

The overall analysis of the 8 scenarios allows drawing conclusions. The presence or the absence of rain is the main factor which affects the demand, according to what came out from the calibration made by the illumination factor. From a design point of view it is important to underline that the presence of guaranteed seat on board makes a significant impact on the modal share, which increases in favour of CTS/Minibus of about 5% under different conditions.

In conclusion, the most important data is that the CTS, under the same conditions of weather, illumination, on-board comfort and walking distance, has a 10% higher modal share than the Minibus. This means that, in the scenarios proposed, the users of P1 car park prefer using innovative transport systems, because they probably consider them more reliable.

5 The analysis of interaction between the demand and socioeconomic attributes

5.1 Methodology

After the first stage, the presence of relationships between the demand and the socioeconomic attributes has been analysed. This analysis was possible because in the anonymous questionnaire submitteded to the users there were also questions related to respondent's socioeconomic attributes, and, in detail, those ones useful for the analysis were:

- Gender;
- Age;
- Education;
- Income.

As for the first three attributes, the answers are present in all questionnaires, while as to income, about 50% of respondents preferred not to answer. For this reason this socioeconomic attribute has not been considered.

As for the methodology of analysis, one of the most widespread method for the analysis of the interaction between the demand and the socioeconomic attributes is the sample segmentation. Through this approach the sample is divided into segments according to the socioeconomic attribute which will be included in the analysis and a demand model is calibrated for each segment. For example, in the case of the age, the submodels are calibrated on age segments such as 21-30 years, 31-40 years, etc. Even if very popular, this approach has two limits:

- The segment might be composed of a limited number of respondents;
- The importance of the socioeconomic attribute in the demand is made explicit only if the segmentation identified allows this explicitation. So, the analyst is forced to test different segmentations and related calibrations for each socioeconomic attribute, until he succeeds in making the presence of relationship explicit or until he reaches the reasonable certainty that this relationship does not exist (Hensher et alii, 2005).

Mostly the second point, which forces the analyst to a difficult iterative process of testing, makes the method of segmentation difficult to use. In order to solve this kind of problems, right in the mid-nineties Mixed Logit (ML) demand models were developed.

5.2 Application of Mixed Logit models to the demand

As shown in the paragraph 4.1, a very short description of random utility models is reported. These random utility models are based on the assumption that the user, belonging to a class of homogeneous users in terms of behaviour, is a *rational decision maker* who maximizes the utility related to his choices.

According to these preliminary remarks, the perceived utility U^i_j can be expressed by the sum of the systematic utility V^i_j, which represent the mean or the value expected for the perceived utility among all users in the same context of choice, with the random residual ε^i_j, which represents the deviation of the utility perceived by the user *i* from this value:

$$U^j_j = V^i_j + \varepsilon^i_j \qquad [8]$$

In detail, as for Multinomial Logit models it is assumed that ε_j related to the different alternatives are Independent and Identically Distributed (IID hypothesis) according to a Gumbel random variable of zero mean and parameter θ.

The IID hypothesis is quite restrictive and does not allow, for example, investigating possible correlations among random residuals of different alternatives or investigating the presence of heterogeneity, as regards a certain attribute like the *ASA* in this case, in population.

The hypothesis is relaxed in the ML and so one or more parameters can take a stochastic value with a mean and a variance among the users, instead of taking a deterministic value. This allows expressing the parameter β_q in the following form:

$$\beta_q = \beta + \delta_k * z_q + \eta_k \qquad [9]$$

where β is not correlated to the observed data, Z_q, η_k is a random component of the parameter, which can take different distribution (normal, uniform, triangular) and δ_k is the part of the parameter correlated to the observed data Z_q.

In detail, in order to make explicit possible relationships between CTS and Minibus transport systems and the socioeconomic attributes, the *ASA* have taken the form:

$$ASA_{qk} = ASA_k + ASA1_k Z_q + \eta_k \qquad [10]$$

Where:

ASA_{qk} *is the ASA of the CTS or the Minibus*

ASA_k *is the component of the ASA not correlated to the socioeconomic attribute*

$ASA1_k$ *is the component of the ASA correlated to the socioeconomic attribute*

Zq *is the socioeconomic attribute*

η_κ *is the random component of parameter for which normal, uniform and triangular distributions have been hypothesized*

5.3 Analysis of the interactions between demand and socioeconomic attributes through Mixed Logit models

The analysis of the interactions between the transport demand and the socioeconomic attributes and the estimate of the related models have been carried out with the software NLOGIT 3.0, which allows also the calibration of ML models.

In the first stage, in order to investigate if *ASA* have a heterogeneity as regards the sample, the reduced form has been used:

$$ASA_{qk} = ASA_k + \eta_k \qquad [11]$$

Where:

ASA_{qk} *is the ASA of the CTS or the Minibus*

ASA_k *is the component of the ASA not correlated to the socioeconomic attribute*

η_κ *is the random component of the parameter for which normal, uniform and triangular distributions have been hypothesized*

So the presence of heterogeneity in the *ASA* has been verified preliminarily and then which socioeconomic attribute determines this heterogeneity is analyzed. The calibrations have been made using the final model (see paragraph 4.3) and both the ASA_{CTS} and the ASA_{MINI} take the form reported in the equation [12].

In Table 5 the calibration results are reported, supposing that *ASA* are stochastic parameters, without any interaction with socioeconomic attributes, with a triangular distribution and variance σ.

As it is possible to note from the results, while the ASA_{CTS} and the σ_{CTS} are significant, the ASA_{MINI} and the σ_{MINI} are not statistically significant (similar results are obtained supposing uniform and normal distributions). So, the ASA_{CTS} has a heterogeneity and is represented as a stochastic parameter and this heterogeneity is correlated to a socioeconomic attribute. However, ASA_{MINI} has not heterogeneity and so it is represented as a deterministic parameter.

Table 5 – Parameter value of the different attributes in the ML model without interaction with socioeconomic attributes - both ASA_{CTS} and ASA_{MINI} are stochastic parameters with triangular distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.0018	-7,141
$\beta_{2\ (light)}$	-0.47790	-4,316
$\beta_{3\ (weather)}$	-1.46365	-11,892
$\beta_{7\ (Comfort)}$	0.32748	2,642
Random Parameter		
ASA_{CTS}	0.98538	3.792
σ_{CTS}	3.18568	1.848
ASA_{MINI}	0.25935	1.390
σ_{MINI}	1.82088	1.055
ρ^2=0,56655		ρ^2adj=0,56518

After having obtained these first results, a new ML model has been calibrated supposing that the only ASA_{CTS} was a stochastic parameter. In Table 6 the results of the model estimate with triangular distribution are reported. As shown before, the ASA_{CTS} is represented as a stochastic parameter.

Table 6 – Value of the different attributes parameters in the ML model, without interaction with socioeconomic attributes - only ASA_{CTS} is a stochastic parameter with triangular distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (piedi)}$	-0.00166	-6.324
$\beta_{2\ (Luce)}$	-0.43165	-3.942
$\beta_{3\ (Clima)}$	-1.31647	-10.124
$\beta_{7\ (Comfort)}$	0.29537	2.688
ASA_{MINI}	0.22632	1.421
Random Parameter		
ASA_{CTS}	0.89475	5.018
σ_{CTS}	2.43928	2.142
ρ^2=0,56704		ρ^2adj=0,56544

Once verified that ASA_{CTS} can be represented as a stochastic parameter, the possible relationships with the following socioeconomic attributes of the sample are analysed:

- Gender classified as: women, men;
- Level of education classified as: primary, junior secondary and secondary schools, three-year degree, specialist degree or PhD;
- Age used for the following categorizations:
  - Continuous value of age (stated by all respondents) minus 17 equal to the age of the youngest respondent. This allowed having in some cases, the part of the stochastic parameter correlated to the age factor equal to 0, making explicit also the part of the stochastic parameter not correlated to age parameter;
  - Binary value of the age with sample divided among the users aged 36 or less and users aged 37 or more (the median age of the sample is 36).

According to these remarks, the ASA_{CTS} takes the following form:

$$ASA_{CTS-par} = ASA_{CTS} + ASA1_{CTS} * Z_q + \eta_{CTS} \qquad [12]$$

Where:

ASA_{CTS} is the component of the ASA not correlated to the socioeconomic attribute

$ASA1_{CTS}$ is the component of the ASA correlated to the socioeconomic attribute

Zq is the socioeconomic attribute of gender, education and age

η_{CTS} is the random component with normal, uniform or triangular distribution

Since the analysis showed that the ASA_{CTS} has a statistically significant correlation with the age, the hypothesis that also the ASA_{MINI} has this correlation has been investigated. In Table 7 the list of ML calibrated models is reported.

Table 7 – ML calibrated models

Model	Random Parameter	Socioeconomic Attribute	Distribution	Significance	ρ^2adj
ML_ASActs_sesso	ASA_{CTS}	Gender	Normal	No	0.56473
ML_ASActs_sesso	ASA_{CTS}	Gender	Uniform	No	0.56473
ML_ASActs_sesso	ASA_{CTS}	Gender	Triangular	No	0.56473
ML_ASActs_edu	ASA_{CTS}	Education	Normal	No	0.56545
ML_ASActs_edu	ASA_{CTS}	Education	Uniform	No	0.56541
ML_ASActs_edu	ASA_{CTS}	Education	Triangular	No	0.56543
ML_ASActs_age_01	ASA_{CTS}	Age, bin.	Normal	No	0.56526
ML_ASActs_age_01	ASA_{CTS}	Age, bin.	Uniform	No	0.56519
ML_ASActs_age_01	ASA_{CTS}	Age, bin.	Triangular	No	0.56522
ML_ASActs_age_con	ASA_{CTS}	Age con.	Normal	Yes	0.56530
ML_ASActs_age_con	ASA_{CTS}	Age con.	Uniform	Yes	0.56604
ML_ASActs_age_con	ASA_{CTS}	Age con.	Triangular	Yes	0.56603
ML_ASActs+mini_age_01	ASA_{CTS}; ASA_{MINI}	Age bin.	Normal	No	0.56574
ML_ASActs+mini_age_01	ASA_{CTS}; ASA_{MINI}	Age bin.	Uniform	No	0.56565
ML_ASActs+mini_age_01	ASA_{CTS}; ASA_{MINI}	Age bin.	Triangular	No	0.56511
ML_ASActs+mini_age_con	ASA_{CTS}; ASA_{MINI}	Age con.	Normal	No	0.56581
ML_ASActs+mini_age_con	ASA_{CTS}; ASA_{MINI}	Age con.	Uniform	No	0.56576
ML_ASActs+mini_age_con	ASA_{CTS}; ASA_{MINI}	Age con.	Triangular	No	0.56578

As the analysis shows, neither the attribute related to "gender" nor one related to "education" have significant correlations with the demand, such as the ASA_{MINI} does not have significant correlations with the age. This emerges from the observation of the related $ASA1_{CTS}$ and $ASA1_{MINI}$, which are not statistically significant.

As for the correlation between ASA_{CTS} and age (when expressed as a continuous variable), they showed to be correlated.

For example, the parameters of some models without a statistically significant correlation with the age are reported in the following Tables. In appendix all results of calibrated models and the codes used in NLOGIT 3.0 are reported.

In Table 8 the model "ML_ASActs_gender" is reported. As it is possible to observe, the statistical significance of $ASA1_{CTS}$ is zero and the other parameters, which are statistically significant, have values not dissimilar to what emerged in the other models.

Table 8 - Model "ML_ASActs_gender", stochastic parameter ASA_{CTS} with interaction with "gender" factor, considering the hypothesis of normal distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.00152	-5.711
$\beta_{2\ (light)}$	-0.43749	-4.247
$\beta_{3\ (weather)}$	-1.24200	-9.148
$\beta_{7\ (comfort)}$	0.27478	2.606
ASA_{MINI}	0.26410	1.727
Random Parameter		
ASA_{CTS}	0.82805	4.941
$ASA1_{CTS}$	0.00927	0.050
σ_{CTS}	0.39515	0.478
ρ^2=0.56656	ρ^2adj=0.56473	

In Table 9 the model "ML_ASActs_edu" is reported. In this model a correlation between the level of education and the ASA_{CTS} has been hypothesized. As it is possible to observe, the statistical significance of $ASA1_{CTS}$ is very low and the significance of σ_{CTS} is even lower (hypothesis of uniform distribution). The other parameters, which are statistically significant, have values not dissimilar to what emerged in the other models.

Table 9 - Model "ML_ASActs_edu", stochastic parameter ASA_{CTS} with interaction with "level of education" factor, considering the hypothesis of uniform distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.00155980	-6.349
$\beta_{2\ (light)}$	-0.43572590	-4.146
$\beta_{3\ (weather)}$	-1.26815188	-10.062
$\beta_{7\ (comfort)}$	0.27955741	2.638
ASA_{MINI}	0.25762755	1.696
Random Parameter		
ASA_{CTS}	1.31235268	3.865
$ASA1_{CTS}$	-.12983188	-1.462
σ_{CTS}	.29743201	1.185
ρ^2=0.56724	ρ^2adj=0.56541	

In **Fout! Ongeldige bladwijzerverwijzing.** the model “ML_ASActs+mini_age_01” with hypothesis of normal distribution is reported. In this model a correlation between the CTS and Minibus *ASA* and the age attribute expressed as binary value is supposed. As it is possible to note, the statistical significance of *ASA1* of both the CTS and the Minibus is very low and the significance of the σ is even lower.

Table 10 - Model “ML_ASActs+mini_age_01”, stochastic parameters ASA_{CTS} and ASA_{MINI} with interaction with the “age” factor expressed as a binary variable, considering the hypothesis of normal distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.00265	-1.398
$\beta_{2\ (light)}$	-0.67438	-1.298
$\beta_{3\ (weather)}$	-2.07698	-1.413
$\beta_{7\ (comfort)}$	0.45806	0.950
Random Parameters		
ASA_{CTS}	1.06919	1.411
$ASA1_{CTS}$	0.79798	0.950
σ_{CTS}	2.20086	0.964
ASA_{MINI}	0.18242	0.598
$ASA1_{MINI}$	0.37303	0.882
σ_{MINI}	1.62244255	0.790
ρ^2=0.56802		ρ^2adj=0.56574

In Table 11 the model “ML_ASActs+mini_age_con” with hypothesis of uniform distribution of stochastic parameters is reported. In this model a correlation between the *ASA* and the age expressed as continuous variable is reported. As it is possible to observe, the statistical significance of all components of the ASA_{MINI} is very low. The other parameters, which are statistically significant, have values not dissimilar to what emerged in the other models.

Table 11 - Model “ML_ASActs+mini_age_con”, stochastic parameters ASA_{CTS} and ASA_{MINI} with interaction with “age” factor, expressed as a continuous variable, considering the hypothesis of uniform distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.00165	-6.849
$\beta_{2\ (light)}$	-0.43010	-3.998
$\beta_{3\ (weather)}$	-1.29363	-11.331
$\beta_{7\ (comfort)}$	0.28608	2.662
Random Parameters		
ASA_{CTS}	0.44891	2.029
$ASA1_{CTS}$	0.02194	2.120
σ_{CTS}	0.06944	2.774
ASA_{MINI}	0.26090	1.332
$ASA1_{MINI}$	-0.00208	-0.356
σ_{MINI}	0.00133	0.029
ρ^2=0.56804	ρ^2adj=0.56576	

5.4 Mixed Logit model and interaction between age and the demand for the CTS

According to the above-reported analyses, only the attribute “age”, when expressed as continuous variable, has a statistically significant correlation with the ASA_{CTS} for any hypothesized distribution. Between the three models included in this category, the one which has a higher ρ^2_{adj} (even if the differences are minimal) is that one in which a distribution of uniform stochastic parameter is hypothesized.

The calibration results of the model “ML_ASActs_age_con” , where a relation between the age, expressed as a continuous variable, and the ASA_{CTS} with uniform distribution is hypothesized, are reported in Table 12.

Table 12 - Model "ML_ASActs_age_con", stochastic parameter *ASA_{CTS}* with interaction with "age" factor, considering the hypothesis of uniform distribution.

	Parameter	Significance
Deterministic Parameters		
$\beta_{1\ (foot)}$	-0.00165	-6.859
$\beta_{2\ (light)}$	-0.42939	-4.006
$\beta_{3\ (weather)}$	-1.28917	-11.332
$\beta_{7\ (comfort)}$	0.28486	2.660
ASA_{MINI}	0.22143	1.425
Random Parameters		
ASA_{CTS}	0.45273	2.054
$ASA1_{CTS}$	0.02132	2.086
σ_{CTS}	0.06693	2.667
ρ^2=0.56786		ρ^2adj=0.56604

As it is possible to observe, the model parameters highlight some aspects which have to be underlined. β_1 is negative and so as the walking distance increases, the modal split of "on foot" alternative decreases. As for β_2 it is negative and, in this case, since it is included in the utility function of the CTS/Minibus, in case of day light the modal split of the CTS/Minibus decreases. β_3, related to the weather conditions, is negative and is also high, so in case of rain a substantial increase of CTS/Minibus modal split will be observed.

Analyzing the values of the *ASA*, it is interesting to note that, regardless of users' age, the ASA_{CTS} is higher than the ASA_{MINI}. In conclusion, the most interesting result is the fact that the component of the ASA_{CTS} correlated to the age is statistically significant and, above all, is positive, showing that, as the users' average age increases, an increase in the demand for the CTS and not for the Minibus is expected under other conditions being equal (Illumination, Weather, On-Board Comfort, Walking Distance). This result shows that the users' average age is not a limit to the diffusion of these systems, quite the opposite.

5.5 Demand analysis with Mixed Logit model

According to the calibration results of the ML model, it is possible to analyse the variation in the demand as the different attributes change. The analysis has been carried out supposing different operating conditions in which the system will operate. In particular, the way the modal split of CTS vs "foot" alternative changes in comparison with modal split of Minibus vs "foot" alternative under different conditions of Illumination, Weather and On-Board Comfort has been analyzed, for a total of 8 scenarios reported in Table 13. In the scenarios it was assumed that the walking distance is fixed and equal to 400 metres, in order to highlight the only effect on the modal split of the age. As for the variation in age, it varies from 20 to 65 years, according to the minimal and maximum age recorded during the interviews.

Table 13 – Scenarios considered as the users' age changes, given a 400 metre distance to walk from the entrance.

	Illumination*	Weather**	Comfort***
Scenario 1	1	1	1
Scenario 2	0	1	1
Scenario 3	1	0	1
Scenario 4	1	1	0
Scenario 5	0	1	0
Scenario 6	0	0	1
Scenario 7	1	0	0
Scenario 8	0	0	0

* 1= Day; 0=artificial light

** 1= Dry; 0=Rain

*** 1= Car; 0=Bus

From Figure 15 to Figure 22 the variation in the modal split of the CTS vs "foot" alternative as users' age changes is reported. Furthermore, in order to provide a reference, the modal split of the Minibus vs "foot", represented as two horizontal lines, since it is invariant to age.

As general remarks valid for all scenarios, it is possible to state that:

- The modal split of the CTS increases as users' age increases considerably;
- The modal split of the CTS is, anyway, higher than one of the Minibus for any age range observed.

In Figure 15 the modal split of CTS vs foot as users' age changes in Scenario 1 (daylight, dry weather and guaranteed seat on board), given a walking distance to reach the entrance equal to 400 metres, is reported. As it is possible to observe, under the given conditions considering users aged from 20 to 65, the modal split of CTS increases substantially from 42% to about 68%.

In Figure 16, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 2 (dark, artificial light, dry weather and guaranteed seat on board) is reported. In comparison with Scenario 1, the dark and the artificial light make the "foot" alternative less attractive and the CTS has a higher modal split than in the previous scenario. However, a marked increase in the modal split of the CTS as the users' age increases and a consequent variation of 20% are observed.

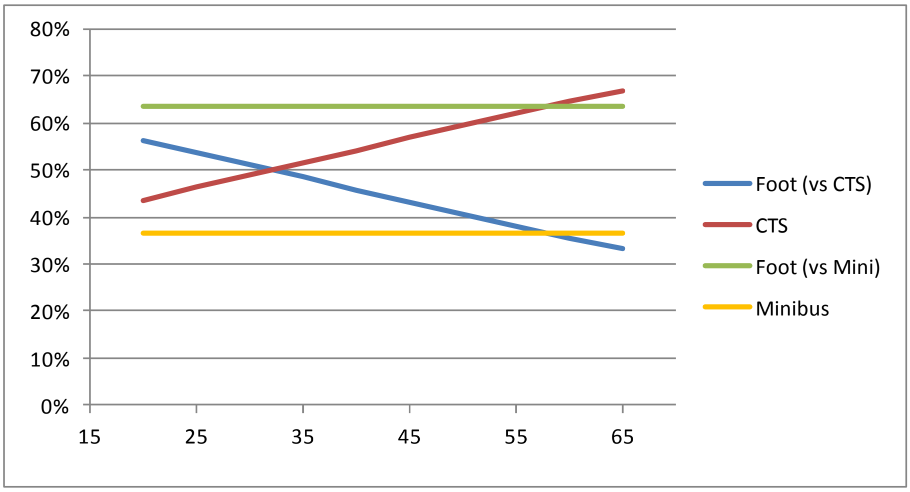


Figure 15 – Modal split in P1 as the users' age changes in the presence of: daylight, dry weather, guaranteed seat on board (Scenario 1) and a 400 metre walking distance from the entrance.

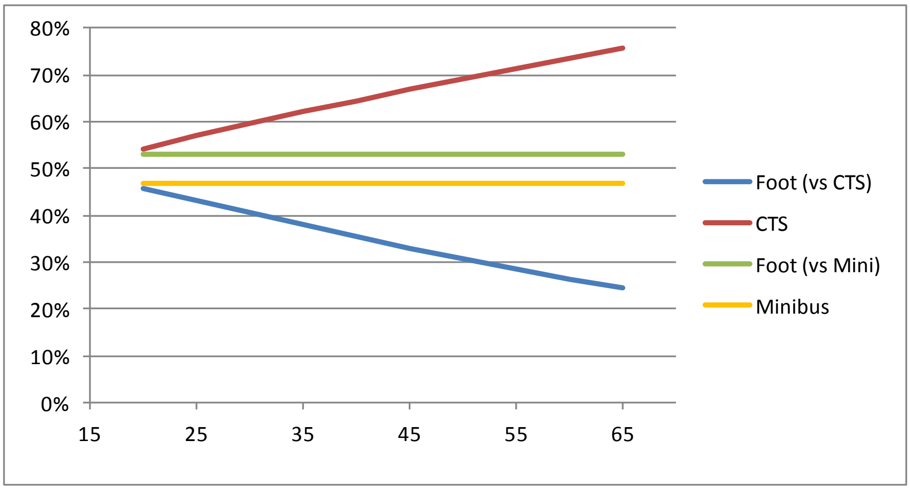


Figure 16 – Modal split in P1 as the users' age changes in the presence of: artificial light, dry weather, guaranteed seat on board (Scenario 2) and a 400 metre walking distance from the entrance.

In Figure 17, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 3 (daylight, rain and guaranteed seat on board) is reported. The presence of the rain in the scenario considerably increases the modal split in favour of the CTS, which increases by about 15% from 20 to 65 years.

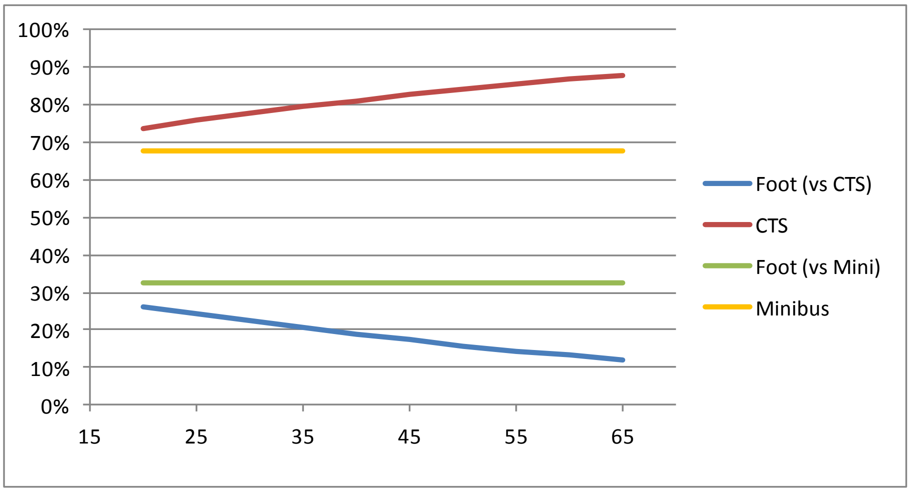


Figure 17 – Modal split in P1 as users' age changes in the presence of: daylight, rain, guaranteed seat on board (Scenario 3) and a 400 metre walking distance from the entrance.

In Figure 18, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 4 (daylight, dry weather and guaranteed seat on board) is reported. This scenario is the most favourable to the "foot" alternative and for users aged up to 45 this alternative has a modal split higher than 50%. Over the age of 45, the majority of the users, under the given conditions, choose the CTS. In all, the modal split of the CTS for users aged from 20 to to 65 varies by more than 20%.

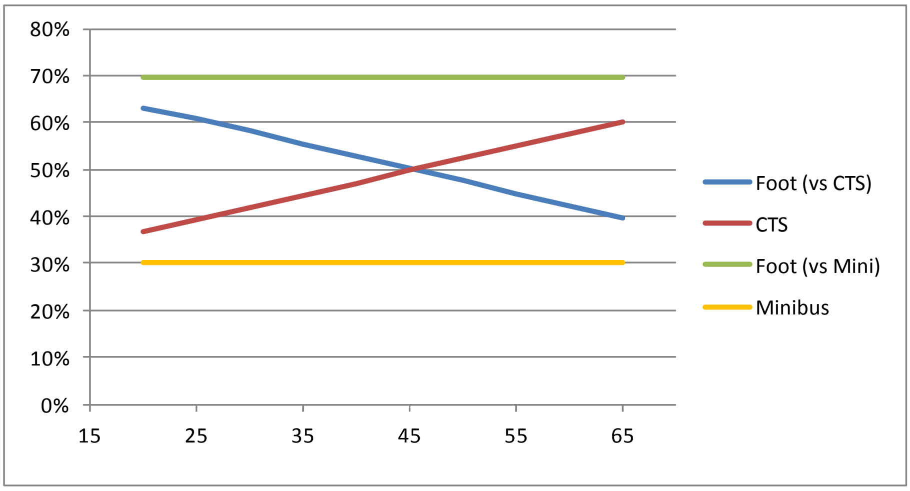


Figure 18 – Modal split in P1 as the walking distance changes in the presence of: daylight, dry weather, NOT guaranteed seat on board (Scenario 4), a 400 metre walking distance from the entrance.

In Figure 19, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 5 (dark, artificial light, dry weather and NOT guaranteed seat on board) is reported. In this scenario, since the seat on board is NOT guaranteed and it's dark, the users aged under 25 have a modal split higher more than 50% for the "foot" alternative, while the users aged over 25 have a modal split higher than 50%. As in other scenarios, the modal split of the CTS increases by about 22% for users from 20 to 65.

In Figure 20, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 6 (dark, artificial light, rain and guaranteed seat on board) is reported. In this scenario the CTS has a more attractive power, and also for the users aged 20 the modal split of the CTS is 80% and for users aged 65 is about 91%.

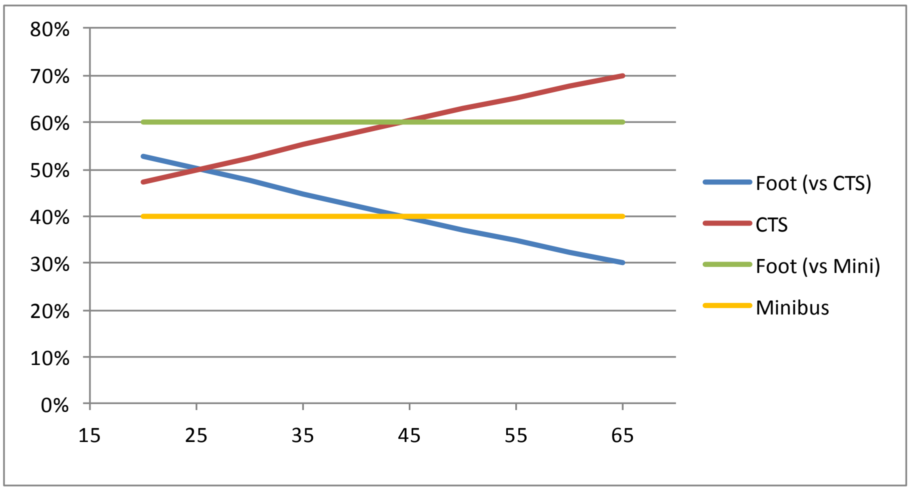


Figure 19 – Modal split in P1 as the users' age changes in the presence of: dark, artificial light, dry weather, NOT guaranteed seat on board (Scenario 5) and a 400 metre walking distance from the entrance.

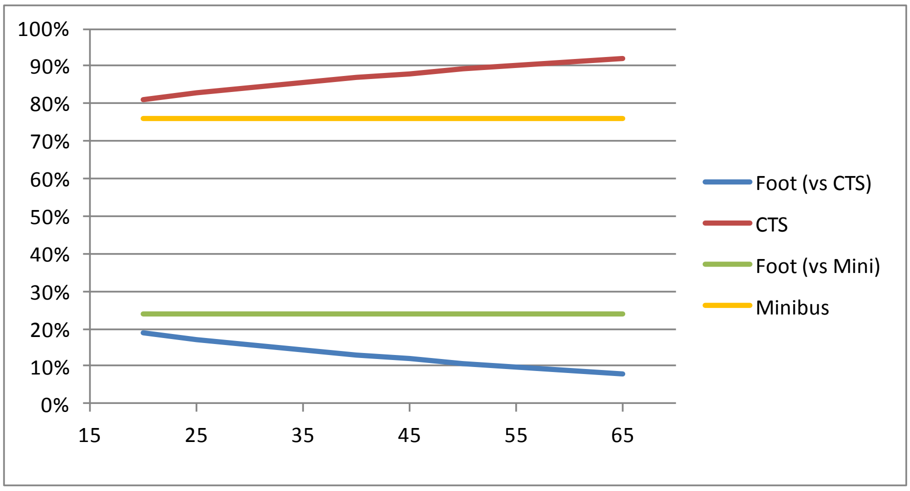


Figure 20 – Modal split in P1 as the user's age changes in the presence of: dark, artificial light, rain, guaranteed seat on board (Scenario 6), a 400 metre walking distance from the entrance.

In Figure 21, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs foot as the users' age changes in Scenario 7 (dark, artificial light, rain and guaranteed seat on board) is reported. In this scenario the modal split of the CTS is 68% for users aged 20 and 84% for users aged 65.

In Figure 22, given a 400 metre walking distance to reach the entrance, the modal split of the CTS vs the "on foot" alternative as the users' age changes in Scenario 8 (dark, artificial light, rain and NOT guaranteed seat on board) is reported. In this Scenario the modal split of the CTS is 78% in the case of users aged 20 and 90% for users aged 65.

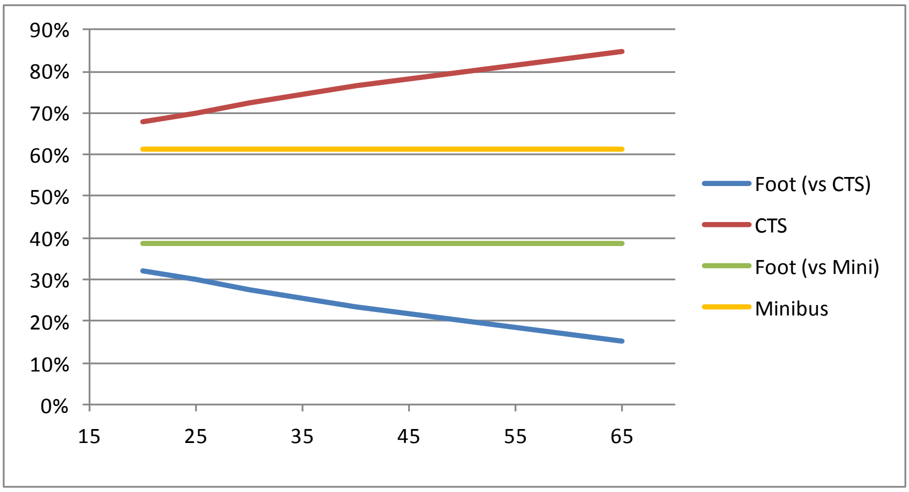


Figure 21 – Modal split in P1 as the users' age in the presence of: dark, artificial light, rain, guaranteed seat on board (Scenario 7), a 400 metre walking distance from the entrance.

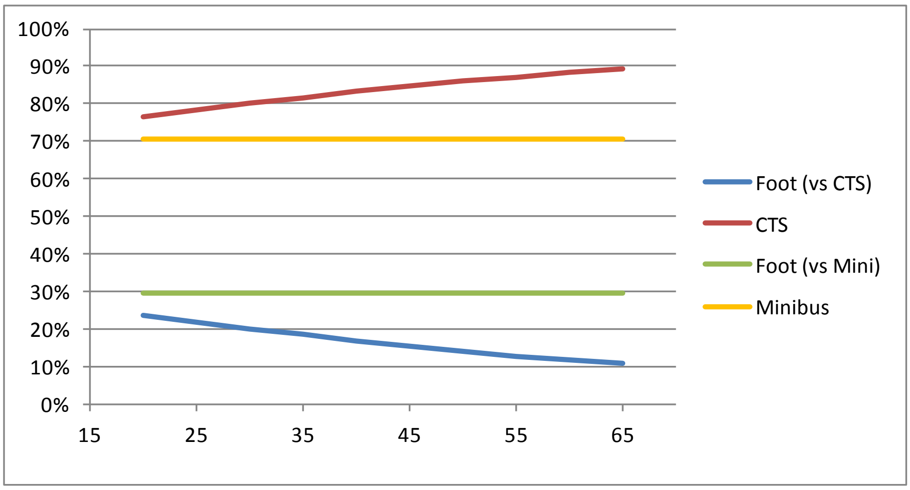


Figure 22 – Modal split in P1 as the walking distance changes in the presence of: dark, artificial light, rain, NOT guaranteed seat on board (Scenario 8), a 400 metre walking distance from the entrance.

6 Final analyses and conclusions

6.1 Comparison between the results of the analyses

To conclude the analyses and draw definitive conclusions, given the same scenarios, a comparison between the modal split trends of both final Multinomial Logit and ML models with an interaction between ASA_{CTS} and age expressed as a continuous variable is necessary, considering a hypothesis of stochastic parameter uniform distribution.

Comparing the parameters of the two models (see Table 14), some differences and similarities can be observed. The parameters signs are identical. As for the attributes of scenario related to Illumination and Weather, they do not vary substantially, and also the attribute value related to On-Board Comfort does not change. On the contrary, as for the attribute related to the walking distance to reach the entrance, in ML model a quite marked increase in comparison with the final Multinomial Logit is observed.

Analyzing the value of the *ASA*, as for the ASA_{MINI}, it decreases in the ML model as its statistical significance decreases. Furthermore, as for the component correlated to the age, also the ASA_{CTS} has a substantial reduction, but it is compensated by the plus sign of the $ASA1_{CTS}$. This shows that the ASA_{CTS} increases even significantly as the age increases. In the case of users' average age of 17 the ASA_{CTS} is worth 0.45273 in all, while in the case of users' age of 60 is worth 1.36949, i.e. a much higher value than one of the ASA_{CTS} of the final Multinomial Logit model.

Table 14 – Comparison between the results obtained by the ML model and Multinomial Logit.

	Mixed logit		Multinomial Logit	
Parameter	**Value**	**Significance**	**Value**	**Significance**
Deterministic Parameter			////	
$\beta_{1\ (foot)}$	-0.00165	-6.859	-0,00145	-7,141
$\beta_{2\ (il.)}$	-0.42939	-4.006	-0,4373	-4,316
$\beta_{3\ (weather)}$	-1.28917	-11.332	-1,2196	-11,892
$\beta_{7\ (cComfort)}$	0.28486	2.660	0,2685	2,642
ASA_{MINI}	0.22143	1.425	0,2740	1,885
Random Parameter			////	
ASA_{CTS}	0.45273	2.054	0,8111	5,522
$ASA1_{CTS}$	0.02132	2.086		
σ_{CTS}	0.06693	2.667	////	////
ρ^2=0.56786		ρ^2_{adj}=0.56604	ρ^2=0.56655 ρ^2_{adj}=0.56518	

The last aspect to be compared is the behaviour of the two models in terms of modal split. The comparison will be made in two scenarios: the Scenario 4 (day light, dry weather, NOT guaranteed seat on board), that is the most favourable to the "on foot" alternative for both CTS and Minibus cases, and in the Scenario 6 (dark, artificial light, rain and guaranteed seat on board), that is the most favourable for the CTS and Minibus alternatives.

This comparison will allow understanding the importance of the age in the demand when it is considered. The comparison is reported in Figure 23 as for the Scenario 4 and in Figure 24 for the Scenario 6. As for the Multinomial Logit, a 400 metre distance has been established in order to allow a direct comparison, since a fixed 400 metre distance was hypothesized for the alternatives modal split defined by ML as the age changes.

Considering the Scenario 4 (see Figure 23) and the pair-choice Minibus vs foot, given a 400 metre distance, the same behaviour observed in the ML is observed in the Multinomial Logit model. As for the pair-choice CTS vs foot, given a 400 metre distance, the modal splits observed in the Multinomial Logit are the same observed in a sample of users aged 40 in the ML model. For users aged more than 40, the ML model gives a higher modal share to the CTS in comparison with to the final Multinomial Logit, while for users aged less than 40 it gives a lower modal share.

Considering the Scenario 6 (see Figure 24) and the pair-choice Minibus vs foot, given a 400 metre distance, the same behaviour observed in the ML model is observed in the Multinomial Logit. As for the pair of choice CTS vs foot, given a 400 metre distance, the modal shares observed in the final Multinomial Logit are the same observed for a sample of users aged 36-37 in the ML model. For users aged more than 36-37, the ML model gives a higher modal share to the CTS in comparison with the final Multinomial Logit, while for users aged less than 36-37, it gives a lower modal split.

According to this analysis, some conclusions can be drawn. As for the pair of alternatives Minibus vs foot, age is irrelevant, even in the case of joint calibration of both DB. The comparison highlights that the pair-choice Minibus vs foot has the same trend of the modal split as the age changes in both Multinomial Logit and ML models.

As for the model CTS vs foot, the presence of the age is decisive in the modal split and final Multinomial Logit and ML models, given a 400 metre distance, have similar behaviours as for users aged between 36 and 40. As for users with different ages, the two models have different behaviours. The use of the final Multinomial Logit model is shown in contexts where there are users with different age and on average aged between 35 and 40. In cases in which the average age of users is considerably different, the final Multinomial Logit might provide false results.

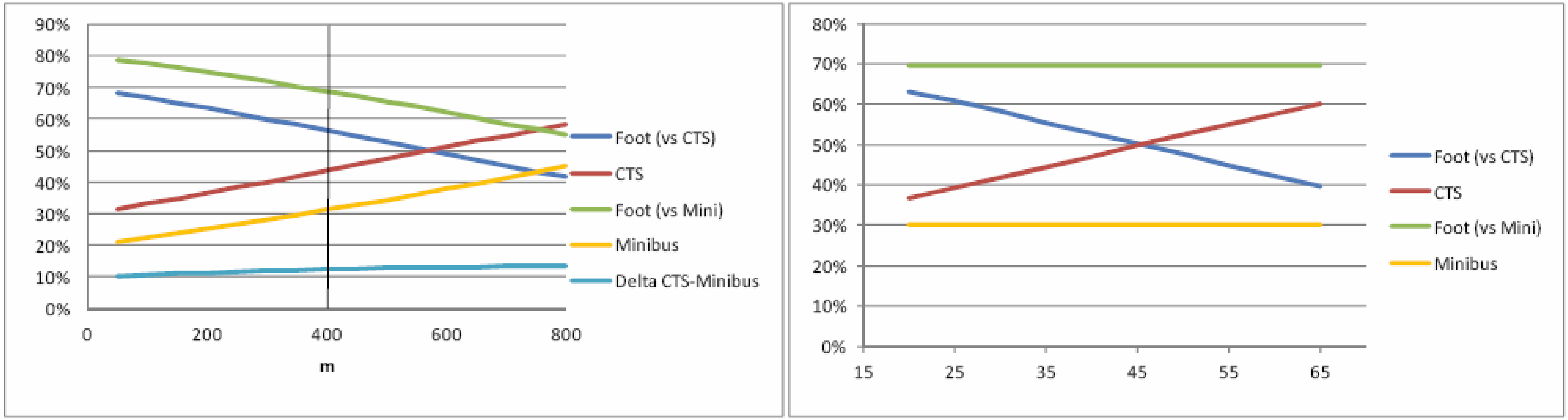


Figure 23 – Comparison between the modal shares in P1 in the Scenario 4 (daylight, dry weather and NOT guaranteed seat on board) of the final Multinomial Logit (on the left) and ML models.

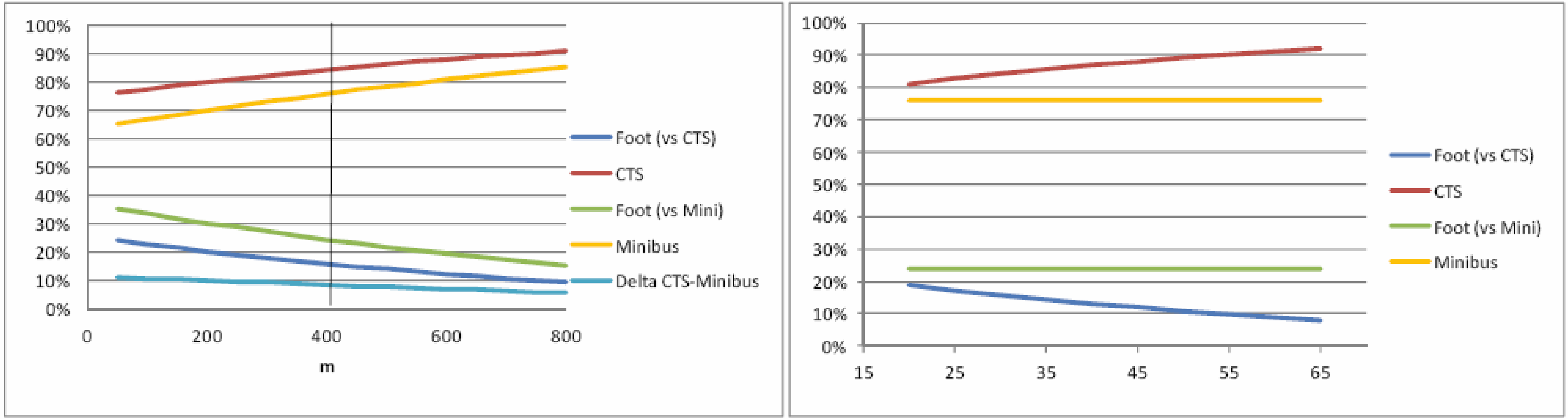


Figure 24 – Comparison between modal shares in P1 in the Scenario 6 (dark, artificial light, rain and guaranteed seat on board) of the final Multionomial Logit (on the left) and ML models (on the right).

6.2 Conclusions

This work completes and enriches the activities of the Rome Demo, estimating the demand for CTS considering the different operating conditions. In this perspective, the objective of this work is *to estimate the demand level as the different operating conditions of the system change.*

However simple it may seem, this objective raises several issues, because the demand is connected to the quality of service offered. As the analyses showed, the innovative character of the system can affect the demand itself and the impact made can vary according the users' socioeconomic attributes.

According to the objective of this work and for the above-stated reasons, the research questions which have answer in this work are:

- How does the demand vary as the quality of service changes?
- Which system do users prefer most? A CTS or a conventional system?
- Are there relations between users' different socioeconomic attributes and the demand?

The first step of the study is a State of the Art analysis about demand studies related to innovative transport systems. It is important to note that in the case of demand studies the literature is not abundant and it often came from projects co-fundend by European Commission (above all CyberMove, EDICT and NETMOBIL) and demand studies related to these projects and then shown in international meetings.

Even if the studies carried out are few, the results obtained are usually favourable to innovative transport systems, highlighting an attractive power of these systems on the users.

A common feature of the majority of these studies is the use of the *Stated Preferences* (SP), since there is a lack of working systems. SP is a method used for submitting hypothetical scenarios of choice to the potential users. In this case, the scenarios include innovative transport system under different operating conditions related to weather and on-board comfort.

Since the CTS of Rome has not implemented yet and the SP method has been used under such conditions, it has been used in this work, too. After having defined this aspect, the alternatives - and the related attributes used to describe them – are defined. The alternatives to propose to users, in order to avoid proposing scenarios too away from users' perception, are used by the CTS to reach the entrances of the Exhibition from P1car park or to reach the entrance on foot, since this will be the choice that users will make once implemented the CTS.

As for attributes, according to what came out from the analysis of the state of the art, three categories have been identified: (i) one related to the scenario attributes, i.e. the presence or the absence of light and favourable weather situation; (ii) one related to the CTS alternative, which is described with the following attributes: distance covered to reach the stops, waiting time at the stops, on-board time and on-board comfort (considered as presence or absence of seats on board); (iii) the last one related to the "foot" alternative, where the only attribute of the walking distance to reach the entrance is considered.

After having defined the scenarios of choice, the questionnaires and their related times and modes of administration are defined. In this phase, in order to highlight possible preferences by users towards innovative or classical transport systems, two scenarios of choice have been submitted to two separate and random samples of users. In a questionnaire, the choice to reach the entrance was between the CTS and the "foot" alternative, and in the other one between an electric Minibus (one of those operating in the centre of Rome) and the "foot" alternative. The two scenarios of choice have identical experimental designs and so the possible preference towards the CTS inside of the Minibus by the users was made explicit in the demand models through the Alternative–Specific Attributes (*ASA*), different in the case of the CTS or the Minibus.

According to this layout, two questionnaires have been defined, focusing the attention on using neutral tones in the description of the alternatives with identical experimental design. In a questionnaire, the choice to reach the entrance between the CTS vs foot was proposed, in the other one the choice between the Minibus vs foot was proposed.

The questionnaires were divided into three sections. The first one, which is different for the pairs-choice CTS vs foot and Minibus vs foot, is related to the description of the alternative and the systems proposed. The second one, common to both questionnaires, is related to the socioeconomic attributes of the sample. Finally, in the third section, which is identical in terms of experimental design in both questionnaires, each user was asked to choose between the CTS/Minibus and "foot" alternative to reach the entrance in four different hypothetical scenarios (according to the attributes above-described). As for the number of choice scenarios proposed to each respondent, the techniques of fractional factorial plan and block decomposition were sequentially used, in order to submit an acceptable number of scenarios to each respondent. So, the 288 possible choice scenarios, considering the attributes and the related levels, were reduced to only 24 scenarios. All scenarios are divided into 6 blocks and each block is delivered to an equal number of interviewees.

The face-to-face interviews have been delivered to two separate and random samples of users in the car park P1 in November and December of 2009. The respondent was stopped by the operators while walking out from the P1 towards the entrance of the Exhibition and he was informed of the study purposes and contents. If he agreed to be interviewed, he was asked to sit in the gazebos and his answers were recorded by the interviewer. 476 interviews were delivered in all and are so distributed between the two samples: 238 interviews for CTS vs foot, 238 interviews for Minibus vs foot.

The interviews results, after having analysed briefly the composition of the interviewees sample, were used to calibrate the demand models. The first calibrated demand model, defined full model, provided for the use of all attributes for four different utility functions. Two utility functions were related to the "on foot" alternative in the case it was compared with the CTS or the Minibus. It is important to underline that for both the "foot" alternative and and the CTS/Minibus alternative the functions structure is identical, and the possible preference by the users towards the CTS/Minibus was made explicit by the *ASA*, the only functions term of utility which differs in the structure of the CTS and the Minibus.

Not all attributes were statistically significant in the context of choice proposed: it is what resulted from the first calibration, made using the data from the two questionnaires administered. In detail, the attributes related to time spent on board, the walking distance to reach the stops and the waiting time at stops are not statistically significant, while the comfort on board is statistically significant and relevant. This result is due to the fact that the time and the distance necessary to reach the service differ little from the time necessary to reach the entrance on foot, and so the user choice is based on other factors. The attributes of scenario related to Illumination and Weather are not only statistically significant, but also very relevant and, as the demand analysis highlighted, the presence or the absence of rain affects considerably the demand, inducing the passengers to prefer most the CTS/Minibus alternatives rather than the "foot" alternative. Even if to a lesser extent, the presence of dark and artificial light induces the users to have the same behaviour. The ASA values highlight a strong preference by the users towards the CTS rather than the Minibus. In conclusion, as for the "foot" alternative, the attribute related to the walking distance to reach the entrance is statistically significant and relevant.

In the light of these results and in order to analyse the demand trend as the walking distance to reach the entrance changes in the different operating conditions, a final Multinomial Logit model was defined and its service attributes are: distance to reach the stops, while waiting time at stops and time spent on board were removed since they are not statistically significant. So, the following attributes are considered in the final Multinomial Logit model: illumination, weather, walking distance to reach the entrance and on-board comfort. Furthermore, in addition to these attributes, there are also the *ASA* of both CTS and Minibus.

Once calibrated, the final Multinomial Logit model highlighted that attributes used in it are statistically significant, and in detail:

- The attributes of scenario related to Weather and Illumination are more relevant, affecting considerably on the demand. In particular, the attribute related to Weather is the most relevant and, in the presence of dry weather, the “foot” alternative is favoured, while in the presence of rain the CTS/Minibus is favoured. As for the attribute related to Illumination, in the presence of dark and artificial light, users prefer the transport system, while by day they prefer the “foot” alternative.
- The attribute related to on-board comfort affects the demand and the presence of guaranteed seat on board favours the transport systems;
- As for the attribute related the walking distance, the modal split of the “foot” alternative decreases in favour of the transport systems as the walking distance increases;
- As for the ASA, they both increase in absolute terms and in terms of statistical significance, probably because they include the effect of those service attributes removed from the model. The ASACTS is three times higher in absolute terms than the ASAMINI. This seems to be the most interesting result and shows that the innovative transport systems are preferred by users, who probably consider them more reliable.

After having calibrated the model, the demand analysis was carried out in 8 scenarios, where the attributes related to weather, illumination and on-board comfort change. For each scenario, the modal split trend as regards the walking distance of the four alternatives was reported, and this analysis highlighted some aspects. The first one is that the modal split of the transport systems considered as the walking distance increases and this trend is considerably influenced by the attributes related to weather and illumination, and to a lesser, but not negligible, extent by the attribute related to on-board comfort. Furthermore, the modal split of the CTS is, under the same conditions, always about 10% higher than one of the Minibus. Besides being the most interesting numerical data, this case is caused by the difference among the *ASA* values, which was observed in the model calibration.

An analysis of the sensitivity of the demand as the walking distance changes highlighted that, in the presence of dry weather, for each additional 100 metre increase to reach the entrance, the modal split of the CTS and Minibus has between a 3 and 3.5% increase. On the contrary, this value is nearly always lower than 3% in the presence of rain. Therefore, since the transport system demand is high even at a short distance in the presence of rain, the increase as the walking distance increases is less marked.

After having carried out the demand analysis through the final Multinomial Logit model, the presence of significant correlations between the socioeconomic attributes of the sample and the demand was analysed, focusing the attention on the following socioeconomic attributes: gender, level of education and age.

Considering the socioeconomic attributes, the segmentation of the sample is one of the most widespread analysis methods in the demand models. The sample is divided into segments through this approach according to the socioeconomic attributes to be included in the analysis, and for each segment a demand model is calibrated. For example, in the case of the age the submodels are calibrated on age segments as 21-30 years, 31-40 years, etc. This approach, even if very widespread, has two limits: the first one is that the segment might be made up of a limited number of interviewees; the second one is that the weight of the socioeconomic attribute in the demand is made explicit only if the identified segmentation permits this explicitation. So, the analyst is forced to test different segmentations and the related calibrations for each socioeconomic attribute, until he succeeds in making the relation explicit or he has the reasonable certainty that this relationship does not exist.

In order to solve these problems, right in the mid-nineties Mixed Logit (ML) demand models were developed and they have been used in this analysis.

The ML models permit to relax the IID hypothesis and investigating possible correlations between the random residuals of different alternatives and the presence of heterogeneity, as regards a given attribute, such *ASA* in this case, in the population. In short, one or more model parameters are considered stochastic rather than deterministic, and so they are represented with a mean, a variance and a possible correlation with the underlying parameters (in this case the socioeconomic characteristics), supposing a distribution (in this case uniform, triangular and normal).

A first ML model has been calibrated to investigate the possibility that *ASA* have heterogeneity and so can be considered as stochastic parameters instead of deterministic parameters. The analysis highlighted that the ASA_{CTS}, rather than the ASA_{MINI}, can be represented as a stochastic parameter**.**

After having obtained this result, the presence of a statistically significant relationship between the ASA_{CTS} and the sample socioeconomic attributes - which are gender, education and age – was investigated. The analysis highlighted that this relation is statistically significant only in the case of the age represented as a continuous variable. This relationship was positive, and so the demand for CTS increases as the age increases (while the demand for Minibus is invariant). Furthermore, the ASA_{CTS} is always higher than the ASA_{MINI} for any age range. These results are very interesting and permit doing some remarks:

- Regardless of age, innovative transport systems are favoured by the population and they might be accepted by the users without problems;
- Suddenly, the innovation is observed more carefully and affects mostly the behaviour of the high-age users. This shows that age is not a limit to the diffusion of the transport demand, quite the opposite.

Once made the ML model calibration, the way the modal split of the CTS changes as age changes from 20 to 65 years is analysed. The 8 scenarios analysed are the same ones analysed in the final Multinomial Loigt model, establishing a 400 metre walking distance.

The analysis highlighted that the demand for CTS increases by about 20% in almost all scenarios as age changes from 20 to 65 years (the age range used). So, in conclusion not only the demand for the CTS increases as age increases, but it can increase even considerably.

The last analysis concerned the direct comparison of the scenarios obtained through the final Multionomial Logit and the ML. The comparison was made in two scenarios: in the Scenario 4 (day light, dry weather, NOT guaranteed seat on board), which was the most favourable to the “foot” alternative in the case of both the CTS and the Minibus, and in the Scenario 6 (dark, artificial light, rain and guaranteed seat on board), which was the most favourable to the CTS and Minibus alternatives.

As for the pair-choice Minibus vs foot, behaviour differences were observed between the two models in both scenarios. As for the pair-choice CTS vs foot, the analysis highlighted that in both Scenarios the final Multinomial Logit model reproduces the behaviour of the ML model related to age ranges from 35 to 40. In the presence of higher age ranges, the modal share of the final Multinomial Logit model is lower than the one calculated through the ML for higher age range, and, vice versa, it is higher for lower age ranges. In the presence of users’ different age and average age between 35 and 40 the final Multinomial Logit model provides adequate information, while as for lower or higher average age it might overestimate or underestimate respectively the demand for the CTS.

6.3 Answers to the research questions and future developments

In conclusion, the extensive analysis of the data collected reach the objective, i.e. it permits ***estimating the demand level as the different operating conditions of the system change*** and answering the research questions posed:

How does the demand change as the service quality changes (distance from the stops, waiting time, on-board time and on-board comfort)?

Given a short distance, the time spent walking is comparable to the time spent using a possible transport system, and probably for this reason the attributes related to the service quality are not relevant, with the exception of the on-board comfort, which affects the demand. This result shows that the on-board comfort related to innovative systems and at a short distance has to be properly treated, and in the specific instance of the Demo of Rome, considering the simplicity of the vehicles uses, this aspect might be considerably improved. Observing also the model attributes, the walking distance and, above all, the illumination and weather conditions affect, more than the on-board comfort, the demand.

Which system do users prefer most? The CTS or a conventional system?

The analysis highlighted that, regardless of the model used, the CTS has a competitive advantage in terms of the demand related to Minibus under other conditions being the same. This difference of demand with the final Multinomial Logit model is always about 10%. This aspect shows that users do not refuse innovative transport systems (at least in the context of choice proposed in this study), but at the same time, it probably has high expectations towards the innovation. Subsequently the validity of the expectations should be verified.

Is there a relationship between the user socioeconomic attributes (age, gender, education) and the demand?

The analysis highlighted that neither gender nor education have statistically significant correlations with the demand for the CTS and the Minibus. On the contrary, the age has a correlation with the demand for the CTS and, quite unexpectedly for the analysts, the demand increases even considerably as the age increases (an increase in demand for the CTS from 15% to 20% is observed in the different scenarios, with age ranging from 20 to 65). This correlation has not been observed between the demand for the Minibus and age. Furthermore, the ASA_{CTS} is higher than ASA_{MINI} for any user age range, showing anyway a general preference by users towards innovative transport systems. These results show that these transport systems will not have probably problems of *user acceptance* among the users, in particular among the older users, and this data is very positive in a society in which the average age is growing.

The results achieved by this work obviously come from questionnaires submitted to users and concerning hypothetical behaviours. So these results achieved through the surveys of users' real behaviours have to be verified.

In conclusion, the achievement of the study objective does not exhaust the field of the research on this subject, on the contrary these results induce to pose other questions.

A first question is related to the grasp of the "reason" why the innovative transport systems have competitive advantage than conventional systems. This study hinted at the possibility that these systems can be perceived by users as more reliable. Is this the correct answer? And why is this preference more marked among older users?

The answer to these two correlated questions might help to better understand how these systems can be proposed to users and the needs which classical transport systems can not satisfy, but which these transport systems can satisfy.

Another question arises out of the conclusions: “could these systems, if integrated with conventional transport systems, represent the last mile solution of the problem for users and make the local public transport more competitive than private vehicles? If so, to what extent?”. In the specific instance of the Rome Exhibition, how many people would reach the Fiera by train, rather than by car, if the station of the Rome Exhibition was connected to the entrance of the Exhibition by a CTS?

This question is fundamental to understand which role these systems will play in the future and if they integrate into the local public transport increasing its attractive power, or if they are installed sporadically in specific contexts such as exhibitions, airports and large commercial areas.

Glossary

Alternative Specific Attribute (ASA): ASA is a parameter for a particular alternative that is used to represent the role of unobserved sources of utility.

Alternatives: options containing specified levels of attributes.

Attributes: characteristics of an alternatives.

Attributes level: a specific value taken by an attribute; experimental design require that each attribute takes on two or more levels., which may be quantitative or qualitative.

Block decomposition technique: Through this technique the possibility to decompose the scenarios in blocks is guaranteed. Each block will be submitted to a sample of users, avoiding that every single user answers to all scenarios. This technique provides some key aspects. The first one is that the "comparison" is provided for every single attribute in the block, i.e. in the same block there are the same number of scenarios of the attribute *J*, which has a high value and a low value. The second aspect is the "orthogonality", i.e. given two attributes *J* and *H*, in the same block the number of cases in which these attributes have concordant values is equal to the number of cases in which attributes have discordant values.

Choice set: the set of alternatives over which an agent makes a choice.

Cybernetic Transport Systems (CTS): CTSs feature fully automated vehicles (cybercars) which provide an on-demand service on a segregated track. The cybercars are equipped with obstacle detection systems which allow operating in mixed environment, at least with pedestrians and bicyclists.

Discrete choice: the selection of one alternative among a set of mutually exclusive alternatives.

Experimental design: the specification of attributes and attribute levels for use in an experiment.

Fractional factorial plan: This technique allows reducing the number of scenarios, though maintaining the "orthogonal" comparison among the remaining scenarios and so allowing estimating the main effects. Essentially, the fractional factorial plan is obtained with a full factorial plan through the definition of "defining relations", which connects a value of an attribute with one of other attributes. If on the one hand this method allows reducing, even considerably, the number of scenarios, on the other hand it leads to loss of chances to estimate side effects of interaction between the attributes confused with kept effects.

Mixed Logit Model: for multinomial Logit models the IID hypothesis is quite restrictive and does not allow, for example, investigating possible correlations among random residuals of different alternatives or investigating the presence of heterogeneity, as regards a certain attribute like the *ASA* in this case, in population.

The hypothesis is relaxed in the ML and so one or more parameters can take a stochastic value with a mean and a variance among the users, instead of taking a deterministic value. This allows expressing the parameter β_q in the following form:

$$\beta_q = \beta + \delta_k * z_q + \eta_k \qquad [13]$$

where β is not correlated to the observed data, Z_q, η_k is a random component of the parameter, which can take different distribution (normal, uniform, triangular) and δ_k is the part of the parameter correlated to the observed data Z_q.

In detail, in order to make explicit possible relationships between CTS and Minibus transport systems and the socioeconomic attributes, the *ASA* have taken the form:

$$ASA_{qk} = ASA_k + ASA1_k Z_q + \eta_k \qquad [14]$$

Where:

ASA_{qk} *is the ASA of the CTS or the Minibus*

ASA_k *is the component of the ASA not correlated to the socioeconomic attribute*

$ASA1_k$ *is the component of the ASA correlated to the socioeconomic attribute*

Zq is the socioeconomic attribute

η_K *is the random component of parameter for which normal, uniform and triangular distributions have been hypothesized.*

Multinomial Logit models: Multinomial Logit models belong to the broader category of random utility models, which is a very widespread category in the simulation of users' choice behaviour.

The random utility models are based on the assumption that the user, possibly belonging to a homogeneous class of users in terms of behaviour, is a *rational decision maker* who maximizes the utility related to his own choices. In particular, the random utility models are based on the following hypotheses:

- While making his choices, the generic user *i* considers mi alternatives which are his choice set I_i.
- The decision maker *i* associates each alternative *j* of his choice set with perceived U_{ij} and choose the alternative which maximizes this utility.
- The utility associated with each alternative of choice depends on a series of attributes of the alternative and the decision maker and takes the form $U_{ij}= U_i(X_{ij})$, where X_{ij} is the vector of the attributes related to the alternative *j* and the decision maker *i*.
- The utility related to alternative j and to decision maker i for different reasons is not known with certainty by the outside observer (the analyst) and therefore it should be represented as a random variable.

So, random utility models do not allow determining the choice of user *i*, but allow defining the probability that, given a set of choice I^i, a certain alternative *j* is chosen.

According to these preliminary remarks, the perceived utility U^i_j can be expressed as the sum of the systematic utility V^i_j, which represents the average or the expected value of the perceived utility among all users with the same context of choice of the decision maker *i* and of a *random residuals* ε^i_j, which represents the deviation of the utility perceived by the user *i* from this value.

$$U^i_j = V^i_j + \varepsilon^i_j \qquad \forall j$$

Among random utility models, Multinomial Logit model is the most widespread and “simple”. This model is based on the hypothesis that ε_j related to the different alternatives are Indipendent and Identically Distributed (IID hypothesis) according to a Gumbel random variable with zero mean and parameter θ .

In particular, the mean and variance of the Gumbel variable apply:

$$E[\varepsilon_j] = 0 \qquad \forall j$$

$$Var[\varepsilon_j] = \frac{\pi}{6}\theta^2 \qquad \forall j$$

Furthermore, the indipendence of random residuals implies that the covariance between any pair of random residuals is nothing:

$$Cov(\varepsilon_j, \varepsilon_h) = 0 \qquad \forall j,h \in I$$

Personal Rapid Transit (PRT): PRT is based on small, energy-efficient vehicles on a dedicated guideway network offering a personal, automated taxi service with point-to-point non-stop travel.

Revealed Preference (RP): responses observed in a market setting.

Stated Preferences (SP): responses observed in an experimental design.

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