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Users’ preferences towards innovative and conventional public transport

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Abstract

The potential in urban environments of innovative public transport systems based on automation is being investigated within the CityMobil project (2006-2011). The Rome demonstration is implementing a cybernetic transport system (CTS) to connect the new fair with the car park. For this, a demand study has been carried out with a view to assessing the attitudes of the users towards innovative and conventional systems. A stated preference survey has been designed based on two questionnaires: one for the choice between foot and CTS, one for the choice between foot and a minibus. The responses to the two questionnaires have been pooled and a logit model has been calibrated using the joint maximum likelihood. The results are indicative of the relative preference of the users for innovation, as the demand for CTS is higher than the demand for minibus, the scenario and level-of-service attributes being the same. The hypothesis of heterogeneity across individuals of the attitude towards innovation is tested using a mixed logit formulation. Finally, the variation of preferences with the characteristics of the users, including gender, age and education, is explored.

Keywords: urban transport; public transport; cyberbetic transport system; minibus; demand; logit

1. Introduction

The last decade has seen an increasing interest for innovative transport systems based on automation and their potential for use in urban environments. This is testified by a number of research projects, funded within the Framework Programmes of the European Commission, which have dealt with the theme. In particular, research has addressed cybernetic transport systems (CTS) and personal rapid transit (PRT).

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. 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. A review on the technical and functional characteristics of these systems can be found in NETMOBIL Consortium (2005). Benmimoun et al.

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(2009) provide an update with the latest developments and a review of the demonstrations that are being carried out within the CityMobil project (2006-2011) of the Sixth Framework Programme.

The potential use of these systems is one aspect that European projects have tackled. The CyberMove project dealt with CTS, the EDICT project with PRT. In these projects (both of the Fifth Framework Programme), feasibility studies and small demonstrations were carried out. After CyberMove and EDICT, the European Commission funded the NETMOBIL project with the aim of providing a review of the existing research in the area of innovative transport systems. NETMOBIL, also of the Fifth Framework Programme, has pooled evidence from demand studies carried out in CyberMove and EDICT.

The available sources on demand studies essentially belong to the grey literature of project deliverables (CyberMove Consortium, 2004; EDICT Consortium 2004a and 2004b; NETMOBIL Consortium, 2004). Only few papers appear to be published on the subject, and all in conference proceedings (Alessandrini and Filippi, 2004; Bekhor and Zvirin, 2004; Minderhoud and van Zuylen, 2005). These studies used stated preference (SP) surveys.

In Haifa (Israel), a study was carried out on the potential demand for a CTS operating within the Technion University Campus and linking the main university buildings with the parking areas and the main bus stops located outside the campus. The proposed CTS line was presented as a complement to existing services. Results showed that 75% of the respondents would choose the proposed CTS in some form, either after parking the car or changing from bus or shuttle van (Bekhor and Zvirin, 2004).

In the city of Antibes (France) the assessment related to the implementation of a CTS linking the outer parking areas with the old city, one of the most touristic place in the French Riviera. Nowadays the parking areas are linked with the old city by a shuttle bus, but the majority of visitors prefer to drive close to the city centre and park causing problems of congestion and pollution. The demand study outlined that the implementation of a CTS would increase by nearly three times the number of users of the shuttle service (CyberMove Consortium, 2004; NETMOBIL Consortium, 2005).

A study of potential demand for a PRT was carried out in the city of Almelo (The Netherlands). The aim was to investigate the willingness to pay for a PRT linking the main points of the city such as a hospital, a train station and the city centre. The majority of the respondents expressed their willingness to use the PRT for their trip when it became available. However, a considerable amount (25%) indicated they would not consider it. The average willingness to pay for the innovative transport system is in the range of 1 EUR (Minderhoud and van Zuylen, 2005).

In Cardiff (United Kingdom) a study was carried out to assess the impact of implementing a PRT in the Cardiff Bay area which at that time had seen regeneration as residential and commercial area. The PRT was predicted to attract 61% of present bus passengers and 9% of present walkers, but also to benefit bus and rail services by attracting 8% of present car commuters who would use the combination of rail or bus into the centre and then onward by PRT. From the study it emerged that the average willingness to pay was well above the intended fare of 1 £ (EDICT Consortium 2004a and 2004b; NETMOBIL Consortium, 2005).

Kungens Kurva is one of the largest growing development areas in Huddinge (Sweden). Based on observations in 2004, most of the site’s visitors travel to the site by car, while only 5.5% reach the area using public transport. The demand study showed that in 2015, with the area fully developed and the PRT implemented, almost 1 out of 5 visitors is expected to go by public transport, 17.3 % of visitors are expected to use the PRT. This modal split is almost four times higher than that revealed in 2004 (EDICT Consortium 2004a; NETMOBIL Consortium, 2005).

The paper here reports on the demand study that has been carried out within the CityMobil project on the CTS of the Rome demonstration. The system is located in the Rome new exhibition centre and links the entrances with the parking area. The demand study has been aimed at assessing the attitudes of the users towards innovative and conventional systems. A comparison between the demand for a CTS and for a conventional minibus is made.

The paper is structured as follows. The next section presents an overview of the Rome demonstration. The core part of the paper relates to the demand study and presents the design of the SP survey and the results of the estimation of the demand model. In the conclusions, a few design and policy implications of the results and directions for further research are highlighted.

2. The CTS of the Rome demonstration

Rome has built a new exhibition centre to replace the old one. The old one is currently within the city centre of Rome with significant problems of parking and connections with mass public transport and with a limited exhibition
area. The new one aims to become one of the most important European exhibition areas. It is located in the direction of the Fiumicino airport (the main Rome international airport), 3 km outside of the outer ring road, 16 km away from the city centre, along the airport highway and railway link.

The new exhibition is provided with several parking areas. The largest (about 2500 parking lots), namely parking area P1, is located in front of the exhibition. To link parking area P1 with the main entrances of the exhibition it was decided to implement a CTS. The CTS is provided by Robosoft (see Figure 1), has a maximum speed of 24 km/h, and 29 passengers capacity. The obstacle detection system is composed by a scanner laser and a safety bumper.

![Figure 1 The cybercar](image1)

The track is provided with 11 stops, two located close to the two main entrances of the exhibition. The round trip length is about 1,600 m (Figure 2).

![Figure 2 The layout of the CTS](image2)

As no CTS has ever been certified in Europe, the Italian Ministry of Transport proposed a step-by-step certification approach. In the first step the CTS will operate in a fully-segregated track providing a shuttle service and the stops will be provided with platform doors. Once the CTS will be certified in this configuration, other features will be progressively added such as on demand functionality and pedestrian crossings.

The CTS implementation is well advanced and the first two cybercars are ready and fully tested. The first vehicle arrived in Rome late July 2010 and is now under testing in a track made available by ATAC (the Mobility Agency of Rome). Some civil works are needed for the track to allow the insertion of the CTS in the already existing parking area P1. The end of the civil works and the first certification of the CTS are expected in summer 2011.
3. The survey

Respondents of the SP survey have been faced with the choice of the mode of transport for reaching the exhibition entrance from the parking place. Two choices have been considered:

- the choice between a CTS and foot,
- the choice between a minibus and foot.

The attributes and corresponding levels are shown in Table 1. The attributes selected have been suggested by SP surveys conducted for automated systems within European projects (CyberMove Consortium, 2004; EDICT Consortium, 2004a). The attributes include two sets: scenario attributes and level-of-service attributes. The same attributes and corresponding levels have been considered for the CTS and the minibus alternative. The on-board comfort attribute includes two levels: the car level means that passengers certainly sit, while the bus level means that passengers may have to stand. The distance attribute for the foot alternative is the distance between the parking lot and the exhibition entrance. Levels considered for attributes such as on-board time and distance are based on the peculiar layout characteristics of the CTS designed for the Rome new exhibition centre.

| Table 1. Attributes and levels |
|--------------------------------|
| alternative | attribute | number of levels | levels |
| CTS/minibus | distance from stop | 3 | 20/75/150 m |
| CTS/minibus | waiting time at stop | 2 | 2/5 minutes |
| CTS/minibus | on-board time | 2 | 3/10 minutes |
| CTS/minibus | on-board comfort | 2 | car/bus |
| foot | distance | 3 | 200/400/800 m |

The SP survey design includes, for each choice, 288 distinct choice sets. Experimental design techniques have been used to reduce the number of choice sets while preserving orthogonality (Cascetta, 2009). The number is reduced to 24 choice sets by fractional factorial design. The 24 choice sets are in turn subdivided into 6 blocks with 4 choice sets each.

The CTS/foot choice survey has included 238 respondents, with each person responding to 4 choice sets, i.e. a sample of 952 observations. Equally, the minibus/foot choice survey has also included 238 respondents, with each person responding to 4 choice sets, again totalling 952 observations. Face-to-face interviews with users of the parking area of the exhibition took place in November and December 2009. The questionnaires included three parts. A first part where the aim of the interview and the characteristics of the transport supply are described. A second part with questions relating to personal characteristics of the respondent (age, gender, education, occupation, income). And a third part with the SP questions.

The shares of the two alternatives that result from the preferences of the two samples is in Table 2. The relative preference for the CTS in comparison with the minibus is already apparent from the sample data (66% share of CTS vs 56% share of minibus).

| Table 2. Shares from the sample data |
|-------------------------------------|
| sample | alternative and share |
| CTS/foot choice | CTS 66% |
| CTS/foot choice | foot 34% |
| minibus/foot choice | minibus 56% |
| minibus/foot choice | foot 44% |
4. Modelling and results

We consider multinomial logit models to estimate the probability of choosing an alternative. There is one model for the CTS/foot choice, one model for the minibus/foot choice.

The systematic utilities of the model representing the CTS/foot choice are:

\[ V_{\text{CTS}} = \beta_1^T \cdot X_1 + \text{ASC}_{\text{CTS}} \]
\[ V_{\text{foot}} = \beta_2^T \cdot X_2 \]

where:
- \( \beta_1 \) and \( \beta_2 \) are the vectors of coefficients;
- \( X_1 \) is the vector of attributes including the two scenario attributes (illumination and weather) and the four level-of-service attributes (distance from stop, waiting time at stop, on-board time, on-board comfort);
- \( X_2 \) is the vector of attributes including only the distance between the parking lot and the exhibition entrance;
- \( \text{ASC}_{\text{CTS}} \) is the alternative specific constant of the CTS.

The systematic utilities of the model representing the minibus/foot choice are:

\[ V_{\text{minibus}} = \beta_1^T \cdot X_1 + \text{ASC}_{\text{minibus}} \]
\[ V_{\text{foot}} = \beta_2^T \cdot X_2 \]

where the symbols have the same meaning as above and \( \text{ASC}_{\text{minibus}} \) is the alternative specific constant of the minibus.

In the two models, the utility of the CTS has the same attributes and coefficients as the utility of the minibus, the only difference between the utility of the CTS and the utility of the minibus is in the alternative specific constant. The utility of the foot alternative has the same specification in the two models.

With this formulation we have that, the other attributes being the same, any difference in the preference between the CTS and the minibus originates from the difference in the alternative specific constants. This way we will be able to assess the relative preference between the innovative system (CTS) and the conventional system (minibus), once the attributes that are common between the two systems are discounted.

The two models are estimated simultaneously, because this yields common values for the coefficients in the utilities of the CTS and of the minibus, by maximising the joint likelihood function:

\[ L = \prod_{i \in S_1} p_1^i \cdot \prod_{i \in S_2} p_2^i \]

where:
- \( i \) is the index denoting one observation (i.e. one choice set responded by an individual of the samples);
- \( S_1 \) is the sample of observations of the SP survey for the CTS/foot choice;
- \( S_2 \) that for the minibus/foot choice;
- \( p_1 \) is the probability of the alternative chosen in the observation according to the CTS/foot choice model;
- \( p_2 \) that for the minibus/foot choice model.

The expression (3) assumes that the two samples \( S_1 \) (CTS/foot choice) and \( S_2 \) (minibus/foot choice) are independent. It is further assumed that the two samples have error terms with the same variance (homoschedasticity hypothesis), which means assuming a unity scale factor. This latter hypothesis is justified as both samples refer to SP data (we are not combining here revealed preference data with SP data). The two models have been estimated using NLOGIT®. The estimation results are shown in Table 3. The procedure suggested by Swait and Louviere (1993) was used to estimate the relative scale factor between the two samples but it was found that the loglikelihood is flat with respect to the relative scale factor (over the interval between 0.85 and 1.15).
The results for the full models, i.e. the models where all the attributes mentioned above are included in the utility functions, show that a few attributes are statistically not significant (on the basis of the t statistic). Scenario attributes, i.e. illumination and weather, are statistically significant. Also the on-board comfort and the distance travelled on foot are significant. On the other hand, other level-of-service attributes of the CTS and minibus are not significant.

Therefore, in a second stage reduced models have been estimated where the following non-significant attributes are dropped: distance from stop, waiting time at stop, on-board time. The significant attributes have all the right sign: artificial illumination, rainy weather and comfort as a car favour CTS/minibus. Lower distance travelled favours the foot mode.

The analysis of the part-worth utility of the CTS/minibus for the two scenario attributes and for the comfort attribute shows that the impact (in terms of utilities and, hence, probabilities) of switching from the worst to the best attribute value is highest for the weather attribute, second is illumination, third comfort.

### Table 3. Estimation results

| Attributes          | full models | reduced models |
|---------------------|-------------|----------------|
|                     | coefficient | t statistic    | coefficient | t statistic |
| CTS and minibus     |             |                |             |            |
| illumination (1=day)| -0.43662    | -4.316         | -0.43732    | -4.327     |
| weather (1=dry)     | -1.21951    | -11.892        | -1.21963    | -11.896    |
| distance from stop (m)| 0.00062 | 0.645          | -          | -          |
| waiting time at stop (minutes)| 0.02178 | 0.640          | -          | -          |
| on-board time (minutes)| -0.00191 | -0.131         | -          | -          |
| on-board comfort (1=car)| 0.26725 | 2.642          | 0.26850    | 2.662      |
| ASC CTS             | 0.69716     | 2.937          | 0.8110     | 5.522      |
| ASC minibus         | 0.15993     | 0.676          | 0.27410    | 1.885      |
| foot                |             |                |             |            |
| distance (m)        | -0.00148    | -7.141         | -0.00148   | -7.142     |
| number of observations: 1904 |         |                |             |            |
| rho-squared adjusted| 0.56465     |                | 0.56518    |            |

The alternative specific constant of the CTS is higher than the alternative specific constant of the minibus which is indicative that, having discounted the attributes that are common to the two systems, the CTS is relatively more preferred than the minibus. The difference between the two alternative specific constants is statistically significant as the t statistic for the difference is 5.304.

As the alternative specific constant can be seen as a proxy of all other attributes not explicitly represented in the utility, it is possible to state that this relative preference is due, among the others, to attributes specifically related to automation. This is inclusive of how users perceive features such as absence of drivers and safety. It is also possible that users perceive the innovation as a value per se.

A further analysis has been carried out on the modal shares to estimate the difference in the number of users between CTS and minibus, having discounted the attributes that are common to the two (i.e. the scenario attributes and the on-board comfort). Figure 3 and 4 show the results. Figure 3 relates to the extreme case favourable to the CTS/minibus mode: artificial illumination, rainy weather and comfort as a car. Figure 4 to the extreme case favourable to the foot mode: day illumination, dry weather and comfort as a bus.

The Figures show the change in the modal shares with the distance between the parking lot and the exhibition entrance. In the case favourable to the CTS/minibus (Figure 3) the shares of both the CTS and the minibus are higher than the share of the foot mode for the entire distance interval. The reverse occurs in the opposite extreme case. In the case favourable to the foot mode (Figure 4) the share of the CTS is lower than the share of the foot mode up to a certain distance, the share of the minibus is lower than the share of the foot mode for the entire distance
interval. In both cases the CTS shows a higher share than the minibus and the difference in the modal share is in the range of 10%.

![Figure 3 Modal share with changing distance parking lot – exhibition entrance (illumination: artificial; weather: rain; comfort: car)](image)

![Figure 4 Modal share with changing distance parking lot – exhibition entrance (illumination: day; weather: dry; comfort: bus)](image)

A mixed logit formulation with random coefficients (Hensher and Greene, 2003) has been used to test heterogeneity in the alternative specific constant of the CTS. NLOGIT® has been used for estimation. Table 4 shows that the statistical significance of the standard deviation of the alternative specific constant of CTS is supported with a low value of the t statistic (only 1.5). The Table refer to a uniform distribution for this coefficient. Other distributions (normal, triangular) showed a lower statistical significance of the standard deviation.
Table 4. Estimation results: mixed logit

| Reduced models               | coefficient | t statistic | standard deviation | t statistic |
|------------------------------|-------------|-------------|--------------------|------------|
| Illumination (1=day)         | -0.43446    | -4.041      | -                  | -          |
| weather (1=dry)              | -1.29084    | -9.586      | -                  | -          |
| on-board comfort (1=car)     | 0.28589     | 2.628       | -                  | -          |
| ASC CTS                      | 0.87720     | 4.852       | 1.46041            | 1.5        |
| ASC minibus                  | 0.23783     | 1.495       | -                  | -          |
| distance (m)                 | -0.00162    | -5.908      | -                  | -          |
| rho-squared adjusted         | 0.56509     |             |                    |            |

The next step is the investigation of the sources of heterogeneity. The alternative specific constant of CTS has been interacted with gender, age and education. Only the interaction with age resulted statistically significant. The utility takes the form:

\[ V_{CTS} = \beta_1^T \cdot X_1 + ASC_{CTS} + ASC_{1CTS} \cdot AGE \]  

(4)

where the variable AGE is the age in years minus the minimum age in the sample (so that ASC_{CTS} provides the alternative specific constant for the youngest). Table 5 shows the estimation results of a mixed logit where the two alternative specific constants of CTS ASC_{CTS} and ASC_{1CTS} are random independent coefficients with a triangular distribution. In the estimation, the ASC_{1CTS} has been constrained to take one sign only. This has been obtained by giving to NLOGIT® the instruction to constrain the standard deviation of ASC_{1CTS} to equal the mean times 0.40284. This is equivalent, in the case of a positive sign, to a triangular distribution with density which starts at zero, rises linearly to the mean, and declines to zero at twice the mean.

Based on the estimation results, the alternative specific constant of CTS increases with age. The elderly show a higher preference for CTS. This can be explained with the perception of safety, the negative perception of the driver and, related to this, the perception of a higher comfort due to factors other than the guaranteed seat, such as a higher riding comfort (acceleration, jerk) which is expected from automation.

Table 5. Estimation results: mixed logit with age interaction

| Reduced models               | coefficient | t statistic | standard deviation | t statistic |
|------------------------------|-------------|-------------|--------------------|------------|
| Illumination (1=day)         | -0.43666    | -4.312      | -                  | -          |
| weather (1=dry)              | -1.22409    | -11.848     | -                  | -          |
| on-board comfort (1=car)     | 0.26781     | 2.653       | -                  | -          |
| ASC CTS                      | 0.40905     | 1.409       | 0.28206            | 1.956      |
| ASC1 CTS                     | 0.01105     | 1.595       | 0.00451            | 1.595      |
| ASC minibus                  | 0.28206     | 1.956       | -                  | -          |
| distance (m)                 | -0.001469   | -7.146      | -                  | -          |
| rho-squared adjusted         | 0.56552     |             |                    |            |

Figure 5 and 6 show the change in modal share with age. These shares have been obtained from mixed logit probabilities calculated on the basis of 500 random draws of the coefficients ASC_{CTS} and ASC_{1CTS}. For comparability, the same draws have been used across the age values explored. The figures refer to a distance parking lot – exhibition entrance of 400 m. Only the choice between foot and CTS is subject to changes with age, while the modal shares for the choice between foot and minibus are unaffected by age. In the case favourable to CTS (Figure
5), the increase in the share of CTS when age changes from the minimum (17 years) to 65 years is less than 10%. In the case favourable to foot (Figure 6), the increase in the share of CTS between minimum and maximum age is higher than 10%.

Figure 5 Modal share with changing age (illumination: artificial; weather: rain; comfort: car)

Figure 6 Modal share with changing age (illumination: day; weather: dry; comfort: bus)
5. Conclusions

The demand study carried out for the Rome demonstration has provided useful indications for the application of innovative systems based on automation in contexts of parking areas serving an exhibition or a congress centre.

First, the results highlight the attributes that have the highest potential to influence the choices of the travellers between the foot mode and a (motorised) public transport mode. These are the scenario attributes, such as weather and illumination (in this order of importance), the on-board comfort (whether sitting or standing), and the distance travelled on foot. In terms of system design the implication is that, for this particular application context, more attention is to be paid on comfort aspects than on speed.

Second, the results are indicative of a relative preference of the users for innovative systems. The conclusion can be drawn that, the level-of-service provided being the same, the users prefer an innovative system based on automation to a conventional system such as a minibus. When the users are confronted with a choice between the foot mode and a public transport mode, the difference in the modal share of the public transport mode that can be expected if a CTS is used instead of a minibus is in the range of 10%. Moreover, the investigation of the socio-economic variables has shown that age is a source of heterogeneity in the alternative specific constant of CTS, and that the relative preference for CTS increases with age, presumably because a higher riding comfort is expected from automation. This is a remarkable point in the current policy debate on mobility in an ageing society. However, as the analysis here does not allow to disentangle specific unobserved attributes because they are confounded in the alternative specific constant, future research may further investigate factors that affect how users perceive automated systems.

When the Rome demonstration will be operating, it will be possible to compare the actual share of the CTS with the predictions of the study here. A new demand study is possible in the near future if an extension of the layout of the CTS will be decided to connect the exhibition entrance with the existing railway station. The study would be aimed at assessing the impacts of the implementation of the CTS on the modal share between rail and car of the trips directed to the exhibition.

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