On the Asymmetric User Perception of Transit Service Quality

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ABSTRACT

In this paper, heterogeneity of transit users in perceiving service quality is investigated. Users' perceptions of transit services are heterogeneous for many reasons: the qualitative nature of some service aspects, the different users' socioeconomic characteristics, the diversity in tastes and attitudes towards transit. In this research, heterogeneity is treated through a mixed logit model with a non-parametric distribution of the coefficients, allowing the asymmetry in user perception heterogeneity to be considered. Although the results presented apply to the specific population in the sample, represented by university students, the proposed methodology is general and transferable to other case studies.

INTRODUCTION

Transit service quality is an aspect markedly influencing travel user choices. Improving service quality is important in order to convenience the current users and to attract new users, nowadays increasingly inclined to make use of a private car. Transportation use in general has consequences on safety, congestion, fuel consumption, vehicle emissions, and access (Richardson, 2004). The increase of environmental externalities has been expedited by the continuing trend of modal shift in favour of the private car, which is the most detrimental form of motorized transport; the impacts have to be reduced in order to make the transport sector more environmentally sustainable (Rienstra and Vleugel, 1995). According to Goldman and Gorham (2006) the first emergent strategy deploys creative new technologies to provide competitive alternatives to the private automobile; these 'new mobility' strategies encourage new and more efficient ways of interacting with the city by providing customers with more flexible, convenient and integrated travel options. Modal substitution represents hence an important strategy of demand management for the achievement of a sustainable transportation; this can be accomplished by providing better modal options (Deakin, 2001), such as transit systems characterized by high quality levels. In order to guarantee better transit services, transit agencies must provide methods for measuring and monitoring their performances. Many researchers consider the customers' satisfaction the most relevant measure for evaluating the performances of transit services; as an example, Berry et al. (1990) pointed out that "customers are the sole judge of service quality". Therefore, capturing passenger perceptions about the service aspects provides a service quality measure.

The aspects generally describing transit services can be distinguished into characteristics that more properly describe the service, and characteristics depending more on customer tastes and less easily measurable. There are many research studies in the literature in which transit service aspects have been analysed and the user perceptions have been investigated.

One of the most relevant and investigated transit service aspects is reliability. Turnquist and Blume (1980) define transit service reliability as "the ability of the transit system to adhere to schedule or maintain regular headways and a consistent travel time". Strathman et al. (1999) and Kimpel (2001) agree that reliability is mostly related to schedule adherence. As well as Beirao and Sarsfield-Cabral (2007), who state that the lack of control, due to the uncertainty of the vehicle arrival, makes the service unreliable. Transit reliability is strongly associated with transit accessibility, which is the suitability of a system to move people from their origins to their destinations with reasonable cost (Koenig, 1980; Murray, 2003). Unreliable service results in additional travel and waiting time for passengers (Wilson et al., 1992; Strathman et al., 2003). Service unreliability can lead to loss of passengers, while improvements in reliability can lead to attraction of more passengers (El-Geneidy et al., 2007). A study proposed by Eboli and Mazzulla (2010) confirmed that service reliability is one of the most important service aspect for the users. Research studies conducted in the seventies have already shown that arriving on time at destination is often seen by travelers as more important than minimizing elapsed travel time (Nash and Hille, 1968; Hartgen and Tanner, 1970). The study of Wachs (1976) found that reliability or variance in travel time is an important component of attitude toward transportation modes, and also revealed that time spent in waiting, walking, transferring modes, or parking a vehicle is consistently viewed by travelers as more onerous than time spent on board. Dowling et al. (2002) propose an interesting study reporting a methodology for measuring the user-perceived quality of service from a multimodal perspective. The time spent in walking for reaching the bus stop defines the level of accessibility to the transit service. Therefore, a transit stop must be located within walking distance, and the pedestrian environment in the area should not discourage walking (TRB, 2003). However, Hu and Jen (2010) found that the distance one has to walk from home to the bus stop is not a major issue for the bus passengers.

Service frequency is another important factor in one's decision to use transit. The more frequent the service, the shorter the waiting time when a bus or train is missed, and the greater the flexibility that customers have in selecting travel times (TRB, 2003). Tyrinopoulos and Antoniou (2008) found that service frequency is the most important attribute across transit operators. Also, in Eboli and Mazzulla (2008) service frequency resulted to be the attribute with the highest weight on overall transit service quality measures.

There is extensive literature supporting the thesis that costs affect the mode choice behavior of travelers. Traditional fixed route transit demand elasticity relies on the Simpson-Curtin demand elasticity of -.33, meaning for every one percent increase in fare, there will be a corresponding 1/3 percent loss of ridership (DiJohn et al., 2008). On the other hand, many studies of attitudes toward transportation system alternatives found that the monetary travel cost does not constitute a salient factor in modal-choice decisions. As an example, Wallin and Wright (1974) concluded that "cost does not play a major role in the choice of a transportation mode". Beirao and Sarsfield-Cabral (2007), who conducted a qualitative study in a European context, stated that public transport is generally perceived as cheaper than car and monetary cost does not appear as a key factor for changing to public transport, with the exception of the users with low income, who consider travel cost very important.

Also the comfort during the journey is important for transit users. Comfort means having soft and clean seats, climate control, not many people on board, low levels of noise and vibrations, no nasty odours. These many factors are differently evaluated across different groups of users. Beirao and Cabral (2007) found that habitual public transport users consider the new vehicles with air-conditioning and lower floor as "very good and very comfortable", but the overcrowding on board at peak hours is considered a problem. On the other hand, car users and occasional public transport users usually see buses as uncomfortable, overcrowded, smelly and airless. Wachs (1976) underlined that vehicle comfort is less important to the traveller's decision process than other service aspects.

Another service aspect affecting transit service quality is represented by information. Passengers need to know how to use transit service, where the access is located, where to get off in the proximity of their destination, whether any transfers are required, and when transit services are scheduled to depart and arrive. Without this information, potential passengers will not be able to use transit service (TRB, 2003). Passenger information includes information during the trip, information at stops, and pre-trip information (Nathanail, 2008). Beirao and Cabral (2007) found that several respondents think that the bus system is difficult to use and information is difficult to obtain; among bus users the main problem occurred when the bus company changed timetables or routes and did not provide enough information to users.

Safety during a journey may be considered a not very relevant aspect in the modal choice decision; in fact the probability of being involved in an accident or of becoming the victim of a crime is not explicitly considered as part of the choice mechanism. However, when explicitly queried about the importance of safety, this factor is given an extremely high rating of importance (Solomon et al., 1968). These findings are confirmed by Iseki and Taylor (2008) on their study about safety and security at stops, and by Eboli and Mazzulla (2010) who explicitly investigated safety and security on board.

Another aspect characterizing transit services consists of passenger amenities, which are those elements provided at a bus stop or station to enhance comfort, convenience, and security. Amenities include shelters, benches, vending machines, trash receptacles, lighting, phone booths, and so on. The effects that particular amenities have on transit passenger are not well known. Some researchers have argued that the term “amenities” implies something extra and not necessarily required (TRB, 2003). Iseki and Taylor (2008) found that stop and station-area amenities were ranked as least important by the users.
There are also other transit service aspects that are not much investigated, such as service coverage, personnel appearance and helpfulness, environmental protection, and customer services.
Various studies about transit service quality have shown that users have different perceptions of the service aspects and of the factors affecting each aspect. These perceptions can be heterogeneous because of the qualitative nature of the aspects, the different attitudes of the users towards the use of transit services, the user social background. In the next section, a review describes the ways heterogeneity in user perceptions has been treated in the literature. In this research we propose the analysis of the heterogeneity in user perceptions by means of a discrete choice model in which an asymmetric distribution of the parameters is introduced. The research is supported by a sample survey addressed to students using bus services in an urban area.

HETEROGENEITY IN USER PERCEPTIONS

Differences among users in their perceptions and responses should be accounted when evaluating the quality of the transit services. Users’ heterogeneity depends on individual’s socioeconomic characteristics and on the choice context. In the great majority of empirical studies based on the use of discrete choice models, the fixed parameter assumption forces preferences for each attribute of a service to be homogeneous. However, in the analysis of consumer preference behaviour the possibility for unobserved heterogeneity is real. The most general way of accommodating heterogeneity in consumer tastes is to recognise that the underlying distribution of preferences is continuous. This has given rise to a literature on continuous mixing distributions in which analysts estimate mixtures of distributions for parameters of one or more attributes (Hensher, 2001).
In the proposed literature review we have examined only the choice contexts referred to the users of a specific transport system, omitting from the consideration the between mode choice contexts in which service quality aspects are marginally considered. There are not many studies in the transportation literature in which qualitative aspects of the service are considered in discrete choice models, and the heterogeneity in the user perceptions of the qualitative aspects is introduced. The large majority of the studies reviewed have adopted mixed logit (ML) formulation to introduce heterogeneity in passenger perceptions.
In ML models with random parameters a number of attributes have a predefined functional form, such as normal, triangular, uniform and log-normal. In the case of coefficients with an a priori sign assumption, the use of the normal distribution should be avoided, as it leads to a positive probability of wrongly signed coefficients (Hess et al., 2004). In these cases, the log-normal form is often used. For the triangular distribution, the density function shows a peak in the centre and dropping off linearly on both sides of the centre (Hensher, 2001). Hensher and Greene (2003) have shown that for this distribution, when the mean parameter is constrained to equal its

spread, the density of the distribution rises linearly to the mean from zero before declining to zero again at twice the mean. As a consequence, all individual specific parameters are constrained to be of the same sign. The symmetry of this distribution avoids the problem of long tails often associated with drawing from a log-normal distribution. On the other hand, the uniform distribution is sensible when we have dummy variables (Hensher, 2001). Although ML models may help in uncovering preference heterogeneity for attributes, they assign non-zero parameter estimates to individual decision makers, even though their marginal utility for an attribute may be zero. This assumption creates a bias in the population parameter estimates and introduces some problems in the willingness to pay (WTP) calculation (Rose et al., 2005).

In Hensher (2001) ML models were proposed for analysing unobserved heterogeneity in bus passenger perceptions. Three specifications of ML models were proposed; each presented a different distribution for the random parameters (normal, uniform and triangular). The author explored also the possibility that this unobserved heterogeneity might be converted to observed heterogeneity around the mean estimates; parameters were then estimated as function of passengers' characteristics. The random parameters were related to the reliability, access and travel time, and safety.

Analogous ML models with normal distribution of the parameters were proposed in Eboli and Mazzulla (2008). Differences in perceptions were recovered from a sample of habitual bus users in an urban context; the focus of the analysis was on reliability, bus overcrowding, information and personnel attitude.

Yang et al. (2003) formulated a ML model within a two-stage choice structure that accommodated taste heterogeneity of bus users. The first stage is a probabilistic choice set generation model, while the second stage is a probabilistic alternative choice model conditioned on the choice set. They considered some service attributes, such as reliability, convenience, comfort, fare, etc. The only individual heterogeneity identified in the alternative choice stage was the response heterogeneity to actual fare.

Hess and Polak (2005) presented an analysis on airport choice based on ML model in which a log-normal function is adopted for the parameter distribution. They investigated taste heterogeneity on fare, frequency, access time and cost, flight time. The results indicated that there is significant heterogeneity in tastes, especially with respect to the sensitivity to access time.

Rose et al. (2005) proposed a study about the choice of airline carrier depending on ticket price, flight time, departure time and flight time variability. They considered the heterogeneity in passenger perceptions by using an ML model. In specifying the models, the parameters associated with the design attributes were drawn from a constrained triangular distribution.

Lijensen (2006) explored the possibilities of measuring the value of schedule delay for air passengers, by estimating an ML model. Several attributes were considered, such as travel time, access time, fare, time of arrival and so on. The ML specification allowed the distribution of preferences with respect to time of arrival over the population to be tested, and explicitly took into account variations in desired arrival times. The uniform distribution yielded the best fit for the valuation of arrival times.

Espino et al. (2008) examined different model specifications to detect the presence of preference heterogeneity in an airline choice context. They analyzed individual's preference for the main attributes defining the service offered by the airlines, such as price, penalty for changes in the ticket, free food, comfort, frequency and reliability. They proposed multinomial logit models which accounted for systematic taste variation by including some interactions of socioeconomic variables with level-of-service attributes. They also considered taste variations in the preferences by means of ML, in which a normal distribution was considered for the random parameters. They concluded that random heterogeneity does exist for all the parameters considered with the exception of food.

In addition to the studies based on the ML model estimation there are also some studies in which other model structures were adopted for accounting heterogeneity.

Berry et al. (1997) attempted to capture airline customers' heterogeneity by allowing customers' preferences over various product specifications to be drawn from a binary distribution. A demand model with heterogeneous tastes for product characteristics and unobserved product characteristics was proposed; in addition, a nested logit formulation was introduced to include the decision not to fly. They considered two very distinct types of passengers, tourists and business travellers. Under the assumption that the distribution of consumer tastes was a discrete bi-modal, the taste of the model parameters was found to vary across consumers, yielding random coefficients for attributes such as distance, density and flight frequency.

Huse and Evangelho (2007) investigated business traveller heterogeneity amongst airline passengers by using ordered discrete response models. They firstly adopted a factor analysis to group travellers on the base of their preferred attributes. Then, ordered discrete response methods were used to assess which attributes are perceived differently by business travellers, controlling for observed heterogeneity in the form of route and passenger characteristics. They analysed punctuality, ticket selling, check-in, parking, hotel, red-eye flights.

Teichert et al. (2008) applied latent class modelling in order to identify segments along behavioral and socio-demographic variables among frequent-flyer passengers. In a first step they estimated a multinomial logit model making use of class flown as an a priori segmentation criterion (business and economy-class). The results of the first analysis of preferences based on the traditional business/economy dichotomy led them to test the degree of homogeneity within both segments. Then, they used a latent class approach to market segmentation, which provided customer segments with homogeneous preferences. Among the attributes analysed there were flight schedule, fare, flexibility and reliability.

We can conclude this section by saying that studies about user perceptions of the transit services have focused more on the analysis of service attribute concerning travel times and cost; qualitative aspects such as reliability, comfort, information, and so on, have been less investigated. In general, the methods proposed to account for heterogeneity are based on a predefined functional form of the parameters. Problems are reported when an a priori sign assumption is made and when the user perceptions have an asymmetric distribution. In these cases, the introduction of non-parametric distribution in ML coefficient estimates can represent a valid alternative.

RANDOM COEFFICIENTS MIXED LOGIT

We use mixed logit formulation to estimate heterogeneity in individual taste (Train, 2003). Supposed that the decision maker faces a choice among J alternatives, the utility of person n from alternative j is specified as:

$$U_{nj} = \beta_n x_{nj} + \varepsilon_{nj} \tag{1}$$

where x_{nj} are observed variables that researcher obtains from the decision maker, β_n is a vector of coefficients of these variables for person n representing that person's taste, and ε_{nj} is an unobserved random term that is independent and identically distributed (IID) extreme value, independent of β_n and x_{nj}. The coefficients among the population vary over decision maker with density $f(\beta)$ which is the function of the parameter θ that for example represent the mean and standard deviation of the β 's in the population. The conditional choice probability becomes

$$L_{ni}(\beta_n) = \frac{e^{\beta_n x_{ni}}}{\sum_j e^{\beta_n x_{nj}}} \tag{2}$$

Since β_n varies across population and the researcher does not know β_n for each respondent, the unconditional choice probability is therefore the integral of conditional choice probability over all possible variables of β_n which is

$$P_{ni} = \int \left(\frac{e^{\beta_n x_{ni}}}{\sum_j e^{\beta_n x_{nj}}} \right) f(\beta) d\beta \tag{3}$$

For maximum likelihood estimation, the probability of each person's sequence of observed choices is needed. Let $i(n,t)$ denote the alternative that person n chooses in period t. Conditional on β_n, the probability of person n 's observed sequence of choices is the product of standard logit:

$$S_n(\beta_n) = \prod_t L_{ni(n,t)t}(\beta_n) \tag{4}$$

where the unconditional probability for sequence of choice is:

$$P_n(\theta^*) = \int S_n(\beta_n) f(\beta_n \mid \theta^*) d\beta_n \tag{5}$$

where θ^* are the true parameters of this distribution.

This choice probability cannot be calculated analytically since the integral does not have a general closed form; therefore the exact maximum likelihood estimation is not possible. Instead, the probability is usually approximated through simulation (Bhat, 2001, 2003; Bastin et al., 2006).

NON-PARAMETRIC MIXED LOGIT

A non-parametric approach is introduced in this paper to resolve difficulties associated with the identification of asymmetric random distributions. Non-parametric distributions do not rely on

the assumption that parameters' estimates follow a pre-determined statistical distribution (i.e. normal, log-normal etc.) and have therefore the potential to guide the analyst in search for the real shape of the coefficients' distribution. We adopt, in this paper, a non-parametric B-spline formulation which has been recently proposed by Bastin et al. (forthcoming).
By assuming that independence holds between the random components of the mixed logit models, they can be considered separately. As *X* is a univariate random distribution, the draw is then generated from the uniform distribution *U*[0,1] and the inverse cumulative distribution function F_X^{-1} is applied to these draws:

$$S_X = \left\{F_X^{-1}(U), U \sim U[0,1]\right\} \tag{6}$$

where S_X represents the sample set drawn from the random variable *X*. Here, it is assumed that the distribution of the random variable *X* is not known, but its inverse cumulative distribution function F_X^{-1} is able to be approximated. The properties F_X^{-1} has to satisfy are:

- $F_X^{-1} : [0,1] \to \Re$
- F_X^{-1} is monotonically increasing
- F_X^{-1} is continuous

This requires function approximation technique to estimate F_X^{-1} under domain [0,1] which is monotonically increasing. In order to seek an adequate balance between estimation capabilities and the condition satisfaction, the inverse cumulative distribution function is expressed as some element of the functional space:

$$F_X^{-1}(.) = \sum_{k=1}^{\infty} p_k h_k(.) \tag{7}$$

where $\{h_k, k = 0,\ldots,\infty\}$ constitute a basis of this space and p_k are the coordinates of F_X.
Assuming that the random variable *X* has a bounded support, the B-spline function is used to achieve such balance. This bounded support assumption exploits the advantage of eliminating extreme value of extraordinary behavior that imposes difficulties in our model interpretation. A B-spline function of degree *p* is a polynomial function of degree *p*, defined n the interval [*a*,*b*], that can be expressed as a linear combination of *n+1* basis functions $N_{i,p}(u)$, as follows:

$$C(u) = \sum_{i=0}^{n} P_i N_{i,p}(u). \tag{8}$$

where the coefficients $P_0, P_1, \ldots, P_n$ are the control points, and *u* is the knot vector $(u_0 = a, u_1, \ldots, u_m = b)$. Then the basis function by recurrence on the degree *p* can be constructed as:

$$N_{i,0} = \begin{cases} 1 & \text{if } u \in [u_i, u_{i+1}), \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

and

$$N_{i,p} = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) + \frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u) \tag{10}$$

so that the dimension of the control points *n* is equal to *m – p – 1*.

The knot vector chosen for the purpose of our paper is the non periodic (clamped or open) knot vector, taken the form

$$U = \left\{ \underbrace{a,\dots,a}_{p+1}, u_{p+1},\dots,u_{m-p-1}, \underbrace{b,\dots,b}_{p+1} \right\} \tag{11}$$

where the first and last knots have the multiplicity of *p+1* (*38*).

In our formulation, we chose five equally spaced knot points per spline approximation; the knot vector is based on the percentiles 0, 1/4, 1/2, 3/4, 1 and has the form:

$$U = \left\{ \underbrace{0,0,0,0}_{4}, 0.25, 0.5, 0.75, \underset{4}{1,1,1,1} \right\}$$

The basis function has degree p = 3 and, according to eq. (10), the dimension of the control point vector to be estimated is equal to seven (7 = 11 – 3 – 1).

EXPERIMENTAL CONTEXT

The survey supporting this research was addressed to students of a university campus located in Southern Italy. The survey, realized in the winter of 2006, involved a random sample of 470 students who habitually use urban bus services to reach the campus. In a typical working day, about 8,000 students travel by urban bus; therefore, the sampling rate was approximately 5.8%. Respondents were interviewed at the bus terminal close to the campus while waiting the bus and were asked to provide information about their socioeconomic characteristics and trip habits, and about the quality of the service used. A Stated Preference (SP) experiment was submitted to the users, in which they were called to make a choice between their habitual bus service and two hypothetical bus services. The choice alternatives are defined by nine attributes varying on two levels (Table 1). All the service quality attributes are defined as dichotomous variables, except “walking distance to the bus stop” and “ticket cost” that are continuous, measured in minutes and in Euros respectively. The variable linked to the walking distance varies from the current value stated by each user to a value increased by 10 minutes, in order to propose to the users a worsening in service attribute. The same reasoning was applied to the attribute linked to fare, which varies from the current ticket cost to a 25% higher fare. Finally, we propose to the user a service frequency of 15 minutes; this results to be an improvement over the actual 30 minutes or hourly frequency. The choice of the attribute level values in the experiment was driven by an accurate review of similar works reported in the literature (e.g. Hensher, 2001; Hensher and Prioni, 2002) and by the analysis of the existing service characteristics. The current alternative is defined by each user at the moment of the interview by assigning a value to the quality attributes. Each SP alternative is composed by a combination of the attribute levels.

Table 1 Service quality attributes and levels

Only three alternatives were submitted to the users because it was considered that they could have some difficulties in making a choice between more than three alternatives when several attributes define the alternatives (Hensher and Prioni, 2002). SP alternatives were coupled and joined to the current alternative producing several types of experiment, each of which was submitted to a group of users. The selection of the alternatives and the definition of the SP experiments were complex because of the large number of combinations. Traditional methods, such as fractional factorial design and block decomposition, were not sufficient and adequate for our experimental design. Therefore, a simulation procedure was adopted for selecting and coupling the alternatives. A detailed description of the procedure and of the resulting experimental design is reported in Eboli and Mazzulla (2008). In Table 2 are shown the main socioeconomic characteristics of the sample; it should be observed the young age of the respondents and the relative high percentage of the population without a driving licence.

Table 2 Socio-economic characteristics of the sample

MEASURING HETEROGENEOUS USER PERCEPTION OF TRANSIT QUALITY

Individual preferences over bus service are modelled in this paper using discrete choice methods. In Table 3, we present the results obtained by using multinomial logit with fixed coefficient (MNL), random coefficients mixed logit with parametric coefficients (ML-Normal) and mixed logit with non-parametric coefficients (ML-Spline). We estimate nine transit level-of-service variables: walking distance to the bus stop, service frequency and reliability, bus stop facilities, bus crowding, cleanliness, fare, availability of information at the bus stop and personnel attitude.

Table 3 Model results

The logit model includes two additional socio-demographic valiables: gender and car availability, that are added to the utility function as specific of the alternative. The mixed logit models present four random coefficients, for which we intend to estimate users' taste heterogeneity. All the estimated coefficients in the logit model (with the exception of gender) and in the parametric mixed logit are significant at 95% level of significance (including both means and standard deviations), although improvements in the final value of the log-likelihood function obtained with mixed logit formulations are marginal. More complex is the significance of the points in the knot vector defined for the spline specification. Five out of the seven points result to be significant for the schedule reliability and the bus overcrowding; P0 and P1 corresponding to the right tail of the spline are not significant. It should be said that it is well known in the literature that splines have difficulty in recovering the tails of the distributions especially when not enough information is available for extreme cases. Knot points for the information coefficient are all not significant, while just tails estimated for the perception of personnel attitude are found to be signifcant. Although the non parametric formulation provides more flexibility in capturing the heterogeneity, many knot points are found to be non-significant.

This might explain why the non-parametric specification is not superior to the parametric mixed logit. It is worth mentioning here that in a simulated experiments (Bastin et al., forthcoming), where normal, lognormal and spline distributions were compared, the true asymmetry in individual preferences was recovered just by non-parametric distributions.
We turn our analysis on the subjective willingness to pay and where appropriate on the asymmetry of taste distributions. The fixed coefficient model formulation indicates that transit users have a positive attitude toward higher frequency, reliable schedules, not owercrowded vehicles, services and facilities offered at the bus stop. In all the three specifications considered, users are willing to pay about 0.2 Euro to save 10 minutes walking time, about 0.5 Euro to have a service running every 15 minutes, 0.1 Euro for facilities at the bus stop and 0.14 Euro for cleaner vehicles. The consistency of the results obtained with different specifications indicates that differences in parameters' estimates are due to scale factors (the smaller the scale factor, the bigger the coefficients). The low values of WTP are explained by the socioeconomic condition of the sample, which is made up of students from low-middle income household (85% of the sample).

Figure 1 Heterogeneity in preferences over transit quality attributes inverse of the cumulative distribution functions (ICDF)

Taste heterogeneity has been estimated on the remaining four transit quality attributes: reliability, overcrowding, information and personnel attitude. Figure 1 reports normal and non-parametric distributions for all the four random parameters. When estimating the non-parametric mixed logit model we define the knot vector at the percentiles 0, 0.25, 0.5, 0.75 and 1; consequently the B-spline distributions is identified by seven control points (P0,…,P6) as defined in equation 8. Distribution around the mean indicates that reliability is positive for almost all the population considered. Reliability shows an asymmetrical behaviour when B-spline are applied; half of the population has very low willingness to pay for reliable transit services, while about 20% has high propensity to pay for buses coming on time to the stop. Asymmetry is also revealed by the percentiles given in Table 4; we measure WTP for reliability between 0.11 and 0.34 Euro per trip, which are respectively the 25th and the 75th percentiles of the distribution estimated. The sign of the variable representing bus overcrowding is found to be positive for about 80% of the respondents. We note that a mass exists at about -0.2 Euro; masses at zero or at specific values cannot be recovered with symmetrical distributions (i.e. normal).

Table 4 Percentiles of the WTP distributions (Euro/trip)

Moreover, 30% of our respondents seem to be indifferent to information provided at the bus stop, more than 50% have very low propensity to pay for this kind of service and only 17% show interest in timetable and announcements of possible delays. Again, the 20% negative values for the information coefficient reported by the normal distribution is in reality a mass at zero. More than half of our respondents ignore the personnel attitude and their willingness to help transit riders. This can be explained by the relative young age of our sample, which is mainly constituted of students. To conclude this section, it seems important to say that respondents in our sample were really concerned about the frequency of the service and the walking distance to the stop. Facilities offered, cleaning status of the buses, reliability and the crowding of the transit service, (for the last two coefficient we estimate a median WTP respectively of 0.13 Euro and

0.15 Euro) were found to be significant for the quality of the service but WTP was low and varies between 0.1 Euro and 0.15 Euro. Information and help received by the personnel were not perceived as very important and consequently the WTP calculated is very low.

CONCLUSIONS

In this paper we have estimated transit users' perception of service quality. We have analysed the heterogeneity in user perceptions by means of a mixed logit model with non-parametric distribution of coefficients. The non-parametric approach has allowed the asymmetry of certain coefficients to be estimated. This approach is even more useful when the attributes affecting users' behavior have a qualitative nature. In these cases verifying the heterogeneity in user perceptions is fundamental for obtaining more realistic estimates. Service characteristics analysed in this study such as reliability, comfort on board, information, personnel manners showed an asymmetrical behaviour when B-spline distribution was applied. In spite of the non-significance of some knot points, the spline model has provided more flexibility in capturing random heterogeneity.

To summarize the main findings from our analysis on asymmetric preferences, it can be said that reliability is highly evaluated by the bus riders and that one third of the sample has a relative high willingness to pay for services that are on time. A mass at -0.2 Euro exists for overcrowd coefficient and a high percentage of the respondents is not interested in the information provided at the bus stop or in the help received from the personnel. This can be justified by the fact the respondents are in general young and therefore well informed about timetable and not in need of help. The asymmetry estimated gives more accurate WTP measures; WTP values may be used for calculating the project revenues in transport service investments.

This study is now limited by the sample size and its composition (mainly students); if extended the importance of heterogeneity and asymmetric tastes across the population can be found to be even more significant for the quality evaluation of transit services.

Our analysis can be easily transferred to other cases where asymmetry in behavioural responses is judged to be important and demonstrates that advanced modeling techniques are mature and can be applied to real planning studies.

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Table 1 Service quality attributes and levels

Service quality attributes	Levels of variation
Walking distance to bus stop	same as now (1); 10 minutes more (0)
Service frequency	every 15 minutes (1); same as now (0)
Schedule reliability	on time (1); late (0)
Bus stop facilities	bus shelter, seats and lighting (1) no shelter, no seats, no lighting (0)
Bus crowding	No overcrowded (1); overcrowded (0)
Cleanliness of the facilities	clean enough (1); not clean enough (0)
Fare	25% more than the current fare (1); same as now (0)
Information at the bus stop	timetable, map, announcement of delays (1) no timetable, no map, no announcement of delays (0)
Personnel attitude	very friendly (1); very unfriendly (0)

Table 2 Socio-economic characteristics of the sample

Characteristics	Statistics
Gender	male (46%), female (54%)
Age	18-20 (43%), 21-24 (46%), > 24 year-old (11%)
Number of members in the household	1 (0%), 2 (1%), 3 (11%), 4 (50%), 5 or more members (38%)
Household income	low (17%), low-middle (18%), middle (50%), upper-middle (11%), upper (4%)
Car driving licence	did not own car driving license (12%), own car driving license (84%)
Household members with car license	0 (0%), 1 (3%), 2 (17%), 3 (41%), 4 (30%), 5 or more members (9%)
Number of cars in the household	0 (0%), 1 (26%), 2 (61%), 3 (12%), 4 or more cars (1%)
Access mode to bus stop	walking (99%), others (1%)
Ticket type	one-way ticket (25%), one-day travel card (50%), monthly travel card (22%), other (3%)

Table 3 Model results

Variable		MNL		ML-Normal			ML-Spline	
		Est.	t-stat	Est.	t-stat		Est.	t-stat
Walking distance to bus stop	m.	-0.101	4.3	-0.207	7.6		-0.224	6.7
Service frequency	m.	2.678	11.5	4.424	7.1		4.980	5.3
Schedule reliability	m.	1.202	7.6	2.370	7.1	P0	-0.734	0.6
	s.d.	-	-	1.090	3.1	P1	1.344	0.6
						P2	1.344	3.0
						P3	1.344	2.0
						P4	3.369	3.7
						P5	8.534	2.9
						P6	8.635	2.8
Bus stop facilities	m.	0.583	3.8	0.952	3.6		1.282	2.2
Bus overcrowding	m.	0.643	3.4	1.138	3.6	P0	-6.282	1.5
	s.d.	-	-	1.980	2.9	P1	-2.479	1.0
						P2	1.340	3.0
						P3	1.868	3.2
						P4	2.660	2.9
						P5	2.904	2.1
						P6	4.653	2.8
Cleanliness of the facilities		0.741	5.0	1.390	4.9		1.557	4.6
Fare	m.	-5.451	4.2	-11.617	7.2		-12.541	7.4
Information at bus stops	m.	0.561	3.6	0.936	3.6	P0	-0.399	0.2
	s.d.	-	-	1.533	2.2	P1	-0.399	0.3
						P2	-0.399	0.3
						P3	0.274	0.4
						P4	1.931	0.8
						P5	2.196	1.0
						P6	11.004	1.3
Personnel attitude	m.	0.451	3.1	0.981	3.9	P0	-4.917	2.0
	s.d.	-	-	2.496	4.5	P1	-0.255	0.1
						P2	-0.255	0.3
						P3	-0.255	0.3
						P4	1.614	0.8
						P5	8.004	2.0
						P6	8.004	2.9
Gender	m.	0.328	1.8	-	-		-	-
Car Availability	m.	0.422	2.0	-	-		-	-
Log-likelihood at zero		-703.11		-703.11			-703.11	
Log-likelihood (final)		-462.86		-455.45			-453.03	

Legend:
m = mean
s.d. = standard deviation
P0, P1, P2, …, P6 = spline supporting points

Table 4 Percentiles of the WTP distributions (Euro/trip)

Distribution of coefficient	Distribution	Percentiles		
		25%	50%	75%
Schedule reliability	Normal	-0.25	-0.19	-0.13
Schedule reliability	Spline	-0.34	-0.13	-0.11
Bus overcrowding	Normal	-0.19	-0.09	0.02
Bus overcrowding	Spline	-0.21	-0.15	-0.003
Information at bus stops	Normal	-0.16	-0.07	0.01
Information at bus stops	Spline	-0.14	-0.04	0.02
Personnel attitude	Normal	-0.21	-0.08	0.06
Personnel attitude	Spline	-0.22	-0.005	0.02

Figure 1 Heterogeneity in preferences over willingness to pay for transit quality attributes, (inverse of the cumulative distribution functions - ICDF)