Latent Variables Definition for a New Mobility Model in Barcelona

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ABSTRACT

In many European cities, mobility patterns are changing mainly due to advances in information and communications technology. Besides from this, people living in urban areas have now more transport mode alternatives to travel and the ownership of a vehicle is losing relevance to the modern world. In addition, the new generations value the time spent in the trip in a different way and they take advantage of travel time by means of connectivity (i.e. multitasking).

As a result of the complexity of transport supply and transport demand preferences, the choice of transport alternative does not currently depend only on traditional cost, time and socioeconomic aspects. Therefore, we have focused the investigation on attitudes, habits and perceptions, to incorporate latent variables in the individual utility function.

For this purpose, we have designed a web-based survey, based on qualitative in-depth interviews that revealed indicators of the travellers of Barcelona. The first section includes individual questions about a recent trip experience and the second part tests attitudinal aspects. A principal component analysis of the items asked in the attitudinal section has been carried out, obtaining 11 relevant factors that allocate respondents to different groups of users according to their attitudes and perceptions.

The results show that in Barcelona, users, especially millennials, take advantage of new technologies in their journeys, their time perception changes if they do activities during the trip and they perceive car and bike sharing as a good mobility solution instead of the ownership and use of a private car.

1. INTRODUCTION & BACKGROUND

Mobility patterns in large European cities are becoming increasingly complex. This complexity concerns daily transport mode and route choices, and is growing due to information technology, the growing array of travel alternatives and the way in which new

generations perceive and make use of time spent travelling.

Research on travel behaviour attempts to capture this inherent complexity in the choice of transportation and its determinants, with the aim of obtaining an effective tool that provides fundament to the choice, because understanding the modal choice is a key element in the ability to model and predict demand.

For years, socioeconomic factors and attributes of transportation alternatives (instrumental variables) were considered key elements of many models that served as support to stakeholders in decision-making (Shiftan et al., 2008). The socioeconomic and demographic variables and the traditional attributes of time and travel costs have been very relevant to these models to explain mobility. However, there is growing recognition that when an individual makes a decision in our society, the interplay between different factors is becoming increasingly complex. Several authors have shown that attitudes and perceptions influence the user's election process regarding transportation modes (Ashok et al., 2002; Ben-Akiva et al., 2002).

After all, there are different travel patterns in homogeneous socioeconomic groups (van Wee, 2002). This indicates that the modelling of travellers' behaviour should not only focus on objective measures and structural variables, but also in variables addressing attitudes, personal attributes or even lifestyles (van Acker et al., 2011). Segmentation approaches have been a subject of interest in regard to segmentation based on attitudes (Shiftan et al., 2008; Marco and Mokhtarian, 2009), showing that these market segmentations are very useful for identifying potential modal shift users.

The literature has provided different ways to take into account, along with the effect of traditional variables, these psychometric or unmeasurable variables in the choice model (Greene, 1984; Bollen, 1989; Keane, 1997). However, in recent years the use of hybrid models that integrate discrete choice models with latent variable models has gained popularity, aiming to turn abstract attributes into measurable variables so that they can be included as part of the utility. Thus, both known and latent variables are included in the modelling. Ben-Akiva et al. (2012), Bahamonde-Birke and Ortúzar (2012), Daziano and Bolduc (2013), Di Ciommo et al. (2013), Glerum et al. (2014), Hess and Stathopoulos (2013), Kamargianni and Polydoropoulou (2014), Paulssen et al. (2014), Raveau et al. (2010), Vredin-Johansson et al. (2006) and Tam et al. (2010), among others, have theoretically and empirically proven the advantages of these types of models.

The aim of our research was to design a survey targeted at a future hybrid model for Barcelona and identify, within a part of the data set provided by the survey, the subjective indicators of travel attributes, some of which are identified as latent attributes.

The paper is divided into five sections. The second section, after the introduction, discusses

attitudinal and behavioural indicator variables. The third section describes the research methodology used for the survey. Section 4 investigates the determinants of users' behaviour, and shows how the perceptions and attitudes identified using the principal components helps to find the relevant factors of users. Section 5 draws conclusions, finalizing with some future lines of research.

2. RESEARCH METHODOLOGY AND SURVEY DEVELOPMENT

After identifying, thanks to qualitative surveys, the Key Performance Indicators (KPIs) that are representative in the current modal choice (Creafutur, 2015), we were then able to define a quantitative survey. The analysis of the attitudinal part of the survey suggests a set of latent variables for modelling the mobility in Barcelona.

2.1 Analysis of the qualitative interviews and KPIs

The main objective was to understand and define the variables that affected the modal choice of Barcelona's travellers and should be included into the online survey. To define the KPIs, 14 individual qualitative interviews were conducted with daily users of public and private transport in Barcelona and 4 interviews with commuters with origins or destinations outside of Barcelona (Creafutur, 2015).

Different types of patterns have been identified based on the frequency of travel (routine or occasional trips) and the trip reason. Thus, three types of variables were identified: variables based on rational thought; those that were emotional, related to environment factors; and variables that were emotional from a perspective of feelings (stress, relaxation, etc.).

Conducting the interviews has proven interesting in avoiding, to the greatest extent possible, the questionnaire being influenced by the interviewer's point of view. Thus, thanks to the in situ interviews and an examination of existing literature, both essential, we had been able to define the travel experience we intend to portray. Therefore, these observations were important to increasing the probability of creating valid measures for the city, exploring a long list of potential variables that were then used to define the questionnaire.

2.2 Online survey

We had designed an online survey, based on the qualitative interviews using the emerging variables (e.g. knowledge and familiarity with the route or line to get to destination, privacy and control of the own space, weather conditions or need for an open space sensation). First, we defined the way in which the survey had to approach the experience of travel. Then we designed a questionnaire reflecting all the key points and factors that we extracted.

2.2.1 Study of travel experience

As recently do some other authors like Bahamonde-Birke et al. (2015), we wanted to emphasize the difference between attitudes and perceptions. Users often have a predisposition or tendency to act in a certain way, depending on their individual experiences and personality (Pickens, 2005). In this case, the approach depends only on the individual, and attitudinal indicators are considered constant in each user for all alternatives.

But perceptions (although they are very close to attitudes) should be interpreted as the process through which each individual experiences their environment. It depends on both the individual and the stimuli around them (Bahamonde-Birke et al., 2015). To work with perceptions and perceptual indicators, it is necessary to propose a new set of indicators for each transport mode alternative that users face. On occasion their choices are not strictly governed by the expected reaction given their attitude.

Some latent variables refer to the attitude of the users with respect to the trip and others deal with their perceptions of each mode of transport. Thus, in the online survey we had questions of revealed preferences (preferences that are revealed by traveller habits) complemented with questions about the perceptions and attitudes toward their choices.

Once we were able to obtain the revealed preferences of the users, we asked about their stated preferences (choice preferences of users towards alternatives that the user has not experienced). With a Stated Choice (SC) experiment, the study can gather information about the preferences of individuals, based on a series of games, where individuals are forced to choose what they would do, facing a trade-off between different attributes and thus declaring their preferences regarding them.

It is necessary to be cautious with these types of questions, as they are linked to the image that individuals have of themselves about risk, moral satisfaction and the provision of public resources, all related to a possible enhancement of self-image. With this in mind, the hypothetical scenario can offer the respondents an opportunity to alter their image (Carlsson et al., 2010).

According to Carlsson et al. (2010), in the hypothetical case in which the election doesn't have any real cost, users often tend to focus on the benefits, without really being aware of the costs involved. In this way the survey would reveal more about the respondents' attitudes rather than their real preferences (Kahneman and Sugden, 2005). This is why, in order to measure the attribute of interest, the different alternatives have been shown together with the actual costs it would entail.

2.2.2 Final design of the survey

Having defined the scope of the survey, the questionnaire included three main sections: (i)

questions on the users' profile and their experience of specific trips, (ii) attitudinal questions about their travels and their choice of mode, and (iii) experiment of choices made only to car users.

1st part: User profiles and their revealed experience
In the first part of the survey, we asked users about their personal characteristics, such as age, gender, educational level, employment status and access to different vehicles and services. Thus, the entire questionnaire was addressed to the individual. For example, owning a vehicle is not the same as having access to a vehicle.

The respondents have been asked about their most recent workday or weekend. It is important to note that information on travel must not be asked in general (i.e., in terms of average values), but must refer to a specific time milestone or a recent reference to avoid bias in the data (Ortúzar and Willumsen, 2011).

In this section we asked about each stage of the trips on that day, to then be able to map out a pattern for the trips and their motives and choices in each context. Thus, all available modes of transport and reasons for travel have been dealt with separately.

The information about time has also been questioned in a customized way for each mode of transport marked by the respondent; for example, in the case of cars, time spent parking and time spent in traffic jams, among others, and in the case of public transport, time required to access transportation or time spent in transfers. We have aimed to have a complete view of segregated journey times for each mode. How travel time is used in each mode or how certain stages of the journeys are perceived is changing a lot in the city with the use of new technologies, most especially among the Millennials (Mans et al., 2012).

2nd part: Attitudinal and perception questions
With regard to the attitudinal part, respondents had rated all the important variables chosen on a 5-point scale (from "strongly disagree" to "strongly agree"). 56 items had been raised, formulated in such a way that they would measure their attitude towards an individual factor or their perception of a service. They were originally grouped into 8 groups of variables based on the qualitative interviews (Table 1).

Factor	Nº of items
Sensitivity to cost and time variables	8
Comfort and convenience	9
Information of travel modes and routes	5
Image and attractiveness of transport modes	2
Attitudes regarding the alternative choice	15
Security during the trip	5

| Environment of the travel mode | 5 |
| Feelings during the trip | 7 |

Table 1 – Travel components considered in the attitudinal questions

In the case of any available information to carry out their trips, we measured user perception of these services and how technology affects these perceptions. In the case of comfort and convenience, certain items had been asked from an attitudinal point of view, such as the need for a neat appearance, and others from a perceptional standpoint, such as cleanliness or the feeling of open space.

The same occurs with the environment of transport mode, the image or appeal of the transport, security, the users' mood during the trips and attitudes when choosing a mode of transport, where some items measured the users' direct attitude and others their perception. Thanks to this combination of ways of asking about the items, we are able to not only measure the attitude of users regarding the decision variables, but also a set of feelings that the chosen transport provide them with.

3rd part: Stated Choice Experiment

Finally, a Stated Choice (SC) experiment was carried out on users who reported having used the car for any of their day trips. We proposed the SC just to car users with the aim of analysing the importance of car ownership and the fidelity to the car, to obtain the real potential users of sharing services. In the case in which the respondent, according to the attitudinal questions, would not give up on having own vehicle, the game was between the current situation and carpooling services. However, if the ownership of the car was not important for the respondent, the game was between the current situation and car sharing.

The question presented respondents with three scenarios, giving them a choice between their current situation (baseline) and two alternative services. The attributes associated with each option were the variable monthly cost of the use of the car, a fixed annual cost, and owning or not owning the car. These were identified in the literature as the factors that currently differentiate users from different car services (see for example Kim and Park, 2015). In the experiment, each of the three alternatives was described by a drawing and a description of the service in line with these attributes.

Attribute levels were linked to the current use of the car that respondents indicated. This means that although most of the SP experiments have levels set in advance for each sample of users, in our case the levels of attributes were not known in advance and were adapted to the respondent. Therefore, it was necessary to assume a priori levels to design the experiment. The defined costs were different depending on the hours travelled each month. It should be noted that all attribute levels were consistent with actual data on monthly hours and the cost of trips. Thus, for each choice, respondents were aware of the real trade-off between costs and the ownership between services.

2.2.3 Survey implementation

Respondents were chosen through the database panel of Netquest, an independent provider of online services for research and marketing in Spain, Portugal and Latin America. In Spain it has more than 150.000 panel members listed on the database. They have their own survey software (Survey Manager) and respondents are exclusively recruited by invitation (without voluntary registration), to ensure a proper representation of the sample and the reliability of the information.

In total 1022 users completed the survey, with an average duration of 25 minutes. From this sample, 222 users went on to complete the last task of the SC questionnaire, because they reported having used the car for any of their trips. Table 2 shows the distribution of the respondents' characteristics.

Characteristics of the respondents		N	%
Gender	Male	529	52%
	Female	493	48%
Age	14-17	130	13%
	18-30	268	26%
	31-45	280	27%
	46-65	228	22%
	more than 66	116	11%
Level of education	Middle School	115	11%
	High School	205	20%
	University degree	518	51%
	Occupational training	145	14%
	Other	39	4%
Employment status	Employed	619	61%
	Unemployed	32	3%
	Retired	111	11%
	Student	206	20%
	Housewife	6	1%
	Other	33	3%
Number of household members	1	86	8%
	2	315	31%
	3	291	28%
	4	266	26%
	more than 4	64	6%
Month income in household	1300€ or less	152	15%
	1300-2500€	306	30%
	2500€ or more	265	26%
	No answer	298	29%
Accessibility	Driving licence	758	74%
	Access to a usable car	521	51%

	Access to a shared car	157	15%
	Access to a usable motorcycle	187	18%
	Access to a usable bicycle	400	39%
	Private parking lot	414	41%

Table 2 – Summary of respondents characteristics

Concerning the socio-economic characteristics, the rate of women and men is almost the same. The range of ages is similar; the majority of the respondents consist of people whose age is between 31 and 45 years old, but it is remarkable the high proportion of young people in the survey. It represents one of the first survey in Europe including people beyond 14 years old. Most of the respondents present an educational level higher that High School (85%) and the majority of the respondents (61%) are employed. The number of household members is high in contrast with the month income in household.

Finally, a high proportion of the respondents have a driving licence (74%), a half of the respondents have access to a car for their displacements and a 41% of respondents have a private parking lot. It means that there is a high percentage of respondents who are oriented to the car. It is also high the proportion of respondents with access to a bicycle (39%).

3. ANALYSIS OF RESPONDENTS' ATTITUDES AND DISCUSSION

The first main goal of our survey was to capture the users' views and preferences of different transport modes and to identify their attitudes and perceptions of some important factors that define the travel experience. Moreover, the survey aimed to verify these main factors or dimensions as the ones that explain the decision of each type of user.

Due to the number of variables and data we collected from the survey, it is important to analyse what elements have resulted in being relevant in the travel experience. In the exploratory data analysis, a Principal Component Analysis have been undertaken, where the dimensionality of the data set have been reduced. This technique is used to find the causes of variability in a data set, detecting structural relationship among the variables while retaining the explanatory power of data. This result is obtained by projecting the data, according to which they are best represented in terms of least square (Washington et al., 2011).

The 56 items of the second part of the survey were analysed using factor analysis to guarantee a correct specification of the latent variables. The principal component analysis was conducted to explore the interrelationships among these attitudes and to define new combined indicators. To enable easy interpretation, the factors were rotated using Varimax technique so that each variable loaded heavily onto a single factor.

In this way, instead of the eight dimensions considered in the survey, it was possible to identify eleven components explaining the 53% of the variance of the perceptual indicators (Table 4) without correlation between them. Table 3 presents the factor loadings extracted from the rotated component matrix for both types of indicators.

Components (attitudes)	Items	Factor loadings
1. Sensitivity to cost and time	Monetary cost	0,464
	Travel time	0,583
	Punctuality	0,687
	Number of transfers	0,654
	Knowledge of routes	0,581
	Frequency	0,722
	Proximity of the stops	0,708
	Real time information at stops	0,467
	Accessibility	0,329
2. Loyalty to the car	Parking as an incentive	0,574
	Not being altruistic in the election	0,678
	Shift depending on facilities to bike	0,535
	Punctuality depending on schedule	0,370
	Shift depending on parking	0,497
	Own vehicle	0,678
3. Flexibility and tendency to change the travel mode	Flexibility in return trip	0,487
	Shift depending on congestion	0,418
	Shift depending on weather	0,728
	Shift depending on mental conditions	0,726
4. Time using	To use travel time to work	0,448
	New technologies travelling	0,675
	Careless of driving	0,485
	Allow distractions	0,635
5. Awareness of shared economy	Awareness of pollution	0,375
	Share vehicles to reduce cost	0,693
	Shift depending on health	0,396
	Parking facilities as incentive to share	0,561
6. Concerns about big city problems	Less polluting vehicle preference	0,458
	Road congestion	0,525
	Parking as a problem	0,658
7. Technology friendly	Online information of routes	0,562
	App for the availability of vehicles/parking	0,719
	App to pay parking	0,697

8. Need of freedom sensation	Relaxing time	0,643
	Independence	0,470
Components (perceptions)	**Items**	**Factor loadings**
9. Each mode's environment	Open space sensation	0,439
	Pleasing surroundings	0,673
	Design of vehicles	0,645
	Security guard	0,467
	Transport driver presence	0,457
	Abruptness of drivers	0,468
	Privacy traveling	0,496
	Own space without stress	0,619
10. Comfort	Cleanliness	0,447
	Temperature	0,444
	Ventilation	0,436
	Noise	0,645
	Neat appearance	0,484
	Seat availability	0,520
	Phone coverage	0,600
	Free WiFi	0,616
	Extend service hours	0,362
11. Service level of public transport	Easiness to pay	0,407
	Safety in stops	0,765
	Safety at night	0,746
	Interaction with others in public transport	0,401

Table 3 – List of items classified into eleven travel components, grouped into attitudes related components and perceptions related components

Components	Eigen value	Variance explained (%)	Cumulated variance explained (%)
1. Sensitivity to cost and time	12,007	21,441	21,441
9. Each mode's environment	3,798	6,783	28,224
10. Comfort	2,503	4,469	32,694
6. Concerns about big city problems	2,069	3,695	36,388
2. Loyalty to the car	1,619	2,892	39,280
3. Flexibility and tendency to change the travel mode	1,521	2,716	41,996
4. Time using	1,410	2,517	44,513
7. Technology friendly	1,331	2,377	46,890
5. Awareness of shared economy	1,207	2,156	49,046

11. Service level of public transport	1,151	2,056	51,102
8. Need of freedom sensation	1,024	1,829	52,931

Table 4 – Explained variance of each component of the principal component analysis

Regarding the attitudinal indicators, the first factor is identified as the "sensitivity to cost and time", as it is related to the importance given to cost and time indicators during the trip. This component explains the 21% of the variance of the data. The second component is associated with the "loyalty to the car", including a positive predisposition toward automobiles, and the third component is related to individuals who have great "flexibility and tendency to change the travel mode". These results are interesting for our analysis as it was possible to identify a non-alternative and an alternative related attitude. The factor four is "time using" related, joining the use of the travel time to work or to the use of new technologies (i.e. multitasking), with careless of driving and also allowing distractions while travelling.

The factor five is related to the appreciation for the development of services that take into account the "awareness of shared economy". In the same line, the sixth factor shows "concerns about big city problems", such as pollution, congestion and parking problems. These two components are interesting to evaluate future strategies in the city. The eighth component comprises the "technology friendly" attitudes, and finally, the last component added the value of the "need for freedom sensation" during the trips.

According to the travel perceptions, the ninth component is called "each mode's environment", as it is associated with situations causing privacy, security, stress, open space sensation and attractiveness during the trip. The tenth factor comprises the "comfort" items, such as cleanliness, temperature, noise, seat availability etc. These two factors explain another 11% of the variance. Finally, the factor eleven refers to the "service level of public transport", as the easiness to pay or safety travelling.

The attitudinal factors uncovered as part of this study were compared to those reported by other similar studies. Sensitivity to travel time or to transportation cost are common factors that emerged from this research as well as from Lieberman et al. (2001) or Proussaloglou et al. (2001). The willingness to use a mode and the loyalty to the mode are important attitudinal constructs uncovered by the analysis presented in this research, a finding supported by Shiftan et al. (2008) and Shiftan et al. (2015). Lieberman et al. (2001) and Popuri et al. (2011) also found concern for the comfort and the perceived safety in the level of service of public transport.

However, there are some new factors reported by this research as the concerns about big city problems, the time using, the technology friendly attitude and the awareness of shared economy. These variables may be emerging from a new paradigm of mobility in big cities like Barcelona. This has been verified by analyzing the differences of these new factors
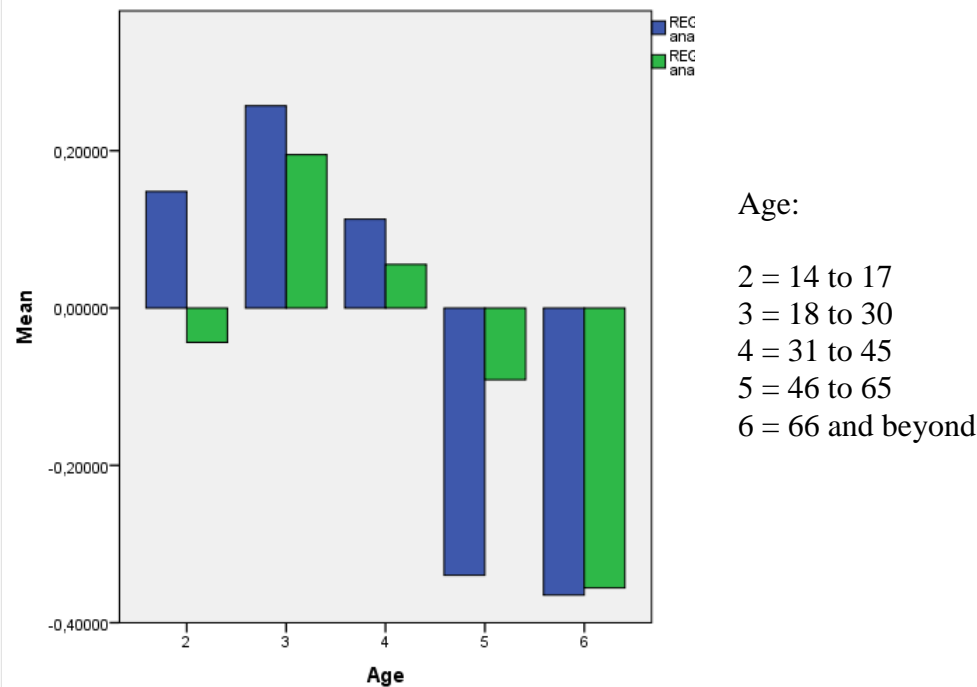
between different ages.

Fig. 1 –**Mean of "time using" (blue) factor and "technology friendly" (green) factor loadings according to the age.**

We can see that the attitude about the use of travel time (blue in Figure 1) is different according to the age. Young people valuate positively to use the travel time to work or to enjoy new technologies and they like the modes that allow distractions and to be careless of driving. Moreover, regarding the technology friendly factor (green in Figure 1) they are in favour of having applications to search vehicles or to pay parking, as they also see useful the online information of transport routes. The exception would be the teenagers between 14 and 17 because they do not have the need to use such applications, even if they have a positive reaction to the use of technologies in travel time.

4. CONCLUSIONS

This article presents, firstly, a methodology for conducting surveys aimed at obtaining not only socioeconomic and objective variables concerning travelling, but also user attributes and perceptions when choosing their travel method. The respondents have been specifically asked about their travel patterns for daily journeys, including all travel modes and the reasons for travelling. Afterwards, ratings on the various attributes considered were obtained in order to extract subjective indicators for their choices.

Once the survey was completed, a factor analysis of the items asked in the attitudinal section has been carried out, obtaining 11 relevant factors that group the subjective

indicators showing correlation. On the one hand, factors relating to user attitudes have included concerns about big city problems, loyalty to their cars, flexibility and a tendency to change travel modes, the use of time, being a lover of technology, an awareness of shared economy, and the feeling of freedom during the trip. On the other hand, the factors resulting from user perceptions of the alternatives have included factors related to costs and time, each mode's environment, the comfort and service level of public transport.

These factors have proven to be consistent with what has been read in literature; see Lieberman et al. (2001) and Shiftan et al. (2015), among others. Thus, we have obtained possible latent variables that could improve a discrete choice model for Barcelona.

Our empirical analysis shows evidence that supports the thesis that attitudes can affect the way in which different individuals attribute certain values to a given alternative. In the same vein, it is shown that perceptions could explain a significant portion of the variability that is normally seen for the alternative concrete variables. Therefore, besides presenting a methodology for obtaining latent variables, this article provides an initial insight into how attitudes and perceptions can explain the selection process for the travel mode, serving as a first step towards a hybrid model to explain the travel behaviour of the users in the city.

The results show that in Barcelona, users, especially millennium users, take advantage of new technologies in their journeys, their time perception changes if they do activities during the trip and they perceive car and bike sharing as a good mobility solution instead of the ownership and use of a private car.

ACKNOLEDGEMENTS

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