STATED PREFERENCES IN TRAVEL DEMAND MODELLING

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1. INTRODUCTION

In most transportation planning studies the modelling of travel demand constitutes a vital part. In fact, while the supply-demand equilibration process is usually discarded in short term applications, the sensitivities of demand to the variables under control of the planner or operator, such as fares, always need to be known. Now, in the last two decades models of individual choice among discrete alternatives have become firmly established as the prevalent approach to travel demand modelling in most contexts, and in the last few years stated preferences (SP) techniques which allow the consideration of non-existent or difficult-to-measure options and attributes have become a fundamental element of the analyst's tool kit. On the other hand the great importance of travel time savings in the economic evaluation of transportation projects has prompted a renewed interest in their proper valuation, hence the myriad of subjective value of time (SVOT) studies in the last few years (see Department of Transport, 1987; HCG, 1990 for the two most important recent studies in Europe). The government in Chile has adopted the British practice but there is some preoccupation as the best values reported in the country are far larger than those recommended by the British government (see for example Gaudry et al, 1989; Jara-Díaz and Ortúzar, 1989).

This paper considers the use of SP methods in demand model estimation and the derivation of subjective values of time, based on two projects recently completed in the country. Section 2 summarises these two experiences and presents the models and SVOT values derived from them, and section 3 briefly presents our main conclusions.

2. STATED PREFERENCES EXPERIMENTS IN SANTIAGO

2.1 Determining the Importance of Level-of-Service Attributes

The first study (Ortúzar et al, 1991) was designed with two main objectives: first, the identification of relevant level-of-service (LOS) attributes to users and potential users of the public transport system, and second, the determination of the perceived importance of these variables; for this users were stratified by income, time of day of travel, sex and location in the city. The study results will be used to design bus services 'to measure' if necessary, in order to keep current levels of public transport patronage in the city.

Information about relevant variables was obtained through in-depth 'focal group' interviews on the basis of spontaneous or induced opinions, the support these gathered and the number of times each attribute was mentioned during the session. A preliminary list of variables obtained from a Delphi type exercise proved important, firstly as a means of revitalising the conversation when it decayed and secondly, as a means of contrast with the variables mentioned freely by the interviewees. Seven variables were finally chosen and a sample of 284 individuals were submitted to two SP games, with four attributes each, in order to estimate the weights attached to each variable in the level-of-service vector. Two games were needed because it is not recommended to design experiments where more than five attributes may vary at a time. In order to have a common basis to assess differences in importance one variable (Travel cost) was kept in both games. The variables considered in the first game were the following:

- Travel cost, two levels (0 and 30% increment)
- In-vehicle travel time, three levels (-15, 0 and 15% increment)
- Variability of waiting time, two levels (with and without variability)
- Accident risk, three levels (hanging, riding in an old bus, riding in a new bus)

and those used in the second game were:

- Travel cost, the same two levels
- Waiting time, three levels (-50, 0 and 50% increment)
- Bus occupancy, three levels (crowded, standing with few others, seated)
- Vehicle comfort, three levels (old and dirty bus, new and clean minibus, new and clean omnibus).

The variables Waiting time and its variability were separated; also, more traditional and easier to measure variables, such as In-vehicle travel time were mixed with more subjective attributes such as Accident risk and Vehicle comfort. The SP games were designed and conducted using Game Generator, a program developed by the UK consulting firm Steer Davies Gleave (SDG, 1990). This allowed us to build custom made situations for each respondent, by probing initially for their usual travel costs and times. Both peak and off-peak period interviews were conducted at the workplace, the latter at large retail stores located at both the CBD and high district as their employees enter work after the peak (between 9:30 and 10 am). The design (only main effects) required nine options which were combined into 14 pairs of 'cards' in each case. Users were asked to choose one card from each pair and the data was later analyzed using a multinomial logit routine. A series of checks were performed (i.e. violations of transitivity, selection of dominated options) and the offending cases were removed. Table 1 describes the options (nine at each stage) presented to each individual and Table 2 presents the final number of clean 'choices' which resulted from the SP interviews.

Table 1: Definition of alternatives at each stage

GAME 1 Alternative	Travel Cost	Travel Time	Waiting Time Variability	Accident Risk
1	1.3 TC	0.85 TT	1	0
2	1.3 TC	0.85 TT	1	2
3	TC	0.85 TT	0	2
4	1.3 TC	TT	0	0
5	1.3 TC	TT	1	2
6	TC	TT	1	1
7	TC	1.15 TT	1	0
8	TC	1.15 TT	0	1
9	1.3 TC	1.15 TT	1	2
GAME 2 Alternative	**Travel Cost**	**Waiting Time**	**Bus Occupancy**	**Vehicle Comfort**
1	TC	0.5 WT	0	0
2	TC	0.5 WT	1	2
3	1.3 TC	0.5 WT	3	3
4	1.3 TC	WT	0	2
5	TC	WT	1	3
6	TC	WT	3	0
7	TC	0.5 WT	0	2
8	1.3 TC	0.5 WT	1	3
9	TC	0.5 WT	3	0

Notes: TC, TT and WT are the cost, travel and waiting time values declared by the individual; for Waiting time variability 1 and 0 indicate regular/irregular service; for Accident risk 0, 1 and 2 indicate hanging, riding an old bus, and riding a new bus respectively; for Bus occupancy 0, 1 and 3 indicate standing in a crowded bus, standing with few others, and seated respectively; finally, for Vehicle comfort 0, 2 and 3 indicate old and dirty bus, new and clean minibus, and new and clean omnibus respectively.

Table 2: Number of choices for logit analysis in each SP game

	Peak Period	Off-Peak Period	Students
GAME 1			
Low income	587	-	-
Medium income	1065	1145	-
High income	225	-	-
Total	1877	1145	438
GAME 2			
Low income	597	-	-
Medium income	1039	1137	-
High income	234	-	-
Total	1870	1137	479

Before presenting the results it is important to discuss some issues related to the modelling task. First, note that the alternatives presented to the individuals are just variations (in the level-of-service) of only one physical option: public transport, so the interpretation of results is not straightforward (see Ortúzar et al, 1991). Secondly, there were problems with the treatment of the more subjective/less easy to measure variables (i.e. Bus occupancy, Vehicle comfort). The use of dummies did not yield reasonable results, so an alternative approach (admittedly rather arbitrary) was devised, as follows:

- Waiting time variability: If the service was punctual the variable was assigned the waiting time value declared by the individual; this value was incremented in 10 min if the service was irregular (the survey described an irregular service as one where the usual waiting time of which could be incremented in up to 10 min).

- Accident risk: The three levels described in the survey: hanging, riding in an old bus, and riding in a new bus, were characterised by the values 0, 1 and 2 respectively; thus the coefficient of this variable should have a positive sign.

- Bus occupancy: The three levels described in the survey: crowded, standing with few others, and seated, were characterised by the values 0, 1 and 3 respectively; thus the coefficient of this variable should also have a positive sign.

- Vehicle comfort: The three levels described in the survey: old, dirty and noisy bus, new and clean minibus, new and clean omnibus, were characterised by the values 0, 2 and 3 respectively; thus the coefficient of this variable should also have a positive sign.

Table 3 shows the estimated coefficients of the LOS variables at both SP games (t-tests are shown in parenthesis) for all strata. As can be seen all coefficients have the correct sign and most are significant at the 95% level. As mentioned above these results have a certain degree of uncertainty because they vary with the values assigned to the levels of the subjective variables.

Table 3: Estimated coefficients of the level-of-service vector

	Peak Period				Off-Peak
Attribute	Low I.	Middle I.	High I.	Student	Middle I.
Game 1 (Sample size)	587	1065	225	483	1145
Travel Cost	-0.0644 (-10.4)	-0.0279 (-8.2)	-0.0204 (-2.2)	-0.0588 (-6.9)	-0.0232 (-7.4)
Travel Time	-0.0926 (-3.7)	-0.1220 (-6.4)	-0.1587 (-2.9)	-0.1613 (-5.0)	-0.1483 (-7.3)
Wait Time Variability	-0.0282 (-1.5)	-0.1169 (-7.7)	-0.2685 (-4.9)	-0.1450 (-6.2)	-0.1451 (-8.9)
Accident Risk	1.3270 (10.0)	1.5030 (16.3)	1.9710 (8.1)	1.5220 (10.9)	1.7150 (17.4)
Game 2 (Sample size)	597	1039	234	479	1137
Travel Cost	-0.0569 (-8.6)	-0.0183 (-5.1)	-0.0092 (-1.0)	-0.0274 (-3.9)	-0.0154 (-4.5)
Waiting Time	-0.0630 (-3.3)	-0.1043 (-6.5)	-0.2764 (-4.4)	-0.1559 (-6.0)	-0.1606 (-7.9)
Bus Occupancy	0.1829 (2.1)	0.4509 (6.1)	0.6611 (4.3)	0.6505 (5.9)	0.7352 (8.4)
Vehicle Comfort	0.8933 (7.9)	0.9599 (11.6)	0.8680 (5.8)	0.7819 (7.1)	1.3130 (14.1)

Subjective values of travel and waiting time (in Ch$ per min) derived from these results are shown in Table 4. They were computed following Gaudry et al (1989) as the ratio of the parameters of the time and cost variables. The t-ratios in parenthesis were computed using equation (1) following Jara-Díaz et al (1988), under the assumption of no correlation between the time and cost variables given the orthogonal design of the SP experiments. Most values are significant and all appear reasonable: they increase with income, waiting time values are in general bigger than those associated to travel time, and all are notably lower than prior values estimated using RP data in Chile.

$$t_{*}=[\frac{1}{t_c}+\frac{1}{t_t}]^{-1/2} \qquad (1)$$

Table 4: Subjective values of time for public transport users

Subjective Value of	Peak Period Low I.	Peak Period Middle I.	Peak Period High I.	Peak Period Student	Off-Peak Middle I.
Travel Time	1.48 (3.49)	4.37 (5.05)	7.78 (1.75)	2.74 (4.05)	6.39 (5.20)
Waiting Time	1.11 (3.08)	5.70 (4.01)	30.04 (0.98)	5.69 (3.27)	10.43 (3.91)

Finally, and to put these values into perspective, it might be worth noting that the Chilean minimum wage rate was Ch$ 3.2 per minute in 1991, but actual salaries start at twice that figure (1 US$ = 340 Ch$).

2.2 Evaluation of SP data collection methods in Santiago

The second project (Ortúzar and Garrido, 1991) started by building a data bank with SP data about people with at least two mode choice options who could benefit from the introduction of a new alternative. The data was obtained in the form of rankings, ratings and choices, in order to estimate discrete choice models with the three types of data and compare them, taking into account the relative cost of obtaining each type of data and model. We used a sample of individuals coming to work or study at the San Joaquín Campus of the Catholic University of Chile (the sample size was 20% of the total Campus population). Table 5 shows the general distribution of the sample.

All SP experiments had two options: that normally used by the individual and a new, hypothetical, semimetro option on elevated track similar to one of the alternatives under consideration for the future Line 5 of the Santiago underground. The alternatives were presented in relation to a fictitious trip with congestion conditions, cost, walking and waiting times, as defined in the experimental design. The sample was divided into three groups; the first was submitted to a rank exercise, the second completed a rating questionnaire and the third participated in a computerised choice game. Although most academics and students were of middle to high income, the rest of the staff presented strong variations in this sense. In all cases information was also gathered about sex, age, income level, driving licence and number of cars in the household.

Table 5: Distribution of the sample by person type and transport mode

	Usual Transport Mode		
Person Type	Car	Bus	Total
Member of staff	142	243	385
Male	69	106	175
Female	73	137	210
Student	187	179	366
Male	121	106	227
Female	66	73	139
Total	329	422	751

Only four reasonably objective attributes were considered: travel cost (varying at three levels), travel time (varying at two levels), walking distance (varying at three levels) and service headway (varying at two levels). Thus we had a $3^2 2^2$ factorial design and since we were looking for main effects only, we just required nine options. These were based on the differences between the bus (or car) attributes and those of the semimetro. The levels of these attribute differences, for the bus and car cases, are shown in Table 6 (however, the value for the headway in the car case is obviously that of the semimetro). Another peculiarity of the car option is that its cost of travelling is not a fare as in the other two options, but the sum of petrol cost (Ch$) and parking charge (in Ch$/hr times eight - the assumed number of hours parked).

Table 6: Attributes and levels for the experimental design

	Bus Form			Car Form		
Attributes\Levels	0	1	2	0	1	2
Travel cost (Ch$)	-10	60	80	20	80	560
Travel time (min)	15	25	na	5	15	na
Walking distance (sq)	-7	-3	0	0.5	3.5	7.5
Headway (min)	-3	2	na	3	8	na

Different methods were used to analyze the data after it was thoroughly checked for consistency errors. In the ranking case we first 'exploded' the rank orders (Chapman and Staelin, 1982) and then estimated logit models with as many options as valid pseudo choices were generated from the rank explosion; thus, options and actual modes were not the same in this case. In the rating case we applied the Berkson-Theil transform to the choice probabilities associated to the semantic scale (i.e. 0.1, 0.3, 0.5, 0.7 and 0.9) and then estimated linear regression models. Finally, in the choice case we estimated binary logit models. In the last two cases options and actual modes are indeed the same.

Table 7 presents the best models estimated for the complete subsample of the ranking case. All the level-of-service parameters have a correct sign and are significantly different from zero at the 95% level.

Table 7: Best models obtained for the SP data on rankings

	Car User		Bus User	
Attribute	Student	Staff	Student	Staff
Travel cost	-0.0073	-0.0066	-0.0241	-0.0157
Travel time	-0.1544	-0.1437	-0.1127	-0.0852
Headway	-0.1812	-0.1642	-0.2184	0.1771
Walking distance	-0.4812	-0.4170	-0.4215	-0.3563
Sex	-	0.6370	0.3961	0.8565
Age	0.0618	0.0325	-0.0178(2)	-0.0386
No. of cars	0.2667	-	-	-
Semimetro(1)	-	-0.8175(2)	1.0150	1.5120
Sample size(3)	550	425	670	787

Notes: (1) Specific constant of Semimetro options; (2) Not significant at the 95% level; (3) Not actual but pseudo individuals (i.e. depends on rank size).

Table 8 presents SVOT (in Ch$/min) derived from these models. The values are again significantly smaller than values obtained previously in the country with RP data (see Gaudry at al, 1989), and internally consistent: car user values are higher than bus user values and waiting time is valued higher than the rest. Table 9 presents the best models estimated for the rating case and Table 10 the equivalent results to Table 8. As can be seen most parameters have a correct sign and are significantly different from zero at the 95% level. The SVOT are again reasonable and internally consistent; also, they are very similar to those shown in Table 8. Table 11 presents the best models estimated for choice case, and Table 12 the equivalent information to Tables 6 and 8.

As above, all models and results appear reasonable and internally consistent.

Table 8: Subjective values of time for ranking data

	Car User		Bus User	
Value of Time	Student	Staff	Student	Staff
In-vehicle	21.15	21.77	4.68	5.43
Waiting(1)	49.64	49.76	18.12	22.56
Walking(2)	35.16	33.70	9.33	12.10

Notes: (1) Assuming an average waiting time of half the headway; (2) Assuming an average walking speed of 4 km/hr.

Table 9: Best models obtained for the SP data on ratings

	Car User		Bus User	
Attribute	Student	Staff	Student	Staff
Travel cost	-0.0029	-0.0019	-0.0085	-0.0087
Travel time	-0.0463	-0.0641	-0.0341	-0.0211
Headway	-0.0759	-0.0608	-0.0878	-0.0148(2)
Walking distance	-0.2010	-0.2770	-0.3770	-0.2557
Sex	-	-	0.2250	-0.3452
Age	0.0427	0.0109	-	-
No. of cars	0.0866(2)	0.0866	-	-
Semimetro(1)	-0.7550	-0.8010	1.0418	1.5120
Sample size(3)	675	432	423	675

Notes: (1) Specific constant of Semimetro; (2) No significant at the 95% level; (3) Not actual but pseudo individuals (depends on valid responses).

2.3 Discussion

To end this section it is interesting to note first that the subjective values of time reported above, although obtained with different methods from different individuals, are very similar in magnitude for each strata. Furthermore, the values for public transport users (across studies) are also very similar indeed and much lower than those obtained for car users. This is interesting because the individuals interviewed in both cases were very different indeed. Finally, it is important to consider that the SVOT values of in-vehicle time reported vary between roughly 33 and 120% of the wage rate of the individuals interviewed, while those found in previous RP studies using linear specifications in the country had varied between 150 and 350% of the wage rate (see Gaudry et al, 1989). This means that the SP methodology does not only offer a good value-for-money approach to travel demand modelling, but an approach which is competitive in terms of credibility and coherence with current practice.

Table 10: Subjective values of time for rating data

	Car User		**Bus User**	
Value of Time	Student	Staff	Student	Staff
In-vehicle	15.97	33.39	4.01	2.43
Waiting(1)	52.34	63.33	20.68	3.42(2)
Walking(3)	36.97	76.94	23.68	31.88

Notes: (1) Assuming an average waiting time of half the headway; (2) Not significant at the 95% level; (3) Assuming an average walking speed of 4 km/hr.

Table 11: Best models obtained for the SP data on choices

	Car User		**Bus User**	
Attribute	Student	Staff	Student	Staff
Travel cost	-0.0029	-0.0033	-0.0169	-0.0082
Travel time	-0.0922	-0.1142	-0.0684	-0.0633
Headway	-0.0895	-0.1141	-0.1761	0.0228(2)
Walking distance	-0.2982	-0.3312	-0.7160	-0.5918
Sex	-	0.9776	-	-0.6369
Age	0.0263	0.0182	-0.0570(2)	-
No. of cars	-	0.1250	-	-
Semimetro(1)	-	-0.8175	4.0740	1.5550(2)
Sample size(3)	447	455	455	763

Notes: (1) Specific constant of Semimetro; (2) Not significant at the 95% level; (3) Not actual but pseudo individuals (i.e. depends on valid responses).

Table 12: Subjective values of time for choice data

	Car User		Bus User	
Value of Time	Student	Staff	Student	Staff
In-vehicle	31.79	34.61	4.04	7.71
Waiting(1)	61.72	69.15	20.83	5.55(2)
Walking(3)	54.84	53.53	22.58	38.44

Notes: (1) Assuming an average waiting time of half the headway; (2) Not significant at the 95% level; (3) Assuming an average walking speed of 4 km/hr.

3. CONCLUSIONS

This paper has briefly reviewed two, fairly different, studies conducted in Santiago which serve to illustrate the role that SP methods can play in the modelling of travel demand and in the derivation of subjective values of time. In the first one the ordering and relative importance of a set of level-of-service variables for public transport users was determined. These variables included most of the typical attributes used in mode choice models, such as travel cost, and travel and waiting time, with the exception of walking time which was not judged sufficiently important probably because the current system allows the great majority of prospective users to access it with a minimal walking effort. Other variables considered were of a more subjective nature, but in one form or another had been mentioned and examined in the specialised literature (i.e safety, comfort and reliability).

In the second one the three more important SP data collection methods were compared in terms of model quality and cost of acquiring and processing the data. All models estimated appeared reasonable in the sense of being endowed with respectable goodness-of-fit indices, and parameters which were generally significant and had a correct sign.

The paper reported on the computation of subjective values of time with all the above models. One important conclusion is that all values appear sensible, in the sense of increasing with income and conforming to the usual finding of waiting time being valued more highly than travel and walking time. Also, values for car users were consistently higher than values for public transport users, and values obtained using different approaches and in different contexts showed remarkable similarities. Notwithstanding, perhaps the more interesting finding in this case is that all the values are significantly lower and thus much more credible, in terms of international practice, than similar values estimated using RP data in the country.

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