THE VALUE OF ROAD FATALITIES AND ROAD SEVERE INJURIES

Pablo Hojman, Juan de Dios Ortúzar[*] and Luis Ignacio Rizzi
Department of Transport Engineering, Pontificia Universidad Católica de Chile
Casilla 306, Cod. 105, Santiago 22, Chile
Tel: 686 4822; Fax: 553 0281: E-mail: jos@ing.puc.cl

Abstract

To evaluate the benefits of transport safety projects we must have values associated to road accident reductions. A correct microeconomic approach to obtain such values entails the use of individual preferences. The usual way to obtain these values is through contingent valuation. On the other hand, the values due to risk reductions in the case of fatal and non fatal accidents are usually obtained separately, producing an aggregation problem. To improve on both these weaknesses in the state of practice, we set up a novel stated preference survey in which individuals had to choose between two routes for a hypothetical trip between two large cities. The routes differed in travel time, toll charge, number of fatalities and of severely injured victims per year. Respondents had to state their preferences for safety in an implicit way, both in terms of the reduction in fatal and severely injured victims. Using discrete choice models, we obtained values of approximately US$500,000 and US$70,000 for one reduction in the number of fatalities and severely injured victims respectively. We also derived subjective values of time consistent with values obtained in previous studies; this confirmed our belief that respondents both understood the exercise and answered it seriously.

Keywords: Valuation of Road safety; Stated preference surveys; Discrete choice modelling
Topic Area: E3 Valuation of Internal and External Benefits / Costs

1. Introduction

As in most developing countries, road fatalities are not valued systematically in project evaluation in Chile. There are only some indicatives values (CITRA 1996) calculated on the basis of the Human Capital approach. This considers the present value of lost income for an average road victim (be it a fatal victim or a severely injured victim). However, this is not correct from a microeconomic viewpoint as it does not consider the individual's preferences for risk reductions.

The objective of this research is to improve on the state-of-practice for valuing risk level reductions in road accidents worldwide. Usually, this involves using the heavily criticised contingent valuation method (Hausman, 1993) and the required appraisal by individuals of changes in very low levels of risk, which is an unusually difficult task (see the discussion in Rizzi and Ortúzar (2003b). Instead, we propose to estimate individual preferences using conjoint analysis methods and to avoid the use of low level risk comparisons. Our approach requires respondents to choose between alternative routes on the basis of pre-defined attributes, in an experimental design that provides several responses per individual.

The rest of the paper is organized as follows. Section 2 describes the design of the stated preference experiment. Section 3 briefly explains how the survey was conducted.

[*] Corresponding author

Section 4 discusses our main modelling results and the values derived from them. Finally, section 5 presents our main conclusions.

2. Experimental design

A first important issue is to characterize the risk concept for fatal victims and for severely injured people. In the latter case the problem is even more complex as the concept includes a wide variety of traumas. A second relevant point is how to design a familiar situation for each person considering the presentation, quantity and complexity of the choice situations.

There is a well-established literature about risk perceptions. Bronfman and Cifuentes (2002) analyse some ten attributes associated to risk and their influence in risk perception. Two attributes stand out here: controllability and knowledge. When someone considers she does not have control over a certain activity (i.e. a subway trip), the risk perception increases. In the same way, a better known activity will be probably evaluated as less risky. For these reasons we decided to conduct a route choice stated preference (SP) survey for car trips between the cities of Santiago and Valparaíso (i.e. the capital city and the main port of Chile respectively). The distance between both cities is 120 km via a Class A road called Route 68, which is fairly safe for Chilean standards.

The survey development proceeded in the following way. First, a self-completion pre-test survey was carried out. Thirty people answered the pre-test including a short questionnaire asking their opinions and suggestions. Then an in-depth analysis of the survey form was done through focus groups searching for clearer and simpler definitions. With this experience, a four part survey instrument was designed. The first part asked about the frequency with which the respondent had driven on interurban roads in general, and on Route 68 in particular, during the previous year. The second part included the choice experiment itself and the third part different types of questions, some related to the choices themselves and others to road accidents experience and attitudes. Finally, the fourth part of the survey enquired about socio-economic data.

2.1. Statistical design of the choice experiment

We decided to consider four variables for the choice experiment: *travel time, toll charge, fatal victims per year* and *severely injured victims per year.* The way to present the two risk variables came up from the pre-test survey and from the focus group work. Although Rizzi and Ortúzar (2003a) referred to fatal accidents, as we were adding severely injured victims, we found that respondents felt more comfortable with *victims* than with *accidents*.

With these four attributes a six-variable factorial design was considered. One variable was associated to *time* and another to *toll,* working as differences between both routes; each of these had three variation levels. The attributes *Fatalities per year* and *Severely injured victims per year* were associated with two variables, one corresponding to a *low* number and another to a *high* number of victims; three levels were also used for these variables (i.e. nine differences can be built combining all the *high* and *low* values). The reason to include these "split" variables was to analyse the existence of different risk parameters according to the risk level (i.e. a larger risk level implies a greater parameter absolute value). This result can be interpreted as a Prospect Theory variation. This theory (Kahneman and Tversky, 1992) poses that individual tend to evaluate the increase and reduction in risk levels in a different manner. The compensation required for a risk level increase is bigger than the willingness to pay for a risk level reduction of the same size.

As emphasis should be given to the realism of the choice situations, for the travel time and toll variables we used observed average values and for the risk level attributes we used historical data provided by the Chilean government. Table 1 shows the variable differences and the reference values to which these differences apply. Table 2 presents the absolute values used for the risk variables.

Table 1: Differences levels and reference levels associated to the *time* and *toll* variables

Differences levels		Reference levels	
Toll (US$)	Time (minutes)	Toll (US$)	Time (minutes)
2.1	-20	3.6	80
-1.4	-10	5.7	90
0.7	-30	4.7	85

*1 US$ =700 Ch$

Table 2: Absolute level values associated to *fatalities* and *severely injured victims*

Absolute Levels			
Severely injured		Fatalities	
High	*Low*	*High*	*Low*
52	35	16	11
56	40	17	12
65	46	20	14

A full factorial design would entail 729 combinations[1] so we set to reduce it to a reasonable[2] number of choices. We finally obtained three orthogonal blocks which allow us to estimate the main effects and some two way interactions, to obtain a full replication we obviously need three respondents. In Table 3 the three blocks are presented showing the attribute levels and the corresponding differences or absolutes values, depending on the attribute as explained before. In Table 4 the resulting orthogonal choice situations are presented. Regrettably these blocks have some undesirable characteristics. In some choice situations (three by block) one of the routes dominates the other. On the other hand, one would hope that the more expensive route should be superior in the other attributes; nonetheless, some situations did not accomplish that. Also we would like that the probability of choosing one alternative was not too different from that of choosing the other or the choice situation would not contribute useful information (Huber and Zwerina, 1996). Nonetheless, if both probabilities are too similar the increase of cognitive burden may induce respondents to err too frequently[3]. Thus, there are various delicate issues which need to be considered and several methods that help improving the choice situations in Table 4. For example, some attributes values can be traded between routes or some attributes can be re-labelled, keeping the difference level but changing the reference values. Although these methods may break the original orthogonality in the design, they should allow us to obtain better estimates; the final blocks used in the survey are shown in Table 5.

2.2. The choice context

When respondents are confronted with the choice situations it is important to set this up in a realistic context. In our case we proposed them a trip from Santiago to Valparaíso with a social purpose and the following characteristics:

> "…you drive your car;
> you travel during a regular weekend (without extra holiday days);
> you pay for the total cost of the trip, including the toll;

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[1] We obtained this number by combining all the attributes in all their levels i.e. 3^6 combinations.
[2] Although this is a controversial issue, it is usually accepted that nine choices can definitively be answered without problems by respondents.
[3] To estimate these probabilities we applied a Logit model and route choice parameters from other studies.

you have to choose between two routes (both are similar to Route 68), taking into account the following four elements: 1) *toll charge,* 2) *travel time*, 3) *number of fatal victims per year* and 4) *number of severely injured victims per year..".*

A little explanation was also given about what *are* a fatal victim and a severely injured victim. This definitions where analysed in the focus group and in the pre-pilot survey. Finally, statistical data was also given about the number of fatalities and severely injured victims during 2002 and the total annual flow in Route 68. The real risk numbers are not handled in a good way by individual, in despite of that, they have a good notion of the different risk levels between different routes.

Table 3: Orthogonal design tables and application of the corresponding values

	Variable*						Variable**					
	A	B	C	D	E	F	$	Time	accnf-a	accnf-b	accf-a	accf-b
Block 1	0	0	0	0	0	0	2.1	-20	52	35	16	11
	0	1	1	2	0	1	2.1	-10	56	46	16	12
	0	2	2	1	0	2	2.1	-30	65	40	16	14
	1	0	2	0	2	2	-1.4	-20	65	35	20	14
	1	1	0	2	2	0	-1.4	-10	52	46	20	11
	1	2	1	1	2	1	-1.4	-30	56	40	20	12
	2	0	1	0	1	1	0.7	-20	56	35	17	12
	2	1	2	2	1	2	0.7	-10	65	46	17	14
	2	2	0	1	1	0	0.7	-30	52	40	17	11
Block 2	0	0	2	2	1	1	2.1	-20	65	46	17	12
	0	1	0	1	1	2	2.1	-10	52	40	17	14
	0	2	1	0	1	0	2.1	-30	56	35	17	11
	1	0	1	2	0	0	-1.4	-20	56	46	16	11
	1	1	2	1	0	1	-1.4	-10	65	40	16	12
	1	2	0	0	0	2	-1.4	-30	52	35	16	14
	2	0	0	2	2	2	0.7	-20	52	46	20	14
	2	1	1	1	2	0	0.7	-10	56	40	20	11
	2	2	2	0	2	1	0.7	-30	65	35	20	12
Block 3	0	0	1	1	2	2	2.1	-20	56	40	20	14
	0	1	2	0	2	0	2.1	-10	65	35	20	11
	0	2	0	2	2	1	2.1	-30	52	46	20	12
	1	0	0	1	1	1	-1.4	-20	52	40	17	12
	1	1	1	0	1	2	-1.4	-10	56	35	17	14
	1	2	2	2	1	0	-1.4	-30	65	46	17	11
	2	0	2	1	0	0	0.7	-20	65	40	16	11
	2	1	0	0	0	1	0.7	-10	52	35	16	12
	2	2	1	2	0	2	0.7	-30	56	46	16	14

* In this design only some of the two way interactions can be estimated
** The variable definitions are: $ = toll (in US$); Time = travel time; accnf-a = severely injured victims per year at the high level; accnf-b = ditto for the low level; accf-a = fatalities per year at the high level; accf-b = ditto for the low level

Table 4: Orthogonal choice situations

	Route 1				Route 2			
	US$	Time	acc-nf*	acc-f**	US$	Time	acc-nf*	acc-f**
Block 1	3.6	80	52	16	5.7	60	35	11
	3.6	90	56	16	5.7	80	46	12
	3.6	85	65	16	5.7	55	40	14
	5.7	**80**	**65**	**20**	**4.3**	**60**	**35**	**14**
	5.7	**90**	**52**	**20**	**4.3**	**80**	**46**	**11**
	5.7	**85**	**56**	**20**	**4.3**	**55**	**40**	**12**
	4.7	80	56	17	5.4	60	35	12
	4.7	90	65	17	5.4	80	46	14
	4.7	85	52	17	5.4	55	40	11
Block 2	3.6	80	65	17	5.7	60	46	12
	3.6	90	52	17	5.7	80	40	14
	3.6	85	56	17	5.7	55	35	11
	5.7	**80**	**56**	**16**	**4.3**	**60**	**46**	**11**
	5.7	**90**	**65**	**16**	**4.3**	**80**	**40**	**12**
	5.7	**85**	**52**	**16**	**4.3**	**55**	**35**	**14**
	4.7	80	52	20	5.4	60	46	14
	4.7	90	56	20	5.4	80	40	11
	4.7	85	65	20	5.4	55	35	12
Block 3	3.6	80	56	20	5.7	60	40	14
	3.6	90	65	20	5.7	80	35	11
	3.6	85	52	20	5.7	55	46	12
	5.7	**80**	**52**	**17**	**4.3**	**60**	**40**	**12**
	5.7	**90**	**56**	**17**	**4.3**	**80**	**35**	**14**
	5.7	**85**	**65**	**17**	**4.3**	**55**	**46**	**11**
	4.7	80	65	16	5.4	60	40	11
	4.7	90	52	16	5.4	80	35	12
	4.7	85	56	16	5.4	55	46	14

* acc-nf corresponds to the *severely injured victims per year* variable
** acc-f, corresponds to the *fatalities per year* variable

3. Data collection and sample characteristics

The entire survey was programmed in a web page (http://www2.ing.puc.cl/~phojman/) following the excellent results obtained in a previous experience (Iragüen and Ortúzar, 2003). It was sent by e-mail to a universe of three hundred and fifty academic and administrative staff at our university (i.e. clearly not a random sample); we obtained 113 responses (32% response rate). The survey period was 16 days and one reminder to visit the web page was sent after the first week. Table 6 shows the number of interviews received per day (the first request was sent on day 10 and the reminder was sent on day 22)

Table 7 summarises the age and gender distribution of the sample. Most people had a college education and 69 individuals did not have children less than 18 years. Finally, 28 respondents indicated that they, or some relative, had been involved in a severe or fatal accident. Table 8 presents their stated income distribution; examining this data confirms that our sample is not representative of the Chilean population as a whole, but private car interurban drivers are not truly representative of the Chilean population either.

Examining the data we found that 27 respondents answered lexicographically (i.e. they always picked up that alternative which was better in just one of the four attributes); this is a fairly standard result (Saelensminde, 2001). Of these, five were lexicographic in the toll variable, three in the time variable, 17 in the fatal accidents variable and only two in the severe accidents variable. The main problem associated to these respondents is that they do not exhibit the required compensatory behaviour (Rizzi and Ortúzar, 2003a).

Table 5: Final choice situations

	Route 1				Route 2			
	US$	Time	acc-nf*	acc-f**	US$	Time	acc-nf*	acc-f**
Block 1	3.6	80	52	16	5.7	60	35	11
	3.6	90	56	16	5.7	80	46	12
	3.6	85	65	16	5.7	55	40	14
	4.3	80	65	14	5.7	60	35	20
	4.3	90	52	20	5.7	80	46	11
	4.3	85	40	20	5.7	55	56	12
	4.7	80	56	17	5.4	60	35	12
	4.7	80	65	17	5.4	90	46	14
	4.7	85	52	17	5.4	55	40	11
Block 2	3.6	80	65	17	5.7	60	46	12
	3.6	90	52	17	5.7	80	40	14
	3.6	85	56	17	5.7	55	35	11
	4.3	80	56	11	5.7	60	46	16
	4.3	90	65	16	5.7	80	40	12
	4.3	85	35	16	5.7	55	52	14
	4.7	80	52	20	5.4	60	46	14
	4.7	80	56	20	5.4	90	40	11
	4.7	85	65	20	5.4	55	35	12
Block 3	3.6	80	56	20	5.7	60	40	14
	3.6	90	65	20	5.7	80	35	11
	3.6	85	52	20	5.7	55	46	12
	4.3	80	52	12	5.7	60	40	17
	4.3	90	56	17	5.7	80	35	14
	4.3	85	46	17	5.7	55	65	11
	4.7	80	65	16	5.4	60	40	11
	4.7	80	52	16	5.4	90	35	12
	4.7	85	56	16	5.4	55	46	14

* acc-nf, corresponds to the *severely injured victims per year* variable
** acc-f, corresponds to the *fatalities per year* variable

Table 6: Number of interviews received per day

Interviews received per day																
Day	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Interviews	7	14	0	1	8	3	1	1	0	0	0	0	14	56	6	2

Table 7: Age and gender distribution

Age	Male	Female
Less than 30	20	8
Between 30 and 49	26	7
Between 50 and 64	29	18
Over 65	1	1
No response	4	

Table 8: Stated income distribution

Income (Chilean $)	
Less than 1 MM	31
Between 1 and 2 MM	41
Between 2 and 3 MM	24
Between 3 and 4 MM	7
Over 4 MM	2
Do not answer	7

4. Discrete choice modelling

Binary Logit models where estimated using ALOGIT (Daly, 1998). We used linear models in which the deterministic part of the indirect utility was given by functions such as:

$$V_{iq} = \sum_{k=1}^{K} \beta_{ki} x_{kiq} \ , \qquad (1)$$

where V_{iq} is the utility of alternative i for individual q, x_{kiq} are attributes and β_{ki} parameters to be estimated. The statistical tests required for the specification searches reported below are conveniently summarised in Ortúzar and Willumsen (2001).

Table 9 presents three models. The first (A1) has a time and a toll parameters, and two fatal victims and severe victim parameters, as explained in the design section. However, a test of parameter equality shows that the latter sets of parameters are not significantly different. Model A2 used one parameter for the severe victims variable and kept two for fatal victims, but again the parameter equality test rejected the null hypothesis that these were different. Finally, model A3 model specifies just one parameter per attribute. Although a likelihood ratio test allows us to reject the null hypothesis that this model is equivalent to A2, results from the latter tend to be suspicious so we decided to choose model A3. We reached the same conclusion (model B3) when lexicographic individuals were excluded. As can be seen in Table 10, all the parameters in these models are significant and with a correct sign.

Table 9: Binary choice models for the complete sample

Coefficients (t-ratios)	A1	A2	A3
Time	-0.0749 (-10.6)	-0.07522 (-10.8)	-0.07474 (-10.9)
Toll	-0.00149 (-7.9)	-0.001505 (-8.4)	-0.00141 (-8.1)
Fatal accidents (high / low)	-0.0606 (-2.1) / -0.02285 (-0.5)	-0.06036 (-2.1) / -0.02254 (-0.5)	-0.1237 (-7.3)
Severe accidents (high / low)	-0.02022 (-2.2) / -0.0213 (-1.7)	-0.01861 (-3.1)	-0.01812 (-3.1)
Log-likelihood	-564.16	-564.19	-567.74
Sample size	1017	1017	1017

Table 10: Binary Logit models for the complete sample and excluding lexicographic individuals.

Coefficients (t-ratios)	A3	B3
Time (α)	-0.07474 (-10.9)	-0.1042 (-11.3)
Toll (β)	-0.00141 (-8.1)	-0.002096 (-8.9)
Fatal accients (χ)	-0.1237 (-7.3)	-0.1131 (-5.5)
Severe accidents (δ)	-0.01812 (-3.1)	-0.02852 (-3.8)
α/β	53.01	49.71
χ/β	87.73	53.96
δ/β	12.85	13.61
RRV (US$)	463,716	285,217
SAV(US$)	67,921	71,939
Likelihood	-567.74	-405.75
Sample size	1017	774

Table 10 also presents more detailed results for these models. Firstly the ratios of the time and accident parameters with respect to the toll charge parameter, which can be interpreted as willingness-to-pay (WTP) or subjective values (Gaudry *et al*, 1989). In particular, the subjective value of time is consistent with values found in previous studies in Chile (see Ortúzar, 2000). This means that the survey was answered seriously by the respondents. The table also presents the R*isk Reduction Value* (RRV) and the *Severe Accidents Value* (SAV). The former is equal to the product of the individual WTP for avoiding a fatality and the total number of route users (approximately 3.7 million) and the latter is calculated in the same way but using the individual WTP for a severe accident reduction; in the table both values are further divided by the US$ rate at the time of the study (1US$ = 700 Ch$).

Table 11 summarises the above subjective values and their respective confidence intervals (Armstrong *et al*, 2001). It is interesting to compare these results with those obtained by Rizzi and Ortúzar (2003a). In that study, a similar experience was conducted but considering only the fatal accidents, time and toll variables. The subjective value associated to the fatal accidents variable was $US 771,226 for the entire sample and $US 392,817 if the lexicographic individuals were excluded.

Table 11: Subjective values for fatal accidents (χ / β), severe accidents (δ / β) and time (α / β) and their confidence interval

Model	χ/β (Chilean $)	δ/β (Chilean $)	α/β (Chilean $)
A3	87.73 (66.43-114.19)	12.85 (5.78-18.22)	53.00 (44.42-65.02)
B3	53.96 (37.52-71.20)	13.61 (8.00-17.86)	49.71 (42.74 - 58.95)

Table 12: Mixed Logit models

Coefficients (t-ratios)	**MA3**		**MB3**	
	Parameter	Standard dev.	Parameter	Standard dev.
Time (α)	-0.201 (-6.6)	0.0771 (6)	-0.2025 (-7.5)	0.0816 (3.8)
Toll (β)	-0.0036 (-6.2)	0.0029 (4.3)	-0.0039 (-6.5)	0.0022 (3.3)
Fatal accidents (χ)	-0.3765 (-4.6)	0.3981 (3.5)	-0.2255 (-5.6)	0.0873 (1.4)
Severe accidents (δ)	-0.046 (-2.5)	0.1011 (4.9)	-0.0485 (-3.4)	0.087 (4.1)
α/β	55.82		51.3	
χ/β	104.57		57.14	
δ/β	12.77		12.29	
RRV (US$)	552,727		302,026	
SAV (US$)	67,499		64,961	
Likelihood	-420.31		-322.70	
Sample size	1017		774	

If we wanted to directly compare our values with theirs we would need to modify our dollar by the Chilean inflation rate[4]. Doing that we obtain a value of $US 574,518 for the fatal accidents variable and a value of $US 84,157 for the severe accidents variable, for the whole sample. Excluding the lexicographic individuals we obtain the values $US 353,366 and $US 89,107 respectively.

Clearly we can observe a decrease in the RRV in contrast to the Rizzi and Ortúzar (2003a) results. This situation may be explained by the fact that the previous study did not consider the severe accidents. So, when individuals stated their choices they may have assigned a larger weight to the fatal accidents variable to compensate for non-fatal victims.

The last modelling activity was to allow for individual taste variations by estimating a Mixed Logit model (Train, 2003) assuming a normal distribution for all the parameters (Table 12). The MA3 model is similar to the A3 model but allowing for taste variation and the same occurs with models MB3 and B3. As can be seen, the Mixed Logit models present a better fit to the data than the standard models but the subjective values are similar except for RRV which shows an increase. On the other hand the standard

[4] When we do that we obtain an increase of 13%, yielding a US$ value of 565 Ch$.

deviations of the parameters all are significantly different from zero at 95% level, except for that corresponding to the fatal accidents variable in model MB3.

5. Conclusions

We were able to develop a survey instrument where people had to make choices among alternative routes that differed in four attributes, implicitly stating their risk preferences. To our knowledge, this is a novel use of the stated preference technique due to the inclusion of a non fatal accidents variable. Despite the difficulties associated to this kind of experiment we believe that respondents were capable to answer the exercise in a serious and adequate way; this can be confirmed by comparing our subjective values of time value with values obtained in specific time value studies previously conducted in the country.

In terms of subjective values we were able to construct confidence intervals associated to the fatal and non fatal risk reductions. For the complete sample we obtained a rather large confidence interval for fatal risk ($US 351,151 - $US 603,564) using a binary Logit model. The interval became smaller ($US 198,322 - $US 376,344) if we removed lexicographic individuals. On the other hand, the intervals associated to the non fatal accidents variable were ($US 30,553 - $US 96,287) for the entire sample and ($US 42.270 - $US 94.394) when lexicographics were excluded. Point estimates obtained with the more flexible Mixed Logit model were in the same range. Finally, we can mention that the values currently used in Chile are only approximately US$ 33,000 for a fatal accident reduction and approximately US$ 5,000 for a severe accident reduction (CITRA, 1996)

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