Introduction

The value to society of improving safety is an important factor in the evaluation of all road safety projects, programmes and policies. An improvement of safety means a reduction in risks of crashes and/or injuries. Under the willingness to pay approach, the value of this risk reduction to society is determined by the amount of money society is willing to spend for it. We refer the value of preventing a statistical fatality as the Value of Statistical Life (VOSL).

Economic theory suggests that the VOSL should be determined by the mean of all individual values of marginal rate of substitution of wealth for reduction in risk of death. Similar values should also be determined for the prevention of non-fatal injuries. These monetary expressions of values of reductions in the risks of death and injury are essential in economic evaluations of safety programmes (including roading projects) and policies as they enable us to compare the safety benefits against the costs of providing them in monetary terms.

When safety projects, programmes and policies are selected on the basis of an economic evaluation using the WTP-based VOSL, it suggests that people are willing to pay for these programmes. However, questions on equity arise regarding the price (or tax) incidence, that is, whether the net benefit is distributed inequitably for different socio-economic groups. These issues are analysed in this paper using the results of a Willingness to Pay (WTP) survey carried out in New Zealand in 1997-98 (Guria et al 1999).

The Value of Safety survey and the relevant data for this analysis are discussed in the next section. The third section discusses the relationship between level of travel and level of income on WTP-based VOSL. In the fourth section, we discuss the effect, if any, of ethnicity and income on the determination of WTP-based VOSL, including formal statistical tests carried out to compare the WTP-based VOSL for Maori and Pacific Islanders as a group with that for other New Zealanders as a group, by household income per person[1]. The last section discusses the conclusions drawn from the analysis.

The Value of Safety and Travel surveys

During 1997-98, two major household surveys were carried out in New Zealand, a Travel Survey and a Value of Safety (VOS) Survey.

With the participation of about 14,000 respondents, we have obtained valuable information on people’s travel behaviour from the Travel Survey. Some of the useful information includes risk-related measures such as mode of transport, age, gender, ethnicity and kilometre travelled.

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[1] Hereinafter we shall use income groups to refer a collection of respondents with different level of household income per person.

One of the major findings of the Travel Survey is that high-income people tend to spend more time travelling and travel further than low-income people. Moreover, high-income people spend more time driving than low-income people who drive less and do more travel as passengers.

The Travel Survey also shows that New Zealand European travel further and drive more than New Zealand Maori and Pacific people. These travel patterns reflect some cultural and socio-economic differences between these ethnic groups, as discussed later in the paper.

Of those 14,000 respondents, 1,051 also participated in the VOS survey. The VOS survey aimed at estimating the amount of money people are willing to pay for a reduction in risk of injury and also the amount they are willing to accept (or save) as compensation for an increase in risk. As the VOS survey involved a subset of the Travel Survey participants, some of the data used in this paper were originally collected by the Travel Survey.

When designing the questionnaire for the VOS survey, two commonly used approaches were adopted to ensure robustness of the estimates: the '*Standard Gamble'* and '*Matching*' approaches[2]. Another novel feature of the survey was that it used two levels of risk reduction to check if people were considering the level of risk reduction appropriately in their responses. Also it used a lap top computer to facilitate interactive responses.

The sample was randomly divided into two sub-groups, each sub-group receiving only one version of the questionnaire: *Standard Gamble or Matching*. These two approaches estimated the relativity between different severities of injuries: fatal, serious with permanent impairment, serious with no permanent impairment and minor.

Each respondent then faced two WTP-based VOSL (household relocation and safety programme) questions for reduction in risk of injuries and one question (household relocation) for WTA based VOSL estimates. Therefore, we have four different measures of WTP-based VOSLs and two for WTA based VOSLs.

For the household relocation (WTP) question there were two versions selected randomly by the computer software. In one version the risk reduction was 20% and in the other it was 50%. There was no significant difference in estimates from these two versions. In this paper only the WTP estimates have been analysed.

Since the estimates from the two WTP-based VOSLs (from household relocation and safety programme) were not significantly different, we took a simple arithmetic mean for each of the two sub-groups (Standard Gamble and Matching) and joined them vertically, along with the two versions of risk changes, in order to obtain a reasonable size of data. In this case, the average value from the two questions was taken a

[2] 'Standard Gamble' type questions involved a choice between pairs of risky treatment and we can obtain the WTP estimates indirectly. 'Matching' type questions required the respondents to choose between projects preventing different severities of injury and we can therefore obtain the WTP estimates somewhat more directly.

response of an individual. So the number of observations to consider was twice the total number of respondents. An advantage of combining the data in this way is that when later on we sub-divided the VOSL by income groups, the combined sample gave us a reasonable number of households within each income group and thereby minimised the extreme value effects, if any, of a small sample.

As mentioned earlier, the number of responses for the VOS survey was 1,051. After removing some inconsistent responses and those without details on either ethnic, household income or kilometre travelled, the resulting number of observations for this analysis became considerably smaller. As has been commonly observed, the distributions of all VOSL estimates were skewed to the left with a long tail on high values. To minimise the likely extreme value effects, we trimmed the top 15% of the estimates and the following analysis is based on the remaining observations. The sample sizes used in the third and fourth sections were 708 and 586 respectively. The difference was due to missing information on ethnicity.

WTP and income

One of the major sources of funding for road transport (roading projects and safety programmes) in New Zealand is the Motor Spirit Duty (MSD) or generally referred to as petrol tax. As petrol tax is charged according to petrol usage, road users from different income groups pay the same rate per litre of petrol consumption. Some view this as a homogeneous price of safety, regardless of differences in income. In the evaluation of safety projects or programmes, the VOSL is the dominant benefit component, in terms of savings in social costs of traffic injuries. If WTP responses are positively related to the level of income and the average WTP is used in the valuation of a programme, the value used would be lower than the amount high-income people would be willing to pay and higher for low-income people.

Now consider the only price paid by each individual is the petrol tax. The price will then be relatively low for high-income people and high for low-income people. This is nothing special. In fact, this is likely to occur in almost every market condition. However, the question that we would like to discuss is the impact of this effect on cross subsidisation, if any, from low to high-income group.

Cross subsidisation

Cross subsidisation between two income groups occurs if one group pays higher than their fair share and the other group pays less. This happens when the total price paid by the subsidised group is less than the cost of the goods or services they enjoy and the difference is borne by the other group. In the case of roading, the benefit of a safety programme is enjoyed more by those who travel more and the total benefit of the programme depends on the level of total exposure. The cost does not vary in the same manner. A major part of the total cost is fixed. Once the programme is in place whether it is engineering or enforcement based, the cost is fixed and the variable part, which may increase with the level of exposure, is relatively small in most cases.

The cost to an individual depends on the price structure. That will have an impact on the individual benefit/cost ratios. In the road safety context and at a given unit price of travel (petrol tax is a proxy), the cost to an individual depends on the level of travel. This in turn determines the total contribution for safety by an individual. On the other hand, the benefit is also related to the level of exposure and hence the level of travel. In this paper we have first looked at the variation in VOSL and household car travel distance for several income groups, to see if a distance based price would vary in the same manner as with people's willingness to pay. If it does, then at a higher income level, people would be contributing more for the safety programme. Therefore, though the VOSL is based on the average amount people are willing to pay per unit of risk reduction (at least theoretically), the overall effect may not be inequitable.

Table 1: Distribution of household income/person

Household income/person ($)	Number of household
0-5000	109
5001-10000	89
10001-15000	170
15001-20000	99
20001-25000	75
25001-30000	51
30001-35000	44
35001-40000	21
40001-45000	19
45000+	31
missing household income	117
Total number of obs.	825
Number of obs. used	**708**

Using the data from the VOS and Travel surveys, we divided the sample into 10 groups by household income per person (Table 1) and obtained the mean values of WTP and VKT (table 2) for each income group. We then took the $20,001-$25,000 income group as the base and obtained the indexed mean values of WTP and VKT for each income group, with a value of 1 for income group $20,001-$25,000.

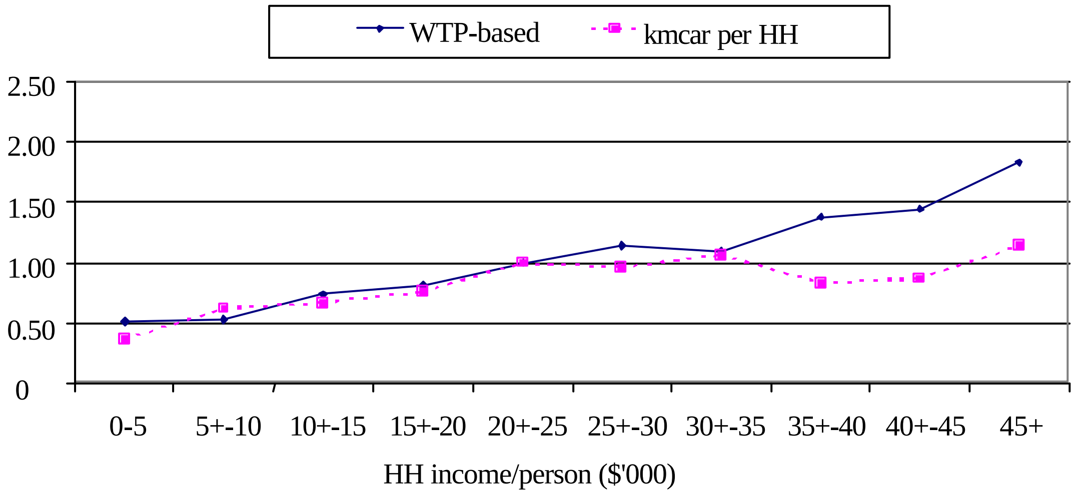
Table 2: Mean WTP index and mean average VKT index

Household income/person ($)	Mean WTP index	Mean average VKT index
0-5000	0.51	0.37
5001-10000	0.53	0.63
10001-15000	0.75	0.67
15001-20000	0.82	0.76
20001-25000	1.00	1.00
25001-30000	1.14	0.97
30001-35000	1.09	1.06
35001-40000	1.38	0.83
40001-45000	1.44	0.87
45000+	1.83	1.14

Figure 1 shows that the mean values of WTP increase with income. Apart from income group of $30,000-35,000 (small sample effect), as the household income per person increases from one group to the next, the corresponding mean WTP increases (solid line). This suggests that the willingness to pay values are positively correlated with per capita income in the household. On the other hand, average VKT driven per household also exhibits a positive correlation with household income per person. This suggests that high-income people tend to drive longer distances.

The difference in index values for VOSL estimate and total household VKT is small up to about $35,000 household income per person. Only for higher income households the relative value of WTP-based VOSL increases at a faster rate. This is not unexpected, as beyond a certain level of travel, the distance is unlikely to increase any further with income.

Figure 1: HH income/person versus Indexed WTP-based VOSL (trimmed top 15%) and Indexed average VKT driven per HH
(with VOSL=1 and average VKT=1 for $20,001-$25,000 income per person



Variation in B/C by income group

Suppose *R(I,O)* is the perceived household risk of road injuries per unit of travel (say, household-km) for a household of income per person (I) and other factors (O). Suppose α proportion of the risk can be reduced by spending certain extra amount of money on a safety programme. Then the safety benefit *(B)*, a household receives per annum is as follows:

$$B(I,O) = a * R(I,O) * V(I,O) * W(I,O) \quad (1)$$

where *V* is the total kilometre driven by car per annum by the household and W is the willingness to pay value per unit of risk reduction.

Suppose *P(I,O)* is the petrol consumption (litre) per kilometre of travel by car and *b* is the fuel tax per litre of petrol collected by the government to fund road safety programmes. For simplicity let us ignore the fixed cost part. Then the total cost (C) borne by a household to obtain the safety benefits during a year is:

$$C(I,O) = b * P(I,O) * V(I,O) \quad (2)$$

The benefit/cost (B/C) ratio for the household is

$$\frac{B}{C} = \frac{a * R(I,O) * V(I,O) * W(I,O)}{b * P(I,O) * V(I,O)} = \frac{a * R(I,O) * W(I,O)}{b * P(I,O)}. \quad (3)$$

Therefore,

$$\frac{\partial B/C}{\partial I} = \frac{aRWI}{bP}\left[\frac{\partial R}{\partial I} * \frac{I}{R} + \frac{\partial W}{\partial I} * \frac{I}{W} - \frac{\partial P}{\partial I} * \frac{I}{P}\right] = \frac{aRWI}{bP}\left[e_R + e_W - e_P\right]. \qquad (4)$$

where e_R, e_W and e_P are the income elasticity of R, W and P.

Equation (4) suggests that the B/C ratio increases with income if the sum of the income elasticities of risk per kilometre (e_R) and willingness to pay per unit of risk reduction (e_W) is greater than the income elasticity of petrol consumption per kilometre of travel (e_P).

As shown in figure 1, we expect $e_W \geq 0$, as high-income people can afford to pay more for safety than lower-income people do. However, e_R and e_P can be greater than or less than zero. Since high-income people tend to use newer vehicles, which would be more fuel-efficient than older vehicles, we would expect $e_P \leq 0$. On the other hand, as income rises, people would also tend to buy larger and/or vehicles with additional features, which would in turn consume more petrol. In that case, we would expect $e_P \geq 0$ at a point when people start acquiring such vehicles. In other words, if we plotted petrol consumption per kilometre travelled on the vertical axis against income on the horizontal axis, it would possibly be a U-shaped curve.

Based on the data we collected from the VOS and Travel surveys, a rough estimation through a relationship between income and perceived risk shows that e_R is estimated at –0.42, while e_W is estimated at 0.51. Both are significant at 1% level. The B/C ratio would increase with income if $e_p < 0.09$.

High-income people tend to use larger but newer vehicles. Besides, those more concerned about the environmental impact, may prefer to buy more expensive newer vehicles with relatively low fuel consumption. Thus, the overall value of e_p is unlikely to be substantially different from 0. Therefore, the B/C ratio is expected to increase with income.
There are certain other aspects worth mentioning here. First, the income elasticity of risk per kilometre is not expected to be constant. For example, with safer vehicles, we only expect to have the risk reduced up to a certain level. Also, most crashes were resulted from human errors. Since e_W is expected to be ≥ 0, at all levels of income, and both e_R and e_p are expected to become zero beyond a certain level, the B/C ratio is expected to increase continuously with income. It can be shown that the result would be similar if we included a fixed annual fee per car or household.

Since with higher level of income, people appear to put higher monetary value for safety, the B/C ratio is likely to increase with income, irrespective of the price structure.

This suggests that the system is more equitable if the total payment for safety programme increases with income.

WTP and ethnicity

Information on ethnicity used in this analysis is based on information provided in the Travel Survey by respondents who indicated that at least one of their household members was a Maori or Pacific Islander, regardless of birthplace or ancestry. Individuals who specified more than one ethnicity were allocated to single categories according to a prioritised order stated in Statistics New Zealand's The Interim Standard for Ethnicity 1996.

Demographically, Maori and Pacific people in New Zealand are younger than other ethnic groups. The median age for these groups is around 20 when compared to the median age of 33 for the total New Zealand population. Moreover, these ethnic groups also have a lower average income. According to New Zealand Income Survey for the June 1999 quarter, the average weekly income for Maori and Pacific Islanders is around $341. For all others it is $457 per week and for the total New Zealand population, it is $441.

With around 20% of the total New Zealand population being Maori and Pacific Islanders, these demographic and economic characteristics could have direct implications for road safety especially when young and low-income people tend to have higher risk of being involved in road crashes. As these ethnic groups are slightly over represented in hospitalisation statistics (around 23.5% in 1998) overall, the effect of a reduction in road risk will benefit them more than their share in the population. The next question one might ask is whether these ethnic groups have different WTP values. If so, how will they be affected if the projects are selected on the basis of WTP based evaluation.

WTP and income by ethnicity

To find the difference in WTP estimates by ethnicity difference, we determined the distribution of WTP values by each of the two ethnic groups (table 3). The difference between the two distributions is not statistically significant (χ^2=16.36, 11d.f.; $p>0.1$).

At the same time, Table 4 summarises the percentage distribution of household income per person by ethnicity. It shows that the distribution of household income per person for Maori and Pacific people is not significantly different from others (χ^2= 8.55, 6d.f.; $p>0.1$).

Table 3: Percentage distribution of WTP by ethnicity

WTP ($ m)	**Maori and Pacific people** Sample size: 49	**European and others** Sample size: 537
>0 and ≤ 1	28.6%	27.7%
>1 and ≤ 2	16.3%	11.9%
>2 and ≤ 3	10.2%	6.3%
>3 and ≤ 4	4.1%	7.6%
>4 and ≤ 5	10.2%	5.0%
>5 and ≤ 6	6.1%	6.0%
>6 and ≤ 7	4.1%	3.0%
>7 and ≤ 8	0.0%	5.0%
>8 and ≤ 9	8.2%	2.2%
>9 and ≤ 10	2.0%	2.6%
>10	10.2%	22.5%
Total	**100%**	**100%**

Table 4: Percentage distribution of household income per person by ethnicity

Household income per person ($)	**Maori and Pacific people** Sample size: 49	**European and others** Sample size: 537
0	2.0%	2.4%
1 – 5000	20.4%	14.2%
5001 – 10000	24.5%	12.7%
10001 – 15000	20.4%	25.9%
15001 – 20000	14.3%	14.5%
> 20000	18.4%	30.4%
Total	**100%**	**100%**

2-way Analysis of Variances (ANOVA)

Table 5 shows the average WTP for each of the household income group described in Table 4. It shows that Maori and Pacific people tend to have lower WTP values. However, difference in ethnicity does not generate different WTP distribution (see table 3). Hence, in this section, we will conduct a 2-way ANOVA analysis to check the interaction effects, between income group effects and between ethnic group effects.

As we have unequal numbers of observations for each income group and ethnic group, formulae for a standard 2-way ANOVA are not applicable. We have employed a 2-way ANOVA for unequal sample as described in Rao (1973).

Table 5: Average WTP by household income per person and by ethnicity

Household income per person ($)	**Maori and Pacific people**		**European and others**	
	Count	Average WTP	Count	Average WTP
0 – 5000	11	3.59	89	4.25
5001 – 10000	12	3.64	68	4.96
10001 – 15000	10	3.56	139	5.64
15001 – 20000	7	6.00	78	6.70
> 20000	9	5.11	163	8.06
Total	**49**	**4.22**	**537**	**6.21**

The top panel of Table 6 summarises the sum of squares between income groups, ethnic groups, within cells and between cells. The sum of squares due to income ignoring ethnicity is 1,150.5, whereas the sum of squares due to ethnicity ignoring income is 177.8. The bottom panel of Table 6 gives the mean sum of squares for each source of variances. As the within-cell mean square is greater than the interaction mean square, the former is used for testing differences between income and ethnicity.

Table 6: 2-way ANOVA for WTP estimates

Source	**df**	**Total sum of square**	**df**	**Total sum of square**	**Source**
Between income (ignoring ethnic)	4	1,150.5	1	177.8	Between ethnic (ignoring income)
Between ethnic	1	107.2	4	10,79.9	Between income
Interaction	4	32.3	4	32.3	Interaction
Between cells	9	1,289.9	9	1,289.9	Between cells
Within cells	576	26,861.1			
Total	585	28,151.0			
		Mean sum of square		**Mean sum of square**	
Between income		287.6		177.8	Between ethnic
Between ethnic		107.2		270.0	Between income
Interaction		8.1		8.1	Interaction
Between cells		143.3		143.3	Between cells
Within cells		46.6			
Total		48.1			

The test statistics for ethnic groups is F (1,576) = $\frac{107.2}{46.6} = 2.30$, which is not significant at 5% level. This means that we cannot reject the null hypothesis that there is no significant difference between WTP estimates for different ethnic groups.

The test statistics for income groups is F (4, 576) = $\frac{287.6}{46.6} = 5.79$, which is significant at 5% level. Hence, the WTP values for different income groups are different.

The test for interaction is F (4,576) = $\frac{8.1}{46.6} = 0.17$, which is not significant at 5% level. Thus, there is no significant interaction effect between ethnic and income groups.

Conclusion

The analysis based on kilometre travel per annum suggests that low-income people tend to have lower willingness to pay values but also tend to drive less. Both increase more or less at the same rate with income up to a certain level. Therefore, people at a higher level of income contribute more for safety programmes, if the price for road use is related to the level of travel.

The individual benefit/cost ratio increases with household income per person. This is primarily due to higher willingness to pay at a higher level of income.

The analysis on the variation in WTP values between ethnic groups clearly shows that at a given level of income, there is no significant difference in WTP values between Maori and Pacific Islanders as a group and other New Zealanders. Whatever, difference is observed, it appears, is mainly due to the difference in income levels.

Acknowledgement and Disclaimer

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