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Valuation of the Loss of Life Quality due to Non-Fatal Traffic Injuries

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Abstract:

The valuation of the loss of life quality resulting from non-fatal traffic injuries, although an important factor in the benefit cost analysis of transport safety projects, is a complex issue and research in this area has produced only limited results. The Association for the Advancement of Automotive Medicine has recently developed an Injury Impairment Scale (IIS) which indicates the most likely level of long term impairment resulting from an injury. This paper uses IIS and determines a probable range for the expected loss of life quality for hospitalised traffic injuries in New Zealand.

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Introduction

The two major components of the social cost of traffic accidents are the loss of life and the loss of life quality resulting from impairments caused by non-fatal injuries. A majority of non-fatal injuries cause no impairment at all. Most of the minor injuries and a large proportion of serious injuries belong to this category. In other cases, the level of impairment varies between no loss of life quality to total loss of life quality. In fact, in some cases, the loss of life quality is more than 100 percent, where the status of health is considered worse than death. These values have policy implications not only in the resource allocation within the transport sector but also between road transport and other areas of public expenditure. As expressed by Jones-Lee (1989, p1):

> *"... other things being equal - most people prefer lower rather than higher levels of exposure to the risk of death or injury, it follows that the individual or social choice of an optimal level of safety in any particular context has a significant economic dimension in that it is a decision concerning the appropriate trade-off, or balance, between competing uses of scarce resources".*

There has been considerable research, in recent years, on the valuation of the social cost of loss of life, i.e, the value of statistical life. The cost of non-fatal injuries appears to have received less attention.

It is more complex to determine the social cost of non-fatal injuries than the social cost of deaths. One approach is to estimate the level of impairments using some form of health utility index and measuring the loss of life quality by quality adjusted life years. Miller et al (1991) have recently used this method in determining the social cost of traffic injuries in the USA. It is both difficult and expensive to develop a health utility index. Also, the monetary valuation of quality adjusted life years poses some problems.

The "willingness to pay" approach is considered to be the most appropriate method for estimating the marginal rate of substitution of wealth for risk of death or injury. While fatality is a well defined status, there is large variation in the severity of injuries. It may vary from a minor bruise to severe spinal or head injury resulting in a health status even worse than death. Because of this complexity, it is extremely difficult to determine the willingness to pay value for reducing probabilities of traffic injuries.

This paper discusses the Willingness to Pay Approach, the use of Quality Adjusted Life Years in determining social costs of non-fatal injuries, the development of the Injury Impairment Scale and its use in determining the average loss of life quality for hospitalised injuries.

The willingness to pay approach

Traditionally the value of statistical life has been measured by the productive contribution of the person, or the human capital value. The main problem with this approach is that it does not include a very important aspect of life, i.e., the value of one's desire to live and the cost of pain and suffering of the person's loved ones. Besides, it underestimates the value of those who are outside the labour force.

The willingness to pay approach overcomes these limitations of the human capital estimates. Originated by Dreze (1962) and developed later by Schelling (1968) and Mishan (1971), the Willingness to Pay approach aims at maximizing the social welfare. It determines the marginal rate of substitution (MRS) of wealth for risk of death or injury. This approach determines the value of statistical life as an implicit value of the amount society is willing to pay to reduce small risks of death. It does not attempt to measure the value of life as such. In fact, it is wrong to use the term "value of life". To estimate the value of life would be a task of pricing the priceless. The value of statistical life is the society's valuation of small risk reductions, with the expected total effect of saving one life.

Two methods are commonly used to determine the MRS: (1) the revealed preference method and (2) the stated preference method.

In the first case, the MRS is estimated as an implicit value from people's behaviour in actual exchange of wealth for risk. In the second case, it is estimated from surveys. There have been a large number of studies to estimate the value of statistical life following the revealed preference method. Blomquist (1982) and Jones-Lee (1989) provide surveys of empirical studies on the labour market, use of smoke detectors, use of seat belts, speed, accident and gasoline price relationships etc. This approach is generally considered inadequate due to the problems of separating out the effects of many externalities.

In the stated preference method the survey respondents are asked to compare between two scenarios and find their level of indifference in terms of exchange of wealth for risk of death or injury. In a typical question, the respondent is told of the risk of a situation and an alternative where the risk is lower, but it is available only at an additional out of pocket expense. The question is: how much the respondent is willing to pay to benefit from the low risk alternative, considering what the respondent can afford to spend. The main advantage of this method is that it takes a comprehensive view, considering all aspects of the risk. The consideration of the desire to live and the pain and suffering associated with higher risk is the most important aspect of this approach. It is assumed that with the exchange of wealth for lower risk, the respondent is indifferent between the utilities obtained from the high risk situation and the low risk alternative with a sacrifice of wealth.

The main criticism of this approach is that it uses hypothetical situations and there is a possibility of a difference between the response and the behaviour in an actual situation. It has been observed that if the questionnaire uses a realistic situation it gets realistic responses. This aspect is discussed in detail by Mitchell and Carson (1989) and in the context of the New Zealand survey by Guria (1991).

The New Zealand survey

A household survey was carried out in New Zealand over the period October 1989 to February 1990. The survey and its results are discussed in detail in Miller and Guria (1991).

The survey included three types of questions:

(1) valuation of risk changes
(2) time - risk trade off
(3) trade-off between fatal and serious non-fatal injuries

There were five questions for the first category and one question each for the second and third categories.

All responses were critically examined for consistency. Only consistent responses were used in estimating the value of statistical life. The value of statistical life was estimated as the average of the marginal rates of substitution from all consistent responses.

Three components of the value of statistical life

The willingness to pay value of a risk reduction for a person has three components:

(1) The value which the person is willing to pay for the reduction of own risk
(2) The value which the other members of the person's family are willing to pay to reduce the risk of the person
(3) The value which the rest of society is willing to pay to reduce the risk of the person

There were only a few responses to the third component of the value of statistical life. Using the estimates of the first two components and making an adjustment for the third component, the value of statistical life was determined at NZ$2 million. The estimate was based on the mean value of responses. The median value gave an estimate of $1.5 million. In April 1991, the New Zealand government adopted the $2 million value of statistical life, for all transport project and policy evaluations. The value was at 1 April 1991 prices and was to be indexed to the average ordinary wage rate.

Trade-off between risks of death and serious injuries

The survey asked one question on the relative valuation of risks of death and serious injuries. A serious injury in this case was defined as one requiring at least one week's hospitalisation and a month for follow-on treatment to fully recover. Data on the length of hospitalisation show that only about one third of those hospitalised remained in hospital for more than 7 days. This may indicate an over-estimation of the level of indifference. On the other hand, since the question implied no permanent disability, the responses were not likely to have been based

on an appropriate consideration of such possibilities. However, using the ratio obtained from this question and responses from a different question produced estimates of the value of statistical life consistent with those from other questions. If the description of the survey question can be considered to depict the average level of serious injuries, then the survey suggests that about 30 serious injuries are equivalent to one death. In other words, the willingness to pay value for avoiding a serious injury is about 3.3% of the willingness to pay value for saving a life. This appears to be low compared to estimates from other studies (Miller et al 1991).

Quality adjusted life years

Some non-fatal injuries result in long term impairments and consequent disabilities. There are two levels of effects: (1) all injuries are associated with pain and suffering, at least temporarily; and (2) some injuries result in long term impairments. In some cases, the pain and suffering may continue for a long time or even for the rest of the victim's life. This not only reduces the quality of life of the injured person, but also reduces the expected lifespan as a consequence of the disability. As Miller, Calhoun and Arthur (1989, p2) note "those who have been saved from death but not from serious injury subsequently face a different regime of mortality risks than those who have never been seriously injured".

The classification of serious and minor injuries based on hospital treatment may not appropriately measure the injury severity. Some minor injuries may not require hospitalisation, but may result in permanent disability in addition to causing much pain for a considerable length of time.

The research on comprehensive valuation of non-fatal injuries is very limited. However, there are a few studies on the development of multi-attribute utility indexes (see Torrance, 1986 for a review). These studies provide a basis for determining the loss of life quality or utility taking into consideration the physical, mental and social aspects of life. The first comprehensive study on the valuation of impairments resulting from traffic injuries appears to be by Miller, Calhoun and Arthur (1989). By extending Arthur's (1981) model of valuation of risk of death, they determined the social consumption equivalent value of impairments. In this method the value to society of a life saved is the value of the person's enjoyment of life or utility of additional years to the person and others in society less the value of the person's consumption. It is age specific. In case of non-fatal injuries this method provides the valuation of utility adjusted life years saved. In other words, the social cost of an injury is the value of effective life years lost as a result of the injury. Analysing non-fatal injuries from about 30,000 accidents, Miller Calhoun and Arthur (1989) estimated the social cost of impairments per non-fatal injury at US$12,800 using a value of statistical life of US$1.95 million. Thus their estimate of the loss to society per non-fatal injury (including all minor and serious injuries) was about 0.66% of the value of statistical life, in addition to resource costs. This was based on a value of statistical life per year of US$120,000 using an average age of non-fatal injury victims of 38 years, a lifespan of 77 years and a discount rate of 6%.

Table 1: Functional years lost due to injury severity

Severity	Average years lost per injury	% of lifespan
Minor	0.7	0.15
Moderate	1.1	2.3
Serious	6.5	13.8
Severe	16.5	35.0
Critical	33.1	70.0
Ave Non-fatal	0.7	1.5

In a more recent study Miller et al (1991) estimated the loss of functional years by the maximum abbreviated injury scale (MAIS). For each level of injury severity they estimated the expected number of functional years lost and expressed as a percentage of the expected remaining lifespan (table 1).

In this study they used a discount rate of 4% to determine the value of statistical life per year.

They considered seven dimensions of functional capacity: mobility, cognitive, self care, sensory, cosmetic, pain and ability to perform household responsibilities and wage work.

For the first six dimensions, the average health status over time was estimated by medical specialists. They estimated the average productivity loss by MAIS and body region and finally determined a weighted average of the seven ratings. The weight selection used is described in Miller and Associates (1991).

This method is not free from criticisms. Firstly, there is no theoretical basis for using a specific discount rate. Secondly, there is no theoretical justification for converting the willingness to pay estimate of the value of statistical life into the value of statistical life per year. It can perhaps be argued that the utility adjusted life years lost is equivalent to a certain percentage loss of total life quality and that is reflected in this indirect estimate. Even if this is true there is a problem in interpreting the value of statistical life per year. Given that the value of statistical life estimated by the willingness to pay method is not age specific, its conversion into value per year is, therefore, not meaningful.

The New Zealand Survey indicates that the value of statistical life does not vary with age. Only for the age group of 60 years and over the survey estimate was slightly lower. For those below 60 years of age, there was no significant difference

in the values of statistical life. However, there would be a large variation in the value per year by age. For example, the value of a life year of a 20 year old person under this approach would be much smaller than that of a 50 year old person. Is this acceptable? Clearly there is a problem in determining the value of statistical life per year from the willingness to pay value of statistical life.

The abbreviated injury and injury impairment scales

The abbreviated injury scale (AIS) is the most commonly used injury scale. It was first developed in 1969 by a committee of specialists under the joint sponsorship of the American Medical Association, the Association for the Advancement of Automotive Medicine (AAAM) and the Society of Engineers. This has since been revised several times by AAAM, the latest being in 1990.

The AIS has six severity scores: 1: Minor; 2: Moderate: 3: Serious; 4: Severe; 5: Critical and 6: Maximum. The scale is used for assessing the severity of injury in terms of its threat to life. The AIS scores are highly correlated with the probability of death. They do not indicate the consequence of the injury in terms of long term impairments or disabilities. For multiple injuries, the highest AIS score is commonly assigned to the patient and it is known as maximum AIS or MAIS.

AAAM has now developed an Injury Impairment Scale (AAAM, 1991). Impairment is defined here as an abnormality or loss of function. It differs from disability in the sense that disability is the consequence of an impairment or impairments. The scale is based on the valuation of six dimensions of functional capacity: Mobility, Cognitive, Cosmetic, Sensory, Pain and Sexual/Reproductive. Based on valuations of these dimensions for impairments caused by an injury, the IIS has 7 categories ranging from 0 to 6, similar to the AIS. The IIS score of an injury is 0 when the injury does not result in any long term impairment. The definitions of other scores are:

IIS = 1: Impairment detectable but does not limit normal function
IIS = 2: Impairment level compatible with most but not all normal function
IIS = 3. Impairment level compatible with some normal function
IIS = 4. Impairment level significantly impedes some normal function
IIS = 5 Impairment level precludes most useful function
IIS = 6. Impairment level precludes any useful function.

A group of specialists appointed by AAAM considered each injury under the AIS90 classification and assigned to it the most appropriate IIS score. Some of the assumptions used in assigning the IIS scores are:

* The subject is a previously healthy young adult (25-30 years old).
* The survivor of the injury received timely and appropriate medical care.
* Impairment is assessed at 1 year following injury

- No more than 20% of subjects with a particular injury will have impairment that differs from the IIS score
- Impairment relates to whole-body, not organ or system, disfunction.

It is not clear how the scores will differ with the age of the person[1].

The New Zealand Traffic Injury Data

Traffic injuries are coded only for hospitalised injuries in New Zealand. These are coded by ICD-9CM classification. The IIS scores have been determined by AAAM for AIS90 classification of injuries. This is different from ICD-9CM. The Johns Hopkins Health Services Research and Development Centre[2] developed in 1988 a mapping between ICD-9CM and AIS by body region. This mapping does not provide IIS scores by ICD-9CM or a matching between ICD-9CM and AIS90 classification of injuries. A matching between these two sets of codes was carried out in New Zealand, for a selected set of injuries occurring during the year 1990, with the help of two final year medical students. Only those ICD-9CM codes were selected which accounted for at least 0.1% of the hospitalised traffic injury cases, with a total coverage of about 96%. Those codes in ICD-9CM, for which matching in AIS90 could be established, accounted for about 87% of all hospitalised traffic injuries.

IIS Distribution

An application of the IIS score system to the New Zealand hospital data for traffic injuries indicate that 39.7% of all hospitalised injuries do not result in any long term impairment (fig. 1).

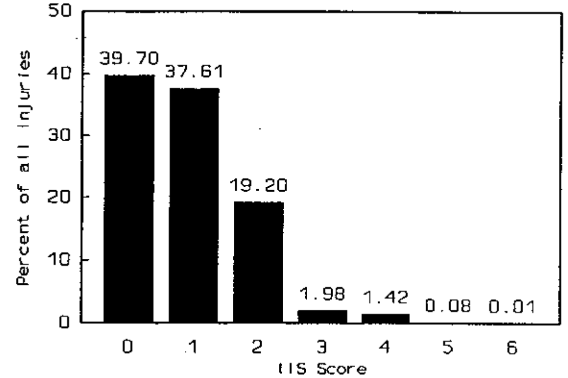
Another 37.6% of injuries have IIS score of 1. Thus over 77% of traffic injuries, which require hospital admission, result in either no long term impairment or only such impairments which are detectable but do not limit normal function.

Estimates of average loss of life quality

The loss of life quality is described here as a function of the severity of long term

1. The document I have used does not include any discussion on this.
2. It was developed jointly with The Maryland Institute for Emergency Medical Services System in collaboration with The Injury Scaling Committee of the Association for the Advancement of Automotive Medicine.

Fig. 1: Observed Distribution of injuries on IIS Scale



impairment. If there is no impairment, then there is no loss of life quality due to impairments. On the other hand, if the injury results in death, there is a total loss of life quality. In New Zealand, as in many other countries, road fatality statistics include only those who die within 30 days of the accident. The loss of life quality is 100% for each death. It should be the same for those who die after 30 days in hospital. The accident statistics in New Zealand indicate that on average 1.8% of those hospitalised due to traffic injuries die in hospital. The expected loss of life quality is, therefore, 0.018 times the number of hospitalised traffic injury patients less the number of deaths which occur within 30 days of accidents. For others, if we know the probability distribution of the loss of life quality over the range 0 to 100%, we can determine the expected loss of life quality.

The IIS scores are ordinal values. The IIS scale has 6 scores. Score 2 indicates higher severity of impairment than score 1. Similarly, score 4 indicates higher severity of impairment than score 3 and so on. A higher score only suggests that the injury results in a more severe long term impairment. It does not provide any cardinal measure of the difference in the severity levels. While a score of 0 means most of the injuries with this score do not result in any long term impairment, a score of 1 does not suggest that the severity of impairment is 5%, 10%, 20% or any such definite level.

Different assumptions will provide different estimates of the expected loss of life quality. The following discussion is based on a few cases that have been analysed. These should be treated as preliminary results. Because of this particular nature of the IIS scale, I have estimated the expected loss of life quality under different scenarios. It is assumed that the loss of life quality has a continuous probability distribution over the range 0 to 100%. The actual shape of the distribution will depend on the range of the loss of life quality for each IIS score.

Beta distribution has been used with different sets of parameters to explore the possibilities of various shapes of the probability distribution. The reasons for choosing Beta distribution are that it is a continuous distribution over the range (0,1) and that the shapes can be easily varied by changing the parameters. The frequency distribution of IIS scores suggests that the probability density is the highest at 0 and that it declines as the impairment severity increases.

Table 2: Estimates of the expected loss of life quality

	Scenario	Expected loss of life quality (%)
1	About 40% of hospitalised traffic injuries cause no loss of life quality (IIS = 0) and about 38% cause up to 5% loss of life quality (IIS = 1)	3.0
2	About 40% of hospitalised traffic injuries cause no loss of life quality (IIS = 0) and about 38% cause up to 10% loss of life quality (IIS = 1)	5.7
3	About 40% of hospitalised traffic injuries cause up to 5% loss of life quality (IIS = 0)	9.1
4	About 77% of hospitalised traffic injuries cause up to 10% loss of life quality (IIS = 0 or 1)	6.6

Given the distribution in figure 1, a range for the expected loss of life quality should be possible to estimate. Assuming that about 40% of hospitalised traffic injuries (IIS = 0) cause no loss of life quality and about 38% cause up to 5% loss of life quality (IIS = 1), the expected loss of life quality is estimated as 3%. If we assume that injuries with IIS score of 1 (i.e., 38%) cause up to 10% loss of life quality then the expected loss of life quality would be 5.7%.

The development criteria of IIS scores suggest that up to 20% of injuries with a particular score could have a different level of impairment severity. This means that some people with injuries of zero IIS score could have some long term impairments and hence loss of life quality. This suggests that the expected loss of life quality due to injuries with 0 IIS score could, in fact, be greater than zero. Assuming that the loss of life quality for these injuries could be up to 5%, the overall expected loss of life quality would be about 9.1%.

On the other hand if we assume that injuries with IIS scores of 0 and 1 will not produce more than 10% loss of life quality, then the overall expected loss of life quality would be about 6.6%. The results are summarised in table 2.

An extreme case would perhaps be one where the loss of life quality for 0 IIS injuries is up to 5% and for other injuries the loss of life quality is proportional to the IIS score. Assuming a uniform distribution in each range of IIS score, the expected loss of life quality would be about 13%. Considering this, a possible range

for the expected loss of life quality resulting from hospitalised traffic injuries in New Zealand would be from 3% to 13%. If the IIS scores of 0 and 1 produce higher losses of life quality than what has been assumed here, the range may change.

Summary and conclusion

The paper has described the advantages of the willingness to pay approach in estimating the social costs of fatal and non-fatal injuries. It provides a methodology for determining the expected loss of life quality based on the distribution of hospitalised traffic injuries over the Injury Impairment Scale, recently developed by the Association for the Advancement of Automotive Medicine.

The preliminary results indicate that a probable range for the average loss of life quality in New Zealand is from 3% to 13%. Further research is needed to reduce the range and also to assess the assumptions made with respect to the loss of life quality associated with IIS scores of 0 and 1.

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