G Model
AAP-4130; No. of Pages 9

ARTICLE IN PRESS

Accident Analysis and Prevention xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Estimation of social value of statistical life using willingness-to-pay method in Nanjing, China

Zhao Yang[a], Pan Liu[b,*], Xin Xu[b]

[a] National Key Laboratory of Air Traffic Flow Management, Civil Aviation College, Nanjing University of Aeronautics and Astronautics, Jiangjun Road No. 29, Nanjing 211106, China
[b] Jiangsu Key Laboratory of Urban ITS, Jiangsu Collaborative Innovation Center of Modern Urban Traffic Technologies, Southeast University, Si Pai Lou #2, Nanjing 210096, China

ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form 19 March 2016
Accepted 25 April 2016
Available online xxx

Keywords:
Willingness-to-pay
Value of statistical life
Mixed logit
Random coefficient

ABSTRACT

Rational decision making regarding the safety related investment programs greatly depends on the economic valuation of traffic crashes. The primary objective of this study was to estimate the social value of statistical life in the city of Nanjing in China. A stated preference survey was conducted to investigate travelers' willingness to pay for traffic risk reduction. Face-to-face interviews were conducted at stations, shopping centers, schools, and parks in different districts in the urban area of Nanjing. The respondents were categorized into two groups, including motorists and non-motorists. Both the binary logit model and mixed logit model were developed for the two groups of people. The results revealed that the mixed logit model is superior to the fixed coefficient binary logit model. The factors that significantly affect people's willingness to pay for risk reduction include income, education, gender, age, drive age (for motorists), occupation, whether the charged fees were used to improve private vehicle equipment (for motorists), reduction in fatality rate, and change in travel cost. The Monte Carlo simulation method was used to generate the distribution of value of statistical life (VSL). Based on the mixed logit model, the VSL had a mean value of 3,729,493 RMB ($586,610) with a standard deviation of 2,181,592 RMB ($343,142) for motorists; and a mean of 3,281,283 RMB ($505,318) with a standard deviation of 2,376,975 RMB ($366,054) for non-motorists. Using the tax system to illustrate the contribution of different income groups to social funds, the social value of statistical life was estimated. The average social value of statistical life was found to be 7,184,406 RMB ($1,130,032).

1. Introduction

With the rapid development of social economy and road transport industry in China, increased attention has been given to improving safety of the roadway system. The valuation of crashes has become an emerging public policy issue, because the value of crashes is a crucial input parameter in the cost-benefit analysis of safety related projects. The costs associated with crashes account for a large proportion of the monetized component in the cost-benefit analysis of major road schemes (Cambridge Systematics, 2008). Rational decision making regarding the safety related investment programs greatly depends on the valuation of crashes.

The valuation of fatalities and injuries are critical for estimating the costs associated with crashes. Usually, the costs for property damage only crashes can be directly obtained, while the costs associated with fatalities and injuries require more investigation. The idea is not to put a tag price on a fatality or an injury, but on reductions in the probability of a fatality or an injury (Iragüen and Ortúzar, 2004). This concept gives rise to the value of statistical life (VSL). More specifically, the VSL represents the value of the improvements in safety that results in a reduction by one expected number of fatality, which is equal to the population average of the marginal rate of substitution between income and fatality risk.

Different methods can be used for estimating VSL. So far the most widely accepted method is based on the maximum utility theory (Rizzi and Ortúzar, 2003; Iragüen and Ortúzar, 2004; Andersson, 2007). This method quantifies the individual perception of the utility of safety improvements when facing fatality risks, which is also

Abbreviations: VSL, value of statistical life; FHWA, federal highway administration; GDP, gross domestic product; AIS, abbreviated injury scale; SVSL, social value of statistical life; AIC, Akaike information criterion; MC, Monte Carlo; WTP, willingness-to-pay.

* Corresponding author.
E-mail addresses: yangzhao@nuaa.edu.cn (Z. Yang), pan_liu@hotmail.com (P. Liu), xuxin_seu@163.com (X. Xu).

http://dx.doi.org/10.1016/j.aap.2016.04.026
0001-4575/

Please cite this article in press as: Yang, Z., et al., Estimation of social value of statistical life using willingness-to-pay method in Nanjing, China. Accid. Anal. Prev. (2016), http://dx.doi.org/10.1016/j.aap.2016.04.026

called the subjective value of statistical life. The subjective value of statistical life is the marginal amount of money that respondents are willing to sacrifice in order to reduce one expected number of fatality. The assumption is that rational decision makers always choose the alternative with the maximum utility. They would like to pay a specific amount of money to reduce fatality risks through traffic improvements if they think their utilities can be increased. Discrete choice models are developed to establish a relationship between the chance that an individual choices an alternative and various influence factors. Usually the models are developed using data obtained through stated preference or revealed preference surveys. With the discrete choice models, the subjective value of statistical life can be estimated as the marginal rate of substitution of the estimated coefficients of fatality risks and costs.

Periodically, the Federal Highway Administration (FHWA) in the United States develops guidance on estimating VSL. The reported VSL estimate was updated over time according to the implicit gross domestic product (GDP) price deflator, which was $2.5 million in 1993, $3.0 million in 2002 and $3.25 million in 2006 (FHWA, 2008). In 2008, rather than simply increasing the 1993 estimate incrementally, the FHWA reported a new estimate of VSL of $5.8 million (value in 2007) based on five most recent research results (Kochi et al., 2006; Mrozek and Taylor, 2002; Miller, 2000; Viscusi, 2003, 2004).

Numerous studies have also been conducted to evaluate the VSL in different countries. Miller (2000) compared the estimated VSL from 68 studies spread across thirteen countries. It was found that the estimated VSL vary significantly across nations. The values are typically about 120 times GDP per capita. Traweín et al. (2002) compared the costs per fatal casualty in crashes adopted by authorities in different countries. It was found that the average cost per fatality has increased between 1990 and 1999 due to both changes in the methodology and changes of valuations. Blaeij et al. (2003) conducted an international meta-analysis of the values of statistical life in road safety that summarized the results of previous research. The study reported the estimates of VSL from thirty different studies. The meta-analysis also sheds some new lights on the variation of the VSL by country, survey method, elicitation method, safety enhancing measure and the format of VSL, etc.

The severity level of a crash could range from a slight injury to a life threatening event. While lots of studies have been conducted regarding the estimation of VSL, few of them used the similar methods for estimating the value of injuries. The major concern is that respondents can hardly perceive the severity of crashes accurately. That is, they cannot distinguish clearly between the money that needs to be devoted to reducing fatal and injury risks. To determine the value of injuries, FHWA proposed the abbreviated injury scale (AIS) to estimate the costs associated with different types of injuries as a percentage of the assumed VSL estimate. A total of six AIS levels were defined according to crash severity, including minor crash, moderate crash, serious crash, severe crash, critical crash, and fatal crash. For each type of crash, the fraction of VSL was determined (FHWA, 2008).

Until recently, little documentation has been available with regard to the estimation of VSL in developing countries like China. Due to the socioeconomic and demographical disparities, people's willingness to pay can be quite different across nations. For example, a large proportion of people in China did not had driver licenses. Their perception of the increased utility due to risk reduction might be different from that of drivers. Also, various factors may affect people's choice behaviors in different ways. The heterogeneity of travelers, compounded by the existence of various trip characteristics, makes the analyses more complicated. In addition, the VSL captures individuals' willingness-to-pay with the consideration of the trade-off between costs and fatality risks. However, in the evaluation of safety related projects, the social view of individual benefits is not necessarily equal to the private view. It is doubted that the subjective value of statistical life cannot be directly used in the cost-benefit analysis of safety related projects. Instead, the social value of statistical life should be used, which represents the ratio between a margin of utility of fatality and a social utility of money (Jara-Díaz et al., 2000). The social benefits of risk reduction require further elaboration.

The present study aims to estimate the social value of statistical life through an empirical application in the specific nature of China. More specifically, this paper tries to: (a) identify how the various factors influence people's willingness-to-pay for the reduction of crash risks; (b) estimate the subjective value of statistical life using discrete choice models, while considering the random tastes that may exist among different respondents; and (c) estimate the social value of statistical life that can be used in the evaluation of transport related projects.

2. Methodology

2.1. Subjective value of statistical life

According to the rational choice theory, if a decision maker is faced up with two alternatives (i and j), with the U_i higher than U_j, the decision maker always chooses alternative i. The expression can be expressed as follows (Train, 2003):

$$Pi, m = Pr(U_{i,m} > U_{j,m}) \quad (1)$$

where $P_{i,m}$ represents the probability that the decision maker m chooses alternative i; $U_{i,m}$ represents the utility that decision maker m obtains from alternative i; and $U_{j,m}$ represents the utility that decision maker m obtains from alternative j. The random utility can be expressed as the sum of the systematic utility and an unobserved error term. The expression can then be transformed to:

$$\begin{aligned} Pi, m &= Pr(V_{i,m} + \varepsilon_{i,m} > V_{j,m} + \varepsilon_{j,m}) \\ &= Pr(\varepsilon_{j,m} - \varepsilon_{i,m} < V_{i,m} - V_{j,m}) \\ &= \int I(\varepsilon_{j,m} - \varepsilon_{i,m} < V_{i,m} - V_{j,m}) \mathrm{f}(\varepsilon) d\varepsilon \end{aligned} \quad (2)$$

where $V_{i,m}$ represents the systematic utility that decision maker m obtains from alternative i; $V_{j,m}$ represents the systematic utility that decision maker m obtains from alternative j; ε represents the unobserved error term; I represents if the statement that the difference between the error terms $\varepsilon_{j,m}$ and $\varepsilon_{j,m}$ is lower than the difference between the systematic utility $V_{i,m}$ and $V_{j,m}$ is true or not (=1 if the statement is true, 0 if the statement is false); $f(\varepsilon)$ represents the priori assumed density function of the unobserved error term ε.

The systematic utility $V_{i,m}$ and $V_{j,m}$ can be expressed as a linear function of the attributes of an alternative, multiplied by their coefficients. The expression is shown as follows:

$$V_{i,m} = \beta_{cost} \times ci, m + \beta_{cau} \times caui, m + \sum_k \beta k \times Xk, i, m \quad (3)$$

$$V_{j,m} = \beta_{cost} \times cj, m + \beta_{cau} \times cauj, m + \sum_k \beta k \times Xk, j, m \quad (4)$$

where $c_{i,m}$ represents the cost if decision maker m chooses alternative i; $c_{j,m}$ represents the cost if decision maker m chooses alternative j; $cau_{i,m}$ represents the fatality rate if decision maker m chooses alternative i; $cau_{j,m}$ represents the fatality rate if decision maker m chooses alternative j; $X_{k,i,m}$ and $X_{k,j,m}$ represents other influence factors that are known to the decision maker for alternative i and j, respectively; $_{\beta cost}$ represents the coefficient of cost; $_{\beta cau}$ represents the coefficient of fatality rate; $_{\beta k}$ is the coefficient of the