Accident Analysis and Prevention 71 (2014) 236–247

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Value of a statistical life in road safety: A benefit-transfer function with risk-analysis guidance based on developing country data

Craig Milligan[a,*], Andreas Kopp[a], Said Dahdah[a], Jeannette Montufar[b]

[a] World Bank, Washington DC
[b] University of Manitoba, Canada

ARTICLE INFO

Article history:
Received 22 January 2013
Received in revised form 13 May 2014
Accepted 30 May 2014

Keywords:
Value of statistical life
Road safety
Transport economics
Developing countries
Risk analysis
Benefit transfer

ABSTRACT

We model a value of statistical life (VSL) transfer function for application to road-safety engineering in developing countries through an income-disaggregated meta-analysis of scope-sensitive stated preference VSL data. The income-disaggregated meta-analysis treats developing country and high-income country data separately. Previous transfer functions are based on aggregated datasets that are composed largely of data from high-income countries. Recent evidence, particularly with respect to the income elasticity of VSL, suggests that the aggregate approach is deficient because it does not account for a possible change in income elasticity across income levels. Our dataset (a minor update of the OECD database published in 2012) includes 123 scope-sensitive VSL estimates from developing countries and 185 scope-sensitive estimates from high-income countries. The transfer function for developing countries gives VSL = 1.3732E−4 × (GDP per capita)^2.478, with VSL and GDP per capita expressed in 2005 international dollars (an international dollar being a notional currency with the same purchasing power as the U.S. dollar). The function can be applied for low- and middle-income countries with GDPs per capita above $1268 (with a data gap for very low-income countries), whereas it is not useful above a GDP per capita of about $20,000. The corresponding function built using high-income country data is VSL = 8.2474E+3 × (GDP per capita)^.6932; it is valid for high-income countries but over-estimates VSL for low- and middle-income countries. The research finds two principal significant differences between the transfer functions modeled using developing-country and high-income-country data, supporting the disaggregated approach. The first of these differences relates to between-country VSL income elasticity, which is 2.478 for the developing country function and .693 for the high-income function; the difference is significant at $p < 0.001$. This difference was recently postulated but not analyzed by other researchers. The second difference is that the traffic-risk context affects VSL negatively in developing countries and positively in high-income countries. The research quantifies uncertainty in the transfer function using parameters of the non-absolute distribution of relative transfer errors. The low- and middle-income function is unbiased, with a median relative transfer error of −.05 (95% CI: −.15 to .03), a 25th percentile error of −.22 (95% CI: −.29 to −.19), and a 75th percentile error of .20 (95% CI: .14 to .30). The quantified uncertainty characteristics support evidence-based approaches to sensitivity analysis and probabilistic risk analysis of economic performance measures for road-safety investments.

1. Introduction

Analyses of investments to prevent road fatalities often use the net present value (NPV), the internal rate of return (IRR) or the social benefit-cost ratio as a prospective transport performance measure. These performance measures require estimates of both the value of a statistical life (VSL) and the value of a statistical injury (VSI). A robust and conservative engineering economic analysis using these performance measures also requires estimates of uncertainty in VSL and VSI. Many developing countries do not have appropriate VSL estimates and need to adapt existing estimates from elsewhere using transfer functions in a process called benefit-transfer. The currently available benefit-transfer functions are based on meta-analyses of datasets composed primarily of high-income country data, which may not be appropriate for application in developing countries.

* Corresponding author. World Bank, 1818 H St NW, Washington DC, 20433. Present Affiliation: University of Manitoba Department of Civil Engineering, E1-327 EITC, 15 Gillson Street, Winnipeg, MB, R3T 5V6; Tel.: +1 204 474 7112.
E-mail address: milligan.craig.a@gmail.com (C. Milligan).

http://dx.doi.org/10.1016/j.aap.2014.05.026
0001-4575/© 2014 Published by Elsevier Ltd.

The objectives of this research are to (1) develop a new VSL transfer function for application to transport safety in developing countries that is based on VSL estimates from developing countries, (2) determine whether this function differs significantly from functions that are based on VSL estimates from developed countries and (3) quantify the uncertainty associated with this new transfer function for practical application to the risk analysis of performance measures.

The study accomplishes these objectives by performing a new meta-analysis on a database of VSL estimates that has been made available as an accompaniment to the publication *Mortality Risk Valuation in Environment, Health and Transport Policies* (OECD, 2012). Meta-analysis, which is widely used in road safety and other fields of research, is "a quantified synthesis of the results of several studies" (Elvik, Høye et al., 2009, 20). The research also expands on the existing techniques for transfer error analysis and interpretation to validate the transfer function and enable its application in a stochastic framework.

The work is a subset of a project at the World Bank to develop a flagship report entitled *Comprehensive Assessment of Transport Policies and Projects* that will provide *ex ante* evaluation instruments to allow engineers to incorporate wider, multi-sectoral benefits of transport as well as environmental and safety costs into decision-making supports.

2. Existing knowledge, practices, and needs

This section is organized into four subsections. Section 2.1 presents the general need for VSL estimates as inputs to the social benefit-cost analysis of road safety investments. Section 2.2 provides an overview of the methods used to create original VSL estimates along with their strengths and weaknesses. Section 2.3 describes the process of transferring VSL estimates to policy contexts in which no appropriate original VSL estimate exists and the current practice for assessing the uncertainty related to these transfers. Finally, Section 2.4 describes the state of existing practice for obtaining VSL estimates in developing countries and the emergence of opportunities to improve the state of this practice.

2.1. The transport safety problem and the need for VSL estimates in benefit-cost analysis

The need for this research is fundamentally predicated on the transport safety problem in developing countries, which has the dimensions of a global disease. While transport risks to individual users may appear low, the cumulative impact of these risks places a high burden on society. Nordfjærn et al. (2012) describe the problem as "increasing towards endemic proportions in developing countries" (p. 1862). Worldwide, there are approximately 1.3 million road transport fatalities per year—or approximately 3500 per day (WHO, 2012). Analysts expect these rates to increase, and developing countries bear a high share of the burden (World Bank and WHO, 2004). Because of the magnitude of the problem and in recognition of health-related millennium development goals, the World Bank focuses on safety as the first of three themes in its transport business strategy for 2008 to 2012, entitled *Safe, Clean, and Affordable Transport for Development* (World Bank, 2008).

Many engineering countermeasures—in the form of policies or projects—are available to reduce the risk of transport fatalities and injuries. Elvik et al. (2009) review the expected effectiveness levels of various countermeasures, as do several other handbooks and toolkits. With the resulting estimated changes to physical indicators in hand (i.e., reductions in fatalities or serious injuries), governments turn to social benefit-cost analysis (BCA) to develop performance measures that evaluate transport safety spending vis-à-vis other potential public spending from the perspective of overall welfare. An in-depth guide to project evaluation using social BCA is provided by Dasgupta et al. (1972). Market prices often provide suitable information about public preferences for use in BCA, but in many cases, they do not. In these cases, social BCA requires the use of shadow prices, which are notional prices for the physical costs and benefits used by the government to reflect public preferences for evaluation purposes (Dasgupta et al., 1972). When social BCA addresses transport safety, shadow prices are required for the benefits of reduced transport risks because no market directly deals in these benefits. Most work to develop shadow prices for road safety produces a VSL or a VSI. The costs of property damage only (PDO) collisions are more amenable to evaluation at market prices because there are functioning markets that deal in the repair or replacement of damaged property (namely, vehicles). Furthermore, although the PDO costs are significant, they are small compared with the costs of injuries and fatalities. It is important to note that the VSL values do not reflect the moral value of a person's life. An appropriate VSL value is one that supports social BCA by reflecting the preferences of individual members of the public related to their individual marginal rates of substitution between risk and income. Although social BCA is a widely used tool to evaluate road safety investments according to public preferences, it is not the only approach. Other approaches to evaluate road safety investments include cost-effectiveness analysis, vision zero (see support in (Rosencrantz et al., 2007) and criticism in (Elvik, 1999)), multi-criteria analysis (e.g., an impact tableau (Manheim, 1979)), and citizen's juries (see arguments in favor by (Hauer, 2011)). Although some researchers prefer and argue for these other approaches, this paper develops a new VSL benefit transfer function for application to road safety BCA in developing countries—though alternative approaches to BCA exist—under the assumption that the conventional practice of social BCA will continue for some time and that social BCA is useful for evaluation purposes.

2.2. Methods to estimate VSL and their strengths and weaknesses

The methods used to estimate the value of a statistical life fall into two categories: the human capital (HC) method and the willingness to pay (WTP) method. The HC method uses lost productivity calculations, and analysts have almost completely abandoned this method because it fails to account for intangible dimensions, such as suffering and grief. They instead favor the WTP method, which implicitly includes these dimensions and is based on consumer preferences, which form the basis of BCA under the new welfare economics paradigm. The WTP method is further classified into two categories: the stated preference (SP) and revealed preference (RP) methods.

The stated preference (SP) method uses surveys that are designed to elicit from participants a statement about the quantity of money that they would be willing to spend to achieve a small reduction in mortality risk. These surveys are based on an assumption that individuals can state their real preferences regarding a marginal rate of substitution between wealth and a specific type of mortality risk reduction when asked hypothetical questions about these preferences. If a person states a willingness to pay $10,000 towards a policy that will reduce their risk of dying from 1.5% to .5%, the value of a statistical life is calculated as the willingness to pay divided by the risk reduction, or $10,000 divided by 1%, giving VSL = $1 million. If there were 100 identical people, the expected number of deaths reduced by implementing the policy for the entire group is 1 (reduced from 1.5 to .5), and as a group, the total willingness to pay to save that one statistical life is $1 million (100 people times $10,000).

The revealed preference (RP) method observes behavior in a proxy market to measure the actual willingness to pay for small