An overview of Value of Statistical Life Estimations- Transportation Perspective

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Abstract

In this paper, I review the value of statistical life (VOSL) definitions/concepts, mainly in the transportation context. After examining the concept, I provide a background, discussing how the estimates should be different for each case study. Next, I overview a variety of previous studies globally, focusing on their estimated values. Finally, I summarize a few interesting observations regarding this extremely important factor for public policy analyses. The adjusted 2024 VOSL in U.S. dollars ranges from 0.1 million in Russia to 32 million in Canada; 320 times difference! In fact, VOSL values differ substantially by income, age, and geographical region as well as the sector of concern. This conclusion significantly impacts the application of VOSL for social welfare evaluations of transportation projects.

Keywords – Value of statistical life; Transportation; Health-related costs of travel; Cost analysis.

Introduction

The human's search for better, long, and possibly immortal lives have a long history. The related question is how we could make our lives longer and at what costs. The question and its answer have evolved dramatically from earlier ages where humans were searching for eternal potions up to present. Notwithstanding, we still encounter analogous challenges in our lives. For instance, the additional money spent on purchasing organic food options in replace of regular ones is mainly justified by saving/improving own lives and even animals. An exceptionally important question then is how we could value lives in numerical terms.

Value of life is defined as the monetary value required to diminish fatality risks. Similar terminologies are used to refer to the same concept, such as value of statistical life (VOSL), value of preventing a fatality and implied cost of averting a fatality. I will discuss VOSL in the next section. Here, I discuss value of life using a more general approach.

Conceptually, the valuation of life should be viewed under two different perspectives. First, it is important to comprehend how each person values his/her own lives. In almost all cases, no one is willing to give his/her life, however, the decisions that we make and the trade-offs we accept would determine how we value our lives in monetary terms. A large body of research exists in terms of how to estimate VOSL, especially considering occupation fatality risks (Lanoie et al., 1995; Arabsheibani and Marin, 2000; Bowland and Beghin, 2001). Even though ethically challenging, we can determine how much an individual values her/his own life, using statistical and theoretical approaches.

The second perspective is how a society should/would value lives. In other words, it is crucial to determine how much the society as a whole should spend to decrease the risk of death. This is slightly different from individuals' perspective, but the same argument applies about the public policy tradeoffs, decisions, and investments. Under this approach, public policies are viewed from the perspective of a policy maker (social planner or any entity who decides to preserve the interest of the public).

For instance, if a policy maker had valued lives indefinitely, s/he should have banned all motor-vehicle-transportation activities to avoid the risk of accidents. This approach should be chosen not only because of the accident risks, but also because of the health implications of the exposure to transport emissions, which could eventually take lives. However, we all know that the public policy approach is completely distinct, i.e., the value of life is not assumed infinite, typically. Hence, there is a realistic, sometimes urgent, need to determine the value for public policy decisions. The question becomes how much the public sector should pay to save lives and which projects/policies to choose accordingly. The answer is extremely important for social cost benefit analyses and social welfare analyses of transportation projects where safety increase and air pollution decrease play imperative roles (Rouhani et al., 2016b; Do et al., 2021).

Although similar conceptually, the two above-mentioned perspectives differ in some aspects because a society might hold a different perspective about the value of life of each individual. For instance, if a global policy maker could decide about the life of Adolf Hitler, s/he would have valued it with a large negative number, i.e., to save others' lives. However, the same question from Hitler himself would have resulted in a different answer, I presume. Nevertheless, since policy makers' perspective might be subjective, the common approach typically involves estimating the value of lives based on individuals' actions and perceptions. Moreover, to preserve equality, we usually consider societies to be monolithic, i.e., the same or at least similar value of life for all individuals.

The concept has been studied in numerous disciplines and in a variety of contexts, ranging from occupational risk (Viscusi and Aldy, 2003; Viscusi, 2004), safety (de Blaeij et al., 2003; Transportation Safety Board of Canada, 2018; Do et al., 2019), climate change (Madani et al., 2011; Weitzman, M.L., 2007; Rouhani 2022a), air pollution (Rouhani and Neimeier, 2011; Rouhani and Niemeier, 2014a; Rouhani et al., 2015b), transportation investment (Rouhani and Gao, 2016; Rouhani et al., 2016a; Rouhani, 2021), public policy and politics (Adler, 2020; Rouhani, 2014; Rouhani, 2022b), systems analysis (Madani, et al., 2014; Rouhani and Gao, 2014), project management (Rouhani and Niemeier, 2014b; Rouhani et al, 2018; Rouhani, 2019), sustainability (Dockins et al., 2004; Rouhani, 2009; Rouhani, 2016), energy modeling (Mirchi et al., 2012; Rouhani, 2010; Rouhani and Beheshtian, 2016; Rouhani et al', 2016a) among others. In the next section, I provide a brief background about how to estimate the value of life for each case study.

Background

The theory behind the value of life concept dates back to when Adam Smith (1776) stated that: "the wages of labor vary with the ease of hardship, the cleanness, the honorableness, or dishonorableness of the employment"). In this regard, the value of statistical life (VOSL) is defined in the reduced-probability-of-death context. VOSL is a balancing factor between additional risk and incremental benefits from any activity. The estimated value offers the public sector a reference point for assessing benefits of fatality risk reduction. In other words, VOSL represents the marginal cost of death prevention for each job/task/policy.

A universally accepted method to calculate VOSL does not exist. Nonetheless, two common systematic methods are used: the revealed preference and the contingent valuation (Lanoie et al., 1995). Moreover, two primary approaches are employed to estimate VOSL: hedonic wage (Majumder and Madheswaran, 2018) and hedonic price models (Riera et al., 2006). My focus is not on these methods/approaches or other existing approaches. Nonetheless, I discuss the methods briefly. The hedonic wage approach is based on the equilibrium of job markets, i.e., between firms' offer curves (wage as a function of job risk) and individual workers' utility functions. The locus of these curves for various markets represents the wage-risk tradeoffs. The estimated slope of the locus curve determines the tradeoffs. The literature, however, focuses mainly on valuing mortality risk by estimating pay-off differentials for the on-the-job risk exposure in labor markets (Viscusi and Aldy, 2003).

Regardless of the employed method, Viscusi and Gentry (2015) argue that the VOSL estimates for one market cannot necessarily be used for another one. Most estimates are based on labor market, for instance, the U.S. department of transportation value of $9.2 million (USDOT, 2016). In fact, the focus of such an estimate is on work/sector characteristics rather than on the nature of the risk. Nevertheless, the nature of the risk generally determines the magnitude of the estimate.

Apart from extremely high-risk jobs, the VOSL estimates could be used in many different contexts. Transportation is the fourth-highest-fatality-risk job in the U.S. (BLS) mainly because of traffic accidents. Accordingly, one can argue that the hedonic-wage VOSL estimates could be used in transport project evaluation approaches (Beheshtian et al., 2017; Rouhani, 2018; Beheshtian et al., 2020), especially for road accidents. Despite similarities, those estimates are quite different in nature from the health outcomes of travel because the type of risk is quite different. In specific, urban travel involves health implications other than fatal accidents such as exposure to air pollution, stress, noise, etc. All of which leads to decrease in lifetime and in rare cases immediate death.

In the transportation context, researchers generally use the concept to evaluate the value of safety, i.e., less accidents (Jones-Lee and Jones-Lee, 1990; de Blaeij et al., 2003). A common definition of VOSL in a road traffic context is based on the trade-off between an individual's willingness to pay (WTP) for a marginal reduction of the risk of dying in a road traffic accident (Persson et al., 2001). A few studies consider the speed limit as the basis for their calculations (Ashenfelter and Greenstone, 2004) and others the impacts of the mode of transportation on the analysis (Carlsson et al., 2004).

In the transportation safety context, the evaluations are based on price premiums instigated by safer cars (Dionne and Lanoie, 2004). Notwithstanding, the transferred benefits should not be limited to safer cars. Viscusi and Gentry (2015) test the validity of the benefits transfer assumption and examine the differences between fatalities from transportation accidents and those from non-transportation events. The study found that the VOSL estimates are generally higher for transport but once non-fatal injury impacts are considered, transport and non-transport estimates are not statistically different. Their overall recommendation is that public agencies should consider the specific risk associated with their policies according to the morbidity type, the preferences of the exposed population, and the nature of the risk.

Numerous studies have considered the VOSL concept for evaluating projects, specifically safety projects (Jones-Lee et al.,1985; de Blaeij et al., 2003; Do et al., 2020). Nevertheless, a simple calculation could indicate that the reduction in our life time (or the risk) is much higher because of the exposure/generation of travel-related criteria air pollutants, compared to fatal accidents (Daher et al., 2019). The key reason is that generally, the fatal-accident risk is extremely low, while we are all exposed to emissions every day, which could reduce a year or more of our lives even in clean cities (Pope et al., 2009), and no one could escape pollution, unlike traffic accidents. To estimate the impacts on VOSL, we can use a concentration response function and determine the health outcomes of any emissions concentration, e.g., see Lepeule et al. (2012), an extended version of the Harvard Six Cities Study. The estimated impacts would be substantially higher for polluted cities in developing countries, like Beijing.

Therefore, the VOSL estimation is extremely important for evaluating transportation projects (Jones et al., 2014; Rouhani et al., 2014). However, most related studies focus only on safety costs. Other few studies use the emissions costs estimated by other studies (Vassanadumrongdee and Matsuoka, 2005; Rouhani et al., 2015a). In some other studies, the VOSL values are borrowed even from fields other than transportation, usually based on the risk of occupational fatalities (Small, 1977; McCubbin and Delucchi, 1999; Mashayekh et al., 2011; Daher et al., 2018; Wolfe et al., 2019). All such assumptions are questionable.

Another commonly ignored factor plays an important role. Not only the VOSL values are different for different income and age groups (Viscusi and Aldy, 2003), the values differ for different countries, states, or even cities. Most studies generally use an average VOSL for their evaluations, perhaps partially because of ethical considerations (Viscusi, 2003). Nevertheless, globally, the average estimates range from U.S.$0.7 million (Liu and Hammitt; 1999) in developing countries to as high as U.S.$21 million (Lanoie et al., 1995), both in year 2000 prices. It should even be different within the country. To answer ethical considerations, we should understand that a statistical value of life is not a human life. In the next section, I will discuss this with further details.

However, the suggested values even differ for the same country and within the same government. For instance in the case of the U.S., the environmental protection agency (EPA) values it at U.S.$7.4 million in 2006 prices (U.S. EPA, 2019) while U.S. Department of Transportation (2016) values it at about US$6.5 million in 2006 prices (U.S. Department of Transportation, 2016), perhaps because of the differences in types of mortality risks. The U.S. office of Management and Budget (OMB) (2003) recommends the use of a tailored study for specific region/population. Despite such recommendation, public organization generally do not apply different VOSL estimates for different population/regional groups. The only exception is the U.S. EPA analysis which differentiate the VOSL according to age (Viscusi and Gentry, 2015).

Overview of VOSL estimates

In this section, I overview a variety of notable previous studies, focusing on the magnitude of estimated VOSLs. My emphasis is on the disparities in the valuations with respect to countries and sector of concern. This examination is important since all public safety projects are immensely sensitive to such valuations. In my analysis, I do not focus neither on the reasons among disparities in VOSL estimates nor on the methods used for estimations.

VOSL is a key parameter to assess the mortality-risk-reduction benefits of public policies/projects. As we discussed before, VOSL is not constant across population/regions, and can even differ according to the cause of death (Viscusi and Gentry, 2015). The VOSL values may vary by risk type since the associated morbidity effects may change. In the context of transport-related health impacts, VOSL could be substantially different from labor-market-based estimates. This is true since the resulting disease (for instance, respiratory issues from transport air pollution) may last long time causing a more painful death than usual. The U.K. His/Her Majesty's (H.M.) Treasury acknowledges such disparity and notes that individuals are not indifferent to the cause of death or injury (H.M. Treasury, 2011). As another example, the U.S. EPA (2010) recommends a 50% premium on preventing cancer-related fatalities because the resulting death could be more painful/stressful.

In addition to the nature of risk, sociodemographic characteristics could significantly impact the value of life estimates. The empirical literature verifies that the VOSL decreases with age and increases with income. For instance, conducting a meta-analysis, Viscusi and Aldy (2003) found out an income elasticity of VOSL in a range of 0.5 to 0.6. As another example, Lindhjem et al. (2011) conducted a global meta-analysis of stated preference surveys and found a mean (median) VOSL of around $7.4 million (2.4 million) (2005 U.S. dollars). Remarkably, the study found that two most important factors explaining the variation in VOSL are gross domestic product (GDP) per capita and the associated health-risk magnitude. The first factor, however, implies that the value could vary from a country to another or even from a region to another. The second factor shows that the estimates should be adjusted according to the type of risk (emissions versus accidents) and by sector.

Examining a range of various sources/regions, Table 1 provides a brief overview of the estimates from various studies. The table shows the country, the estimated VOSL in local currency, the year of analysis, the sector, the adjusted VOSL in 2024 U.S. dollars (USD), and the reference for each study. Note that in order to find the adjusted 2024 values in million USD, I used local interest rate, 2024 exchange rate, and the analysis year (See Table 2 for more information). My rationale is that in order to compare values globally, we need to use analogous values.

Several interesting observations can be made from Table 1. The first observation is that the VOSL estimates range from 0.1 (Russia, various sectors) to 32 (Canada, occupational sector), all in 2024 million USD. In fact, the minimum VOSL is 320 times the maximum value! Generally, we can observe a weak correlation with GDP per capita of the countries, contrary to what found by Lindhjem et al. (2011). The second observation is that even within a country, a substantial variation in estimates exists. As two extreme cases, Canada (2.6 to 32) and Sweden (1.7 to 18.8) have enormously different estimates, according to different studies.

The third observation is that VOSL depends significantly on the sector. Generally, the transportation sector holds higher VOSL, but this is not universal since the sector could pose two inherently different risks (accidents versus air/noise pollution). The fourth observation is that even within the same government, different organizations might recommend different values. For instance, the U.S. department of transportation (13.8 to 15.4) suggests a relatively lower value compared to those of the environmental protection agency (16.8). Even the U.S. DOT value itself seems strange, decrease with time from 15.4 to 13.8 USD million. The final general finding is that stated preference VOSL studies tend to generate lower estimates than those of revealed preference data (Viscusi and Aldy, 2003; Lindhjem et al., 2011; Viscusi and Gentry, 2015).

Table 1 Adjusted VOSL estimates from various previous studies (in 2024 million USD)

	Country	Estimate (Range) in millions	Year of analysis	Sector	Adjusted value (2024 USD million)	Reference
1	Australia	5.4 Aus$	2023	Health	**3.5 USD**	Australian Government (2023)
2	Canada	21 CAD	2000	Occupational	**32 USD**	Lanoie et al. (1995)
3	Canada	3 CAD	2018	Transportation	**2.6 USD**	Transportation Safety Board of Canada (2018)
4	Canada	16 CAD	2018	Transportation	**13.6 USD**	Daher et al. (2018)
5	India	44.7 INR	2018	Manufacturing	**0.8 USD**	Majumder & Madheswaran (2018)
6	New Zealand	2 to 4.2 NZ$	1991-2016	Transportation	**4.6 to 3.4 USD**	Ministry of Transport (2016)
7	New Zealand	10.5 NZ$	2022	Health	**6.5 USD**	Hogan &Song (2022)
8	Singapore	0.9 to 2.1 Sin$	2007	Health	**1.1 to 2.6 USD**	Hoon and Lim (2008)
9	Singapore	1.9 Sin$	2008	Transportation	**2.3 USD**	Le et al. (2011)
10	Sweden	9 to 98 SEK	1995	Health	**1.7 to 18.8 USD**	Hultkrantz (2012)
11	Russia	1.9 to 7.5 Rub	2015	Various	**0.1 to 0.5 USD**	Zykova (2015)
12	Taiwan	0.6 USD	1995	Occupational	**1.1 USD**	Liu and Hammitt (1999)
13	Turkey	0.9 Lira	2012	Health	**0.7 USD**	Tekeşin and Ara (2017)
14	United Kingdom	£1.7	2013	Transportation	**3.6 USD**	Transport Safety Commission (2015)
15	United States	9.1 USD	2010	Environmental	**16.9 USD**	Appelbaum (2011)
16	United States	9.1 to 13.2 USD	2012- 2023	Transportation	**15.4 to 13.8 USD**	USDOT (2021)

* The values in the Table are all point estimates.

Table 2 Components of the estimated adjusted values (for Table calculations)

	Country	Interest rate %	Exchange rate ($ to currency)
1	Australia	4.35	0.63
2	Canada	3.3	0.7
3	India	6.9	0.012
4	New Zealand	4.3	0.57
5	Singapore	3.1	0.74
6	Sweden	2.6	0.091
7	Russia	21	0.011
8	Taiwan	2	1
9	Turkey	32	0.028
10	United Kingdom	4.7	1.26
11	United States	4.5	1

* Formula used for conversion is:

2024 Value = (Original estimate × Exchange rate) × ((1+Interest rate/100) ^ (2024-Year of analysis))

Conclusion

The key reason for studying value of statistical life (VOSL) is to inform public policy analysts regarding the allocation of limited resources. VOSL balances additional risk and incremental benefits from any project/policy, representing the associated marginal cost of death prevention. Therefore, it is an extremely important figure for a variety of public sector decisions that could reduce fatality risks, including safety, healthcare, insurance, environmental, climate change, etc. Moreover, the improvement in VOSL estimates could lead to more informed public policy interventions, especially to address market failures regarding environmental externalities (de Dios Ortúzar et al., 2000). In this paper, I reviewed VOSL from numerous studies. My general finding is that VOSL is radically different in different countries ranging from 0.1 in Russia to 32 in Canada, in 2024 million USD. Even within a country the range could be different, according to the sector of concern, regional difference and socioeconomic factors. Although it might seem questionable from the equity aspect, policy makers should consider such disparities in their public policy/project analyses. Otherwise, they could prescribe uninformed if not entirely wrong choices.

Copyright Note

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