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Research Article

Estimating the Value of Statistical Life in a Road Safety Context Based on the Contingent Valuation Method

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A cost-benefit analysis in a road safety context fundamentally analyzes the advantage of higher safety or lower risk. It can help determine if increasing spending on road safety programs is cost-effective. This study estimates the value of statistical life (VSL)—the amount of money that might be justified to save one person's life. The VSL is calculated using the willingness to pay (WTP) data obtained through a contingent valuation survey. Three discrete choice models are developed: log-logistic, log-normal, and Weibull. The log-logistic model outperforms the log-normal and Weibull models, comparing Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. We consider the log-logistic model's mean and median WTP values to estimate the VSL value in the Ethiopian road transport safety context. The VSL estimate in the Ethiopian road transport safety context is 53.52 million ETB (USD 1.07 million). The respondents' median WTP is ETB 714.44 (USD 14.23). Although the study is in Ethiopia, the findings can be applied to other low- and middle-income countries (LMICs) for the same purpose with modifications. The research findings will aid in a better understanding of the economic efficiencies of increased spending on road safety initiatives. Future research could compare current trends in road safety investment to the amount that should be spent based on the economic justifications from this study.

1. Introduction

Transportation is one of the vital driving engines of global economic development [1]. Despite its importance, transport has several negative externalities. Road traffic crashes are among the most dominant transport externalities. According to the 2020 World Health Organization (WHO) global status report on road safety, road crashes cost 1.35 million lives annually and cause more than 500 million casualties [2]. While there is a significant increase in traffic volume, the number of people killed or injured in road traffic crashes has decreased in recent years. Increased road safety is aided by implementing safety innovations in cars, infrastructure, and traffic behavior [3]. There is no guarantee that these reductions in traffic accidents will continue, especially when introducing and implementing further safety enhancements places a growing load on household and government budgets. A cost-benefit analysis can, thus, help determine the economic efficiency of increased spending on road safety policies [4].

Human life's valuation is commonly discussed in the literature, sometimes focusing on any such calculation's unethical nature. However, the advantage of increased safety or risk reduction is assessed in a cost-benefit analysis. The value of a statistical life (VSL) is the amount of money that can be justified to save one person's life. It is the estimation of the value of a change in risk that saves one life rather than the estimation of a specific individual's life worth [5]. In this study, we are interested in the monetary value of increased safety, particularly in the value of reducing the risk of mortality. Economists commonly refer to the economic worth of reducing mortality risks as the "value of life." This expression has an evident, uncontroversial meaning for individuals familiar with the lexicon. Others may object because it appears to indicate that human life can be valued when it should be "priceless." The term "value of life" is a shortened version of the term "statistical life value," which refers to the monetary value of a mortality risk reduction that prevents one statistical death. As a result, it should not be construed as a measure of how much people are ready to spend to save a specific life [6]. The value of statistical life does not measure what a person is willing to pay to avoid certain death but what a group is willing to pay to reduce the risk of death [7].

Although the willingness to pay (WTP) technique may be used to assess the price of any nonmarket product, it is critical to analyze it carefully in the context of road safety. A cost-benefit analysis in road safety should focus on the WTP for lowering the probability of becoming a fatal victim or suffering a significant injury because of a road traffic crash among a particular demographic group. This method is consistent with the evaluation of transportation projects, in which implementation should be decided before the occurrence of a specific incident [8].

According to past studies, VSL estimate findings are sensitive to the sectors examined, the estimating techniques utilized, the risk reduction levels, and the demographic and economic characteristics of the studied population [9]. The sector chosen in this study to estimate the VSL is the transport sector, and the context is road safety. The risk reduction level is a fifty percent reduction in road traffic fatalities. The investigated population is in Addis Ababa, the capital city of Ethiopia, and the demography is quite mixed. It is a diverse economic society with the highest exposure to the risk of road traffic crashes. The study is conducted based on respondents' WTP collected using an online survey and a contingent valuation method (CVM) for eliciting the WTP information [10]. We chose the CVM statistical approach because it is very flexible, making it feasible to value a wider range of nonmarket commodities and services than is conceivable with any other nonmarket valuation technique. Due to its flexibility, the CVM approach has been extensively utilized for assessing the value of statistical life in numerous countries across various fields, from health to environment and transportation. This is especially useful when comparing the VSL estimates from this study to those from other nations in a similar context or when comparing the estimates across different disciplines to help develop a global policy [11]. In a road traffic safety context, VSL is calculated by looking at the link between an individual's WTP for a marginal reduction and the probability of being killed in a road traffic crash.

Empirically, the marginal rate of substitution (MRS) is estimated by dividing WTP by the change in initial risk. For practical reasons, this change cannot be "marginal," so the difference is denoted as p. This quotient is interpreted as the value of a risk reduction or the VSL [10]. The contingent valuation method (CVM), a survey-based approach, directly examines the amount of money people are ready to pay for a specified reduction in the risk of death in a hypothetical scenario. CVM excels at capturing economic loss and disutility [12]. Correlation analyses are also implemented in this study incorporating the explanatory variables. This approach will explain how WTP is affected by different variables.

Although several VSL studies have been conducted in the US and other developed countries, few have been conducted in the developing world, according to the literature evaluated in this study and the World Bank Research Group report [9]. The study is novel primarily because of this. As far as the researchers are aware and the databases searched, it is the first VSL investigation in the context of road safety in Ethiopia, which makes it unique. Though there are a few studies in low- and middle-income countries, they primarily aim at estimating the willingness to pay for risk reductions. However, this work advances the analysis by evaluating the VSL in addition to modeling and comparing the willingness to pay for risk reduction. Other low- and middle-income countries with Ethiopia-like demographic characteristics can use the study's findings with certain adjustments.

The study's first objective is to elicit the WTP and estimate VSL in the road safety context of Ethiopian transport to assist in the cost-benefit analysis of the additional investment in road safety improvements. The second objective is to fill the gap in the literature on VSL estimation in the road safety context of low- and middle-income African countries. It is essential to make the study since transferring VSL estimates with calibrations from developed countries does not give accurate information for the cost-benefit analysis. The income elasticity of VSL in the developing countries is high and so does the disparity between the VSL estimates. The third objective is to formulate policy recommendations based on the findings of this study.

The paper is generally organized into six sections. The first section is the opening section, which summarizes the study's context and describes the investigation's topic, objectives, and scope. The second section explores the literature to map the existing discussion and identify the gaps. The third section explains the general steps followed in the study and the methodologies used to collect and analyze the data. It also expounds on the underlying mathematical theory that reinforces the analysis. The fourth section deals with interpreting the study's key findings and results. The fifth section discusses the policy implications of the findings. The sixth and final chapter comprises the study's implementations, limitations, recommendations for future works, and concluding remarks.

2. Literature Review

We conducted a comprehensive literature review to map the existing knowledge, identify the gaps, and formulate the research questions. Scopus and Web of Science databases were used to extract the extant literature. On Scopus, we ran the following Boolean operator and extracted 13 documents: *TITLE - ABS - Key ((contingent AND valuation OR willingness AND to AND pay OR value AND of AND statistical AND life OR value AND of AND life) AND (road AND safety OR road AND transport OR transport OR traffic AND safety))*. We used the following key search term on Web of Science and extracted 17 documents: *ALL = (contingent valuation, road safety, willingness to pay, value of statistical life, VSL, and value of life)*. In both databases, the search was refined from 2010 to 2021, and document types were defined as full articles and conference papers. After combining the results from the two databases and removing six duplicate documents, 24 documents were finally picked for analysis.

The literature can be summarized into four main categories based on the nature of the composition, as shown in Table 1, to map the existing knowledge and identify the gap.

Direct elicitation of the VSL or WTP based on various methodologies, ranging from contingent valuation to discrete choice experiment, is the first and largest category. It is evident from the findings of these researches [13–23] that the values vary significantly.

The meta-analysis, the second category of the literature, is an indirect approach to eliciting VSL estimation by linking many direct investigations. In their meta-analysis, [33] employed 26 foreign contingent valuation (CV) studies to empirically determine adjustment factors for "out of context" benefit transfer (BT) purposes. They also discovered that VSL estimations for road safety should be multiplied by 1.8 before being used in the context of air pollution [34]. A global meta-analysis of stated preference surveys of mortality risk valuation calculated the VSL to be between 2.4 and 7.4 million US dollars.

Studies based on any comparison fall under the third category of the literature. [25] compared CV approaches based on the chaining method and found that VSL values for reducing child fatalities highly exceed those for adults, confirming previous assumptions. Finally, they replicated the chaining strategy in a large, nationally representative sample of parents for the first time. [26] looked at the existence of a cancer premium associated with road traffic accidents, sudden cardiac arrest, and amyotrophic lateral sclerosis (ALS). They discovered that VSL drastically changes between situations, with ALS having the highest VSL and road traffic accidents having the lowest. [27] found that respondents place a higher value on the effects of severe accidents than fatal ones after comparing the WTP for nonfatal and fatal traffic accidents. Having evaluated stated and observed WTP for traffic safety and traffic safety equipment, [29] concluded that the stated and observed WTP are not consistent. [28] found out that the effect of the cause of death is as significant as the effect of other sources of VSL heterogeneity. [30] conducted a VSL study in Italy and the Czech Republic using similar protocols. They discovered that when the reason for death is not considered, child and adult VSL are not significantly different in Italy. At the same time, the difference is minimal in the Czech Republic. They distinguish between child and adult VSLs based on the cause of death. They found that values vary at a 1% level for respiratory disorders and road traffic accidents but not cancer risks. Using a choice experiment survey in Sweden, [31] assessed VSL estimates for driving, drowning, and fire incidents. According to the researchers, the VSLs for fire and drowning incidents were around one-third lower than those for traffic accidents. They concluded that, while respondents are more concerned about traffic accidents, this does not explain the disparity in VSL estimates. There was no statistically significant difference between fire and drowning accidents. [32] employed a stated preference survey to show that WTP for a private risk reduction is three times higher than WTP for a public risk reduction and that some of the differences can be explained by respondents' sentiments towards privately and publicly delivered commodities in general.

The fourth and last category of studies comprises those conducted on the methods. [8] summarized the literature's most popular approaches for analyzing the VSL and concluded that the stated choice (SC) approach eliminates some of the alternative approaches' most notable flaws while also providing significant flexibility that can be used to resolve its shortcomings. [35] examined 12 VSL studies conducted in Sweden since 1996 and found some issues with the estimates' validity, including the fact that VSL is highly connected to the extent of the mortality risk reduction, indicating significant scale insensitivity.

There are grey areas in the literature, and African countries are among them. Numerous VSL studies are conducted in Africa in contexts other than road safety, e.g., alcohol-related harms in South Africa [36], malaria control in Zanzibar [37], prevention of mother-to-child transmission services in a Nigerian hospital [38], and water hyacinth control in Ethiopia [39]. In the literature that we examined since 2010, we found only one VSL study conducted in the road transport context in Sudan in 2015 [21] from African countries, according to the databases searched. Even though low- and middle-income countries (LMIC) are the ones who suffer the most from transportation-related issues and road traffic crashes, there is essentially little to no research on the economic justifications for road safety measures. This study is aimed at filling this huge gap.

3. Methodology

3.1. General Procedure. From defining the valuation problem to eliciting the WTP and VSL values and reporting the results, the current study followed the steps presented in Figure 1.

There are numerous approaches to estimating the VSL. The direct approach, scaling approach, and meta-analysis are the most common and broader approaches. This study employed the contingent valuation-based stated survey, a straightforward approach to estimating WTP. The CV approach was first presented by Ciriacy-Wantrup [40], who believed that preventing soil erosion creates certain "additional market advantages" that are public goods in nature, and one of the feasible means of evaluating these benefits is to elicit individuals' WTP for these benefits using a survey method [41, 42]. Davis [43], however, was the first

Table 1: Summary of literature in descending chronological order (source: authors).

No.	Authors	VSL	CV	CE	R	MA	Country of study	VSL estimates (currency)	Ref.
Category I: direct VSL estimation									
1	Sánchez et al. (2021)	√	√	—	—	—	Spain	1.3M-1.7M (EUR)	[13]
2	Mon et al. (2019)	√	√	—	—	—	Myanmar	87K-163K (USD)	[14]
3	Flügel et al. (2019)	—	√	—	—	—	Norway	46M-58M (NOK)	[15]
4	Mon et al. (2018)	√	√	—	—	—	Myanmar	98K-136K (USD)	[16]
5	Mon et al. (2018)	√	√	—	—	—	Myanmar	122K-136K (USD)	[17]
6	Niroomand and Jenkins (2017)	√	—	√	—	—	Cyprus	699K (SIC)	[18]
7	Yang et al. (2016)	√	√	—	—	—	China	505K-587K (USD)	[19]
8	Niroomand and Jenkins (2016)	√	—	√	—	—	Cyprus	315K-1.1M (SIC)	[20]
9	Mofadal et al. (2015)	√	√	—	—	—	Sudan	19K-101K (USD)	[21]
10	Le et al. (2015)	√	—	√	—	—	Singapore	1.9M (SGD)	[22]
11	Liu and Zhao (2011)	√	√	—	—	—	China	1.11M-1.56M (CNY)	[23]
12	Rheinberger (2011)	√	—	√	—	—	Switzerland	6.0-7.8M (CHF)	[24]
Category II: comparative approaches									
13	Balmford et al. (2019)	—	—	—	—	—	United Kingdom	—	[25]
14	Olofsson et al. (2019)	—	√	—	—	—	Sweden	—	[26]
15	Haddak (2016)	√	√	—	—	—	France	—	[27]
16	Alberini and Ščasný (2013)	√	—	√	—	—	Italy	—	[28]
17	Andersson (2013)	√	√	—	—	—	Sweden	—	[29]
18	Alberini and Ščasný (2013)	√	—	√	—	—	Italy and Czech Rep.	—	[30]
19	Carlsson et al. (2010)	—	—	√	—	—	Sweden	—	[31]
20	Svensson and Vredin Johansson (2010)	√	—	—	—	—		—	[32]
Category III: meta-analysis									
21	Dekker et al. (2011)	—	—	—	—	√	Global	26 international CV	[33]
22	Lindhjem et al. (2011)	√	—	—	—	√	Global	2.4-7.4M (USD)	[34]
Category IV: review									
23	Bahamonde-Birke et al. (2015)	—	—	—	√	—	Global	—	[8]
24	Hultkrantz and Svensson (2015)	√	—	—	√	—	Sweden	—	[35]

Note: VSL: value of statistical life; CV: contingent valuation; CE: choice experiment; R: review; MA: meta-analysis; EUR: euro; USD: United States dollars; NOK: Norwegian krone; SIC: Swiss coin; SGD: Singapore dollar; CYN: Chinese yuan; CHF: Swiss franc.

to utilize the contingent valuation technique empirically when they evaluated the advantages of geese hunting through a survey of goose hunters. The CV method is the most common method used today in many disciplines [44]. In many countries, it is also a popular method for eliciting WTP for risk reduction or safety enhancement in the context of road safety.

3.2. Data Collection and Preparation. The study is conducted in Addis Ababa, the capital city of Ethiopia. The questionnaire is designed to have three sections. The first section asks respondents about their demographic information such as age, gender, marital status, income, education, accident seen, and the accident involved. The second section explains the crisis caused by road traffic crashes, the number of lives lost, the property damage every year globally, and the magnitude of the economic burden it imposes, as a piece of background information for the respondents. This section is essential because the respondents' WTP depends on their scientific knowledge of the subject [45]. The third section is the double-bound dichotomous choices (DBDC) given to the respondents. The survey questions ask the respondents, for example, "Are you willing to pay Ethiopian Birr (ETB) 400 annually to reduce road traffic fatalities by fifty percent annually?" Suppose the survey respondents' answer is yes. In that case, they will be asked for a follow-up question, "Are you willing to pay ETB 800 annually to reduce road traffic fatalities by fifty percent annually?"

Suppose the respondents' answer to the first question is no. In that case, the follow-up question will be, "Are you willing to pay ETB 200 annually to reduce road traffic fatalities by fifty percent annually?" The lower bound is assumed to be zero for respondents who answer "no" to both the initial and the follow-up questions. The upper bound is infinity for respondents who answer "yes" to both the initial and the follow-up questions [46]. Thus, the WTP is interval censored. Using both the first and second replies significantly boosts the statistical power of the WTP estimate, resulting in a much narrower confidence interval for the WTP estimate for any given sample size [47]. Four sets of amounts

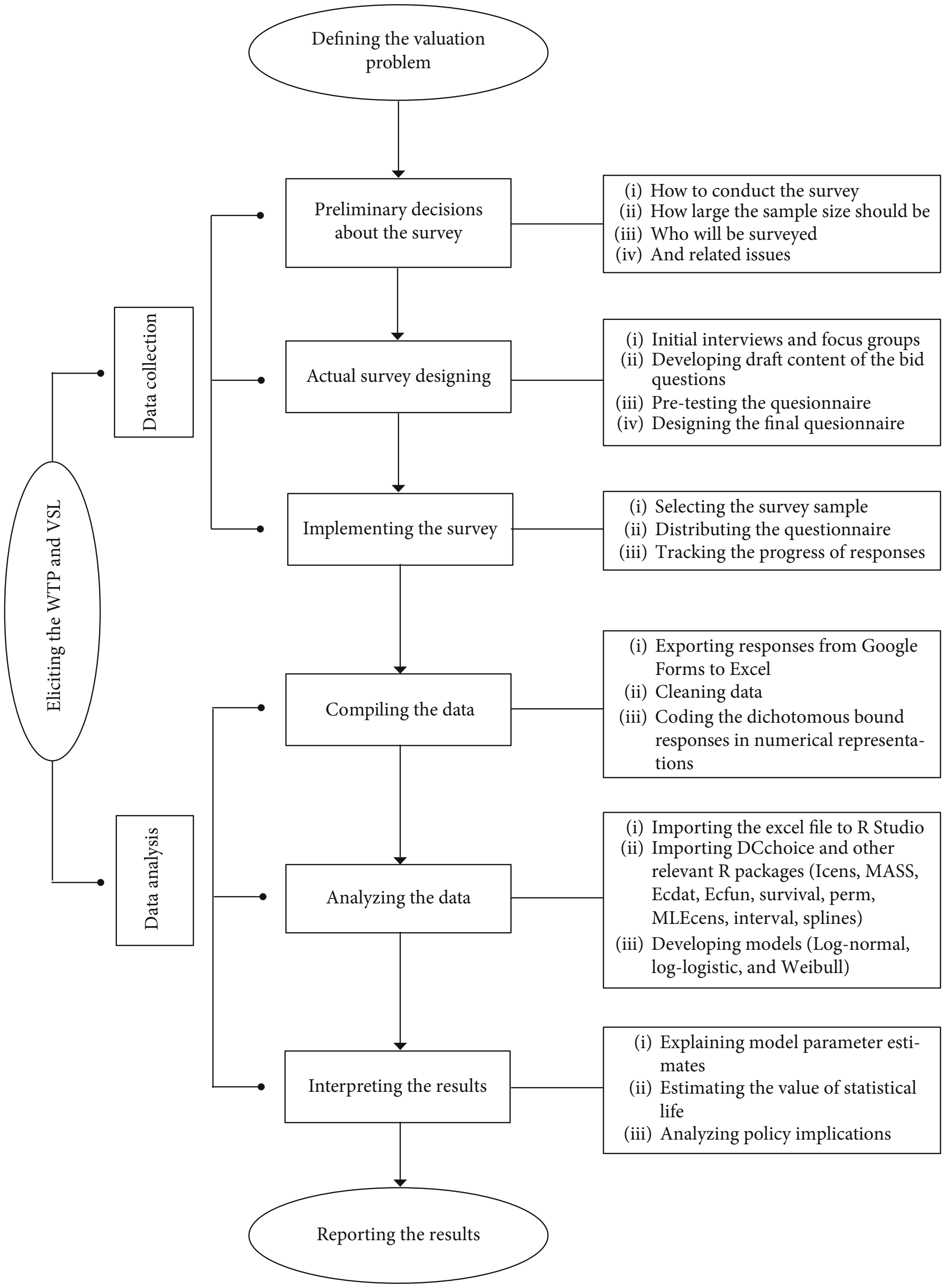


Figure 1: Theoretical framework of the study (source: authors).

(200, 400, 800, and 1600 ETB) are used in this survey, as shown in Table 2.

The sampling technique employed in this study is snowball or network sampling. Start with a few participants and then ask them to nominate or recommend others known to have the profile attributes or desired characteristics. An Internet-based contingent valuation survey was established in this study. Then, a valid questionnaire was filtered after pretreatment. The survey was conducted from December 2020 to August 2021 and was initially distributed to 1000 respondents. After the missing entries of observations were removed, the original data set contains 750 observations, including bids and replies to the DBDC survey, and packed to DCchoice, a subset of the original data, into a data frame object.

After a cluster analysis based on a k-means algorithm, we determined these four initial bids and income categories. With fifty random experimental open format surveys, we queried the maximum WTP and monthly income. Then, we analyzed four clusters and rounded off the cluster centers

Table 2: Sets of bid information (source: authors).

Income range in ETB	Less than 5,000	5,000–9,999	10,000–19,999	More than 20,000
Initial question bid	200	400	800	1600
Follow-up question low	100	200	400	800
Follow-up question high	400	800	1600	3200

Table 3: WTP intervals for four initial bids (source: authors).

Initial bid	Yes-yes	Yes-no	No-yes	No-no
200	[200, +∞)	[200,400]	[100,200]	(-∞,100]
400	[400, +∞)	[400,800]	[200,400]	(-∞,200]
800	[800, +∞)	[800,1600]	[400,800]	(-∞,400]
1600	[1600, +∞)	[1600,3200]	[800,1600]	(-∞,800]

Table 4: Description of variables (source: authors).

Variable	Definition	Category
GEN	Gender	1 if female, 0 otherwise.
AGE	Age group in years	1 if 18-29, 2 if 30-39, 3 if 40-54, 4 if >55.
EDU	Educational level	1 if college diploma and below, 2 if bachelor, 3 if masters, 4 if PhD and above.
SEEN	Accident seen	1 if seen, 0 otherwise.
INV	Accident involved	1 if involved, 0 otherwise.
MAR	Marital status	1 if married, 0 otherwise.
INC	Income group in ETB	1 if less than 5,000, 2 if 5,000-9,999, 3 if 10,000-19,999, 4 if more than 20,000.

Table 5: Acceptance probability, mean, and median WTP functions.

Distribution	Acceptance probability	Mean	Median
Log-normal	$\Phi(\alpha - \beta \ln (t))$	$\exp\left(\frac{\alpha}{\beta}\right) \exp\left(\frac{\alpha}{2\beta^2}\right)$	$\exp\left(\frac{\alpha}{\beta}\right)$
Log-logistic	$\frac{1}{1+\exp(-\alpha+\beta \ln (t))}$	$\exp\left(\frac{\alpha}{\beta}\right)\Gamma\left(1-\frac{1}{\beta}\right)\Gamma\left(1+\frac{1}{\beta}\right)$	$\exp\left(\frac{\alpha}{\beta}\right)$
Weibull	$\exp\{-\exp(-\alpha+\beta \ln (t))\}$	$\exp\left(\frac{\alpha}{\beta}\right)\Gamma\left(1-\frac{1}{\beta}\right)$	$\frac{\exp(\alpha/\beta)}{(\ln(2))^{\beta}}$

Source: [44, 53]. Note: in the log-logistic and Weibull distributions, a finite median exists when $\beta > 1$. Otherwise, it becomes infinity [54].

to the nearest multiple of 100 and considered them as initial bids, while we considered four ranges of the clusters along the horizontal axis as income levels. The bids were asked in Ethiopian birr [48]. The WTP intervals for the four initial bids are presented in Table 3. The final questionnaire distributed to the respondents can be found in Supplementary Materials (available here) of this article.

The seven sociodemographic variables are coded as follows. Income denotes monthly household income in ETB and is categorized as one for less than 5,000, two for 5,000-9,999, three for 10,000-19,999, and four for more than 20,000. Age is coded as one for respondents between 18 and 29 years old, two for 30-39, three for 40-54, and four for those above 55 years old. Education is coded as one for college diploma and below, two for bachelor's, three for master's, and four for PhD and above. Gender is coded as one if the respondent is female and zero otherwise. "Accident seen" is coded as one if the respondent has seen an accident before and zero otherwise. "Accident involved" is coded as one if the respondent experienced an accident and zero otherwise. Marital status is coded as one if the respondent is married and zero otherwise. Gender, accident seen, the accident involved, and marital status are all dummy variables. All the variables considered in the analysis are described in Table 4.

3.3. Data Analysis Methods. The data from this study's double-bound dichotomous choice survey were analyzed using the DCchoice package for R [49]. The model selection criteria were minimizing AIC and BIC values. Individual variables' and models' statistical significances were also measured. The goal is to determine the mean or median WTP

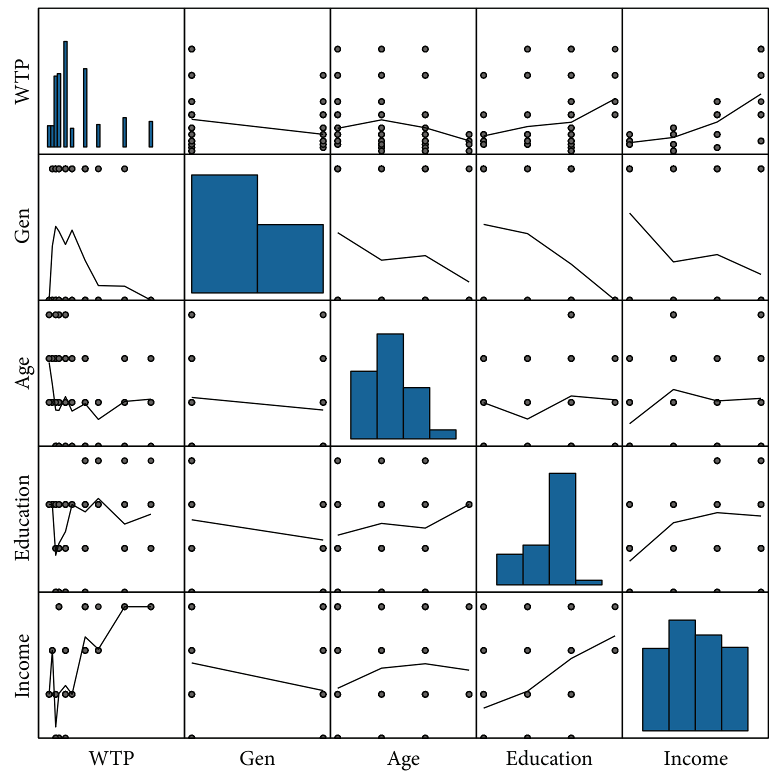


FIGURE 2: WTP against the profile of the respondents that are among the explanatory variables (source: authors).

TABLE 6: Correlations (source: authors).

		WTP	Gen	Age	Education	Income
WTP	Pearson correlation	1	-0.274**	-0.041	0.224**	0.663**
	Sig. (2-tailed)		0.000	0.258	0.000	0.000
	N	750	750	750	750	750
Gen	Pearson correlation	-0.274**	1	-0.169**	-0.282**	-0.285**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000
	N	750	750	750	750	750
Age	Pearson correlation	-0.041	-0.169**	1	0.138**	0.175**
	Sig. (2-tailed)	0.258	0.000		0.000	0.000
	N	750	750	750	750	750
Education	Pearson correlation	0.224**	-0.282**	0.138**	1	0.440**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000
	N	750	750	750	750	750
Income	Pearson correlation	0.663**	-0.285**	0.175**	0.440**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	
	N	750	750	750	750	750

**Correlation is significant at the 0.01 level (2-tailed).

for the proposed change based on the responses to the WTP questions. Even though both the mean and the median are valid measures of central tendency, most studies have focused on the median WTP. The median WTP can be considered a price that half of the population would be willing to pay and a value that most of the community supports.

Furthermore, various technical considerations must be made while determining the mean WTP, complicating the

Table 7: Correlations of different combinations against WTP (source: authors).

	MLEDU	FLEDU	MHEDU	FHEDU	FLINC	MHINC	FHINC	MLINC
Pearson correlation	0.209*	0.171*	0.152**	a	0.908**	0.518**	0.131	0.184**
Sig. (2-tailed)	0.016	0.036	0.005		0.000	0.000	0.193	0.007
N	131	152	344	123	175	261	100	214

Correlation is significant at 0.01 (**) and 0.05 (*) levels (2-tailed), respectively. a: cannot be computed because at least one of the variables is constant.

Table 8: Parameter estimates of the log-normal model (source: authors).

	Estimate	Std. error	*Z* value	*p* value
Intercept	6.64316	0.34976	18.994	<2.2*e*-16 ***
Gender	-0.34313	0.09074	-3.781	0.000156 ***
Age	-0.31801	0.05364	-5.929	<2.2*e*-16 ***
Education	0.25290	0.05469	4.624	4*e*-06 ***
Accident seen	0.86526	0.16088	5.378	<2.2*e*-16 ***
Accident involved	0.15981	0.09467	1.688	0.091396 .
Married	0.27533	0.08385	3.284	0.001025 **
Log(bid)	-1.13555	0.04029	-28.186	<2.2*e*-16 ***
Log-likelihood	-992.564903			
LR statistic	118.108 on 6 degree of freedom (DF)			
p value	≤0.001			
AIC	2001.129805			
BIC	2038.090391			
Iterations	57 13			
Convergence	True			
Distribution	Log-normal			
WTP estimates:				
Mean = 1080.016				
Mean = 999.7369, i.e., truncated with the max bid				
Mean = 1049.144, i.e., truncated with the max bid with adjustment				
Median = 732.8736				

Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1.

analysis. The "yes"/"no" data from the responses to the WTP survey question was coded as "yes" = 1 and "no" = 0. So, the response variable is a dichotomous [0, 1] variable in the statistical analysis. Therefore, we applied the general statistical procedures for the dichotomous data for CV analysis.

Although several R packages can be used to analyze CV data, this study employed the DCchoice package distributed from the Comprehensive R Archive Network (CRAN) [50]. The DCchoice package (i) is explicitly created for CV analysis; (ii) includes a range of additional features that add value to CV studies, such as the ability to estimate nonparametric models; and (iii) is (relatively) easy to use. The log-logistic model derived from the random utility function examines the binary response data received through the double-bounded dichotomous choice format [51]. Related parameters, median, and mean WTP are derived from the maximum likelihood estimation. According to the random utility theory, an individual's indirect utility function, $U(q, y)$, consists of a systematic component, $V(q, y)$, and a random component, ε. The former is determined by the attribute variables related to the alternative, whereas the latter cannot be observed and is, thus, random to the analyst.

$$U(q, y) = V(q, y) + \varepsilon, \quad (1)$$

where q represents the level of provision of nonmarket goods and y represents an individual's demographic profile like income, age, gender, and education, among others. However, the study refers to only "income" for simplicity. One fundamental assumption is that everyone is certain of their utility function and wishes to maximize it. The indirect utility function can take many forms, and the simplest form is the linear utility model, given by

$$V_j = \alpha_j + \beta_y + \varepsilon_j \, j = 0, 1, \quad (2)$$

where α is constant and β is the marginal utility of income. When respondent n is offered an amount of money t_n as the first bid, then t_n^U represents the second bid when respondent n's answer is "yes" to the first initial bid, whereas t_n^L represents the second bid when the respondent answers "no" to the initial bid. Moreover, respondent n's maximum WTP is represented by y_n^*.

The probability of respondent n's answer to be "yes" to both the first and second bids (P^{yy}), i.e., when they are willing to pay both amounts, is given by

$$P^{yy}\left(t_n, t_n^U\right) = \Pr\left(t_n \le y_n^*, t_n^U \le y_n^*\right) = \Pr\left(t_n^U \le y_n^*\right) = 1 - F\left(t_n^U\right). \quad (3)$$

Likewise, the probability of respondent n's answer to be "no" to both the first and second bids (P^{nn}), i.e., when they are unwilling to pay both amounts, is given by

$$P^{nn}\left(t_n, t_n^L\right) = \Pr\left(y_n^* \le t_n, y_n^* \le t_n^L\right) = \Pr\left(y_n^* \le t_n^L\right) = F\left(t_n^L\right). \quad (4)$$

The probability of respondent n's answer to be "yes" to the first bid and "no" to the second bid (P^{yn}) or "no" to the first bid and "yes" to the second bid (P^{ny}), i.e., when they are willing to pay one of the amounts offered, are given by, respectively

$$\begin{aligned} P^{yn}\left(t_n, t_n^U\right) &= \Pr\left(t_n \le y_n^*, y_n^* < t_n^U\right) = \Pr\left(t_n \le y_n^* < t_n^U\right) = F\left(t_n^U\right) - F(t_n), \\ P^{ny}\left(t_n, t_n^L\right) &= \Pr\left(y_n^* < t_n, y_n^* \ge t_n^L\right) = \Pr\left(t_n^L \le y_n^* < t_n\right) = F(t_n) - F\left(t_n^L\right). \end{aligned} \quad (5)$$

Therefore, the corresponding log-likelihood function for independent observations of a given sample N is written as follows:

$$\begin{aligned} \ln L = \sum_{n=1}^{n} &\left[d_n^{yy} \ln\left\{P^{yy}\left(t_n, t_n^U\right)\right\} + d_n^{nn} \ln\left\{P^{nn}\left(t_n, t_n^L\right)\right\}\right. \\ &\left.+ d_n^{yn} \ln\left\{P^{yn}\left(t_n, t_n^U\right)\right\} + d_n^{ny} \ln\left\{P^{ny}\left(t_n, t_n^L\right)\right\}\right], \end{aligned} \quad (6)$$

where d_n^{yy}, d_n^{nn}, d_n^{yn}, and d_n^{ny} are binary-valued indicator variables. For example, d_n^{yy} is equal to one if respondent n answers "yes" to both the first bid t_n and the second bid t_n^U and zero otherwise. The above log-likelihood equation can be rewritten in the following form to estimate parameters accordingly:

$$\begin{aligned} \ln L = \sum_{n=1}^{n} &\left[d_n^{yy} \ln\left\{\exp\left(\alpha - \beta t_n^U\right)\right\}\right. \\ &+ d_n^{nn} \ln\left\{1 - \exp\left(\alpha - \beta t_n^L\right)\right\} \\ &+ d_n^{yn} \ln\left\{\exp\left(\alpha - \beta t_n\right) - \exp\left(\alpha - \beta t_n^U\right)\right\} \\ &\left.+ d_n^{ny} \ln\left\{\exp\left(\alpha - \beta t_n^L\right) - \exp\left(\alpha - \beta t_n\right)\right\}\right]. \end{aligned} \quad (7)$$

Then, it can be expressed using a log-normal, log-logistic, and Weibull cumulative density function (CDF) [52], as shown in Table 5, where t is the bid offered for the respondent.

The model's mean and median WTP are estimated using the predicted coefficients from each model [51]. Once the WTP value is estimated, the next step is estimating the VSL—the amount an individual is willing to pay to reduce one fatality. The formula to calculate the VSL is given by [16].

$$\text{VSL (MRS)} = \frac{\text{mean or median WTP}}{\Delta p}, \quad (8)$$

where Δp is the probability of risk reduction. The correlation analysis and descriptive statistics are conducted using the IBM SPSS Statistics 25 software. Correlation analysis is conducted in this study incorporating the explanatory variables to explain how WTP is affected by different variables and their combinations.

4. Results and Discussions

4.1. Descriptive Statistics. A total of 1000 people were invited to fill out the survey, and 823 responded. After cleaning responses with missing entries, 750 of them were finally bundled with the DCchoice package as a data frame. 37% of the respondents are female, and 63% are male. 92% of the respondents had seen a traffic accident happen to others before, while 8% had not. 25% of the respondents had been involved in a traffic accident themselves. In comparison, 75% of them had not experienced an accident at all. 54% of the respondents are married, while the remaining 46% are not.

The relationship between the demographic characteristics, including gender, age, education, and income, and people's willingness to pay for risk reductions are shown in Figure 2. The respondents' willingness to pay rises as their income levels do. Given that costs grow in proportion to earnings, this seems obvious. When respondents' ages rise, their willingness to pay rises for age groups 1 and 2, but it falls for age groups 3 and 4. As people get older, their perception of death might also change. The alternative explanation is that older people may be more susceptible to and concerned about mortality from other causes in addition to those brought on by traffic crashes. Due to the nature of contingent valuation surveys, where respondents may not be aware of the extent of the risk they are being asked to assume, respondents' willingness to pay also rises as their education level does. In this case, those with higher levels of education are more likely to comprehend the risks and demonstrate a willingness to pay for risk reduction. Male respondents are more willing to spend than female respondents are. This may be explained by the nature of their prior exposure to transportation or mobility systems.

Correlations and statistical significance values are presented in Table 6. Income has the strongest correlation with WTP compared to other variables and is statistically significant at a 99% confidence level. In contrast, age is not a statistically significant variable.

Table 9: Parameter estimates of the log-logistic model (source: authors).

	Estimate	Std. error	Z value	p value
Intercept	11.01571	0.61388	17.944	<2.2e-16 ***
Gender	-0.55847	0.15118	-3.694	0.000221 ***
Age	-0.47396	0.08986	-5.275	<2.2e-16 ***
Education	0.51626	0.09228	5.594	<2.2e-16 ***
Accident seen	1.61644	0.29585	5.464	<2.2e-16 ***
Accident involved	0.32372	0.15870	2.040	0.041359 *
Married	0.45683	0.14353	3.183	0.001458 **
Log(bid)	-1.97137	0.07876	-25.031	<2.2e-16 ***
Log-likelihood	-990.363963			
LR statistic	123.200 on 6 DF			
p value	≤0.001			
AIC	1996.727927			
BIC	2033.688513			
Iterations	51 18			
Convergence	True			
Distribution	Log-normal			

WTP estimates:
Mean = 1138.83
Mean = 970.2766, i.e., truncated with the max bid
Mean = 1020.762, i.e., truncated with the max bid with adjustment
Median = 714.4393

Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1.

The influence of other combinations of subgroups under different variables was also tested for their impact against WTP. Eight combinations were identified and, namely, they are less educated male (MLEDU), less educated female (FLEDU), highly educated male (MHEDU), highly educated female (FHEDU), low-income male (MLINC), low-income female (FLINC), high-income male (MHINC), and high-income female (FHINC). The low-income female (FLINC) combination has the highest impact on the WTP for risk reduction, followed by the high-income male (MHINC). Table 7 summarizes the estimates of each combination. Except for FHINC, the correlation of other combinations with the WTP is statistically significant.

4.2. Model Estimation. We estimated the three models the log-normal, the log-logistic, and the Weibull and presented the results below. The models are compared with Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC). Table 8 presents the parameter estimates of the log-normal model. The model is accepted as it is statistically significant. All the variables are statistically significant at a 99.99% confidence level except for "married" and "accident involved", which are statistically significant at 99% and 90% confidence levels, respectively.

The parameter estimates of the log-logistic model are presented in Table 9. The model is accepted as it is statistically significant. All the variables are statistically significant at a 99.99% confidence level except for "married" and "accident involved", which are statistically significant at 99% and 95% confidence levels, respectively.

The parameter estimates of the Weibull model are presented in Table 10. The model is accepted as it is statistically significant. All the variables except for "accident involved" are statistically significant at a 99.99% confidence level.

The DCchoice package for R comes with the Krinsky and Robb method (kr) and the bootstrap (bo) method of constructing confidence intervals (CI) for different WTP estimates. Both methods depend on the simulation techniques of varying settings.

The confidence intervals of WTP estimates from the log-normal, log-logistic, and Weibull models are presented in Tables 11–13. The default 1000 iterations (boots) and 95% CI are considered for the estimation.

In both confidence interval generation approaches, the log-normal model parameter estimates of the bid satisfy the criteria for the presence of a finite mean WTP.

In both confidence interval generation approaches, the log-logistic model parameter estimates of the bid satisfy the criteria for the presence of a finite mean WTP.

In both confidence interval generation approaches, the Weibull model parameter estimates of the bid satisfy the criteria for the presence of a finite mean WTP.

The indicator "Convergence" in all three models is "True", which indicates that the optimization was successful in achieving convergence. Returning the lowest AIC and BIC values and the highest Loglikelihood ratio compared to the

Table 10: Parameter estimates of the Weibull model (source: authors).

	Estimate	Std. error	Z value	p value
Intercept	8.01325	0.41347	19.3804	<2e-16 ***
Gender	-0.61336	0.10339	-5.9324	<2e-16 ***
Age	-0.36989	0.05966	-6.2001	<2e-16 ***
Education	0.27540	0.06038	4.5614	5e-06 ***
Accident seen	0.72847	0.16249	4.4831	7e-06 ***
Accident involved	-0.03251	0.10282	-0.3162	0.7519
Married	0.45536	0.09000	5.0596	<2e-16 ***
Log(bid)	-1.23593	0.04586	-26.9514	<2e-16 ***
Log-likelihood	-1022.225879			
LR statistic	138.870 on 6 DF			
p value	≤0.001			
AIC	2060.451758			
BIC	2097.412344			
Iterations	61 14			
Convergence	True			
Distribution	Weibull			

WTP estimates:
Mean = 1099.226
Mean = 1015.419, i.e., truncated with the max bid
Mean = 1067.647, i.e., truncated with the max bid with adjustment
Median = 747.1968

Significance codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1.

Table 11: Confidence intervals for the WTP of the log-normal model (source: authors).

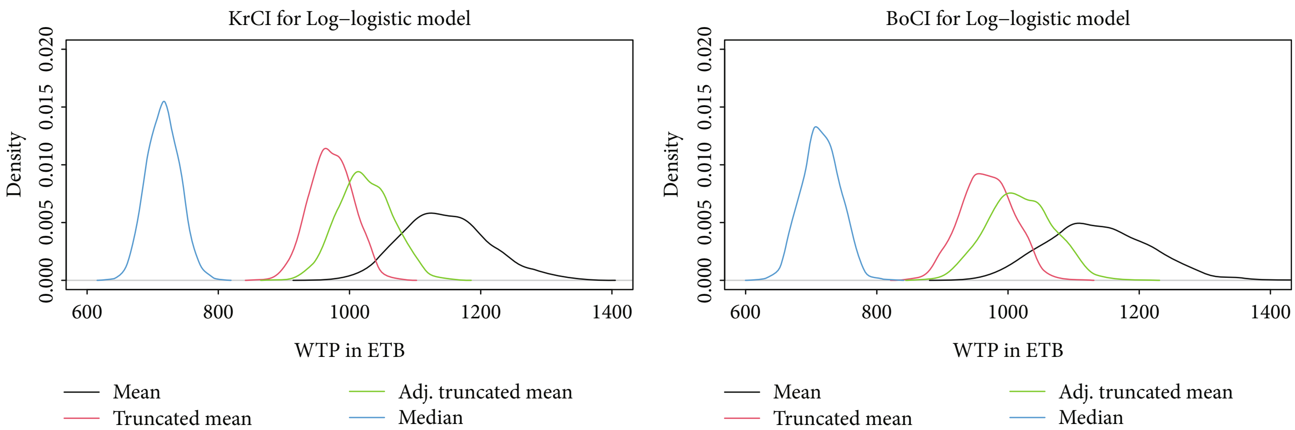
	Estimate	Krinsky and Robb		Bootstrap	
		LB	UB	LB	UB
Mean	1080.02	986.44	1197.50	973.80	1197.94
Truncated mean	999.74	934.69	1071.89	924.64	1075.14
Adjusted truncated mean	1049.14	968.96	1142.31	954.31	1149.35
Median	732.87	685.74	785.72	678.88	786.38

Table 12: Confidence intervals for the WTP of log-logistic model (source: authors).

	Estimate	Krinsky and Robb		Bootstrap	
		LB	UB	LB	UB
Mean	1138.83	1027.70	1281.16	993.70	1291.06
Truncated mean	970.28	906.02	1034.38	886.31	1045.31
Adjusted truncated mean	1020.76	942.61	1105.76	920.41	1116.08
Median	714.44	666.94	764.62	656.34	772.09

Table 13: Confidence intervals for the WTP of the Weibull model (source: authors).

	Estimate	Krinsky and Robb		Bootstrap	
		LB	UB	LB	UB
Mean	1013.57	942.78	1087.04	924.85	1097.71
Truncated mean	999.02	934.00	1062.44	915.52	1072.78
Adjusted truncated mean	1021.77	948.03	1098.27	929.19	1110.06
Median	806.85	744.97	862.03	742.11	869.89



(a) Krinsky and Robb confidence interval for log-logistic model

(b) Bootstrap confidence interval for log-logistic model

Figure 3: The simulated mean, median, truncated mean, and adjusted truncated mean of the WTP empirical distribution (source: authors).

Table 14: VSL in Ethiopia (1USD = 50ETB as of February 2022, according to the National Bank of Ethiopia) (source: authors).

	WTP ETB (USD)	Δp (×100,000 pop)	VSL ETB × 10^6 USD × 10^6
Mean	1020.76 (20.42)	13.35	76.46 (1.53)
Median	714.44 (14.23)	13.35	53.52 (1.07)

other two models, the log-logistic appears to be the best model. We run the log-logistic model with 51 iterations of the objective function and 18 evaluations of the objective function's gradient.

Density curves of the empirical distribution of the simulated, mean, truncated mean, median, and adjusted truncated mean of the WTP for the selected model (i.e., log-logistic model) are constructed with both simulation techniques (kr and bo) as shown in Figure 3. In both the Krinsky and Robb and the bootstrap confidence interval simulations, the highest and the lowest WTP amounts are found in the mean and the median, respectively, while the WTP amounts of the simulated truncated and adjusted truncated mean are closer. The final VSL estimation can be presented as a range instead of a single VSL estimate. In that case, the WTP amount with the highest density of the simulated median is considered a lower value of the range or the WTP amount, whereas the highest density of the simulated mean is regarded as a higher value of the range.

Since the log-logistic model is the best, the final WTP value to be considered in the VSL estimation would be 714.44 ETB. Ethiopia's road traffic death rate is 26.7 per 100,000 population, according to the WHO global status report on road safety [2]. The value taken for a 50% risk reduction is 13.35 per 100,000 population. The VSL estimates in Ethiopia's road transport safety context are calculated, and the results are presented in Table 14.

The study elicits the WTP of the Ethiopian transport stakeholders for a reduced risk of road traffic fatalities and evaluates the VSL. Therefore, the respondents' mean WTP is ETB 1020.76 (USD 20.42), while their median WTP is ETB 714.44 (USD 14.23). According to the mean and median WTP estimates, the VSL is found to be ETB 76.46 million (USD 1.53 million) and ETB 53.52 million (USD 1.07 million), respectively. If we compare the VSL estimate based on the median WTP finding in this study—USD 1.07 million—it is less than the average VSL estimate of the literature reviewed in the second section of this study—-USD 2.14 million. In their global meta-analysis of mortality risk valuation, [34] found a median VSL value of approximately USD 2.4 million as being comparable. In the literature that we examined in this study, we can witness a considerable disparity in the VSL estimates from the lowest, i.e., USD 19-101K for Sudan, to the highest, i.e., CHF 6-7.8M for Switzerland. Income elasticity of VSL is responsible for the disparity between the VSL estimates in this study and the global average. To ensure reliable data for the cost-benefit analysis of investments in improving road safety, it is crucial to conduct a VSL study that is geographical and context specific instead of transferring the VSL estimates of the developed nations because VSL estimates are sensitive and differ greatly across different countries and circumstances. The sensitivity of the method is even more significant in low- and middle-income countries.

5. Policy Implications

The value of statistical life estimates will be a significant input in regulations and policies' cost-benefit analysis. To overcome market failures in road traffic fatality risks, governments can make better-informed judgments and interventions. Before the implementation of the VSL methodology in regulatory impact analysis, governments used to assign a finite benefit value to these risks. Ethiopia and other low- and middle-income countries' transport regulatory bodies can use the findings of this study in the cost-benefit analysis (CBA) of additional investment in road safety improvements. Based on a meta-analysis, the Organization for Economic Cooperation and Development (OECD) recently developed an eight-step mechanism to transfer VSL estimates from current studies in environmental, health, and transportation policies [55]. The OECD recommends estimating VSL for countries within the OECD by transferring VSL from studies with similar demographic characteristics and adjusting for income using gross domestic product (GDP) per capita and income elasticity. In the same vein, the results in the current study are transferrable to other low- and middle-income countries with comparable demographic characteristics to Ethiopia's. The results will help formulate a more comprehensive road safety policy and plan that includes suitable strategies, priorities, quantifiable goals, and relevant actions.

6. Conclusions

This study is a first attempt to elicit the willingness to pay estimates in the road safety context of Ethiopian transport and analyzes the value of statistical life. It can also be transferred to other low- and middle-income countries, especially in Africa, where such studies are scarce but have similar demographic characteristics. The study will contribute to a better understanding of the economic efficiency of additional spending on road safety improvement policies. Authorities or decision-makers can introduce a broad range of safety enhancements in vehicles, infrastructure, traffic behavior, and management and regulations to increase road safety based on the findings of this study by making a cost-benefit analysis. The first key finding of the study is the respondents' median and mean WTP estimates and the VSL estimates. Given that most studies have focused on the median WTP, it can be concluded that the VSL estimate in the Ethiopian road transport safety context is 53.52 million ETB (USD 1.07 million). Another finding from this study is that age, gender, education, and income level all influence respondents' WTP to a varying degree, while income has the most significant impact. This research, therefore, provides insights for future studies as it is a novel study based on a well-established reliable approach and a relatively big sample size, and the findings are transferrable. The first limitation of the study is that the study used a uniform road traffic fatality rate for all types of road users. The second limitation is that during the VSL analysis, the traffic crash data are considered from the 2018 WHO global status report on road safety. The crash data in the WHO report vary from the data reported by the traffic police, which may affect the WTP and VSL estimates. The third limitation is that the scale bias as one of the fundamental concerns in all WTP surveys is whether respondents grasp the extent of the risk changes they are being asked to value or not and people's preferences have not yet been developed. Future research can be carried out to compare the current trends of road safety investments to the amounts that should be spent based on the economic justification of this study so that governments and relevant stakeholders can maximize their investments to help improve road safety and reduce property and life loss that occur due to road traffic crashes. Future studies can avoid scale bias in the CV approach by using visual assistance throughout the survey. Other advanced stated preference methods like choice experiments can be used to elicit the VSL. They can compare with the findings of this study. Different traffic fatality rates should also be used for different road users. The questionnaire should be designed with different risk reduction levels to examine insensitivity to scale. As Ethiopia and other low- and middle-income countries are grappling with the consequences of transport externalities, mainly road traffic crashes, this study significantly contributes to assisting policymakers in their cost-benefit analysis of additional investments in road safety improvements.

Data Availability

The data used in this study can be accessed by communicating via the corresponding author's email.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

AAM was responsible for conceptualization, methodology, survey design, data collection, formal analysis, software, coding, visualization, and writing the original draft. AAM and ADB were responsible for investigating, reviewing, and editing the original draft. TS supervised the study.

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Supplementary Materials

The survey used for the contingent valuation data collection in this study can be accessed through the following link and can be used by others for similar studies with proper citation of this article. *(Supplementary Materials)*

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