ANALYSIS AND PREDICTION OF ROAD ACCIDENT COST

Thesis

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

SUMAYYA NAZNIN P H

(187511CV506)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA

SURATHKAL, MANGALORE - 575 025

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DECLARATION

I hereby *declare* that the Research Thesis entitled "**Analysis and prediction of road accident cost**" which is being submitted to the **National Institute of Technology Karnataka, Surathkal** in partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **Civil Engineering**, is a *bonafide report of the research work carried out by me.* The material contained in this Research Thesis has not been submitted to any University or Institution for the award of any degree.

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Place: NITK Surathkal

Date: 01-08-2024

CERTIFICATE

This is to *certify* that the Research Thesis entitled **"Analysis and prediction of road accident cost"** submitted by **SUMAYYA NAZNIN P H**, (Register Number: **187511CV506**) as the record of the research work carried out by her, is *accepted as the Research Thesis submission* in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy**.

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ABSTRACT

Road traffic accidents (RTAs) significantly impact a country's economic advancement by consuming a large portion of its Gross Domestic Product (GDP), especially in developing countries. The proportionality of road accidents with urbanization mandates road accident cost analysis as a prime component in the planning and designing of road projects. The quantification of accidents and their associated parameters remains challenging, as it demands a meticulous approach. Moreover, allocation towards road safety infrastructure should be based on a cost-benefit analysis to ensure the most efficient use of available resources in formulating road safety policies, reinforcing the significance of road accident cost estimation. Different countries use varying methodologies for this estimation, rendering international comparisons unreliable. Notably, the existing methodologies mainly focus on developed countries, leaving a gap in the literature for developing nations.

Human Capital (HC) and Willingness to Pay (WTP) are two commonly used approaches for estimating accident costs. The HC method, using diverse data sources such as police accident databases, questionnaire surveys, private hospital records, and vehicle garage bills (considering collision types), provides a component-wise breakdown of costs. The RTA cost estimation using the HC method reveals the loss of productivity, accounting for 49% of total costs, as the most significant component. Medical costs comprised 24%, vehicle damage 10%, human costs 16%, and administrative costs accounted for a mere 1%. However, this method overlooks intangible factors like pain, grief, and suffering (PGS) along with the contribution of post-retirement victims and caregivers of RTA victims.

In contrast, the WTP-stated preference methodologies, Contingent Valuation (CV), and Discrete Choice Experiments (DCE) used in this study provide insight into the intangible costs, although with varying degrees of accuracy. Notably, WTP-CV estimates tend to have a lower bound, whereas WTP-DCE estimates are substantially higher. WTP-CV payment card approach reveals that accident costs are mostly influenced by population and risk reduction, with socioeconomic factors and driving behaviour also playing a major role. Meanwhile, the WTP-DCE method indicates that travel attributes have a greater impact on WTP than socioeconomic factors.

Taking into account the limitations of both HC and WTP, a Hybrid method is proposed. This approach modifies the conventional HC method by incorporating the concept of Value of Statistical Life (VSL) to account for intangibles such as PGS. It also acknowledges the contributions of post-retirement victims and caregivers of RTA victims. The VSL concept, in conjunction with the Maximum Abbreviated Injury Scale (MAIS), enables a more comprehensive cost estimation, with PGS comprising 56% of total costs in the Hybrid method. In contrast, the productivity loss is reduced to 17%, ensuring the method is not solely focussed on lost productivity. Considering the nation's economic situation, using the weighted average method, the VSI for grievous and minor injuries was determined to be 19.4% and 3.6%, respectively, which can be implemented in regions with similar socioeconomic profiles.

A Python-based program is developed, making this methodology more accessible and applicable. This tool can evaluate the severity of an accident, computing the resultant loss. A similar tool is also developed for calculating court-awarded compensations. The comparison results indicate that the cost and compensation differences are substantial and that compensation is typically less than the RTA cost, as it is predominantly based on the subjective judgment of the court. Using an expert opinion survey, the Hybrid method was adjudged as the best suited method for RTA cost estimation for accidents of different severity as more than 60% of the experts chose the RTA cost estimated using the Hybrid method over the other methods across various test scenarios. In conclusion, while the Hybrid methodology provides a more holistic perspective of accident costs, it still provides an estimate with a lower bound. This study does not consider some costs, such as infrastructure damage and traffic congestion. However, the approach highlights the imperative need to comprehend and estimate the true economic and intangible effects of road accidents, particularly in developing nations.

Keywords: Road Traffic Accident (RTA), Human Capital (HC) Approach, Willingness to Pay (WTP) Approach, Hybrid Method

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ABBREVIATIONS

AIS	Abbreviated Injury Scale
AIC	Akaike Information Criterion
AMOS	Analysis of Moment Structures
AVE	Average Variance Extracted
BIC	Bayesian Information Criterion
BTE	Bureau of Transport Economics
CA	Critical Accidents
CV	Contingent Valuation
CFI	Confirmatory Fit Index
CMIN	Chi-square Minimum
DCE	Discrete Choice Experiment
DCRB	District Crime Records Bureau
DOF	Degree Of Freedom
FIR	First Investigation Report
GDP	Gross Domestic Product
GFI	Goodness of Fit Index
HC	Human Capital
HCA	Human Capital Approach
HTMT	Hetrotrait Monotrait
INR	Indian Rupee
iRAP	International Road Assessment Programme
KSRTC	Kerala State Road Transport Corporation
MACT	Motor Accidents Claims Tribunal
MAIS	Maximum Abbreviated Injury Scale
MAV	Multi Attribute Valuation
MNL	Multinomial LOGIT
MoRTH	Ministry of Road Transport and Highways
MRS	Marginal Rate of Substitution
NATPAC	National Transport Planning and Research Centre

NH	National Highway
PDO	Property Damage Only
PGS	Pain, Grief, and Suffering
RMR	Root Mean square Residual
RMSEA	Root Mean Square Error Approximation
RP	Revealed Preference
RPL	Random Parameter Logistic
RTA	Road Traffic Accident
SEM	Structural Equation Modelling
SH	State Highway
SP	Stated Preference
TC	Travel Cost
TT	Travel Time
TLI	Tucker Lewis Index
USD	United States Dollars
USDoT	United States Department of Transportation
VSI	Value of Statistical Injury
VSL	Value of Statistical Life
WHO	World Health Organization
WTP	Willingness to Pay

CHAPTER 1

INTRODUCTION

1.1 GENERAL

India is witnessing a rapid expansion in its road network and enormous growth of the automobile industry as a result of urbanisation. The country ranks second in the world with a 6.671-million-kilometer-long road network next to the United States of America, according to the Ministry of Road Transport and Highways (MoRTH 2024). Despite the fact that these factors contribute to the nation's development, there are negative externalities too. Road Traffic Accidents (RTAs) are one such that pose a severe threat to the prosperity of countries globally, consuming a significant portion of the Gross Domestic Product (GDP), especially in developing countries. Road crashes have catastrophic repercussions on both the economic and public health fronts. Being one of the biggest causes of death, disability, and loss of productive capacity, money, and human resources, it imposes enormous socio-economic costs and is a serious public health concern (MoRTH 2020a). When property damage, medical care, and rehabilitation expenses are factored in, the cost of road accidents becomes enormous. Road accidents cause substantial social and economic consequences, including grief, hardship, property damage, and administrative expenses, in addition to the loss of life and injuries to individuals. In 2022 alone, India reported 4,61,312 road accidents, resulting in 1,68,491 fatalities and injuries to 4,43,366 persons, marking significant increases from the previous year (MoRTH 2023). This demonstrates the inevitability of implementing road safety schemes. It is impossible to determine the annual amount to be invested in road safety countermeasures without a cost estimate of road accidents. These demands estimate the cost of road crashes. To date, only a small number of studies have been conducted in India to estimate the cost of road accidents. Most of these studies have been grossly underestimated due to improper or inadequate data recording and the difficulty of obtaining the crucial data required to compute the accident cost.

1.2 ACCIDENT SCENARIO

The World Health Organization (WHO) statistics reveal that yearly RTA deaths reached 1.19 million in 2021, corresponding to 15 road traffic fatalities per 100,000. Road traffic injuries rank twelfth worldwide as a cause of death. For children and youth aged between 5 and 29, they are the leading cause of death as of 2019. Low-income and middle-income countries share less than 1% of all motor vehicles globally but account for 92% of global fatalities on the road. It was also estimated that low-income countries have a three times greater risk of fatal RTAs than high-income nations, and data from India supports this global pattern (WHO 2023). India ranks highest in the world (11%) in road crash fatalities and injuries. In 2022, there were 53 crashes every hour, and 1 person died in a crash every 4 minutes (MoRTH 2023). Over the past decade, 50 lakh people were injured, and 13 lakh people died on Indian roads (MoRTH 2019; Bank 2021). People of working age group (18–60 years) are mostly (83.4%) killed in crashes on Indian roads. Kerala ranked third among the various Indian states regarding the total number of traffic accidents (9.5%) and the number of persons injured in road accidents during 2022, the first and second being Tamil Nadu and Madhya Pradesh respectively. Kerala is in the second position among the various Indian states regarding the total number of road accidents on highways. The grievous injury accidents account for 72% of total accidents in Kerala (MoRTH 2023).

Even though there exists accident statistics, the underreporting of RTAs in India is a challenge faced by researchers in this area. This affects the data collection, analysis, and even the deployment of safety measures. The currently available database of RTAs is the First Investigation Report (FIR) of the RTAs case registered by the police, which may not necessarily update the physical conditions of the victim. The accident data collection methods need to be improvised in order to obtain a centralised road accident database from various departments like police, hospitals, transportation, motor vehicle departments, etc. One such recent initiative from the MoRTH is integrated road accident database, popularly known as iRAD, which is funded by the World Bank. Another challenge in this area of research is the ambiguity in defining accidents based on their severity. Due to the fact that definitions of accidents differ from country to country, comparing the severity of accidents worldwide is impracticable, highlighting the need for a common definition.

This study adopts the accident definitions from the Indian Penal Code Section 320. An accident that results in the death of one or more persons is a fatal accident. A grievous injury accident is one in which one or more victims suffer a serious injury requiring hospitalization. A minor injury accident is one in which the victim(s) does not require prolonged hospitalization. The following kinds of hurt are designated as "grievous" - permanent privation of the sight of either eye, permanent privation of the hearing of either ear, the privation of any member or joint, destruction or permanent impairing of the powers of any member or joint, Permanent disfiguration of the head or face, emasculation, Fracture or dislocation of a bone or tooth or any hurt which endangers life or which causes the sufferer to be during the space of twenty days in severe bodily pain, or unable to follow his ordinary pursuits.

1.3 ACCIDENT COSTING METHODS

An international analysis of the social cost of road crashes, including total costs, value per casualty, and a breakdown of cost components, revealed methodological differences between countries regarding the considered cost components and the methods used to estimate particular cost components. All nations utilize a cost classification following international norms; however, there are disparities regarding productivity losses, infrastructure damage, human costs of minor injuries, congestion costs, and vehicle unavailability costs. The accident cost is reported to be expressed as a percentage share of GDP (Wijnen and Stipdonk 2016). The expenses associated with accidents are widely categorized as accident-related costs and causality-related costs. The costs associated with an accident include property damage, police and fire services, insurance administration, and legal and court fees. Medical and healthcare costs, including administration, lost production, and human costs, i.e., pain, grief, and suffering (PGS), are stated to be included in casualty-related costs. Total accident appraisal value equals the sum of accident-related and casualty-related expenditures.

According to the Overseas Road Note 10 report (Ghee et al. 1997) published by the Transportation Research Laboratory (United Kingdom), at least six methods are outlined to calculate RTA costs, which are the Human Capital (HC) or Gross Output approach, Net Output approach, Life-Insurance approach, Court Award approach, Implicit Public-Sector Valuation approach, and Willingness to Pay (WTP) approach.

HC approach estimates the RTA cost as the total of lost productivity, medical, vehicle damage, administrative, and human (reflection of PGS) costs. This approach has a drawback: it accounts only for the monetary impact of the loss of life without considering the value and enjoyment of the foregone life. The *Net Output approach* deducts the future consumption of the victim from the gross output value, but it may be challenging to derive a cost estimate based on personal consumption of resources (Hills and Jones-Lee 1983). The *life insurance technique* adds up the actual cost of resources and the amount an ordinary citizen would normally be ready to pay to insure their own lives or limbs to determine the RTA cost (Ghee et al. 1997). This approach has the disadvantage that estimations are determined using the individual's insurance coverage, which disregards the worth of his life. The insurance coverage levels may, therefore, differ depending upon the affordability of the victim (Bora et al. 2018).

The *court award approach* contemplates court compensations to the dependents of the RTA victims as the representation of the costs that society connects with deaths or the value placed on its prevention. This entails complex factors, such as the defendants' carelessness, whether the dead or injured were partially at fault, and, in the latter case, whether he or she has filed for compensatory benefits (Hills and Jones-Lee 1983). The RTA cost estimation by the *implicit public-sector valuation approach* was based on principles that society attributes to accident prevention in safety legislation or public sector policies. The implied values of life vary widely within the same sector, depending on whether the policies support or oppose investment programs affecting traffic safety (Hills and Jones-Lee 1981). The *WTP* approach estimates the accident cost based on how much a person is ready to spend to improve traffic safety for a marginal reduction in the likelihood of a fatal crash. This approach is rarely used in lower-income and middle-income nations due to the dearth of necessary data (Bora et al. 2018). The RTA cost based on implicit public sector valuation is very low, whereas the cost estimates using the WTP approach are quite high.

1.3.1 HC Approach

The HC method is one of the most well-known approaches for estimating the costs of traffic accidents in developing nations since it is more accurate, consistent, and theoretically sound. The HC is based on the assumption that human beings are an asset for economic output; therefore, preventing crashes will prevent the loss in productivity caused by human deaths or injuries as a result of the crashes. The generic HC approach calculates the expected societal worth of foregone output ex-post (in other words, after the fact). This method has been widely adopted in developing nations due to its relative ease of calculation in comparison to the WTP method, which is prevalent in developed nations. The advantage of the HC approach is that it delivers a transparent, verifiable, and very simple-to-estimate value. It can reveal age and gender disparities in societal output losses. In addition, it can provide a lower-bound estimate of the losses due to traffic fatalities and injuries (Jadaan et al. 2018).

1.3.2 WTP Approach

WTP is the highest price a respondent is willing to pay for a product or service. The WTP value can vary considerably amongst individuals. This variation is often attributable to either extrinsic or intrinsic differences in the respondent population. The WTP methodology was introduced into road accident costing as a concept with economic justification. Using the Pareto principle, each individual's WTP for risk reduction must be evaluated in relation to any anticipated loss or gain of life. It is regarded as the best cost-benefit analysis tool (Mishan 1971). The two primary methods for determining WTP are Revealed Preference (RP) and Stated Preference (SP). SP can be used to value both market and non-market products, but RP can only be applied to market goods (observable market interactions for assessing the value of economic goods and services) that are readily available on the market. SP approach circumvents the absence of markets by generating hypothetical scenarios in which agents make decisions that resemble the actuality of markets (Munirah Abdullah and Ahmad 2012)

Typically, results derived from price responses are known as RP data. In contrast, SP refers to the estimation of WTP using a survey-based technique, such as a direct or indirect survey, to collect the relevant data. Merino-Castello (2003) provides a classification that clarifies how various methodologies and their approaches are categorised as shown in Fig 1.1.

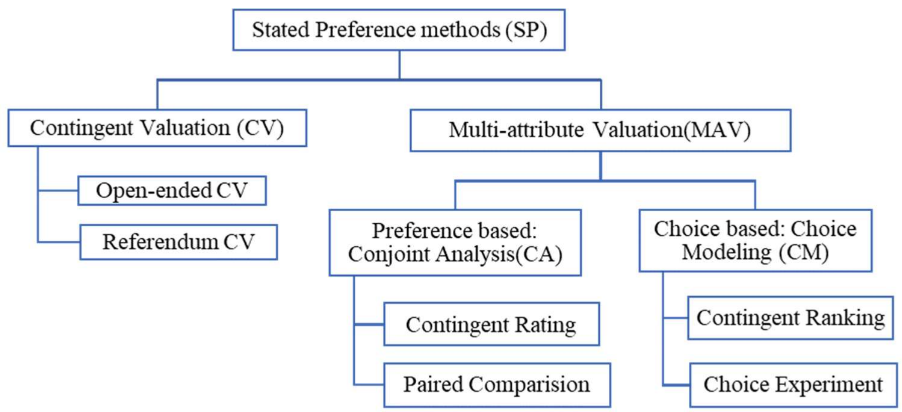

Figure 1.1: Classification of SP Methods (Merino-Castello 2003)

The WTP value that was elicited by adopting various survey methods is used to compute the Value of Statistical Life (VSL). VSL is the economic valuation of a risk reduction that prevents one "statistical" loss of life. In other terms, VSL is the additional cost that individuals are willing to endure for safety improvements (risk reductions) that reduce the anticipated number of fatalities by one. The concept of Value of statistical Injury (VSI) is similar to VSL. The accident cost estimation using WTP method employs the estimated VSL value and the calculated VSI value.

1.3.3 Hybridisation of Accident Costing Methods

Existing approaches for estimating the cost of road accidents have various advantages and disadvantages; therefore, researchers propose hybridizing existing methods to combine the missing components of various methodologies. The Hybrid method can be implemented globally, making global comparisons of road accident costs feasible. The cross-comparison appears to be unreliable because, in the current context, different nations use different approaches. Analyzing the features of existing accident costing methods, the HC method is significant in the estimation of direct cost components, whereas the WTP method is prominent in the calculation of indirect cost components. Therefore, this study considers a hybridization of the aforementioned accident costing methodologies. Grievous injuries are conventionally considered a single severity category, which is unrealistic. The severity of the grievous injury can range from a fracture of a bone to the bedridden or paralyzed condition of the victim. This study suggests scaling the grievous injury based on an accepted injury severity scoring system, i.e., the Maximum Abbreviated Injury Scale (MAIS). To derive the value of VSI from VSL, some countries have established a fixed percentage value, which this study attempts to modify based on the severity scale.

The Abbreviated Injury Scale (AIS) is an anatomical-based coding system created by the Association for the Advancement of Automotive Medicine to classify and describe the severity of injuries. Instead of a thorough evaluation of the injury's severity, it represents the life-threatening nature of the injury. The AIS is one of the most widely used anatomic scales for traumatic injuries. The first version of the scale was published in 1969, with major updates in 1976, 1980, 1985, 1990, 1998, 2005, 2008, and 2015. AIS is a scale of 1 to 6, with 1 representing a mild injury and 6 the most serious (currently untreatable), as shown in Table 1.1. An AIS-Code of 6 is not the arbitrary code for a deceased patient or fatal injury, but the code for injuries specifically assigned an AIS-Code of 6. An AIS code of 9 is used to represent injuries for which there is insufficient data to code them more precisely.

The AIS scale is a measurement tool for single injuries. Even though the injury severity score and its variants are superior aggregators for clinical settings, there isn't yet a universally approved function for aggregating injuries. MAIS is a helpful tool for comparing specific injuries and their relative severity in different contexts, such as vehicle design and occupant protection.

AIS remains a system that codes single injuries and is the foundation for other methods to assess multiple injured patients. Before using any of these methods, injuries for a given patient are coded in AIS and then used to assess the cumulative effects of more than one injury. All these methods formulate a single numerical score to grade a patient's overall outcome. The two most widely used methods are the MAIS and the Injury Severity Score.

Table 1.1: Description of AIS code

AIS Code	Description
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximal

The MAIS is the highest (i.e., most severe) AIS severity code in a patient with multiple injuries. It is widely used by researchers, particularly in the motor vehicle crash-injury field, to describe an overall injury to the whole body. The MAIS is especially useful for comparing the frequencies and relative severity of specific injuries. It helps assess changes in injury frequencies that may result from vehicular design changes, such as airbags, or public policy changes, like compulsory seat belt usage. The data quality available to various data collection systems appears to be increasingly disparate. This factor causes polarization between users who require extreme specificity in injury descriptions and those whose data sources have relatively more general injury descriptions. Consequently, there is a perceived need to develop two systems: one for databases with only limited medical detail and a second where a detailed medical description of injuries is available.

1.4 COURT COMPENSATION

The compensation awarded by the Courts or Tribunals to the surviving dependents of those who perished or were injured in traffic accidents can be viewed as an indication of the estimated cost of the road accident by society. When determining compensation, consideration is given to the value of people's future productive output. It is determined using a formula that considers the victim's age, income status, and position. In most cases, the amount of compensation awarded falls short of the victim's or his family's real expenditures or claims, primarily due to insufficient verification of income or employment. In India, the treatment of RTA casualties devastates many middle- and low-income families financially, affecting the education and careers of the remaining family members. A competent accident costing method can also address the inadequacy of the court's compensation to road accident victims and the necessity to update the rules and procedures to be followed when evaluating the court's compensation awarded to them. If proper bills and proofs are submitted to the court, calculating the victim's compensation for direct costs is not complicated. The evaluation of intangible expenses is primarily subject to the judgment of the honourable court. The same RTA case in different jurisdictions may be awarded highly varying compensation for PGS, which is a matter of concern.

Motor Accidents Claims Tribunal (MACT) has been constituted by the Motor Vehicles Act, 1988. It has been established to expedite compensation for victims of motor vehicle accidents. The Tribunals deprive civil courts of jurisdiction over disputes pertaining to the MACT. The High Court adjudicates appeals from the Claims Tribunal. The appeal must be filed with the High Court within 90 days after the Claims Tribunal's judgment date.

According to Section 166 of the Motor Vehicles Act, 1988, compensation may be claimed by the injured party, by the owner of the property damaged, by the lawfully authorized agent of the wounded person, or by all or some of the legal representatives of the deceased who died in the accident. The claim Petition may be filed with the Claims Tribunal with jurisdiction over the area where the accident occurred, or with the Claims Tribunal within the local limits of whose jurisdiction the claimant resides or conducts business, or with the Claims Tribunal within the local limits of whose jurisdiction the defendant resides.

This study compares court compensation and the estimated cost using the Hybrid method. Comparisons of compensation with estimated costs based on the Human Capital Approach (HCA) or WTP methods are irrational. The accident cost, or VSI/VSL, from the WTP method, is a very high value, and the VSI/VSL remains the same for each injury severity level, i.e., fatal, grievously injured, and slightly injured, and therefore cannot be used to compare compensation awarded by the court. The cost estimation using HCA is conventionally conducted by adopting Silcock's method. In this method, the cost components are estimated in relation to one another. For instance, 4% of the cost of vehicle damage and the human cost is accounted for as administrative costs in cases involving grievous injuries. When comparing the accident cost with compensation, the vehicle damage cost component should be omitted since it will be covered by the insurance company. Including the vehicle damage cost would make it impractical to compare the cost calculated using HCA with the compensation.

1.5 SIGNIFICANCE OF THE PRESENT STUDY

The estimation of accident costs in various countries around the globe is based on varying methodologies, making international comparisons of accident costs unreliable. Although very few studies propose conversion ratios for the estimated accident costs by HC and WTP approaches, most are mainly based on developed countries and are, therefore, inapplicable to developing countries. Very little research has been carried out in the area of accident costing in developing countries, highlighting the significance of this study. The HC and WTP approaches are commonly adopted in developing and developed countries, respectively. The HC approach has a few limitations on the computation of cost components, such as lost productivity and human cost. Time spent by the caregivers of the injured, as well as the lost productivity of the retired individuals, are not considered in the existing methodology. Also, the human cost component, calculated by adopting the guidelines of Silcock and Transport Research Laboratory (2003), is often underestimated. The WTP approach is used to estimate the road accident cost using the concept of VSL. This method's limitations are the absence of component-specific cost distribution and the anticipated overestimation compared to the HC approach. Perkins et al. (1998) recommended a standard percentage value for determining VSI from VSL, but it primarily applies to developed nations. In addition, the VSI estimation generalizes grievous injuries of varying severity, which requires modification. Thus, injury scaling using a suitable system must be extended to the individual and collective VSI estimation. Despite the fact that Wijnen (2021) introduced the hybrid methodology concept in the accident cost estimation in Kazakhstan, the study's data set was adopted from similar countries, which can be considered a limitation. In addition, the VSI calculation uses the same proportion as proposed by Perkins et al. (1998), paving the path for similar studies in developing nations.

1.6 RESEARCH OBJECTIVES

This study aims to develop a procedure for the estimation of the cost of road accidents incorporating the essence of existing quantitative and qualitative methodological aspects. The following objectives serve to accomplish this.

(a) To compare the road accident cost estimates obtained by adopting HC and WTP approaches
(b) To develop and apply a Hybrid method for the estimation and prediction of road accident cost
(c) To compare the estimated accident cost with the economic compensation awarded by the Court

1.7 SCOPE OF THE RESEARCH

The scope of this research is limited to the aspects listed below.

a) The study is carried out in the city limits of Ernakulam District in Kerala State, South India. The particulars adopted in the study are based on this study area.
b) The RTAs reported during the study period (2018-2021) are considered for the estimation of accident costs. There are huge chances of under-reporting of accidents; hence, the estimated cost can be assumed as a lower bound estimate.
c) The WTP value is population-specific, and the value is taken as the same for the study period considering the fact that the factors on which the WTP depends do not vary much during the study period.
d) The FIRs of the RTAs, which lack the detailed medical description of the victims, are used as the basis for the cost estimation. A detailed medical description of the victim can improve the applicability of the methodology.

e) In order to compare the court compensation and the individual estimated RTA costs, similar MACT case verdicts from courts in the study area were collected as the MACT case verdicts of the FIRs were unavailable.

1.8 ORGANIZATION OF THESIS

The thesis is organized as follows:

Chapter 1: This chapter gives a general introduction and a brief overview of the accident statistics and the existing costing methods. It also includes the scope and objectives of the research work.

Chapter 2: A brief summary of literature focusing on research carried out related to accident costing is presented. An attempt has been made to identify the improvements made in the accident costing methodologies. The research gaps have been identified.

Chapter 3: This chapter deals with the data collection and the methodology followed in the study towards the fulfillment of the objectives set forth.

Chapter 4: This chapter describes the specifics of accident cost estimation using the HC method.

Chapter 5: This chapter provides the details of accident costing using the WTP-Contingent Valuation and WTP-Discrete Choice Experiment approaches.

Chapter 6: This chapter discusses the hybridization of accident costing methods and the RTA cost estimation using the Hybrid approach.

Chapter 7: This chapter details the accident cost comparison, adopting the different methods. Also, this chapter compares the estimated accident cost obtained by adopting the Hybrid method with Court compensation.

Chapter 8: This chapter summarizes the main outcomes of this research. The significant conclusions are listed, highlighting the importance of the Hybrid method in accident costing.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter provides a comprehensive review of research carried out by various researchers in the area of road accident costing. The Human Capital (HC) and Willingness to Pay (WTP) approaches were most commonly used to estimate Road Traffic Accident (RTA) costs in various developed and developing countries. The pros and cons of the existing methodologies and the necessity of using them in tandem are discussed in detail, and finally, the gaps in the literature are also included.

2.2 ACCIDENT COSTING

According to the Global Status Report on Road Safety, among 180 nations, the estimated Gross Domestic Product (GDP) lost due to traffic accidents ranges from 0.2% GDP in Chile to 7.8% GDP in South Africa, which is a disproportionately large amount when compared to the entire amount of development aid that low-income nations get. Yet another fact to be noted is that 106 countries among the 180 do not have an estimate of the same. India's estimated GDP lost due to RTAs was 3% (WHO 2015).

2.2.1 Accident costing in developing countries

The extensive literature review carried out by Bougna et al. (2022) concludes that accident cost studies are very limited in developing countries. The findings from the research conducted on developed countries cannot be used to derive inferences for developing or underdeveloped countries (Dimitriou and Poufinas 2016; Bougna et al. 2022; Suthanaya and Sugiana 2022) due to various reasons.

According to Bougna et al. (2022), developed countries generally possess better infrastructure, which lowers the frequency and severity of accidents. On the other hand, the lack of infrastructure in developing nations causes more severe and costly accidents.

Suthanaya and Sugiana (2022) draw attention to the impact of disparities in the contribution of socioeconomic status. Road accidents place a greater financial strain on individuals and families due to lower income levels, a lack of comprehensive insurance, and restricted access to treatment in developing nations. Additionally, these areas incur greater indirect costs, such as lost productivity and long-term disability, which harm their economies.

Dimitriou and Poufinas (2016) emphasized the institutional and regulatory differences. Developed countries have well-established systems for accident reporting, data collection, and policy implementation, which lead to accurate cost estimation. In contrast, developing countries often deal with inconsistent data collection, underreporting, and weaker regulatory frameworks.

These gaps necessitate context-specific approaches to road accident cost analysis in developing regions. This indicates the need for more research in this area, especially in lower-middle-income countries.

2.2.2 Accident costing in India

Very few attempts have been made to estimate the costs of RTAs in India. In one of the earlier studies cited in Mohan (2002), Srinivasan, Hingorani, and Sharma (IRC, 1975) analysed the costs of traffic accidents in Delhi in 1968. The inaugural road user cost analysis conducted in India, which was supported by the World Bank in 1982, incorporated road accidents within the framework of road user expenses (Central Road Research Institute, 1982). Medical charges, property damage costs, legal fees, insurance costs, and production loss due to fatality were evaluated as cost components. The RTA cost estimated by the study was 0.29% of the GDP. The current scenario regarding the fatality-to-injury ratio and the life expectancy at birth is significantly different from all of this earlier research. Since a significant portion of Minor injury and Property Damage Only (PDO) traffic incidents in India go unreported, the costs linked to vehicle damage are often underestimated. In addition, indirect expenses such as cost of life, psychological harm, permanent disability costs, suffering, and socio-economic repercussions have not been accounted for in these studies (Mohan 2002).

In 1999/2000, the estimated social cost of RTAs in India was 7.9 billion United States Dollars (USD) which was three percent of the nation's GDP. The Planning Commission of India revised this figure to 14.3 billion USD for the year 2011. According to a study undertaken by MoRTH, the Indian Institute of Technology, Delhi, and the Delhi Integrated Multi-Modal Transport System, the estimated socio-economic cost of all reported accidents in India in 2018 was assessed to be 0.77 percent of the country's GDP (Kumaresh et al. 2021). As per the aforementioned study, the socio-economic expenses attributed to RTAs in India total Rs 1,47,114 crore. The same study computes crash-related expenses at 5,960 billion Indian Rupee (INR), which is equivalent to 82.48 billion USD, constituting 3.14 percent of the GDP. These calculations take into consideration the underreporting problem and crash ratios based on MoRTH crash numbers (MoRTH 2019; Bank 2021). The estimated range for these costs was between 15.71 billion USD and 38.81 billion USD, accounting for approximately 0.55% to 1.35% of India's GDP in the year 2019 (Kumaresh et al. 2021). The distinct correlation between socio-economic status and road use patterns depicts that poorer ones are more likely to be involved in road crashes (WHO 2023). The data presented above underscores the formidable challenge of road safety in India. Consequently, the substantial socio-economic costs associated with RTAs make a compelling case for increased investment in accident prevention and road safety initiatives.

2.3 ACCIDENT COSTING METHODS

There are substantial differences in the methodologies of various approaches, which leads to entirely different cost estimates. Furthermore, data systems on the outcomes of traffic safety in different countries are not properly integrated. There are discrepancies, inadequacies, and underreporting of traffic crashes. This, coupled with the absence of a unified approach for evaluating socio-economic costs, could lead to biases or inaccurate estimations (Bougna et al. 2022).

Among the existing methodologies (Hills and Jones-Lee 1981; Bora et al. 2018), HC and WTP are widely recognized as the most prevalent approaches. The former method computes actual costs by analysing historical expenditure data following a road accident, while the latter method endeavours to estimate the actual costs by assessing the measures an individual would take to prevent a road accident. The distinction between HC and WTP is determined by the objectives and the availability of data. If the primary purpose is to maximize national output, then the HC approach should be utilized, whereas the WTP method should be used if the primary objective is to promote social welfare by minimizing injuries and fatalities. The paucity of data required to use the WTP approach, particularly in developing nations, makes the HC approach an interesting alternative (Jacobs 1995).

Wijnen and Stipdonk (2016) did a comparative study to analyze the social costs of RTAs in 17 countries. The cost components taken into account by most countries were production loss, medical costs, human costs, administrative costs, and the cost of property damage. Low and middle-income countries did not consider the cost components like congestion costs. Every country accounted for the human costs in terms of fatalities, as well as severe and minor injuries, with the exception of the Netherlands and the Philippines, where minor injuries were not considered. Human Capital Approach (HCA) was adopted by most countries to estimate production loss. Seven high-income countries used WTP for human cost estimation, and four used the country-specific Value of statistical Life (VSL) approach. Australia and Germany used compensating payments, while Asian countries concentrated on the rule of thumb for analysis. All countries used the insurance approach to estimate property damage.

Safety Cube authors (Wijnen et al. 2017) prepared a report showing the approach used and recommended by Safety Cube for evaluating accident costs in a detailed manner. The authors highlighted the $COST_{313}$ (1994) guidelines as the most comprehensive reference for estimating the costs of RTAs. They also emphasized that, according to these guidelines, medical expenses, property damage expenses, and administrative fees should be determined through the restitution costs method, while costs associated with production loss should be assessed using the HCA. Furthermore, the report recommends employing an individual WTP approach to assess human costs. It underscores the importance of incorporating the omitted elements and adopting a standardized methodology for the comprehensive calculation of crash-related expenses.

The court awards approach is not recommended for cost-benefit analysis due to unpredictability. Schoeters et al. (2018) further noted that variations in cost estimates could be attributed to disparities in the definition of severe injuries and the inclusion of different cost elements. The study advised that future studies on the costs of road accidents within individual countries should incorporate all pertinent cost elements and employ internationally recognized methodologies. This approach would offer a comprehensive representation of socio-economic costs and enhance the comparability of accident cost estimates on a global scale.

2.4 REVIEWS ON THE HC APPROACH

Silcock and Transport Research Laboratory (2003) investigated the potential for enhancing the HC method, as suggested in Overseas Road Note 10, with a particular emphasis on refining the data collection procedures. The scoping study identified the WTP method as the only other suitable RTA costing method, but the method was deemed to be too difficult to apply to developing countries then. Hence, the study recommended the HC method, summing up the pain, grief, and suffering (PGS) costs of the victims and their families, as the starting point of accident costing in developing countries. The application of the HC method by the UK Department of Transport for almost twenty years was mentioned in this study. Alfaro et al. (1994), a European Commission-funded study, the HC method and its variations were used in many Western European countries. Jacobs (1995)analyzed the RTA costs in four developing countries, including India, as a part of the Overseas Road Note series by the Transportation Research Laboratory (TRL). This study was extended to seven other developing countries by Ghee et al. (1997) and published as a report of TRL.

Alfaro et al. (1994) and Silcock and Transport Research Laboratory (2003) generally categorized the RTA costs into two types: those related to injuries and those related to crashes. The injury-related costs encompass losses in productivity, medical expenses, and human costs, while costs related to crashes cover damages to property and administrative expenses. In these studies, human costs were estimated as a portion of the lost productivity costs, varying according to the severity of the RTA.

The HC approach employed by the Bureau of Transport and Regional Economics for estimating accident costs in 1996 was further developed by Risbey et al. (2007). This approach was expanded by incorporating various socio-demographic and additional parameters. This enhancement was aimed at adjusting the current value of lost production to a more accurate value of human life. It provided a practical breakdown of the unit costs of serious injury accidents, thus minimizing underestimation of serious injury accident costs by not obscuring cost differences associated with treating and caring for accident patients with varying degrees of harm. Risbey et al. (2007) reviewed and updated its crash cost framework, and the study presented key methodological, analytical, and other issues that it proposes to consider from the perspective of the information needs of policymakers. The study analyzed a variety of conceptual and empirical advancements during the previous decade.

Partheeban et al. (2008) utilized a systems dynamics approach to devise a model specifically for estimating the costs associated with RTAs in Chennai, India. This model identified various factors contributing to road accidents and their associated costs. It was specially designed to predict future accident rates and their costs, focusing exclusively on bus-related accidents. The model, constructed with data from the year 2000, projected accident occurrences and costs at five-year intervals up to the year 2020. The study examined three different scenarios, altering income growth and discount rates to determine the most effective approach. (Sahu 2012) also conducted a comprehensive review of various global RTA costing methods, including detailed background information. Among the methodologies reviewed in this paper was the HC approach.

Alrukaibi et al. (2015) conducted a study to calculate the overall RTA costs in Kuwait for the year 2012, employing the HC approach. The RTA costs were primarily divided into direct and indirect categories. The study aimed to quantify the economic loss resulting from fatalities and injuries due to traffic accidents in Kuwait. Costs were further broken down into three main categories: human costs, property damage costs, and general RTA costs. The human cost category encompassed several types of expenses, including lost productivity, loss of quality of life, and medical costs. Notably, the loss of quality of life was assessed somewhat objectively, based on a percentage of lost productivity. The PGS costs were determined as a specific percentage of the lost productivity costs, varying by accident severity: 28% for fatal accidents, 50% for serious injuries, and 8% for slight injuries. The property damage cost category was comprehensive, covering costs related to vehicle damage as well as damage to other properties. Additionally, environmental impact costs and costs due to travel delays were grouped together with administrative costs under the general traffic accident cost category. The study successfully estimated both the total and average costs of traffic accidents in Kuwait. A significant finding of the study was that the general crash costs category constituted 60.4% of the total cost, highlighting the substantial economic impact of traffic accidents beyond immediate human and property damages.

Mofadal and Kanitpong (2016) estimated the costs associated with RTAs in Sudan for two consecutive years, 2010 and 2011, by slightly modifying the established HC method framework. Their analysis utilized comprehensive data on RTA fatalities, which was detailed and categorized based on several crucial aspects, such as the severity of the accidents, types of vehicles involved, and other key factors including discount rates, as well as medical and insurance information. This extensive data allowed them to evaluate and compare the overall economic losses caused by accidents in Sudan, providing insights into their significance and impact.

In a related context, Wijnen and Stipdonk (2016) offered an extensive overview of the global trends in assessing the social cost of road accidents. Their work included an analysis of the value assigned per fatality, the overall cost of accidents, and a detailed breakdown of the various cost components. This comprehensive approach provided a broader understanding of the economic and social ramifications of RTAs on a global scale.

Sugiyanto and Santi (2017) emphasized the crucial importance of data on the number of RTA casualties and the associated costs for accurately estimating the economic impact of RTAs. In the study, they applied the HC method to analyze the cost of RTAs in Purbalingga, Central Java, Indonesia, using data collected from 2010 to 2015. This analysis was structured around the severity of casualties resulting from the RTAs. The cost components considered in their study included expenses for vehicle repairs, administrative costs, medical care, the potential loss of human productivity, and human costs. By evaluating these diverse factors, they were able to capture a comprehensive picture of the economic burden of traffic accidents. A significant finding of their study was that the total cost of RTAs in Purbalingga amounted to approximately 1.27% of the region's GDP. This figure underscores the substantial economic impact that RTAs can have on a local economy, highlighting the importance of effective road safety measures and accident prevention strategies.

Bora et al. (2018) conducted a study aimed at identifying the cost components associated with road accidents in Nagpur city, Maharashtra, India. The research methodology adopted was a system dynamics approach, which provided a holistic understanding of the issue, especially relevant to Indian urban contexts. This approach was underpinned by the HC method. The study relied heavily on information provided by the Traffic Department of Nagpur city to gather data, encompassing all road accidents recorded from 2010 to 2015. This comprehensive data collection was critical in evaluating the economic impact of RTAs in the city. One of the key findings of the study was that the total costs attributed to RTAs in Nagpur for the year 2015 amounted to approximately INR 935.5 million. This figure represented 0.09% of the city's GDP, highlighting the significant economic burden imposed by road accidents. Furthermore, the study delved into the major cost components of these accidents, examining how they varied with the severity level of the incidents. This detailed analysis offered valuable insights into the different economic dimensions of road accidents, contributing to a better understanding of their impact on urban economies in India.

In a study, Jadaan et al. (2018) focused on identifying the characteristics and types of road accidents in Jordan to develop a method for estimating RTA costs. They recognized the primary components of RTAs and emphasized the value of such information in evaluating the effectiveness of road safety programs. This knowledge is particularly important for devising the most efficient preventive measures within the constraints of a country's limited financial resources. The HC method was employed in their study for predicting the cost of traffic accidents. This method was chosen due to its simplicity and the ready availability of necessary data. The research was backed by a comprehensive database of road accidents in Jordan. For the year 2017, the study estimated the cost of traffic accidents in Jordan to be approximately 409 million USD. This significant figure underscores the substantial economic impact of road accidents on the national economy. Similarly, Chantith et al. (2020) conducted a study to update previous estimates of the national economic harm caused by RTAs in Thailand. Their research involved extensive data collection and analysis, enabling them to calculate revenue losses over time due to fatalities, permanent disabilities, and both major and minor injuries resulting from RTAs. By adopting the HC method, the study quantified the productivity loss associated with RTAs, offering valuable insights into the economic consequences of road safety issues in Thailand.

MoRTH, India, commissioned an RTA costing study in 2018 (MoRTH 2020b). This study was entrusted to the consortium of Delhi Integrated Multi-modal System Limited and Indian Institute of Technology, Delhi, on the RTA costing in India to boost the research in this area and enable the cost-benefit analysis of road safety infrastructure. The study adopted the HC method for the estimation of accident costs. This study attempted to address many gaps in India's previous accident costing studies by incorporating various concepts into each cost component. The PGS costs were estimated based on the judgments of Motor Accidents Claims Tribunal (MACT) instead of the percentages of lost productivity costs in the previous studies. The estimated RTA cost in this study was equivalent to 0.77% of the country’s GDP. The study addressed the under-reporting phenomenon and used the accident ratios provided by the MoRTH accident numbers; hence, the estimated cost was revised to 3.14% of the country’s GDP.

In summary, the HC method is an ex-post costing approach. HC method is simple to use and gives transparent and consistent results. Hence, as a first step in evaluating accident costs in developing nations, Silcock and Transport Research Laboratory (2003)recommends the HC approach as a practical application technique. Moreover, the reliability and availability of the required data make it easier to use, though a huge amount of data is required, as per the Bureau of Transport Economics (BTE 2000). In the Indian scenario, data availability is not for granted. From the literature, it is evident that developed and developing countries have used the HC method for the estimation and analysis of RTA costs in the near past (Alrukaibi et al. 2015; Mofadal and Kanitpong 2016; Bora et al. 2018; Jadaan et al. 2018). However, this approach has two major limitations, including the inability to handle intangible RTA costs (human costs) and the effects of life extension problems (Mofadal and Kanitpong 2016).

2.4 REVIEWS ON THE WTP APPROACH

The WTP approach can be broadly classified into individual and social WTP approaches to estimate the value of lost life quality (Lindholm and Dideichsen 1998; De Blaeij et al. 2003). In the individual approach, data on WTP is gathered directly from individuals. This can be done either by observing their choices in situations where they must balance reduced risk against other commodities or through surveys and questionnaires. The societal approach, on the other hand, deduces the WTP of society for reduced risk from the values implicit in public policy decisions, such as setting speed limits or regulating hazardous materials (Mitchell and Carson 1989; Wijnen et al. 2009, 2017). Revealed Preference (RP) and Stated Preference (SP) surveys represent the two primary methods for eliciting WTP. As already discussed in Chapter 1, RP surveys are specifically suited for goods available in the market, assessing values through actual market transactions. On the other hand, SP surveys can evaluate both market and non-market goods. SP techniques are a set of methods used for valuing goods and services not usually traded in markets, like travel time, safety measures, pollution, and natural resources. SP overcomes the absence of real markets by creating hypothetical scenarios where individuals make choices mimicking market-like decisions (Mitchell and Carson 1989).

The estimation of WTP using a survey-based technique, i.e., direct or indirect survey for collecting the relevant data, is usually referred to as SP. The SP technique is subdivided into Contingent Valuation (CV) and Multi-Attribute Valuation (MAV). In CV, respondents directly indicate their maximum WTP for specific goods or risk reduction (Beattie et al. 1998; Haddak et al. 2016). CV elicitation methods vary, including open-ended questions, iterative bidding games, payment cards, and dichotomous choice (Bateman et al. 2002). With open-ended elicitation, individuals state their WTP for goods or services, which can lead to challenges and extreme responses, especially among those unfamiliar with these valuations (Bateman et al.

2002; Vloerbergh et al. 2007). The bidding game method asks a series of yes/no questions to pinpoint the maximum WTP but may lead to anchoring bias and unreliable responses, as these authors also observe. In the payment card approach, participants choose or write down a suitable WTP amount, which simplifies the valuation. This method tends to yield higher response rates, minimizes bias and outliers, and places less cognitive strain on respondents (Bateman et al. 2002; Vloerbergh et al. 2007; Mofadal et al. 2015).

CV is the predominant method within SP and has evolved from its initial open-ended question format to referendum-style elicitation (yes/no responses to a suggested payment amount). CV surveys typically aim to determine the public's valuation of hypothetical risk reductions, aggregating these to establish the value of a statistical life. Both conjoint analysis and choice modelling fall under MAV. Choice modelling (Wijnen et al. 2009) involves asking respondents to select among various options with differing attributes like travel time, costs, and accident risk. The primary distinction between CV and MAV is that MAV allows for the valuation of multiple attributes of a product and their trade-offs simultaneously, while conjoint analysis evaluates one set of attributes at a time, as per Merino-Castello (2003). Multi-attribute techniques are divided into preference-based and choice-based approaches. Preference-based approaches, rooted in marketing research, ask individuals to rate various scenarios. In contrast, choice-based approaches, stemming from economic theory as noted by Adamowicz et al. (1998) and Ben-Akiva et al. (1985), require consumers to choose among competing products, reflecting real-life consumer choices. These approaches are based on Lancastrian microeconomics, as explained by Alpizar and Carlsson (2003) and Lancaster (1966), where utility is derived from the attributes of goods, and on random utility theory, which combines deterministic and probabilistic components of utility component (Boxall et al. 1996; Mogas et al. 2006).

Choice experiments are considered the most straightforward among choice-based approaches regarding the cognitive effort required from participants. These experiments effectively emulate real-life market conditions and align with the principles of welfare economics (Merino-Castello 2003). From a policy and management standpoint, they are highly useful because the insights gained can aid in crafting multifaceted policies, as

Hanley et al. (2001) suggest, and are applicable in cost-benefit analyses and legal proceedings, according to Mogas et al. (2006). The CV method, having been more extensively employed for determining VSL estimates across various countries and contexts, is generally regarded as more reliable for generating practical estimates.

Studies have demonstrated that the WTP approach can effectively estimate RTA costs, aiding in tackling the related challenges (Miller 2000; De Blaeij et al. 2003; Rizzi and Ortúzar 2003). For example, the Swedish National Road Administration uses the VSL derived from WTP to calculate the costs of traffic crashes (De Blaeij et al. 2003). Elvik (1995) conducted a study on the economic assessment of traffic accident fatalities in 20 motorized countries using a global RTA database, considering variables like traffic risks, road safety policies, economic factors, and valuation methods. This study revealed that many countries have adopted WTP for valuing traffic fatalities, significantly revising previous cost estimates. It also indicated that the method of cost estimation greatly affects the determined cost of RTAs. Whittington (1998) discussed the complexities of conducting CV surveys in developing nations, including ethical dilemmas, noting that CV is often used to value goods or services unavailable in traditional markets but can be applied to accident costs. CV surveys are particularly effective in developing countries due to higher response rates and lower costs, allowing for extensive sampling.

Rizzi and Ortúzar (2003) proposed a stated choice survey where participants choose among alternatives with varying attributes, aimed at enhancing the precision of estimates. This approach was implemented among car users in Chile, including a route choice experiment featuring travel time, tolls, and risk levels. Bhattacharya et al. (2007) applied the CV method in Delhi, India, to assess the cost of traffic safety improvements and the social cost of traffic crashes.

Determination of WTP involves examining the Marginal Rate of Substitution (MRS) between a vehicle driver's income and the number of RTA fatalities. Additionally, the Value of Risk Reduction is computed by separately assessing WTP for fatalities and all injury categories on specific routes. The use of the covariance matrix in analysis reduces the standard errors and makes the design efficient. The average WTP will be high for non-urban environments compared to urban areas. This may be due to the high speed in non-urban zones (Hensher et al., 2009). Antoniou (2014) attempted to find the costs of road accidents in Greece for urban and rural trip settings using binary route choice analysis. The models were prepared using the R language with the panel generalised linear model package. The urban WTP was found to be lower than the rural case, which is consistent with the works by Hensher et al. (2009).

Chaturabong et al. (2011) used the CV payment card method on motorcyclists for cost analysis in Bangkok city of Thailand, where Open-ended (to ask respondents to state maximum WTP) and close-ended analysis (to ask respondents whether they will give a particular amount as WTP) were conducted. The regression model showed that older people and male riders showed less WTP, while people who often use helmets showed more WTP. Respondents who were impaired by alcohol while riding were unwilling to pay more, and WTP for riders at high speed was more. The most common is the CV payment card method (Mon et al. 2018, 2019a) to determine factors influencing public WTP to reduce causalities. Multiple regression models can be used to explore people's socio-economic status and find how past causality experiences affect WTP decisions. The level of education and vehicle ownership has a significant relation with public WTP and people with previous causality experiences have higher chances of paying more than others. Studies have demonstrated that the WTP is greatest among car drivers, in contrast to bus passengers, who exhibit the lowest WTP. This may be due to the safety offered by public bus transport rather than car transport (Dissanayake.D 2010; Elvik 2018).

The SP approach to determine WTP began gaining importance as Rizzi and Ortúzar (2003) adopted the Route choice Discrete Choice Experiment (DCE) survey for car trip study with the inclusion of lexicographic behaviour (using Binary logit models) of respondents. The inclusion of questions based on CV and SP in the questionnaire design makes the process more reliable (Ainy et al. 2014). Haddak et al. (2016) conducted a study to analyze non-fatal risk reduction in residents of the Rhone Department with 2392 samples (aged 18 and older), focusing on 25% and 50% risk reduction. Three sections were chosen to test the relationship between WTP and injury severity (minor, major, and moderate injury). The WTP was found to be more for protection from the risk of severe injury (45.19 Euros) than minor (40.37 Euros) and moderate(38.51Euros) and the study tended not to vary with the degree of risk reduction (25% vs. 50%). The comparative study conducted by Wijnen and Stipdonk (2016) on the social costs of road accidents in 17 nations found that the VSL, calculated via WTP, generally fell between 2 to 3 million USD. However, in the USA, the VSL was higher at 9 million USD, a difference attributed to the use of RP in the US, as opposed to SP methods used elsewhere.

The decision-making process for WTP is significantly influenced by factors such as travel cost, the frequency of accidents on the chosen route, household income, travel time, and the age of the decision-maker. Zero WTP values can be handled in two ways: to replace the values with the midpoint of the lowest interval of values for the study and to assume that the values are less than the minimum values in the sample (Ainy et al. 2014). Some researchers divided the zero WTP responses as true zeroes (like a low financial background) and protested responses (like they don't want to pay others). Various models were employed to examine these trends. The WTP values of young males are lower compared to other age groups and pedestrians. This may be because of the confidence in their driving abilities and the safety of current systems(Rizzi and Ortúzar 2003, Haddak et al. 2016, Bhattacharya et al. 2007).

To estimate the costs of various categories of accidents, AECOM and the Singapore Land Transport Authority used both the CV approach and the route choice approach to evaluate the value of avoided risks. The CV was used to obtain a range for the costs of road accidents. The study concentrated on the driver population only. The costs for car and motorcycle road accidents involving severe and fatal injury crashes were estimated using binary route choice analysis (Le et al. 2011).

Balakrishnan and Karuppanagounder (2020) employed an SP survey on two-wheeler users in Calicut, Kerala, with 344 samples. The data were categorized into three types: socio-economic, travel-related, and accident-related. A binary route choice survey with DCE modelling was used for WTP estimation. The study's attributes included travel cost, travel time, and the annual number of accidents. Twenty-five percent and 50% reduction of risk of accidents were set for the study. The obtained WTP value and RTA cost for two-wheelers were calculated at Rupees 0.5271 per person per trip and USD 34,700, respectively.

According to Danyliv et al. (2012), DCE and CV were frequently used to assess the value of healthcare benefits. However, it was not thoroughly investigated if the two methods produce converging WTP estimates. The study indicated that DCE yields greater estimates of WTP than CV, and estimates from the two approaches are inconsistent. Systematic differences would eliminate the need to determine which method is the most valid. A recent study in Ethiopia (Mekonnen et al. 2022) calculated the VSL using WTP data obtained from a CV survey, coupled with a suggestion to apply advanced SP methods such as DCE to obtain the VSL. According to the literature review conducted by the authors of the study, of the 12 most prominent direct VSL estimations in various countries between 2011 and 2021, eight studies utilised the CV approach, and four used the DCE method. After 2018, the CV approach was employed by the majority of the examined research. This might be because individuals are directly asked to state their maximum WTP for a product or service in a hypothetical market scenario. In contrast, DCE, a form of conjoint analysis, present two or more scenarios to respondents, asking them to choose their preferred option. This indirect approach typically leads to higher estimated values. (Mirzaee et al. 2021).

The WTP method is an ex-ante costing approach. In general, it estimates the money that a person is ready to spend to prevent an episode of a health calamity (Markandya and Ortiz 2011). The WTP is a wealth-risk trade-off. The acceptance of the WTP approach is very high, especially in developed countries. In lower and middle-income countries, it was not found to be economically viable as it is difficult to implement due to the high cost of data collection and the instability of the population to state their WTP (BTE 2000). Recently, many developing countries have stepped into using this approach for accident cost estimation (Mon et al. 2018, 2019b; Utanaka and Widyastuti 2018; Balakrishnan and Karuppanagounder 2020). According to BTE (2000), the WTP approach is said to be comprehensive, the reflection of the preference of an individual, and also the subjective welfare costs are said to be incorporated. On the other hand, the method demands the understanding and valuing of small risks by individuals, which might be difficult and also vary among the respondents. Furthermore, there will be huge variations in the expenditure pattern of individuals and their real choices. The major cons of this approach are that there are methodological difficulties like inaccuracy in the responses, variations in the individual risk perceptions, and conceptual differences in the statistical life and real life.

2.5 REVIEWS ON HYBRID METHODS

The HC and WTP approaches were used for developing countries by considering the demographic characteristics of the population exposed to accident risks. According to some researchers, the HC method becomes most practical for assessing traffic accidents when it includes costs for PGS of those involved. This approach is deemed effective when considering various cost components such as property damage costs, administrative expenses, medical costs, lost output, and human costs. (Jacobs.G.D 1995; Silcock and Transport Research Laboratory 2003; Wijnen and Stipdonk 2016).

The extensive literature review carried out by Bougna et al. (2022) on the existing socio-economic costs literature reveals the research gaps. The quantitative analysis of the road crash literature emphasized the differences between the HC and WTP methodologies for assessing the socio-economic costs of RTAs. The econometric analysis showed that studies using the WTP approach estimate the impact of traffic accidents on GDP to be, on average, 1% higher than those using the HC method. Additionally, research utilizing the HC method often reports the total socio-economic costs as half of what is estimated through the WTP method. However, this gap narrows when factors like population density, national income levels, and road safety metrics are factored in. The study underscores the value and benefits of using a comparative or integrated approach in assessing the socio-economic costs of traffic accidents. Given the financial and technical challenges associated with the WTP method, the study emphasizes the importance of developing a combined methodology that merges these two approaches with other valuation techniques.

Wijnen (2021) introduced a novel hybrid methodology to calculate the socio-economic costs of road accidents in Kazakhstan, combining the HC approach for production loss, the WTP method for human costs, and the restitution costs method for other components. The study borrowed data from other countries to address data gaps, a noted limitation. The socio-economic costs in Kazakhstan for 2021 were estimated at 6.8 billion USD, equating to 3.3% of its GDP. The breakdown revealed that human expenses constituted 81% of total costs, vehicle damage 11%, and output loss 6%, with administrative and medical costs being minor factors. Over half of these costs resulted from injuries, about a third from fatalities, and around 10% from property damage. The study highlights the need for comprehensive data collection from diverse sources for accurate road crash cost assessments, often a challenge due to data inaccessibility. It also underscores the need for more research on accident costing in low- and middle-income countries. For estimating human costs related to injuries, the study employed value transfer, using 13% of the VSL for severe injuries and 1% for minor injuries. These percentages were based on existing literature and aligned with major European project recommendations regarding the valuation of road injuries.

An initiative of such a kind in India was the study by Kumaresh et al. (2021). The HC method serves as the foundational approach for estimating the socio-economic losses from traffic accidents. This method is expanded by incorporating the VSL concept and specific cost elements into the WTP approach and the International Road Assessment Programme's (iRAP's) rule of thumb method. Recognizing the inherent limitations of the WTP and HC methods, the iRAP rule of thumb approach was developed to approximate VSL in less developed countries, where VSL is often calculated based on the ratio of VSL to GDP per capita. For India, the estimated range of socio-economic losses due to RTAs in 2019 was between 15.71 and 38.81 billion USD, accounting for approximately 0.55 to 1.35 percent of the country's GDP. This study recommends research extension in the areas of each cost component. The scaling of significant injuries according to a nationally recognised scale, such as the Abbreviated Injury Scale (AIS), for the computation of Value of statistical Injury (VSI), has been identified as a research gap. The cost estimate overlooks the time invested by caretakers or family members caring for RTA victims, as well as the lost productivity associated with retired victims.

O’Reilly et al. (1994) conducted a process where experts used a visual analogue scale to rank ten different injury state descriptions as part of their Mapping and Scoring of the Injury State Descriptions study. These injury state descriptions were broken down into various recovery phases to scale the injuries further according to other indices. The experts were then tasked with aligning each recovery phase of every injury state with the respective scales. The points where the experts placed each phase of every injury state were subsequently converted into utility scores. This conversion was based on a matrix derived from the scores given to a sample group in the initial study that established the scale. This process led to the calculation of the estimated value for avoiding a serious injury using Relative Utility Loss Scales.

In some nations, as detailed by (Perkins et al. 1998) in the context of the European Conference Ministers of Transport, fatality costs are used as a reference point for calculating costs associated with other injury severities. Specifically, 13% of the fatality cost is applied to estimate the cost of a serious injury and 1% for a minor injury. The project led by Bickel et al. (2006) (Developing Harmonized European Approaches for Transport Costing and Project Assessment) and conducted from 2004 to 2006, aimed to align the accident cost computation guidelines among European Union partners. This goal was similar to that of $COST_{313}$. The project focused on offering detailed recommendations on methods and components for accident cost calculation. The influence of project’s findings extends to present times, affecting accident cost estimates in various countries, including Malta and Belgium. When specific accident cost data is unavailable within a country, the project's recommended values are often adopted, with adjustments made only for general economic data like GDP growth.

Van Essen et al. (2019) adhered to international standards and utilized the WTP method to estimate the VSL, a key component in calculating the human costs of fatalities. The study deducted consumption loss from the VSL to arrive at the human cost of fatalities. Their research also demonstrated that the WTP method is not limited to assessing the human costs of fatalities but can be effectively used to evaluate the human costs associated with injuries as well. However, it was highlighted that, due to the variability in severity and duration of injury outcomes, the human costs of injuries will be rather variable. According to the study, the simplest method to describe the human costs associated with injuries is as a percentage of the VSL. Based on Richter et al. (2007), a summary of the percentages of VSL that the literature suggests for various injury categories was presented. Importantly, it was recommended that direct comparisons between the majority of research are not ideal because the definition of a "serious" or "slight" injury varies greatly between studies.

The study mentioned that the European Union decided in 2014 to gather data on road injuries using a new common definition. The prior definition differentiated between severe and minor injuries. Since 2014, accident statistics have utilised the Maximum Abbreviated Injury Scale (MAIS) definition, which is comprised of six categories. MAIS 1 and MAIS 2 correspond essentially to the previous definition of a minor injury. MAIS 3, MAIS 4, and MAIS 5 correspond essentially to the previous definition of a severe injury. MAIS 6 is defined as a non-survivable injury and so corresponds to the previous definition of fatality as listed in Table 2.1. It is important to acknowledge that this estimate is quite rudimentary, and further research is warranted for a more precise assessment (Van Essen et al. 2019).

Table 2.1: Recommended fraction of VSL based on AIS scale

Injury Category	**Recommended fraction of VSL based on AIS-scale**
MAIS 1	0.3%
MAIS 2	4.7%
MAIS 3	10.5%
MAIS 4	26.6%
MAIS 5	59.3%
MAIS 6 (Fatality)	100.0%

According to the current European Union definition, there is virtually no relevant literature on estimating the human costs of injuries. One such study examining the monetary value of MAIS categories is that of Blincoe et al. (2015). This study provides a mean estimation of the quality of life lost by accident victims across all six MAIS categories. However, this method is based on Quality Adjusted Life Years lost due to traffic injuries rather than the WTP method. The costs for these categories do not differ considerably from the percentages recommended by the United States Department of Transportation (USDoT 2016, 2021) for the AIS when expressed as a percentage of a fatality. To calculate the human costs of RTAs using the updated MAIS classification, a proposed method involves expressing the costs associated with all other injury categories as a percentage of MAIS 6 (fatalities).

2.6 LITERATURE SUMMARY

As per the 2018 Global Status Report on Road Safety (WHO 2023), RTAs remain a substantial global development challenge, a critical public health issue, and a leading cause of fatalities and injuries worldwide, claiming the lives of over 1.19 million individuals. A staggering 90 percent of these tragic incidents occur in developing countries, with India alone accounting for 11 percent of these fatalities (WHO 2018). India has, unfortunately, the highest number of deadly traffic accidents in the world. According to MoRTH (2020), the costs associated with RTAs in India represent approximately 3.14 percent of the country's GDP, highlighting the significant road safety challenge India faces. The socio-economic costs of RTAs are so enormous that they justify funding accident prevention and road safety programmes.

Very few attempts have been made to estimate the costs of RTAs in India. The total accident appraisal value represents the sum of accident- and casualty-related expenses. There are several methods for RTA cost estimation, including HC, Net Output, Life Insurance, Court Awards, Implicit Public Sector Valuation, and WTP. Among these, the HC and WTP approaches have been most commonly utilized in recent years. The HC method focuses on calculating the discounted value of a victim's lost productivity while not considering the loss of quality of life. In contrast, WTP aims to determine the maximum amount individuals would pay to reduce the risk of death or injury based on their preferences and perceptions. WTP is primarily used for a qualitative assessment of accident costs, while the HC method emphasizes the quantitative aspects of RTAs for post-analysis. It is noteworthy that the WTP method is predominantly employed in high-income countries, while the HC approach is primarily used in low- and middle-income nations. Developing countries face various challenges and resource constraints in this context. Moreover, limited studies have explored the harmonization of qualitative and quantitative aspects in estimating accident costs.

The available information on certain cost components is limited, highlighting the need for further research. The review particularly emphasizes the importance of investigating the human costs associated with fatalities and injuries. A grievous injury can be any hurt that may require a short-term hospitalisation or even may lead to a permanent disability of the victim and hence cannot be generalised. A research gap has been identified in the scaling of grievous injuries according to a nationally recognised scale, such as the AIS, for the computation of the VSI. The current cost estimates do not account for the time spent by caregivers/family members of the victim and the lost productivity of a victim who is retired (Kumaresh et al. 2021). The fact that only 5% of the studies analysed (Bougna et al. 2022) are carried out in low-income nations emphasises the need to boost research in such countries. Considering the economic and technical challenges of applying the WTP method, a hybrid strategy combining these two methods is essential.

2.7 RESEARCH GAPS

a) **Significance for Developing Countries**: The present research is significant for developing countries since very little research has been carried out in the area of accident costing.
b) **Caregivers and Retired Individuals**: Existing studies employing the HC approach rarely account for the time spent by the caregivers of the injured as well as the lost productivity of retired individuals.
c) **Hybrid Methodology**: Establishing a hybrid methodology concept in developing countries by incorporating data acquired from the same region. In contrast, the prevailing study uses data from multiple countries.
d) **Scaling Grievous Injuries**: Past studies consider grievous injury as a single severity, even though it highly varies, emphasizing the necessity of scaling them based on severity.

e) **Estimating VSI from VSL**: A few studies estimated VSI from VSL in developed countries; hence, there is a scope for similar research in developing countries.

CHAPTER 3

METHODOLOGY AND DATA COLLECTION

3.1 GENERAL

Though several works of literature on accident costing studies employing a variety of methods, most notably the Human Capital (HC) and Willingness to Pay (WTP) methods, are available globally (Hills and Jones-Lee 1981; Jacobs 1995; Mohan 2002; Bhattacharya et al. 2007; Alrukaibi et al. 2015; Bahamonde-Birke et al. 2015; Mon et al. 2018; Jadaan et al. 2018; Balakrishnan and Karuppanagounder 2020; Kumaresh et al. 2021; Mekonnen et al. 2022), in India, very few attempts have been made to determine the cost of Road Traffic Accidents (RTAs). The present research focuses on harmonizing the WTP method, widely used in high-income countries, examining the accident cost qualitatively, and the HC method, predominantly used in low- and middle-income countries, emphasizing more on the quantitative aspects of a road accident after its occurrence. Developing countries are confronted with several challenges and have extensive resource needs. There will be disparities in the cost estimates for the same geographic regions due to methodological discrepancies. From the available literature, it is evident that there is very little research that examines the diversity in cost estimates for the same geographic regions. This is the first initiative of its sort, particularly in the developing world. In addition, the qualitative and quantitative harmonization of accident costs has been the subject of very few published studies.

A lack of knowledge regarding certain cost components necessitates further investigation. Based on the review, it is on the human costs or pain, grief, and suffering (PGS) of fatalities and injuries. The grievous injury is to be scaled based on a nationally recognized scale, such as the Abbreviated Injury Scale (AIS), for the Value of Statistical Injury (VSI) calculation. The existing cost estimates do not account for the time and effort spent by caregivers and the productivity loss of a retired victim (Kumaresh et al. 2021). There is a need to increase research in low-income countries, which only account for 5% of the studies that have been analyzed (Bougna et al. 2022). Considering the technical and economic constraints associated with the use of the WTP approach, a hybrid strategy integrating these two methodologies is required. The present research work attempts to address the above-said research gaps. The detailed methodology adopted in the study is discussed in the following sections.

3.2 METHODOLOGY

The step-by-step process involved in pursuing the research objectives is depicted in Fig 3.1.

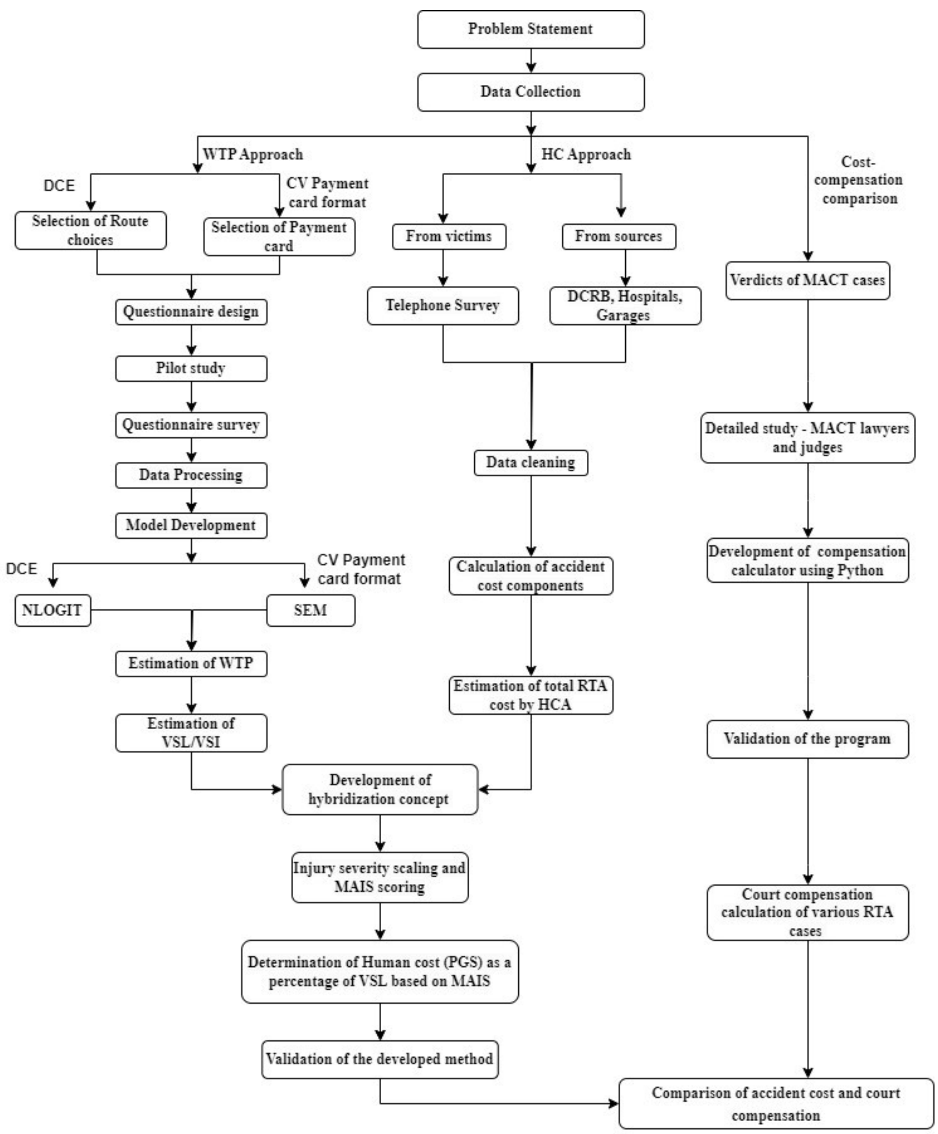

Figure 3.1: Flowchart of the methodology

The subsequent sections elaborate on the various stages shown in the flowchart.

3.3 STUDY ARA

The city limit of a South Indian district, Ernakulam, known as the commercial hub of Kerala, is chosen as the study area. This area has the highest number of blackspots (703 out of 4592) and the highest total number of road crashes in the state. This justifies its selection based on severity, crash proneness, and the number of registered RTAs, according to Kerala Police and the National Transport Planning and Research Centre (Kerala Police 2022; NATPAC 2022a). The Ernakulam District (City and Rural) registered 5,996 RTA cases in 2018. Among the major establishments located here are the Cochin Shipyard, the office of the Kochi Municipal Corporation, and the Kerala High Court. Fig 3.2 depicts the major road networks and significant locations in the city of Ernakulam.

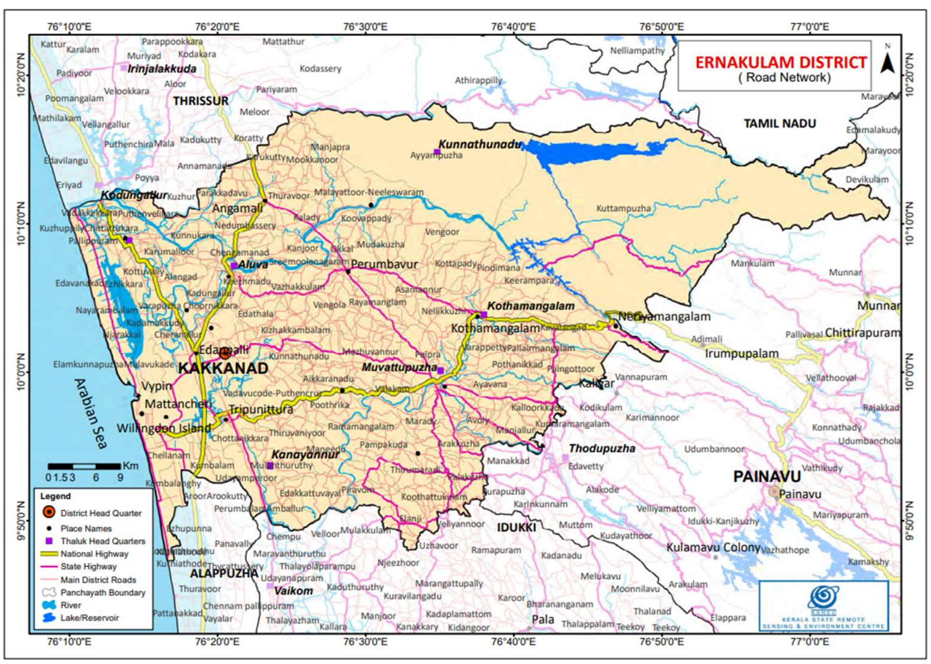

Figure 3.2: Map of Ernakulam District Source: (State Planning Board Government of Kerala 2022)

Socio-economic and demographic features, as well as road transport networks, are described below.

3.3.1 Socio-demographic characteristics

The city's whole population was 6,02,046, out of which 2,96,949 were males and 3,05,097 were females, as per the latest census report. The average sex ratio was 1027 females for every 1000 males. The literacy rate of Ernakulam city was 97.36%, which is higher compared to the entire Ernakulam District (95.89%). The total population of Ernakulam in the urban agglomeration/metropolitan region is 21,19,724. The male population is 10,44,243, while the female population is 10,75,481 (Census 2011). The city's population was estimated for the study period using the apportionment method and the decrease growth rate method, and the average of these two values was taken for each year (Planning 2011).

3.3.2 Road transport

The city is interconnected to the North-South Corridor National Highway (NH) system by four-lane NH 66 and NH 544. The Main Central Road that begins from the capital district Thiruvananthapuram and terminates at Angamaly in Ernakulam district gives connectivity to neighbouring districts like Thrissur, Palakkad in Kerala, as well as Salem, and Coimbatore districts of Tamil Nadu state. The highway covers the full length and breadth of the city at various spots. NH 66 was intended to serve as the Kochi city bypass; however, the rapid urbanisation of Kochi has resulted in the bypass becoming a city road running through the centre of the city, causing the National Highway Authority of India to propose a new Kochi city bypass.

The Kerala State Road Transport Corporation (KSRTC) operates interstate, interdistrict, and city services, mostly from the Ernakulam KSRTC bus terminal, which is Kochi's second-busiest bus stand after the Vytilla Mobility Hub. Ernakulam Jetty and Thevara Depot are two additional bus stations operated by the KSRTC in the Ernakulam region of the city.

3.3.3 Road safety

Road safety is challenging in a populous city like Ernakulam, with surplus traffic conditions. The number of vehicles in Ernakulam has increased by 26.84% over the past five years, and the district holds the highest percentage (14.35%) of the vehicle population in the state (State Planning Board Government of Kerala 2022). The rapidly increasing vehicular population in Ernakulam has resulted in the highest fatal road accidents in recorded history. As a result, the city police have been strictly enforcing traffic violation regulations. Based on the data presented in Table 3.1, it is evident that accident rates have not changed significantly despite the implementation of strict measures to prevent RTAs and fatalities. Even if the number of accidents is reduced in 2021, the number of accident-related fatalities has increased, compared to the previous years, requiring special attention.

Table 3.1: Accident Statistics - Ernakulam City

(Source: District Crime Records Bureau data)

Year	No. of Accidents	Deaths	Total Injuries
2018	2411	141	2619
2019	2290	155	2409
2020	1437	101	1507
2021	1781	141	1899

3.3.4 Specific site selection for the estimation of WTP

The estimation of WTP by the Discrete Choice Experiment (DCE) method requires specific route selection within the city. High-risk road segments are ranked in Ernakulam city according to the number of blackspots, which are accident statistics obtained from NATPAC. In 2021, KSCSTE-NATPAC identified 4,592 crash blackspots in Kerala using crash data from 2018-2020 collected by the Kerala State Crime Records Bureau. The Crash Severity Index for each blackspot was calculated with a weightage of seven for fatal crashes and three for grievous injury crashes, excluding minor and non-injury crashes due to under-reporting. NATPAC performed a corridor analysis of blackspot clusters along National and State Highways using

Geographical Information System (GIS). The severity index of vulnerable road stretches (Blackspot Cluster Severity Index) was computed by summing the normalized crash Severity Index of blackspots and the normalized crash blackspot rate with equal weightage.

In total, Ernakulam has 34 high-risk black spots. The Severity Index for various sections is Edapally to Kundanoor Junction - 0.81; Kundanoor Junction to Aroor Kumbalam Bridge – 0.55; Edapally Junction to Aluva Junction - 0.98; CIFT Junction to Kundanoor Thevara Bridge - 0.23; North Kalamassery to Eloor Junction - 0.40; Nayarambalam Bridge to Goshree Bridge Junction - 0.77; Thoppumpady to Kattiparambu - 0.81; and Kattath Bus Stop to Vallarpadam ICTT: -0.48 (NATPAC 2022b). The Severity Index of all these stretches is almost higher than 0.5. The sections with a Severity Index very close to 1 are considered to be high risk. Although there are many black spots in Ernakulam, these stretches are identified as critical as well as connecting stretches with critical Severity Index, and hence selected for the present study.

Using the aggregated black spots in Ernakulam city based on the district-wise ASI values, the segments of roads housing the most critical accident spots were determined by the NATPAC. This listed data gives an idea about the black spots that are present in Ernakulam. Out of 34 stretches, 17 are on NH, and the remaining 17 are on State highways (SH). The routes which are connecting to each other are taken for this study as this road stretch constitutes a full black spot road.

From the list of high-risk road stretches, the following three were selected.

1. Road Stretch I: Aluva junction to Aroor Kumbalam bridge (Fig 3.3)
2. Road Stretch II: Thoppumpady to Kundanoor Thevara bridge (Fig 3.4)
3. Road Stretch III: Nayarambalam bridge to Vallarapadam ICTT (Fig 3.5)

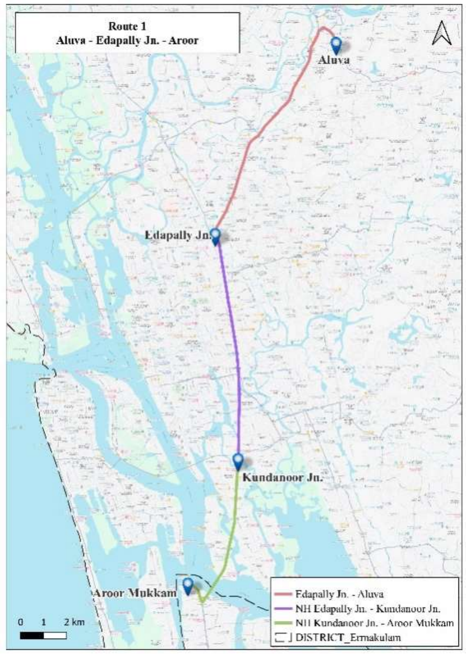

Figure 3.3: Route 1: Aluva junction to Aroor Kumbalam bridge

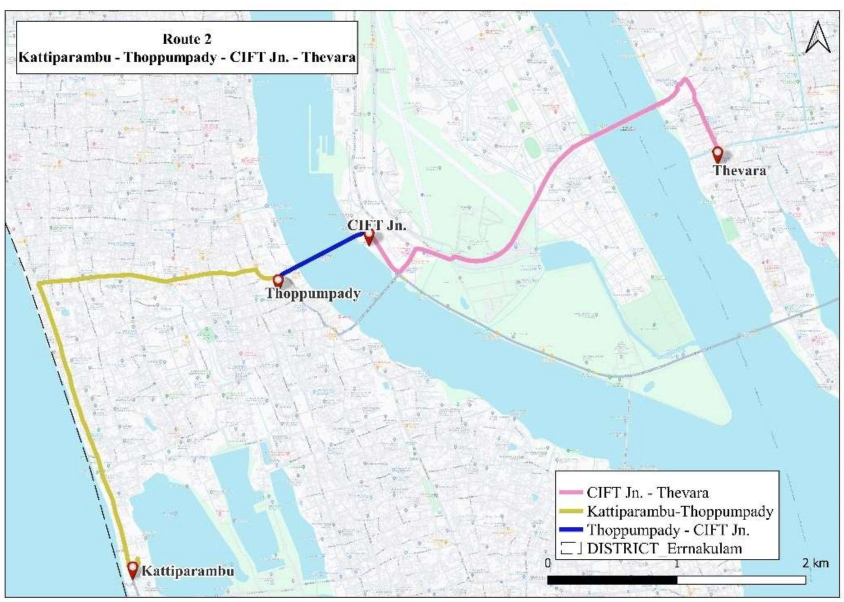

Figure 3.4: Route 2: Thoppumpady to Kundanoor Thevara bridge

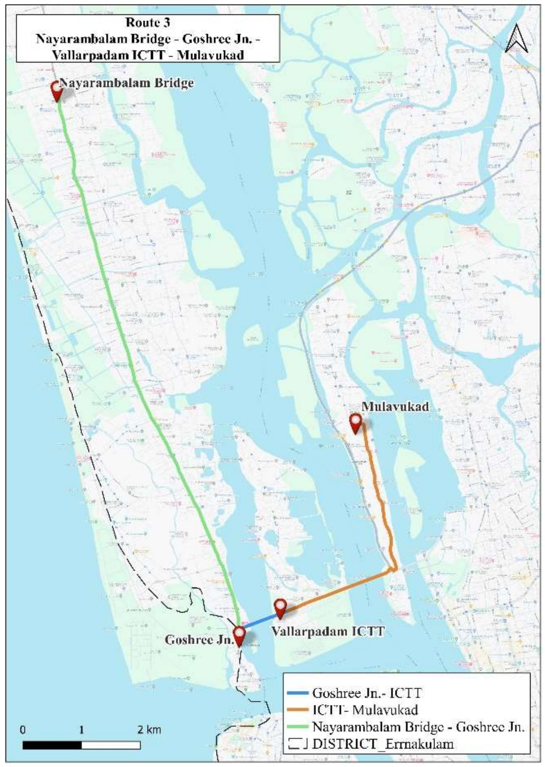

Figure 3.5: Route 3: Nayarambalam bridge to Vallarapadam ICTT

The running speed and journey speed on the above-mentioned road stretches are higher compared to other stretches, even under "stop-go" conditions (NATPAC 2022b). This may be the reason why this section of the road presents a greater risk to motorists than the others. The details about the selected stretches, their traffic conditions, passing SHs and NHs, included traffic, and the number of black spots are detailed in Table 3.2. The present study takes into account all three of these routes, and the distribution of the survey's population is determined by the number of people living in the localities along each route.

Table 3.2: Traffic details – handling of traffic

Route No.	Start point	End point	Passing NH/SH	Total Length (km)	Included traffic	Number of blackspots	Annual accident rate
1	Aluva Junction	Kumbalam Bridge	NH544, NH66	30	Aluva, Edapally, Kundanoor, and Aroor Kumbalam	41	88
2	Thoppumpady	Kundanoor Thevara Bridge	SH66, NH996B	10.3	Thoppumpady, Kattiparambu, CIFT junction, and Kundanoor Thevara bridge	15	17
3	Nayarambalam Bridge	Vallarapada m ICTT	SH63, NH996A	15	Nayarambalam Bridge, Goshree Junction, Mulavukad, and Vallarapadam ICT	19	27

3.4 DATA COLLECTION

The objectives of this study were accomplished using a research design that used a combination of methods. Different methods necessitate diverse data collection procedures, as discussed below.

3.4.1 Data Collection-HC Approach

Based on the proposed cost framework, primary data on road accidents (RTA data for the city of Ernakulam for the years from 2018 to 2021) were obtained from the District Crime Records Bureau (DCRB), Ernakulam, as shown in Table 3.1. The majority of the data used to estimate the lost productivity was taken from the official websites of the Government of Kerala. This data includes the average retirement age, discount rate, Gross Domestic Product (GDP) growth rate, and GDP per capita.

3.4.1.1 Questionnaire survey

A follow-up telephone survey was conducted to obtain the primary data, which consisted of injury descriptions and socio-demographic characteristics. Data were gathered from victims, garages, and hospitals using three sets of questionnaires. To ensure the efficacy of the questionnaire survey, a pilot test was conducted with a subset of prospective respondents. During the pilot test, the response time for each questionnaire was noted, and any ambiguity in the questions was evaluated. All questionnaires were fine-tuned ahead of the main survey based on feedback from respondents. The RTA costs were estimated according to the results of this survey.

The objective of Questionnaire I is to collect data from a follow-up survey of victims regarding the lost productivity cost component. Questionnaire II is for Authorized and Unauthorized Vehicle Garages to determine vehicle damage costs. Questionnaire III aims to determine the medical cost component for the selected hospitals. These questionnaires are given in Appendix I.

3.4.1.2 Sample selection

A total of 7919 First Investigation Reports (FIRs) related to RTAs were received from DCRB in 9 circles, which cover the whole of Ernakulam City. All the FIRs were downloaded, and the required data was extracted from each FIR, which includes the vehicle details, injury details, age, occupation, and contact number. Twelve hospitals are listed for collecting the data regarding medical costs. Out of which, only three hospitals agreed to give their data. Details like hospitalization days and hospitalization cost were collected based on injury type. Bill samples are collected for each vehicle type from Authorized (Hyundai, Royal Enfield, Yamaha) and Unauthorized (Impreza, Topline automobiles, Manohar workshop) vehicle garages to estimate the vehicle damage costs.

Since there were 7919 FIRs, the sample size has to be calculated for conducting the follow-up survey of the victims. The number of samples to be surveyed was obtained using Modified Cochran's formula. The Cochran formula (Eq 3.1) allows us to calculate an ideal sample size given a desired level of precision, desired confidence level, and the estimated proportion of the attribute present in the population. Cochran's formula is considered especially appropriate in situations with large populations. A sample of any given size provides more information about a smaller population than a larger one, so there is a correction through which the number given by Cochran's formula can be reduced if the whole population is relatively small.

The Cochran formula is:

$$n_0 = \frac{Z^2pq}{e^2} \tag{3.1}$$

where, Z is obtained from the Z table, e is the desired level of precision (i.e., the margin of error), p is the (estimated) proportion of the population which has the attribute in question, and q is 1-p. Since a small population is being studied, the sample size is recalculated using the Modified Cochran formula, as shown in Eq 3.2.

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}} \tag{3.2}$$

where, n_0 is the initial sample size calculated using the Cochran formula, N is the population size, n is the new adjusted sample size taking 95% confidence interval, i.e., Z-value as 1.96, and assuming e as 0.05, p-value as 0.05, and q as 0.95, the number of samples to be surveyed obtained using the Modified Cochran formula is 366. These samples have been selected to cover all the injury types and occupation types, and gender bias is avoided. Details regarding their accident, like the number of days of rest at home and the amount they spent at hospitals and other departments due to the accident, were collected through the follow-up telephone survey.

Conducting follow-up telephone surveys with RTA victims presented several challenges that impacted the accuracy and depth of the data. Obtaining accurate contact information from FIRs often proved difficult due to incorrect or outdated phone numbers. Additionally, some contacts were those of traffic police officials instead of the victims, requiring samples to be swapped during the process. The emotional and physical trauma experienced by victims led to reluctance or refusal to participate, which lowered response rates to around 60%. Technical issues such as poor call quality further hindered effective communication. In some instances, the tragic reality that victims had already passed away by the time of contact was encountered. When close relatives, such as mothers or wives, answered the calls, they often became very emotional, requiring considerable time for consoling before the necessary information could be sensitively gathered.

In cases of recently occurred traffic accidents, ongoing MACT cases made victims hesitant to share information, fearing illegal disclosure of evidence or case details. The availability of respondents during working hours was limited, making multiple contact attempts mandatory to collect responses at their convenience. Maintaining detailed records of contact attempts and responses provided insights into factors to improve participation. Overcoming these challenges was essential to ensure the reliability of follow-up surveys and to better understand the long-term effects of RTAs on victims.

3.4.2 Data Collection-WTP Approach

The evaluation of WTP is strictly a survey procedure where the respondents are asked how much they are willing to pay to reduce the risk of getting injured in a road accident. The SP surveys deal with the measurement of WTP value from user behaviour. In this study, the road users' WTP for reducing the injuries' risk and fatalities' risk due to traffic accidents was collected using two prominent SP surveys: (i) the WTP-Contingent Valuation (CV) survey and (ii) the DCE survey.

3.4.2.1 Pilot study

As this study is concentrated on accident costing, the places where the accidents are concentrated were identified. This involved the analysis of accident data from various government sources. The population to be studied was selected based on the accident rates.

The road accident injury and fatality risk were determined from the analysis of official RTA statistics from DCRB and NATPAC. The data analysis revealed that only 1.2% of vehicles involved in the RTA were public vehicles, so the survey concentrated more on private vehicle owners (District Crime Records Bureau n.d.). Also, it was found that two-wheelers and four-wheelers contributed to 60% and 23% of total vehicles, respectively (See Appendix I E – Tables I.1 to I.4).

To conduct a survey, it is necessary to determine the ease with which respondents can comprehend the study's questions and the complexity of the survey form. Although the primary objective is to evaluate the WTP to lower the chance of being involved in a road accident, most people may not be familiar with the term WTP. Thus, appropriate clarifications should be supplied. In questionnaire survey methods, respondents will not spend a great deal of time understanding each question before responding. Hence, the questions must be shorter and easier to comprehend. A preliminary survey form was developed to comprehend the population's features, including questions regarding the socio-economic aspects, CV methodology, and stated choice approaches. The aim of this survey was to determine whether or not respondents could easily comprehend the phrases and concepts included in the questionnaire. The form contained questions regarding the respondent's place of residence, age, gender, household income, occupation, personal income, marital status, and accident history. Questions comparing two distinct risk situations were added to determine if respondents were familiar with risk-related terminology. The CV questions assessed how much they were willing to pay for a specific risk reduction percentage. In addition to CV questions, choice questions with different choice levels (assumed) were presented to check whether they could understand various factors associated with travel. Question sets with varying options of choice were introduced in the preliminary survey.

Instead of just mailing the form, a face-to-face interview procedure was implemented in which the form was delivered to the respondents at the time of the interview, and they were asked to identify any questions that arose while completing the form. All of the questions raised by respondents were noted and thoroughly clarified. Thus, the questions they found difficult to comprehend were modified. In total, 57 individuals participated in the perception survey. On the basis of the responses, some questions (related to the responses) were presented to determine whether the respondents clearly understood the meaning of questions regarding risks. The majority of respondents responded with zero to the direct WTP question, indicating that they are hesitant to pay for risk reduction. Such responses demonstrate protests, asserting that the government is responsible for improving road safety and paying for it with taxes collected from citizens. Nonetheless, the responses to the indirect method of multiple-choice questions in which people select among choices were positive. Bar charts and tabular forms illustrating the variation of attributes among the choices were provided. It was difficult for them to compare attribute values using a table format, but they responded positively to a graphical representation of the alternatives. Choice questions with several alternatives were difficult for them when more choice sets were offered; however, choice sets with two choices were met with a favourable indicator. Based on perception survey results, asking respondents how much they are willing to pay for a specific percentage of risk reduction was eliminated due to the likelihood of partial protest responses. Instead, an stated choice approach that was regarded as simple to respond to by respondents was selected. In addition, in order to simplify the design's complexity, binary alternatives were chosen for attributes that cannot be compromised (See Appendix II).

The reliability of this study's responses was evaluated using Cronbach's alpha, with values for all constructs above 0.70, indicating dependable responses. Additionally, the chi-square tests conducted to assess the association between categorical variables and the outcomes were found to be statistically significant, with chi-square values ranging from 12.59 to 19.99 and p-values all below 0.03 across various constructs. The statistically significant chi-square test results indicate that the observed relationships were not due to chance, supporting the overall validity of the study's findings. This suggested that the major survey could be conducted with improvements proposed by pilot study participants.

3.4.2.2 Sample size estimation

In order to draw accurate inferences from research findings, it is crucial to determine a sufficient sample size. Several methods for determining sample size have been suggested by prior research. These criteria include item-sample ratios, population-sample tables, and general rules of thumb for calculating the sample size. Although there are a variety of tables and rules of thumb to calculate sample size in social science research, many researchers are unsure of which one to use to establish the right sample size for their studies, particularly when survey research is used to collect data.

Green (1991) asserts that researchers undertaking power analyses can acquire better precision and adaptability by going beyond these rules of thumb. In this study, a statistical power level of 0.8 was chosen. This level provides an 80% probability of detecting a true effect while balancing the risks of Type I and Type II errors (Cohen 1988; Green 1991). This standard is widely accepted (Nakagawa et al. 2024; Xu et al. 2024) and ensures the study can detect significant effects without requiring an impractically large sample size, aligning with both practical and ethical research standards. After performing G power analysis for sample size estimation, it was determined that a minimum of 489 samples are required for Structural Equation Modelling (SEM) (i.e., for a model to determine the WTP by CV) and a minimum of 545 samples are required to detect the effect of the selected items.

Table 3.3: G Power Analysis

Parameters	Value
Anticipated effect size	0.15
Desired statistical power level	0.8
Number of latent variables	3
Number of observed variables	22
Probability level	0.05

The distribution of sample size in the localities along the chosen stretch is shown in Table 3.4.

The respondents (above 18 years of age) were selected from 22 vulnerable road locations. Based on population distribution, accident frequency, the proportion of road user categories involved in RTA, and the number of respondents from each locality were estimated. This study consisted of 1,110 road users, including 812 two-wheeler users and 298 four-wheeler users. The sample sizes selected for the study were more than the required range, and it was also sufficient for the Multinomial LOGIT (MNL) model, a random effects model adopted for the DCE survey WTP estimation. Random effects models are commonly used to take the unobservable into account. The main advantage of a random-effects model is that it can produce efficient estimates with finite sample sizes compared to other approaches.

Table 3.4: Sample size distribution – WTP

Route	Locality	Population	Samples required
Route 1	Panangad	15055	18
	Maradu	59090	71
	Ernakulam Town South	12247	15
	Thrippunithura	97095	117
	Ambalamedu	46114	55
	Thrikkakara	104880	126
	Kalamassery	45024	54
	Elamakakra	39629	48
	Palarivottam	20005	24
	Ernakulam Town North	28539	34
	Eloor	31927	209
Route 2	Kadavanthra	22128	145
	Chernalloor	7720	51
	Fort Kochi	10611	70
	Mattancherry	10239	67
	Thoppumpady	14129	93
	Pallaruthy	26660	175
Route 3	Mulavukad	12012	83
	Ernakulam Town North	28539	196
	Chernalloor	15439	107
	Mattancherry	20477	141
	Fort Kochi	10611	73

3.4.3 Data Collection-Court compensation

Initially, a clear and lucid idea of how the Motor Accidents Claims Tribunal (MACT) calculates the compensation for different accident cases is made. An effort is made to identify the factors that are considered by the MACT while calculating the compensation. Different sections of law under the Motor Vehicle Act are studied.

Data is collected from different lawyers dealing with MACT cases from different parts of Kerala state. The data includes court verdicts of MACT cases, including the amount awarded as compensation. The compensation awarded by the tribunal varies highly on a case-by-case basis and highly depends upon the financial and other circumstances of the person involved. Questions on people's awareness regarding compensation awarded by the MACT were included in the survey questionnaire for the HC method.

3.5 ESTIMATION OF RTA COST - HC APPROACH

Estimating the socio-economic loss due to RTAs using the HC approach requires a comprehension of each cost component. Various cost components considered in the estimation of economic loss are lost productivity cost, medical cost, vehicle damage cost, administrative cost, and human cost. The data required for the RTA cost estimation was collected from various sources, such as DCRB, hospitals, and garages, using different sets of questionnaires and analysed to calculate each cost component. The DCRB data was the basis of the overall RTA cost estimation as it provided the details of the RTAs that took place in the study area during the study period, i.e., from 2018 to 2021. The FIRs obtained from the DCRB were extracted to get the details of the accident and the victim. The data from hospitals and garages substantiated the requirements for the calculation of medical and vehicle damage costs, respectively. Further, additional data required for various cost components were collected directly from the victims via telephone survey. In the end, the various cost factors were calculated and summed to get an estimate of the loss brought on by RTAs. A comparison of cost components at different injury severity levels was also carried out. The annual RTA cost estimates were then expressed as the percentage of the GDP of the city.

3.6 ESTIMATION OF RTA COST - WTP APPROACH

Using the WTP approach in this research, the accident cost due to RTAs was estimated by adopting two SP methods - CV payment card format and the DCE. Following the selection of specific sites and routes for the elicitation of WTP, payment cards and route choices were selected for CV and DCE methods, respectively. The questionnaire to collect the required data for eliciting the WTP from the respondents was designed, and the pilot study was conducted. Based on the results of the pilot study, the questionnaire was modified, and the main survey was conducted. The data collected was cleaned and processed. The WTP using the CV payment card method was calculated. The factors affecting the WTP were determined using SEM. The risk and the monetary parameters required for the estimation of WTP using the DCE method were obtained from the MNL model using NLOGIT software. The WTP using the DCE method was then calculated. The Value of Statistical Life (VSL) and VSI were calculated using the obtained WTP values. The RTA cost for the study period was then estimated. The annual RTA cost estimates using the WTP approach were then expressed as the percentage of the GDP of the city.

3.7 HYBRIDISATION OF HC AND WTP APPROACHES

The primary constraints of the HC and WTP approaches are being considered in the development of a Hybrid method. The HC method assesses the cost of an accident by accounting for lost productivity, while the WTP method focuses more on estimating intangible costs, which are sometimes overestimated. The proposed hybrid methodology suggests the revision of conventional HC method cost components to include the VSL concept for PGS. The notional income fixed by the court was adopted as the income in the case of post-retirement age victims, considering the service they provided to society. The lost productivity of the caregivers was also accounted for in the new method. The method does justice to the PGS cost component by adopting the concept of VSL and injury scaling using Maximum Abbreviated Injury Scale (MAIS). Considering the economy of the country, using the weighted average approach, the VSI for grievous and minor injuries was determined. A detailed analysis of the proportion of various accident cost components was estimated using the hybrid approach. The RTA cost was estimated using the hybrid approach. A Python program was developed to estimate the individual accident cost using the hybrid approach for a present date as well as a future date, incorporating the economic concept of inflation.

3.7.1 An Expert Opinion Survey

The efficacy of the hybrid methodology was affirmed using the detailed analysis of the data derived from the responses in the Expert Opinion Survey. Initially, a questionnaire was developed, clearly stating its purpose. Experts were presented with various RTA scenarios differing in intensity, and were asked to select from cost estimates derived using HC, WTP-CV, WTP-DCE, and Hybrid methods. A diverse group of participants was chosen, including academicians, legal professionals, medical experts, insurance representatives, and scientists, considering their varied expertise, geographical backgrounds, and experiences. These experts were invited to join the survey by providing a detailed explanation of its aims and their expected contribution. A preliminary test was carried out with a smaller group of experts, leading to adjustments in the questionnaire. Subsequently, the revised questionnaires were distributed via Google Forms. The responses were gathered, maintaining the anonymity and confidentiality of the participants. The findings were then analysed in relation to the set objectives.

3.8 COMPARISON OF RTA COSTS AND COURT COMPENSATION

The RTA cost estimated using HC, WTP-CV, WTP-DCE, and Hybrid approaches were compared to find the differences between them. A detailed study of the court compensation calculation procedure was carried out using hundreds of obtained verdicts from different courts in the study area and also by approaching MACT lawyers and judges. The accident cost of each of those cases was determined using the developed program. Another Python program was developed incorporating the aspects of MACT compensation. This program was validated using another set of verdicts. It was then used to determine the difference between the amounts of the cost estimated using the Hybrid method and the court compensation in order to draw a comparison between these two aspects. These programs are essential for accomplishing the objective of comparing estimated accident costs with the economic compensation awarded by the Court. Additionally, these tools offer a fundamental understanding of accident cost estimation and MACT compensation calculation, aiding MACT lawyers and accident victims in making informed decisions. The findings from this research help raise public awareness about the financial impacts of RTAs and the compensation awarded by courts, providing a practical tool for the common man to estimate accident costs and compensation.

3.9 SUMMARY

This chapter presents a concise overview of the methodology that was adopted in the development of a Hybrid method for the estimation of RTA costs. A comprehensive description of the study area and the data collection procedures implemented for the various methods involved in this research is also provided. The chapter also offers valuable insight into the diverse approaches to accomplishing the research objectives. Furthermore, the entire research process is visually depicted through a flow chart, illustrating the sequential steps involved.

CHAPTER 4

ESTIMATION OF RTA COST - HC APPROACH

4.1 GENERAL

The Human Capital (HC) method provides the estimates essential to evaluating a project when WTP is difficult and expensive. In this study, the HC approach is used to calculate the total cost of Road Traffic Accidents (RTAs) based on cost components and severity levels of injuries. The results obtained are discussed in depth in the sections that follow. The overall cost of RTA in Ernakulam for four consecutive years (2018, 2019, 2020, and 2021) was estimated and represented as the percentage of Gross Domestic Product (GDP). The total cost of road traffic crashes is expressed as the percentage of GDP and is hence referred to as the GDP method.

4.2 RTA COST FRAMEWORK

The proposed HC accident cost calculation framework and its cost components are depicted in Fig 4.1, which was taken and modified from Alfaro et al. (1994) and Silcock and Transport Research Laboratory (2003).

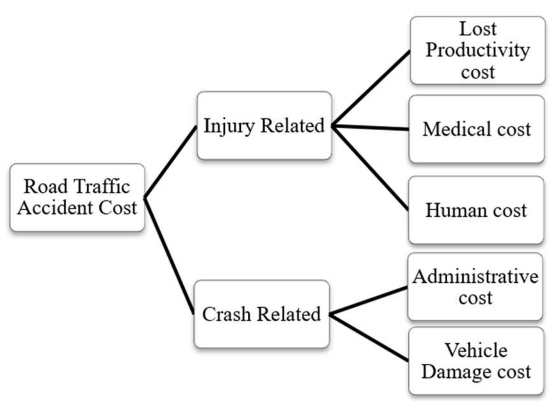

Figure 4.1: HC cost estimation framework

Including the medical and Property Damage Only (PDO) cost categories is a major distinction between the structure used in this study and Silcock and Transport Research Laboratory's (2003) conclusions. As per Fig 4.1, the PDO cost category is now known as the vehicle damage cost.

4.3 COST COMPONENTS

The HC approach demands the calculation of accident costs component-wise. The various cost components included in this approach are detailed below. The data obtained from various official websites and reports for calculating RTA cost components and comparing them with GDP are listed in Table 4.1.

Table 4.1: Socio-demographic characteristics of Ernakulam City

Year	Population[1]	GDP per capita of the State[2] (INR)	GDP of the city (in millions)	Growth rate[3]	Discount rate[3]
2018	6,32,136	1,49,650	9,459.92	5.96	6.25
2019	6,36,435	1,59,878	10,175.19	2.93	6.50
2020	6,40,733	1,62,610	10,418.96	1.71	5.40
2021	6,45,032	1,46,910	9,476.17	-9.66	4.25

[1]Town & Country Planning (2011) [2]State Planning Board Government of Kerala (2022) [3]Louis. (2022)

4.3.1 Lost Productivity Cost

The data required to calculate the lost productivity cost due to injuries (grievous or minor) are the average wage per day and the average number of days hospitalized. A victim follow-up survey was conducted to collect this data, which is given in Table 4.2.

Table 4.2: Data from the victim follow-up survey

Description	Grievous	Minor
Average wage per day (INR)	827	906
Average number of days hospitalized	90	18

According to MoRTH (2020), the worst affected age group in RTA, which accounts for about 70% of total accidental deaths, is 18–45 years, the most productive period in the human lifespan. Hence, the lost productivity cost is the major RTA cost component as per this approach. The average retirement age is a significant factor in estimating lost productivity for RTA. As this estimates a future value in terms of present value, economical methods are adopted, considering the discount and future economic growth rates. The lost productivity of RTA victims with grievous or minor injuries is primarily calculated based on the number of days lost and the severity of the injury. The lost productivity of victims due to fatalities and those due to grievous or minor injuries is calculated using Eq 4.1 and Eq. 4.2, respectively (Alrukaibi et al. 2015; Mofadal and Kanitpong 2016).

$$\text{Lost productivity (fatality)} = \sum_{i=1}^{N} \frac{W(1+g)^i}{(1+r)^i} \tag{4.1}$$

where, W = average annual GDP per capita, g = annual growth rate of population, r = discount/interest rate, i = the average number of productive years lost per fatality.

$$\text{Lost productivity (injuries)} = \text{Number of injuries x Number of days spent in hospital x Average daily wage} \tag{4.2}$$

The estimated lost productivity cost ranges from 3,374.57 lakh to 5,331.79 lakh, emphasizing the monetization of productivity loss with this method. The results clearly indicate that productivity loss is attributable to fatal, grievous, and minor injuries in sequential order.

4.3.2 Medical Cost

The first tangible cost that has to be borne by the accident victim or the victim's family is the medical cost. The direct medical cost includes the expenses related to consultations, diagnostics, medications, surgeries, hospital stays, autopsies, rehabilitation/physiotherapy, and post-discharge care. Though there are standard estimation techniques for the medical costs due to RTA, the specific items contributing to the lists of costs are specific to a region. The scientific, as well as grey literature, reveals that there are variations in the average values and the units of measurement or assessment criteria, even when the following major essential expenses such as first aid, emergency care, ambulance charge, recovery, and rehabilitation are focused (Corazza et al. 2017). Considering the accident severity, the medical cost is estimated using the following Eqs. 4.3 and 4.4 (Alrukaibi et al. 2015; Mofadal and Kanitpong 2016).

$$\text{Medical cost due to Fatalities (brought dead or in} - \text{hospital death)} \\ = (\text{ Number of cases registered) x (Average Total hospitalization cost per person)} \tag{4.3}$$

$$\text{Medical cost due to Grievous or Minor injury accidents} = \\ (\text{ Number of cases registered)x (Average Total hospitalization cost for respective injury)} \tag{4.4}$$

Medical costs include Intensive Care Unit charges, surgery, medicines, room rent, nursing and admission costs, and death care charges (in case of a fatality). Based on data collected from Private hospitals and the telephone survey results, the average medical cost of injuries and fatalities has been determined, as shown in Tables 4.3, 4.4 and 4.5.

Medical costs are generally underestimated as most studies consider solely subsidized expenses of public hospitals. Since this study considers medical costs from various Private Hospitals selected based on their spatial distribution in the city, the estimated medical cost will be realistic.

Table 4.3: Average medical cost for injured victims (INR) from hospital records

Injury Severity	Average amount			
	I	II	III	Telephonic Survey
Grievous	2,65,472	1,77,654	2,62,631	2,51,431
Minor	16,996	11,785	15,479	11,039

Table 4.4: Average medical cost for minor injuries (INR)

Description	Minor Injury
Investigation charges	9,046
Nursing charges	1,375
Cost of medicines	3,404
Total	13,825

Table 4.5: Average medical cost for grievous injuries (INR)

Description (Grievous Injury)	Average amount	Description (Fatality)	Average amount
ICU Charge	44,273	**MLC Charge**	250
Cost of Surgery	88,846	**Clinical support care**	75
Cost of Medicine	75,209	**EM Service charge**	120
Room Rent	12,663	**ECG portable +electrodes**	240
Nursing Charge	18,188	**Death care**	360
Admission Cost	118	**Cost of Medicine**	580
Total	2,39,297	**Total**	1625

Grievous injury accidents have the highest medical costs. As a result of an increased number of accident cases, total medical cost is higher in 2018 and 2019. Following the

Covid-19 lockdown, there were fewer accidents, which resulted in a decline in medical costs during 2020.

4.3.3 Vehicle Damage Cost

This cost component is calculated considering the collision type, the number of vehicles involved in an accident, and the average damage for each. Eq. 4.5 was used to estimate the same based on the accident severity.

$$\text{Vehicle damage cost} = (\text{Number of vehicles}) \text{ x } (\text{Average vehicle damage cost}) \tag{4.5}$$

Other property damages, including infrastructural damage, are not considered due to lack of data. According to the data provided by authorized and unauthorized garages from the study area, the average cost of vehicle damage caused by RTAs has been calculated for various types of vehicles. In this study, the type of collision is also considered, as shown in Table 4.6, which is found to be rarely addressed in the literature.

Table 4.6: Average vehicle damage cost by collision type (INR)

Vehicle Type	Collision Type	Damage Cost (INR)
Scooter/ Motorcycle	Front/Rear/Side	15,835
Car	Front	2,00,187
	Rear	37,775
	Side	41,725
Autorickshaw	Front	55,600
	Rear	25,150
	Side	42,750
Bus/Truck	Front/Rear/Side	28,605

Given the type of collision, there is a considerable difference in the cost of vehicle damage for cars and autorickshaws. If the type of collision is not mentioned in the First Investigation Report (FIR), the average cost is adopted. The total vehicle population engaged in RTA comprised over fifty percent (62.75%) of two-wheelers (2W). Of all the vehicles involved in RTAs, cars account for 25.29%, while other vehicles account for 11.96%.

4.3.4 Human Cost

Human costs, or the cost of PGS, are calculated as a percentage of lost productivity costs (Alfaro et al. 1994; Silcock and Transport Research Laboratory 2003; Alrukaibi et al. 2015; Kumaresh et al. 2021). These are the intangible cost components borne by the victims' families or other close relatives, which is the highest of all other components for ethical reasons. It is the cost associated with the PGS due to the lost life. The human cost is calculated as a percentage of lost productivity for each accident type. According to Silcock and Transport Research Laboratory (2003), the human cost for fatal, grievous injury, and minor injury accidents is 28%, 50%, and 8% of its lost productivity cost, respectively.

4.3.5 Administration Cost

Administration costs include insurance, legal, police, and other emergency services expenses. The time and service rendered to each RTA by the personnel of all these sectors are accountable. According to Silcock and Transport Research Laboratory (2003), the administration cost for fatal, grievous injury, and minor injury accidents are respectively 0.2%, 4%, and 14% of the human cost and vehicle damage cost. For PDO accidents, it is 10% of the vehicle damage cost.

4.3.6 RTA cost calculation for the study period

The overall RTA costs in Ernakulam city were estimated as the sum of the above cost components for the consecutive years from 2018 to 2021 and expressed as a percentage of the city's GDP.

Analyzing the proportion of various RTA cost components, it is seen that lost productivity cost was 49% of total expenditures, which is the highest, emphasizing the importance given to the monetization of productivity loss in this method. Medical costs were the second most significant component, which accounted for 24% of the total estimated costs. Vehicle damage and human costs significantly contribute 10% and 16% of the total costs, respectively. The administrative cost is relatively small, accounting for 1% of the total costs. A pictorial representation of the above discussion is given in Fig 4.2. The percentage of human cost is found to be underestimated as it is calculated conventionally using the percentage suggested by Silcock and Transport Research Laboratory (2003). In the year 2021, over fifty percent of the total costs (54.89%) are related to fatal accidents. Grievous injury accidents account for 41.47% of the total costs, whereas minor injury accidents account for 3.05%, and non-injury accidents account for 0.59% of the total costs. Considering the proportion of accidents with varying injury severity, fatal accidents account for the largest share of lost productivity costs (81.71%) and human costs (72.53%). In contrast, grievous injury accidents account for the largest share of medical costs (96.11%), vehicle damage costs (69.95%), and administrative costs (56.33%).

The overall accident costs in Ernakulam city estimated for the consecutive years 2018 to 2021, component-wise and severity-wise, are given in Table 4.7. Fig 4.2 depicts the share of each cost component in the total cost. It ranges from INR 66.9 crore (6,696.04 lakh) to INR 105.6 crore (10,559.69 lakh), which can be averaged to INR 90.33 crore (9,033.33 lakh). It is evident from the variation in total accident costs in 2018 and 2019 that a marginal fall in the number of grievous injuries or fatalities is not the primary reason for the reduction in RTA costs. Instead, the productive age of the victims plays a significant role, as individuals in this age group contribute to a major share of the total accident cost through lost productivity. This is particularly evident in the cost estimates by the HC approach.

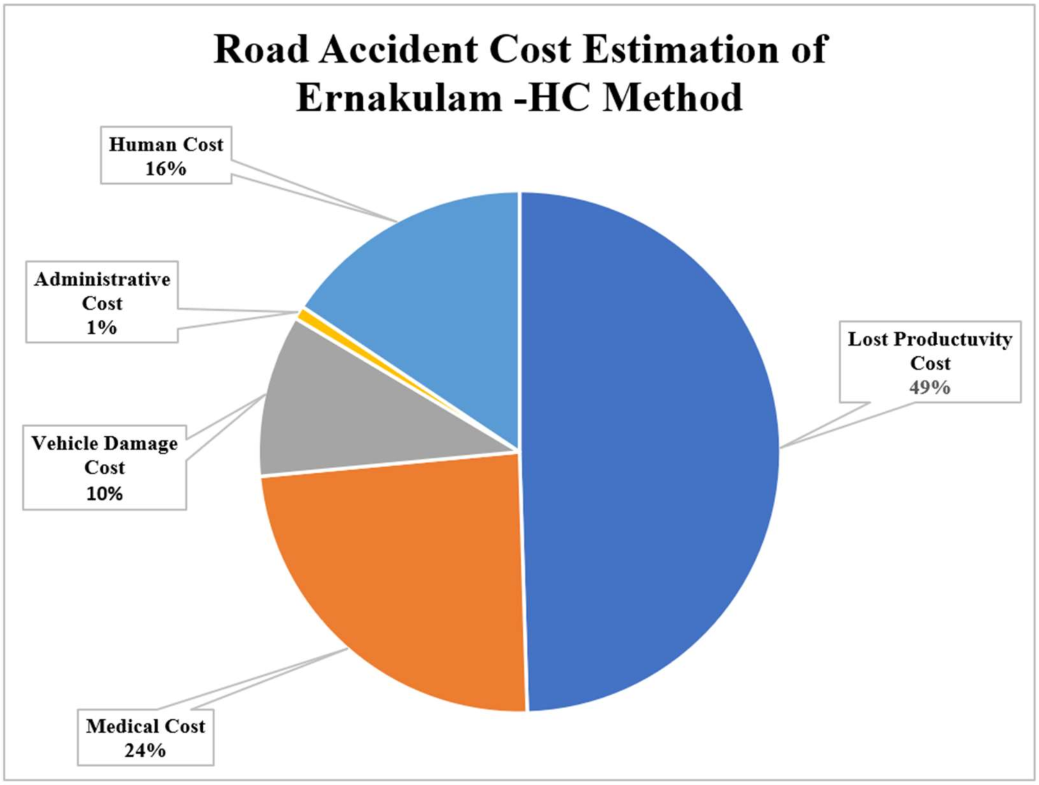

Figure 4.2: Total estimated cost (HC) expressed as a percentage of the total cost

From the obtained results, it is found that the decrease in the number of accidents during 2020 due to the lockdown had a greater impact on the cost estimate using this approach as it directly quantifies the lost output of households and workplaces. This extreme variation in 2020 may be considered an outlier. Thus, the total estimated accident cost by the HC approach in 2020 is replaced by the mean of the other three years. Hence, the estimated accident cost by the HC method can be averaged to INR 98.98 crore (9,898 lakh). Table 4.8 shows that the RTAs are posing a considerable socio-economic burden for Ernakulam city, ranging from 0.91% to 1.10% of GDP between 2018 and 2021.

Table 4.7: Estimated RTA cost (year, component, and injury severity wise) for the years 2018 to 2021 in INR (In Lakh)

Severity	2018	2019	2020	2021
Lost Productivity Cost				
Fatal	3997.61	4378.94	2754.53	3640.24
Grievous	910.56	891.81	588.47	710.91
Minor	70.59	61.03	31.57	45.65
Total	4978.76	5331.79	3374.57	4396.81
Medical Cost				
Fatal	2.13	2.34	1.59	2.18
Grievous	2382.35	2333.28	1539.65	1859.99
Minor	110.42	95.47	49.38	71.42
Total	2494.89	2431.10	1590.63	1933.58
Vehicle Damage Cost				
Fatal	41.07	46.10	30.21	40.63
Grievous	729.77	713.02	453.94	590.08
Minor	251.39	174.35	88.41	123.16
Non-Injury	130.25	102.22	41.81	46.12
Total	1152.49	1035.69	614.37	799.99
Human Cost				
Fatal	1119.33	1226.10	771.27	1019.27
Grievous	455.28	445.91	294.24	355.46
Minor	5.65	4.88	2.53	3.65
Total	1580.26	1676.89	1068.03	1378.38
Administrative Cost				
Fatal	2.32	2.54	1.60	2.12
Grievous	47.40	46.36	29.93	37.82
Minor	35.99	25.09	12.73	17.75
Non-Injury	13.03	10.22	4.18	4.61
Total	98.73	84.22	48.44	62.31
Grand Total	**10305.12**	**10559.69**	**6696.04**	**8571.06**

Table 4.8: Economic loss due to RTAs as %GDP

Year	Estimated Accident Cost in crores (INR)	GDP %
2018	103.05	1.10
2019	105.59	1.05
2020	98.98	0.99
2021	85.71	0.91

4.4 SUMMARY

The RTA cost for the different years of the study period was analyzed and compared in this chapter for a deeper interpretation. The HC approach demands the calculation of accident costs component-wise. The loss is calculated from various data sources, including in-depth accident databases (police), questionnaire surveys, private hospital records, and vehicle garage bills, considering the collision types. The estimated accident cost ranges from INR 66.9 crore to INR 105.6 crore during the study period. The extreme variation in the estimated RTA cost in 2020 due to the COVID-19 lockdown can be considered as an outlier and hence replaced by the mean of the other three years. Consequently, the average estimated RTA cost from 2018 to 2021 can be approximated to INR 98.98 crore. The RTAs are posing a considerable socio-economic burden for Ernakulam city, ranging from 0.91% to 1.10% of GDP between 2018 and 2021.

The conventional HC approach is focused on monetizing lost productivity (49%), giving much less concern to the PGS cost component (16%). Also, the lost productivity of post-retirement-age victims, as well as caregivers, is neglected. The administration cost (1%) is not considered elaborately to account for the current services provided. To rectify these shortcomings of the HC method, the calculation of each cost component was revised later in this research.

CHAPTER 5

ESTIMATION OF RTA COST - WTP APPROACH

5.1 GENERAL

The Willingness to Pay (WTP) approach essentially concentrates on the trade-off between Road Traffic Accident (RTA) risk or crash rate and money (Silcock and Transport Research Laboratory 2003). This approach enables the estimation of the Value of Statistical Life (VSL), which is defined as the additional cost individuals would be willing to pay for safety improvements (i.e., risk reductions) that reduce the expected number of fatalities by a certain value and thus represent the benefit of preventing a fatality. Thus, it is not the cost of life but rather the values of risk reduction that are relevant. Material and immaterial components are comprised in the VSL. The material part, which is formed by all the utility that can be acquired through market transactions, consists of the loss of consumption in the life years lost. In contrast, the immaterial part represents things that have no (market) value, such as the loss of joy of life and the value of pain, sorrow, and distress of the casualties and their relatives, also known as human losses (Wijnen et al. 2009; Bougna et al. 2022). Using two prominent SP surveys, (i) the WTP-Contingent Valuation (CV) survey and (ii) the Discrete Choice Experiment (DCE) survey, the road user's WTP for reducing the risk of injury and the risk of fatality due to traffic accidents was collected for the estimation of VSL and hence the accident cost. The United Nations declared the Decade of Action for Road Safety 2021–2030, intending to prevent at least 50% of RTA fatalities and injuries by the year 2030. Hence, the respondents in the CV approach elicited the WTP for 50% mortality risk reduction (Mon et al. 2019a).

5.2 THEORETICAL FOUNDATION

The terms and theories associated with discrete choice modelling and structural equation modelling (SEM) are explained in the following subsections.

5.2.1 Discrete Choice Experiment

The primary types of data in discrete-choice studies are Revealed Preference (RP) and Stated Preference (SP) data. RP data illustrates the current market situation. Though the SP data generally addresses hypothetical scenarios, it can also encompass generic, proposed, or existing choices. It is incapable of adequately presenting the market and personal constraints. If valuation is the primary concern, SP data alone may suffice.

As outlined below, data are primarily of two types: cross-sectional data and panel data. Cross-sectional data is collected at a certain point in time and does not account for data changes over time. Typical sources of cross-sectional data include government records. Comparatively, panel data is a type of data collected across several time periods. It combines observations at cross-sections across time. Panel data is sometimes termed longitudinal data. Financial, economic, physical science, and medical sectors find extensive use for panel data. It is found that panel data is more useful than cross-sectional data. The following are some advantages of panel data: Detection and assessment of statistical effects that can only be done using panel data; modelling of both individual and common behaviours; panel data provides more information, efficiency, and variability than cross-sectional data; also, the estimation biases can be reduced. SP data are similar to panel data. Often, panel data analysis is in the form of fixed effects and random effects. Fixed effects models do not evaluate the impacts of time-invariant variables, which is the major distinction between fixed effects and random effects analyses. In contrast, random-effects models quantify these effects, though there is a chance of bias.

The objective of discrete choice modelling is to estimate the weights that respondents assign to the attributes of alternatives based on the choice (that offers the highest utility) picked by the respondent. Four elements make up the choice experiment:

The user: This covers the population to whom the study is administered and who must evaluate and select among the choices.

The choices: These are the alternatives from which users can select. The alternatives are subject to the availability of each choice, and the sets are fixed accordingly.

The attributes: The factors that vary among the choices are the attributes, and the user evaluates the choices based on these attributes. The selection of attributes relies on the study context.

The decision: This is the ultimate choice made by the user after analyzing all available factors.

5.2.2 Random Utility Theory

Random Utility Theory enables the analysis and combination of different sources of preference data in order to infer behavioural processes more efficiently. It is explained below in detail.

Let G be the global set of alternatives, and S be the set of vectors of measured attributes. An individual selected at random from a population will have some attribute vector s ∈ S and have some set of alternatives, A ⊂ G. The probability of selecting a choice from a set of attributes 's' and alternatives 'A' across the sampled population can be calculated as in Eq 5.1.

$$P(y \mid s, A) \; \forall \; y \in A \tag{5.1}$$

where 'y' is the selected alternative and the vector 'y' indicates that alternatives are defined in terms of sets of attributes.

Let IBR and SIBR stand for Individual Behavioral Rules and Set of Individual Behavioral Rules, respectively. IBR transforms each vector of observed attributes (s) and a set of potential alternatives (A) into a single alternative of A, whereas SIBR represents the entire sampled population. Hence, if unmeasured attributes vary throughout the sampled population, several IBRs are possible (Louviere et al. 2000). So, the probability of selecting a choice from a set of attributes 's' and alternatives 'A' throughout the sampled population (i.e., the probability of selecting an IBR within an SIBR given that the IBR maps attribute to choice y) may be expressed as in Eq 5.2.

$$P(y \mid s, A) = P[IBR \in \text{SIBR} \mid \text{IBR}\ (s, A) = y] \tag{5.2}$$

Let U_{iq} be the utility of the i^{th} alternative of the q^{th} individual. The utility, expressed as the sum of two components, is given by Eq 5.3, having a systematic component (V_{iq}) and a random component (ε_{iq}).

$$U_{iq} = V_{iq} + \varepsilon_{iq} \tag{5.3}$$

The systematic component is the representative utility given by Eq 5.4, where 'ϕ' represents the utility parameter and 'S' represents the attributes.

$$V_{iq} = \sum_{k=1}^{k} \varphi_{ikq} \times S_{ikq} \tag{5.4}$$

The random component represents the unobserved factors of the individual. An individual 'q' chooses alternative 'i' if and only if Eq 5.5 is satisfied.

$$U_{iq} > U_{jq}, j \neq i \in A \tag{5.5}$$

From Eqns 5.3 and 5.5, Eq 5.6 can be inferred.

$$V_{iq} + \varepsilon_{iq} > V_{jq} + \varepsilon_{jq} \tag{5.6}$$

Eq 5.6 implies Eq 5.7.

$$V_{iq} - V_{jq} > \varepsilon_{iq} - \varepsilon_{jq} \tag{5.7}$$

The researcher cannot verify the compliance to Eq 5.7 as the difference of random components is not observable. Nonetheless, the analyst can infer choice outcomes up to a certain probability, as shown in Eq 5.8.

$$P_{iq} = P(y_i \mid s, A) = P[IBR \in \text{SIBR} \mid \text{IBR}\ (s, A) = y_i] \tag{5.8}$$

The implication of Eq 5.8 is given in Eq 5.9.

$$P_{iq} - P[\{\varepsilon(s, y_j) - \varepsilon(s, y_i)\} < \{V(s, y_i) - V(s, y_j)\}], i \neq j \quad (5.9)$$

The equation states that the probability that a person drawn at random from a population described by attributes 's' and alternatives 'A' will select alternative y_i is equal to the probability that the difference between the random component utility levels of alternatives 'j' and 'i' is less than the difference between the systematic component utility levels of alternatives 'i' and 'j' for all alternatives in the choice set. This is the Random Utility Model.

5.2.3 Goodness of Fit Measures of Random Utility Model

McFadden's pseudo R^2 value - The pseudo R^2 value differs from the R^2 value calculated using linear regression analysis. In addition to pseudo R^2 values, adjusted R^2 values are also generated. The adjusted R2 value is always less than the pseudo R^2 value. McFadden's pseudo R^2 value is given by Eq 5.10.

$$\text{Pseudo } R^2 \text{ value } = 1 - \frac{LL(\Phi)}{LL(0)} \quad (5.10)$$

where, LL(ϕ) = Log-likelihood value of the generated model and LL(0) = Log-likelihood value of the null model. McFadden's adjusted R^2 value is given by Eq 5.11.

$$\text{Adjusted } R^2 \text{ value } = 1 - \frac{(N-1)(1-R^2)}{N-n-1} \quad (5.11)$$

where, 'n' is the number of parameters in the model and 'N' is the number of observations. McFadden suggests a value between 0.2 and 0.4 for the model to be a good fit.

Log-likelihood ratio test - It is one of the common tests employed to compare two models. A model will be superior to another model if the probability of exceeding the chi-square value is less than 0.05 at a confidence level of 95%. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) can also be used for model selection. These values represent the prediction error of the model; hence, the lower they are, the better the model. The t-test is performed to determine the statistical significance of each model parameter. For a parameter to be considered significant, the absolute t-values must exceed the t-value (1.96) at a confidence level of 95%. A significant t-value always indicates that, at a confidence level of 95%, the probability of exceeding the value is less than 0.05.

5.2.4 Marginal Rate of Substitution

The Marginal Rate of Substitution (MRS) is an economic concept used for consumer behaviour analysis for various purposes. To begin with, it refers to the amount of one commodity that can be substituted for another. Second, it can be described in economic terms as the slope of the indifference curve at any point on the curve. Indifference curves are microeconomic tools used to investigate various consumer choice behaviours. The indifference curve, as shown in Fig 5.1, is a simple two-dimensional graph with axes representing economic commodities (Good A and Good B). Goods A and B can represent any two economic commodities. In this study, Good A represents risk estimate and Good B represents cost estimate. Most indifference curves are convex because when one consumes more of one thing, one consumes less of the other, i.e., MRS decreases as one proceeds down the curve. This is known as the law of diminishing MRS. According to the law, as a person consumes more and more of one good, he or she will be willing to give up less and less of another good, resulting in a constant consumer satisfaction level.

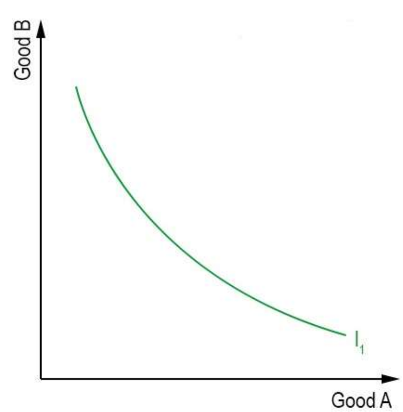

Figure 5.1: Indifference curve (Source: Mankiw, 2017)

If MRS increases, the curves become concave, implying that the consumer will consume more of one commodity in exchange for increased consumption of another (not common). Yet, if the slope is constant, indifference curves can also be straight lines. MRS is mathematically given by Eq 5.12.

$$|MRS_{ab}| = \frac{dy}{dx} = \frac{M_a}{M_b} \tag{5.12}$$

where, M_a = Marginal utility of commodity “a” and M_b = Marginal utility of commodity “ b”.

5.2.5 Model development using NLOGIT-DCE

NLOGIT, developed by Econometric, Inc., is the software used to develop the model in DCE. To develop models for data that requires repeated analysis (i.e., panel data), the software suggests using the Random Parameter Logistic (RPL) estimator. The data in RPL models are fit using maximum simulated likelihood estimation (not maximum likelihood estimation), which means that the finite sample set is evaluated, and the experiment condition is simulated based on the number of repetitions coded. This method is also known as mixed-logit modeling since it considers both fixed and random effects. Halton sequences were used to generate points in the parameter space for simulations. Compared to traditional models, random-parameter logit models require more time for model estimation.

Using maximum simulated likelihood estimation for Random Parameter Logistic (RPL) models, also known as mixed-logit models, is important because it manages unobserved heterogeneity in the population, reflecting individual-specific preferences. This technique is beneficial for panel data as it accounts for the relationship between repeated choices by the same person. By employing simulation to approximate the likelihood function, maximum simulated likelihood estimation delivers more precise parameter estimates for complex models, improving robustness and fit, particularly when handling random parameters.

Each route's stacked data was converted to comma-separated values format because the software preferred this format for data import. The dependent variable was specified as the chosen variable within the RPLOGIT command. The independent variables should be assigned to one of two subcommands: "Rhs" for variables that vary across choices (attributes) and "Rh2" for variables that do not vary across choices (individual-specific variables). The simulations are carried out using the start values provided by Multinomial LOGIT (MNL). The model was interpreted in order to have a better understanding of the different factors.

5.2.6 Structural Equation Modelling

SEM is performed to determine the factors affecting the WTP in this study. The theoretical basis of SEM begins with the intention of testing the relationship between the constructs of interest. A schematic diagram represents the theoretical framework in which the relationships are modelled and the hypotheses to be tested. In order to measure the constructs of interest, a questionnaire with a specific set of items is to be used. SEM stands out from other methods with the following advantages. It enables the simultaneous analysis of the predictor variables' influence on various dependent variables. Measurement errors and errors in the prediction of relationships are accountable using SEM. Also, it has the capability to test an entire model rather than individual relationships. These advantages completely contradict similar techniques like regression, which only allow testing a single dependent variable at a time and do not account for measurement errors. Regression techniques also emphasize individual relationships rather than considering the entire model.

A covariance matrix is being used as an input in SEM, and the correlations between variables, i.e., mutual influence, are being determined. A mere correlation between the variables cannot determine the cause. An experimental design is necessary to determine the cause. Though SEM research more often deals with non-experimental data, it has proven to be efficient in experimental data analysis. For example, SEM can be used to analyze the factors affecting the durability of concrete under different environmental conditions. An experimental study might involve manipulating variables such as temperature, humidity, and load conditions to observe their direct and indirect effects on concrete durability. SEM can separate these effects, allowing researchers to understand both the immediate impact of each variable and the underlying mechanisms influencing durability. Furthermore, SEM is useful in longitudinal experiments to understand how relationships between variables change over time. These features make SEM a powerful tool for experimental research too.

Understanding the Diagram Symbols: Fig 5.2 shows the diagram denoting the relationships to be tested. As this diagram plays an important role in representing the conceptual model in Analysis of Moment Structures (AMOS), it is necessary to understand the meaning of those symbols. There are possibilities in SEM that multiple terms are being used to represent the same concept; hence, clarity of the nomenclature is essential.

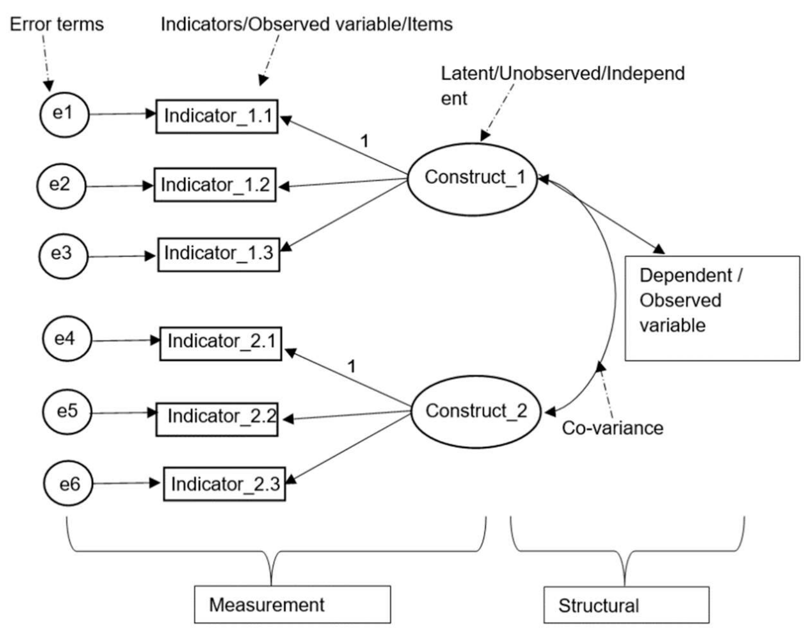

Figure 5.2: Terms and symbols - AMOS

5.2.7 Terminologies and Symbols

A *latent variable or construct* is often described as an "unobservable" variable, i.e., it cannot be directly observed. A few examples of unobservable constructs are anxiety, motivation, trust, etc. It would be ideal to be able to gauge a person's level of anxiety simply by observing him or her. Still, the reality is that some individuals are adept at masking their genuine emotions. In certain situations, it is impossible to establish a person's level of anxiety only from observation. Consequently, concepts like anxiety are "unobservable" and necessitate the researcher devising alternative methods, such as survey questions, to capture the concept. The latent or unobservable constructs are also referred to as "factors". Typically, these unobservable constructs are measured using "indicators" or "measurement items", often using survey questions.

Observed variables or indicators are the measures taken to capture an unobservable item using observable means. Survey questions are ideally used to collect this. It is also termed manifest variables or reference variables. The terms “items” and “indicators” also refer to observed variables. Observed variables or indicators are, essentially, the raw data that will be employed to illustrate ideas and concepts in the SEM model. These variables and indicators may be categorical, ordinal, or continuous.

Measurement error or residual term is the variance that cannot be explained by the indicator used to measure the respective latent construct. The variance in a measurement that is unexplained while assessing an unobservable concept is an error or "measurement error." Alongside the indicator, a dependent latent construct also contains an error term, which is the unexplained variance at the construct level due to the relationships among the independent variables. Error terms for latent variables are often referred to as disturbance terms or residual terms. AMOS recognizes measurement error and residual terms as unobserved variables since those represent unexplained variance.

Covariances represent the change in one variable that is associated with the change in another variable. In other words, it is the degree to which the two variables change simultaneously in a consistent and reliable manner.

Independent and Dependent Latent Variables - Independent variables, often known as exogenous variables, are those constructs that influence the dependent variables.

Dependent variables, or endogenous variables, are those constructs that are affected by independent variables.

5.2.8 Factor analysis

Factor analysis is a statistical approach that reduces a set of variables in the data to a smaller number of factors by identifying their relationships. It is also known as data reduction. Certain common patterns emerge by examining many variables; these are referred to as factors. These factors serve as an index of all the associated variables and can be used for further assessment. When a researcher assumes these variables, there are chances of getting amalgamated into one or more factors. In order to yield insights, factor analysis relies on the following assumptions: data free of outliers, a sample size greater than the factor size, and the absence of perfect multicollinearity between any variables due to the technique's interdependence. Since factor analysis works as a linear function, it does not require homoscedasticity across variables, and nonlinear variables can be transformed into linear variables upon transfer. Additionally, the existence of interval data is assumed. Factor analysis is of two types: Exploratory Factor Analysis and Confirmatory Factor Analysis.

In Exploratory Factor Analysis, the researcher makes no assumptions about the factors' prior associations. Any variable may be associated with any factor using this method. This aids in identifying complex correlations between variables and categorizing them according to common criteria. On the other hand, Confirmatory Factor Analysis presumes that variables are associated with specific factors, and a pre-established theory is used to verify the model's expectations. Being the initial step of SEM, Confirmatory Factor Analysis examines the extent to which indicators can measure unobserved constructs and whether the unobserved constructs are significantly distinct from one another or not.

In the diagrammatic format, a circle or oval represents an unobserved variable. Each indicator that measures the unobserved variable will be connected to the unobserved construct by a single-headed arrow. A single-headed arrow will connect each indicator measuring the unobserved variable to the unobserved construct. The indicators are represented by rectangles or squares. The single arrow line from the factor or unobservable construct to the indicator demonstrates the impact of the unobservable construct on its indicators. Statistical estimates of these direct effects are referred to as "factor loadings" and are perceived as unstandardized or standardized regression coefficients.

Indicators that "reflect" an unobservable component or construct are known as reflective indicators. For the majority of indicators, there is a degree of error. Each indicator's measurement error implies "unique variance," or variance that the factor level cannot describe.

Measurement errors are represented by two different kinds of unique variance: random error and systematic error. A random error happens when the measurement of a concept fluctuates unpredictably due to random or unforeseeable influences. This form of error is referred to as "noise" due to the inconsistency of the measurement error. Owing to a systematic influence in measuring a concept, the results of a measurement may be consistently high or low. In contrast to random error's "noise," systematic error is frequently referred to as "bias." In order to notice "unmeasured covariance," a double-headed arrow is formed between all independent unobservable variables. All unobserved variables are treated as exogenous or independent variables in a Confirmatory Factor Analysis. It is necessary to draw a double-headed arrow (covariance) between each unobservable construct. Otherwise, AMOS will display an error message indicating the same.

Before determining whether one construct influences another, it is necessary to ensure that observable variables or indicators capture the construct of interest. Prior to the analysis, the first step is to review the data to ensure there are no errors, outliers, or respondent misconduct. In addition, it is necessary to identify any missing data.

5.2.8.1 Measurement and Structural Models

The measurement model in SEM is used to assess the validity of each construct's indicators. It is possible to get the structural model by obtaining a valid measurement model. The structural model focuses on the significance and influence between constructs. The term "full structural model" indicates that the testing of the model includes the measurement and structural relationships of each construct. The term "parameter" refers to the size and nature of the interaction between two model objects. Parameters can either be fixed to a constant value or freely estimated from the data. A parameter estimate will be obtained on both the measurement level (using indicators and error terms) and the structural level between constructs.

5.2.8.2 Reliability and Validity

Using Cronbach's Alpha and composite reliability, construct reliability can be evaluated. Each study construct's Cronbach Alpha must be above the minimum level of 0.70 (Kline 1999). The convergence validity of scale items was assessed using the Average Variance Extracted (AVE) (Fornell and Larcker 1981). The AVE must be close to 0.50, the threshold value (Fornell and Larcker 1981). In this study, the Heterotrait-Monotrait (HTMT) ratio was used to measure discriminant validity. When evaluated using the HTMT ratio, all ratios must be smaller than the 0.85 threshold (Henseler et al. 2015). The AMOS-generated SEM was utilized to test the relationships. A model is said to be a good fit and acceptable if the CMIN/DF value is less than 5 (where CMIN stands for Chi-square Minimum and DOF stands for Degree of Freedom), and the goodness of fit (GFI) indices (Hair et al. 2010), the Tucker and Lewis index (TLI) (Tucker and Lewis 1973) and the confirmatory fit index (CFI) (Bentler 1990) are greater than 0.90 (Hair et al. 2010). In addition, if the AMOS computed value of the standardized root mean square residual (RMR) was less than 0.05 and the root mean square error approximation (RMSEA) is between 0.05 and 0.08, a model is found to be acceptable (Hair et al. 2010).

5.3 QUESTIONNAIRE DESIGN

The questionnaire consists predominantly of the following sections: general socio-demographic characteristics, travel behaviour, accident history and risk perception, CV employing the payment card method, and the choice experiment. The only difference between the CV and DCE questionnaires was the final section, which included the payment card and choice experiment. The questionnaires were retained intact to facilitate the individual analysis of both methods, even though the data for both surveys were collected concurrently. Detailed explanations of the contents of each of these categories are given below.

General socio-demographic characteristics: This part gathered information on the socio-economic characteristics of respondents, including questions about age, gender, marital status, occupation, personal income, household income, household size, and vehicle ownership, i.e., the number of two-wheelers and four-wheelers.

Travel behaviour: This section includes questions regarding respondents' travel behaviours, such as trip purpose, the primary vehicle used during the journey, driving frequency, seatbelt use, driving against traffic flow, cell phone use while driving, drunk driving, and over-speeding.

Accident history and risk perception: Direct experiences with RTA, such as personal exposure or family or friends who have recently been involved in RTA. Moreover, the severity of the accident witnessed or experienced.

CV using payment card method: The respondents were given a list of options (Fig 5.3) from which they could select the highest amount they would be willing to pay for safety, i.e., to protect themselves from injury.

Choose maximum price that you would pay extra (per year) for the risk reduction			
₹ 0	₹ 33	₹ 299	₹ 1,068
₹ 3	₹ 43	₹ 385	₹ 1,281
₹ 5	₹ 65	₹ 470	₹ 1,495
₹ 9	₹ 86	₹ 555	₹ 1,708
₹ 13	₹ 129	₹ 640	₹ 1,922
₹ 18	₹ 171	₹ 769	₹ 2,135
₹ 22	₹ 214	₹ 854	> ₹ 2135
₹.......(Any other amount not mentioned above)			

Figure 5.3: Payment card format

Before asking the WTP question to respondents, they were alerted that the items valued in the WTP question were hypothetical and used as examples for risk reduction evaluation. In the case of CV, respondents were asked how much they would be willing to pay each year for a helmet that would halve their risk of fatality in a traffic accident. Before asking the maximum amount to be paid for 50% risk reduction, respondents were evaluated on their risk comprehension with the following question: “Which of the following would you select? Helmet A has a likelihood of 10 people out of 1,00,000 being injured each year, whereas Helmet B has a probability of 5 people out of 1,00,000 being injured each year.". Those who select the second option are omitted from the evaluation of risk reduction. This question is intended for 2W users. Similarly, another hypothetical case is presented for 4W users, namely, for the installation of a speed control device or the rental of a speed control device, what is the maximum amount the respondent is willing to pay annually for a 50% risk reduction?

Choice experiment: An stated choice experiment involving two alternatives was designed. Attributes chosen for the design were Travel Time (TT), Travel Cost (TC), and Critical Accidents rate (CA), as these factors play a significant role in the decision-making process in selecting a route for travel. Initially, base levels were fixed with the support of the literature (Balakrishnan and Karuppanagounder 2020), and then the pilot study was conducted by adopting the base levels. Depending upon the absolute dominance of certain base levels during the pilot survey, different levels of attributes were then presented to the respondents. Finally, the attribute levels with perceived differences from the respondents were finalized. To make a balanced design, equal levels of two were chosen for all the attributes. The initial levels of attributes chosen were revised based on pilot studies. Since the accident rates are comparatively high, a higher difference level was chosen for the travel time (TT) and travel costs (TC) to prevent the complete neglect of attributes fixed for the study. Table 5.1 shows the finally selected attribute levels. It was selected based on the literature (Balakrishnan and Karuppanagounder 2020) and the responses obtained from the pilot study. The most compact orthogonal design (Table 5.2) was generated using statistical analysis software.

Table 5.1: Attributes and its chosen levels

Attributes	Levels
Travel Time (mins)	± 50 %
Travel Cost (Rs.)	± 50 %
Critical Accidents rate	-25% and -50%

Table 5.2: Experimental design

Card ID	Travel Time	Travel Cost	Critical Accidents rate
1	0.5 x TT	0.5 x TC	0.75 x CA
2	0.5 x TT	0.5 x TC	0.50 x CA
3	0.5 x TT	1.5 x TC	0.75 x CA
4	0.5 x TT	1.5 x TC	0.50 x CA
5	1.5 x TT	0.5 x TC	0.75 x CA
6	1.5 x TT	0.5 x TC	0.50 x CA
7	1.5 x TT	1.5 x TC	0.75 x CA
8	1.5 x TT	1.5 x TC	0.50 x CA

Each generated design depicts the alternatives offered to respondents alongside the primary or reference levels of TT, TC, and CA rates. Of the eight generated choices, the first and second profiles have all values that are lower than the reference level, resulting in a total dominance of options; therefore, those choices must be discarded. As shown in

Table 5.3, six choice sets with two options (including base levels) were selected. The questionnaires were provided with six choice sets each, separately stating the attribute values corresponding to the three routes of the study. Alternatives were created based on the reference values of attributes associated with the trip.

Thus, a total of 6 choice sets, each with distinct attribute values corresponding to the three study stretches (Aluva Junction to Aroor Kumbalam Bridge, Thoppumpady to Kundanoor Thevara Bridge, and Nayarambalam Bridge to Vallarapadam ICTT) were provided.

Table 5.3: Choice sets

Choice set No.	Attributes	Reference	Alternative
Choice set 1	Travel Time	TT	0.5 x TT
	Travel Cost	TC	1.5 x TC
	Critical Accidents rate	CA	0.75 x CA
Choice set 2	Travel Time	TT	0.5 x TT
	Travel Cost	TC	1.5 x TC
	Critical Accidents rate	CA	0.50 x CA
Choice set 3	Travel Time	TT	1.5 x TT
	Travel Cost	TC	0.5 x TC
	Critical Accidents rate	CA	0.75 x CA
Choice set 4	Travel Time	TT	1.5 x TT
	Travel Cost	TC	0.5 x TC
	Critical Accidents rate	CA	0.50 x CA
Choice set 5	Travel Time	TT	1.5 x TT
	Travel Cost	TC	1.5 x TC
	Critical Accidents rate	CA	0.5 x TT
Choice set 6	Travel Time	TT	1.5 x TC
	Travel Cost	TC	0.75 x CA
	Critical Accidents rate	CA	0.5 x TT

Alternatives were generated based on the reference values of attributes related to the trip. Options were derived by applying the levels to the actual values of TT, TC, and CA rates for a specific trip along the aforementioned road segments. Before each choice experiment, respondents were given adequate explanations of the questions so that their responses would be more reliable.

Even though there were multiple choice sets, the graphical depiction helped them understand the attributes and their levels more easily than the tabular representation. To prevent a low response rate, a limited number of personal information questions were included in the survey.

5.4 PREREQUISITES OF CHOICE SURVEY

For the stated choice survey, data collection and analysis are performed to calculate the travel time (TT), travel cost (TC), and critical accident rates (CA). The estimated travel costs for private vehicles are as follows. The travel costs were determined considering the cost of ownership for two-wheelers and cars. To estimate the ownership costs, a survey was conducted among the road users of Ernakulam. The costs comprised the cost of fuel consumed, service/maintenance charges, and capital costs of vehicles.

A total of 265 survey samples of private vehicle users of Ernakulam city (132 Two Wheeler (2W) users and 133 Four Wheeler (4W) users) were collected. The capital cost per unit distance was determined by considering the average service life of vehicles (Bansal and Kockelman 2017), along with the fuel, maintenance, and capital costs. The average cost per kilometre value for two-wheelers and cars was evaluated as Rs. 5.00 and Rs. 13.00, respectively. The values of the cost of travel via public vehicles were used as per the rates fixed by the Motor Vehicle Department, the Government of Kerala, and the Kerala State Road Transport Corporation (KSRTC).

The distribution of costs per kilometre for 2W and 4W users is shown in Appendix III. Travel time was fixed based on the data obtained using the Google Cloud Application

Programming Interface with the help of coding using Python. The annual average accident rate was obtained from the combined analysis of District Crime Records Bureau (DCRB) data and NATPAC data. Since the area under study involves high-risk road accident spots, only the accidents involving fatalities were taken to present the risk to the respondents.

The average values of the attributes involving 2W and 4W, along with the trip setting, are shown in Table 5.4.

Table 5.4: Trip settings

Trip Setting	Travel Time (Mins.)	Travel Cost (Rs.)	Accidents (Per Year)	Length (Km)
Aluva Junction to Aroor Kumbalam Bridge	59	428	88	34
Thoppumpady to Kundanoor Thevara Bridge	19	113	17	9
Nayarambalam Bridge to Vallarapadam ICTT	42	290	27	23

5.5 MAIN SURVEY

The questionnaire survey for CV and DCE methods was carried out among the selected population. Due to the population's tendency to ignore online questionnaires, face-to-face interviews were conducted using the designed questionnaire. Typically, questions in CV surveys were intended to ascertain how much individuals value hypothetical risk reductions; these valuations are then pooled throughout the population to calculate the VSL. The WTP was also estimated using a binary route choice survey with discrete choice modelling, considering attributes such as travel time, travel cost, and the number of accidents each year.

In this study, survey respondents were initially asked CV questions to determine their WTP for risk reduction in two distinct scenarios. Then, SP choice options were provided.

It was expected that using both approaches would increase the likelihood of generating reliable results and allow a comparison of the accident costs obtained from both approaches (Le et al. 2011).

The target population of road users was chosen randomly from various age groups, including those who were victims of road accidents that resulted in injury and addressing a wide range of factors that affect the route choice behaviour of the respondents. A limited number of personal information questions were included in the survey to prevent a low response rate.

The preliminary analysis of survey data (after removing the inconsistent responses) was carried out to explore the different sample characteristics. The data was further analysed statistically using various software packages like Statistical Package for the Social Sciences (SPSS), AMOS, and NLOGIT. The WTP and the VSL of the population were estimated using the aforementioned methods, and hence the accident cost was determined.

The responses collected from the questionnaire survey included various data like socio-economic characteristics, trip characteristics, and travel behaviour. The inconsistent responses were eliminated, and thus the data was cleaned. Then, it was analysed statistically to determine the characteristics of the population. This data analysis helped in comparing the population of different routes.

5.5.1 Socio-economic Characteristics

The WTP approach highly depends on socio-economic characteristics, travel behaviour, and the population's RTA experience or risk perception. The descriptive statistics of the above-mentioned factors are shown in Tables 5.5, 5.6, 5.7 and 5.8.

It is clear that there were more men than women among 2W users (69.21%) and car drivers (62.08%). 50.59% of 2W users and 39.50% of car drivers who responded to the survey had a diploma or a bachelor's degree, with 34.56% of car drivers having a master's or above. Most of the respondents (2W users: 67.51%; car drivers: 72.34%) were employed.

Table 5.5: Socio-economic characteristics of respondents - Part 1

Particulars		**2W**		**Cars**	
		No.	**%**	**No.**	**%**
Gender	Male	562	69.21	185	62.08
	Female	250	30.79	113	37.92
Age	18 - 25 years	180	22.17	37	12.42
	26 - 35 years	211	25.99	49	16.44
	36 - 45 years	225	27.71	101	33.89
	46 - 60 years	146	17.98	75	25.17
	> 60 years	50	6.16	28	9.4
Marital Status	Single	229	28.2	46	15.44
	Married	583	71.8	252	84.56
Education	≤ High-school	301	37.07	77	25.84
	Diploma or Bachelor	410	50.49	118	39.6
	≥ Master	101	12.44	103	34.56
Occupation	Unemployed or below 10th class	110	14.63	68	24.55
	Student	98	13.03	22	7.94
	Employed	544	72.34	187	67.51
	Retired or looking for job	60	7.98	21	7.58
Individual income	< 30,000	594	73.15	151	50.67
	30,000 - 75,000	200	24.63	111	37.25
	> 75,001	18	2.22	36	12.08

73.15% of 2W users and 50.67% of car drivers who responded claimed their monthly income was less than INR 30,000. Additionally, 37.25% of car drivers and 24.63% of 2W users reported monthly income between INR 30,000 and 75,000. The major proportion of 2W users (44.09%) claimed their household income to be less than INR 30,000.

Table 5.6: Socio-economic characteristics of respondents - Part 2

Particulars		2W		Cars	
		No.	%	No.	%
Household income	< 30,000	358	44.09	106	35.57
	30,000 - 75,000	355	43.72	118	39.6
	> 75,001	99	12.19	74	24.83
House-ownership	Own	726	89.41	271	90.94
	Renter	86	10.59	27	9.06
Household member	1	70	8.62	37	12.42
	2	7	0.86	11	3.69
	3	205	25.25	69	23.15
	4	335	41.26	97	32.55
	5	195	24.01	84	28.19
Number of children	0	163	20.07	67	22.48
	1	513	63.18	155	52.01
	2	84	10.34	34	11.41
	3	41	5.05	36	12.08
	4	11	1.35	6	2.01
No. of dependents	0	198	24.38	80	26.85
	1	383	47.17	111	37.25
	2	69	8.5	41	13.76
	3	89	10.96	37	12.42
	4	48	5.91	21	7.05
	5	25	3.08	8	2.68
No of 2W	0	39	4.8	115	38.59
	1	698	85.96	160	53.69
	2	50	6.16	16	5.37
	3	25	3.08	7	2.35
No of Car	0	400	49.26	20	6.71
	1	404	49.75	251	84.23
	2	5	0.62	21	7.05
	3	3	0.37	6	2.01

Table 5.7: Travel behaviour of respondents

Particulars		2W		Cars	
		No.	%	No.	%
Trip purpose	Work trips (office)	498	61.33	176	59.06
	Non-work trips (like education, shopping, recreational trips)	314	38.67	122	40.94
Main vehicle used	2W	197	66	197	66
	Car	63	21	63	21
	Bus	36	12	36	12
	Other	6	2	6	2
Driving frequency	Not Often	103	12.68	36	12
	Often	709	87.32	262	88
Seatbelt usage	Frequently	667	91.8	274	91.8
	Sometimes	19	6.5	19	6.5
	Rarely	3	1	3	1
	Never	2	0.6	2	0.6
Riding against traffic	Frequently	6	1.9	266	89.2
	Sometimes	25	8.3	25	8.3
	Rarely	2	0.6	2	0.6
	Never	650	89.2	6	1.9
Speak phone	Frequently	4	1.2	4	1.2
	Sometimes	4	1.2	4	1.2
	Rarely	31	10.4	31	10.4
	Never	665	87.1	260	87.1
Drunk driving	Frequently	3	1	3	1
	Sometimes	1	0.2	1	0.2
	Rarely	6	2.1	6	2.1
	Never	730	96.7	288	96.7
Usual operating speed: 2W/4W	Below speed limit	249	83.56	249	83.56
	Above speed limit	49	16.44	49	16.44

In the case of car users, 39.6% had their household income in the range of INR 30,000 – 75,000. The primary trip purpose for the majority of respondents (61.33% 2W users and 59.06% vehicle drivers) was work-related. 21.55% of 2W users and 13.09% of car users had personal RTA experiences in the past. 9.61% (2W) - 10.74% (cars) of respondents assessed their accident risk as average or above average, whereas 89.26% (cars)-90.39% (2W) rated personal RTA risk as lower than average.

Table 5.8: Accident experience and risk perception of respondents

Particulars		2W		Cars	
		No.	**%**	**No.**	**%**
Accident experience	Personally experienced	175	21.55	39	13.09
	Family or friend has accident history	55	6.77	24	8.05
Perceived risk of accident	< Average risk	734	90.39	266	89.26
	≥ Average risk	78	9.61	32	10.74

Comparable findings were seen in earlier research (Andersson and Lundborg 2007). It was suggested that the observed underrating of mortality risks might be attributed to "optimism bias or availability heuristic" because the majority of individuals believed that adverse outcomes were less likely to occur because their lifestyle was relatively secure.

5.6 ESTIMATION OF WTP, VSL, AND ACCIDENT COST

The main objective of this part of the study is to estimate the WTP values for the critical stretches of Ernakulam city. In CV, the WTP estimates can be obtained directly from the values they chose in the payment card. The mean, as well as median WTP, is obtained from the responses. In DCE, the WTP estimates can be obtained from the final models of the corresponding road segments using the MRS. As the focus is on estimating the WTP to lower the risk of road accidents, the theory of the MRS can be applied as the trade-off between the risk and the monetary parameters. Here, the critical accidents rate and the travel costs are the risks and the economic parameters, respectively. In this study, the risk and cost parameters were treated as non-random, so the WTP value can be estimated by dividing the parameter of risk by that of cost, as shown in Eq 5.13 (Le et al. 2011; Antoniou 2014; Balakrishnan and Karuppanagounder 2020).

$$WTP = |MRS| = \frac{\Phi(\text{ risk })}{\Phi(\text{ cost })} \tag{5.13}$$

where, Φ(risk) and Φ(cost) parameters are estimated for risk and cost, respectively.

The applicability of this theory is constrained by the fact that the analysis is restricted to two variables, and the utility of both comparable goods is assumed to be equal despite the fact that this assumption may not be true. In the CV study, accident cost is estimated using concepts like the VSL and VSI (Persson et al. 2001). VSL refers to the amount a person is willing to spend to avert an anticipated fatality (Hensher et al. 2009; Chaturabong et al. 2011; Mon et al. 2019b). VSL is calculated by dividing the mean or median WTP value by the change in fatality risk (Δρ) as given in Eq 5.14 (Andersson and Lundborg 2007; Mon et al. 2018, 2019b). VSI is estimated to be 13% of VSL (Perkins et al. 1998).

$$VSL = \frac{\text{Mean / MedianWTP}}{\Delta\rho} \tag{5.14}$$

In the case of DCE, the ratio of estimated WTP parameter coefficients corresponds to the perceptions of a single road user and must be converted to the actual condition. This can be achieved by converting the WTP based on exposure to risk. Given that the study focused on fatal accidents per year and the experiments were conducted on vehicle users, the WTP values should be multiplied by the number of exposed road users along each road segment. The standard VSL is given by Eq 5.15 (Antoniou 2014).

$$\text{VSL} = \text{WTP} * \text{Exposure} \tag{5.15}$$

where, exposure is a measure of traffic volume on the selected road stretch. The equation can be further simplified for road segments, as shown in Eq 5.16 (Antoniou 2014).

$$VSL = WTP * RU \tag{5.16}$$

where, RU is the number of road users (passenger vehicles) per year passing through the road stretch, derived from traffic volume, trip rate, and average occupancy rate. The exposure estimate is dependent on the survey design.

For instance, if the risk is expressed in fatalities per year and the average annual daily traffic is assumed to be 'x' number of vehicles, then this number must be multiplied by 365 to determine the annual flow. Another method of correlating fatalities with exposure would be to utilise the number of daily road users. This amount might be determined from average annual daily traffic assuming a typical occupancy rate of, say, 'y' persons per vehicle. In this case, average annual daily traffic is used as it's readily measurable (e.g., by manual counting, traffic counters, or toll plaza receipts).

The accident cost due to fatality or grievous injury is the product of VSL/VSI (Persson et al. 2001) and the count of fatalities or grievous injuries, respectively (Mon et al. 2019b; Balakrishnan and Karuppanagounder 2020). The accident cost is then expressed as a percentage of Gross Domestic Product (GDP) to facilitate comparisons of accident costs across various approaches, countries, cost-benefit analyses of safety infrastructures, etc.

5.7 RESULTS FROM WTP APPROACH

The estimated WTP value, VSL, and the accident cost of the population for Ernakulam city by adopting the WTP approach using the SP methods are discussed in the following sections.

The CV payment card format and the stated choice survey results are discussed in detail. The codes used in defining the variables are given in Table 5.9.

Table 5.9: Definition of Observed Variables

Code	Definition of Variables	Code	Definition of Variables
G	Gender	TP	Trip purpose
A	Age	ETT	Exposure to the traffic (driving frequency)
MS	Marital status	SB	Seatbelt usage
EL	Education level	TR	Obeying traffic rules
ES	Employment status	DD	Drunk driving
IIL	Individual income level	CD	Cell phone driving/ Speak on phone
HHIL	Household income level	OS	Usual operating speed
HHM	Household member	PEA	Personally experienced accident
NOM	No of motorcycle	FFEA	Family or friend has experienced accident
FW	No of car	PR	Perceived risk of accident
HO	House ownership status	WTP	Willingness to pay

5.7.1 WTP - CV method

The mean WTP and median WTP values for a 50% reduction in mortality risk are given in Table 5.10. A smaller proportion of 2W users (0.6%) and car drivers (7.5%) chose a zero WTP. The example provided within the survey may have misled the respondents. Drivers who prefer driving slowly may have believed they did not require a speed control device, and some may have believed that the driver, not the vehicle, was the primary cause of accidents (Mon et al. 2019b).

The average WTPs for 2W users and car drivers were 896 INR and 1,539 INR, respectively. The median WTP values for 2W users and car drivers were 800 INR and

1,000 INR, respectively, substantially less than the mean values of WTP. The car drivers' WTP was greater than that of 2W users.

The income levels could partly explain the variation in WTP, as car drivers were from high-income backgrounds. The average mean WTP and median WTP values for the two types of road users were INR 1,217 and INR 900, respectively.

Table 5.10: WTP value for 50% mortality risk reduction

Vehicle type	Mean WTP (INR)	Median WTP (INR)	Standard Deviation (INR)	Skewness	Std. error of skewness	Sample size	'Zero' WTP (no. (%))
2W	896	800	682.81	0.71	0.09	812	5 (0.6)
Car	1539	1000	1721.71	2.73	0.14	298	23 (7.8)
Average	1217	900					14 (4.2)

5.7.1.1 VSL and accident cost

Table 5.11 depicts the results of the analysis of RTA statistics of Ernakulam city. In 2018, Ernakulam city had a population of 6,32,136. The rate of RTA was 20.72 fatalities and 261.18 grievous injuries per 100,000 population, respectively. The change in risk ($\Delta\rho$) for a 50% risk reduction in RTA fatalities was 10.36 fatalities per 100,000 population. Similar data for 2019, 2020, and 2021, along with their average values, are given in Table 5.11.

Based on the average of the mean WTP and median WTP values, the VSL was calculated (Eq.5.14), and VSI was 13% of VSL (Perkins et al. 1998). In this study, the WTP value is taken as a constant for all four years, as shown in Table 5.12. The RTA cost was determined as the product of VSL and the number of fatalities in case of fatal accidents, and the product of VSI and the number of grievous injuries in case of grievous injury accidents in the corresponding year (Table 5.12 and Table 5.13).

Table 5.11: Accident statistics data requirement for VSL estimation

Year	Population	No: of fatality	Fatality /100,000 population	No: of grievous Injury	Grievous Injury/100,000 population
2018	632136	131	20.72	1651	261.18
2019	636435	144	20.63	1617	254.07
2020	640733	98	15.23	1067	166.53
2021	645032	134	20.77	1289	199.83
Average	638584	127	19.85	1406	220.18

The estimated VSL of Ernakulam city road users ranged from INR 32.81 lakh to INR 46.29 lakh, and the VSI ranged from INR 0.33 lakh to INR 0.52 lakh. The accident cost of fatalities is found to be in the range of INR 153.89 crore to INR 157.03 crore, and that of grievous injuries is about INR 20 crore annually from 2018 to 2021.

Table 5.12: VSL and accident cost of fatalities (INR)

Year	WTP		$\Delta\rho$ (*10^5)	VSL (Lakh)	Accident Cost in Crores
2018	Mean	1217	10.36	32.81	153.89
	Median	900		24.26	113.78
2019	Mean	1217	11.31	34.20	154.94
	Median	900		25.29	114.56
2020	Mean	1217	7.65	46.29	155.99
	Median	900		34.22	115.33
2021	Mean	1217	10.39	41.99	157.03
	Median	900		31.04	116.11

The sum total accident cost of fatalities and injuries ranged from INR 173.9 crore to INR 177.4 crore. The most important aspect of this method is that accident costs are indirectly independent of the number of fatalities and injuries. It depends exclusively on the population and risk reduction percentage. Therefore, it can be concluded that this method is not suitable for estimating the accident cost but rather for estimating WTP and VSL in various scenarios, especially in developing countries.

Table 5.13: VSI and accident cost of grievous injuries (INR)

Year	WTP		Δρ (*10^5)	VSI (Lakh)	Accident Cost in Crores
2018	Mean	1217	130.59	0.33	20.01
	Median	900		0.24	14.79
2019	Mean	1217	127.04	0.36	20.14
	Median	900		0.26	14.89
2020	Mean	1217	83.26	0.52	20.28
	Median	900		0.38	14.99
2021	Mean	1217	99.92	0.42	20.41
	Median	900		0.31	15.09

5.7.1.2 Factors affecting WTP (CV)

SEM was employed to identify the factors influencing WTP (CV Payment card format). From the SEM analysis, the WTP value is found to be positively influenced by socio-economic characteristics (Socio-Economic), RTA risk perception (risk) and good driving behaviour (driving), which were the three structural hypotheses in serial order (H1, H2 and H3) depicted in Fig 5.4. Hence, it would be constant as the above situations remain the same for a period of time in the absence of external shocks or unforeseen circumstances. The full structural model obtained by the SEM analysis indicating the factors influencing the WTP is shown in Fig 5.4.

From the results of SEM analysis (Table 5.14), it is found that the socio-economic characteristics were measured using the following observed variables: highest level of education (EL), highest household income level (HI) (i.e., greater than INR 75,000 income per month) and four-wheeler (car) ownership (FW). Each of these variables is statistically significant at the 0.001 level and positively influences socio-economic characteristics. The findings indicate that participants with higher education levels showed a greater willingness to invest in traffic safety, which aligns with Yang et al. (2016) and Mon et al. (2019). The study also revealed that respondents with higher income levels were more inclined to spend on traffic safety, aligning with economic theory and consistent with findings from previous research conducted by various researchers (Persson et al. 2001; Andersson and Lundborg 2007; Haddak et al. 2016).

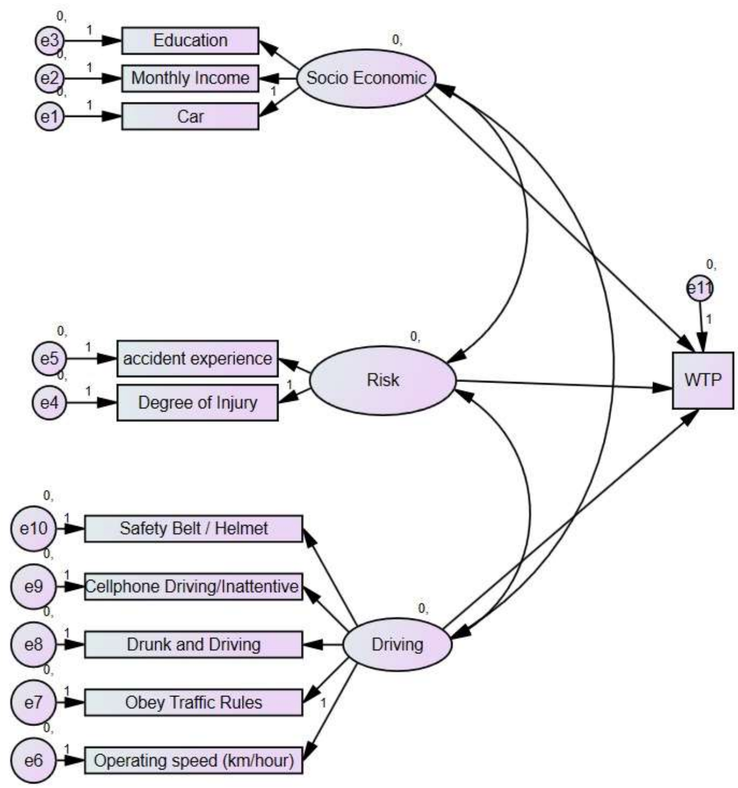

Figure 5.4: Full Structural Model

Respondents owning more four-wheelers (cars) in their household showed a heightened willingness to invest in traffic safety, a tendency that can be indirectly related to economic theory. This observation aligns with the conclusions drawn by Mon et al. (2019).

Among the three items, HIL (β= 0.59) and FW (β = 0.63) have the strongest influence. As demonstrated in Table 5.15, the socio-economic characteristics factor had a positive impact (β = 0.24) on WTP. The factors used to evaluate good driving behaviour attributes are: never drink and drive (DD), seatbelt usage (SB), never using a cell phone while driving i.e., never speaking on a mobile phone while driving (CD), obeying traffic rules (TR), and over-speeding (OS).

Table 5.14: Parameter estimate of SEM: Measurement Model

Standardized Regression Weights			Estimate
EL_1	<---	Socio-economic Characteristics	0.44
HIL_1	<---	Socio-economic Characteristics	0.59
FW_1	<---	Socio-economic Characteristics	0.63
FFE_2	<---	Risk perception	0.88
DOI_2	<---	Risk perception	0.43
SH_3	<---	Good driving behaviour	0.65
TR_3	<---	Good driving behaviour	0.62
CD_3	<---	Good driving behaviour	0.68
DD_3	<---	Good driving behaviour	0.96
OS_3	<---	Good driving behaviour	0.63
WTP	<---	Socio-economic Characteristics	0.24
WTP	<---	Risk perception	0.55
WTP	<---	Good driving behaviour	0.14

Each of these variables demonstrated statistical significance at the 0.01 level and exhibited a positive influence ($\beta = 0.14$) on the WTP. DD is found to have the highest parameter estimate value ($\beta = 0.96$), revealing that the never drink and drive factor had the utmost impact on good driving behaviour, which is in line with Mon et al.(2019). Moen (2007) discovered comparable findings, showing that drivers with negative attitudes towards traffic regulations were less inclined to invest in reducing the risk of road accidents.

The RTA experience of family or friends in the past (FFE), as well as the degree of injury (DOI), were used to estimate the risk perception factor. These variables revealed a statistical significance of 0.05 with a positive correlation to risk perception. Furthermore, the factor of risk perception positively impacts WTP ($\beta = 0.55$). This suggests that respondents who view their risk of RTA as average or higher are more inclined to invest in traffic safety compared to those who consider their RTA risk below average. This finding was in line with Mon et al. (2019) and Andersson and Lindberg (2009). Moreover, individuals who had family or friends involved in RTA showed a higher likelihood of paying to mitigate accident risks. The magnitude of the parameter estimate ($\beta = 0.88$) was higher in the case of FFE than in the case of personal RTA experience. Overall, it was observed that the factor of risk perception had the most significant impact on the WTP for the reduction of fatality risk, in line with Mon et al. (2019).

Table 5.15: Parameter estimate of SEM: Path Model

Hypothesized Relationship	Std. Estimates	t-value	p-value	Decision
Socio-economic characteristic→ WTP	0.24	3.671	<0.001	Supported
Risk perception → WTP	0.55	2.533	<0.05	Supported
Good driving behaviour →WTP	0.14	2.845	<0.01	Supported
CMIN/DF = 1.385, GFI = 0.987, TLI = 0.992, CFI = 0.994, SRMR = 0.0245 and RMSEA = 0.022				

The AVE values were used to estimate the convergent validity of scale items. These were nearly the threshold value of 0.50 (Fornell and Larcker 1981). Consequently, the scales utilised in this study provide the needed convergent validity. Discriminant validity in the study was assessed using the HTMT Ratio. All ratios fell below the 0.85 threshold that was stipulated (Henseler et al. 2015). Hence, discriminant validity was confirmed. The path model also has perfect fit measures. The study assessed the impact of socio-economic characteristics, good driving behaviour, and risk perception on the WTP of respondents. The influence of socio-economic characteristics on WTP was found to be positive and statistically significant ($\beta = 0.24$, $t = 3.671$, $p < 0.001$), thereby supporting H1. The effect of good driving behaviour on WTP was also positive and significant ($\beta = 0.14$, $t = 2.845$, $p < 0.01$), validating H2. Additionally, the impact of risk perception on WTP was positively significant ($\beta = 0.55$, $t = 2.533$, $p < 0.05$), confirming H3. Therefore, the factors influencing WTP were successfully identified using SEM.

5.7.2 WTP – Stated Choice method

The WTP estimation by using route choice modelling requires the use of NLOGIT software. The data obtained from the survey needs conversion. First, the data was stacked into panel form using spreadsheet software. So, each individual's response corresponds to 12 rows of data, i.e., each choice set has two alternatives and six choice sets. The attributes vary across the choice sets, while demographic, socio-economic, and trip variables remain the same for each individual. The stacked data was checked using Microsoft Excel software. The variables were arranged into two forms: continuous/scale variables and categorical variables. The categorical variables with two levels were placed using ones and zeros under the specific variable, as shown in Table 5.16.

For a better interpretation of categorical variables with more than two levels, the commonly used reference cell coding or dummy coding method was used. This method uses dummy variables, keeping one level as a reference. Let 'K' be the number of levels of the categorical variables, and the number of dummy variables is given by K-1, i.e., instead of K-level categorical variables, K-1 dummy variables are used so that the variables corresponding to the levels can be interpreted concerning the reference level of categorical variables. Each dummy variable takes the values zeros and ones, as shown in Table 5.17.

Table 5.16: Coding of simple dichotomous variables

Variables (2 levels)	Coding
Gender	0, for male 1, for female
Marital status	0, for single 1, for married
Accident history	0, if no 1, if yes

Table 5.17: Coding of multilevel categorical variables

Variable (more than two levels)	Coding
Education	1, if Graduate and 0, else 1, if Post Graduate and 0, else 12^{th} and below –Reference level
Occupation	1, if student and 0, else 1, if unemployed and 0, else 1, if private job and 0, else 1, if other job and 0, else Government job- Reference level

The attributes and other socio-economic variables were taken as continuous variables. Since the choice sets are binary, two distributions can be used: a logistic distribution (Logit) and a probabilistic distribution (Probit). For finite samples, Logit and Probit models provide exact estimates. However, this study involves repeated evaluation of an individual with the help of different designed choice sets. So, there is a good chance that heterogeneity is present among the individuals. This unobserved heterogeneity should be taken into account while estimating the model. There are various approaches to incorporating this into the models. Random effects models are commonly used to take these unobservable components into account. The main advantage of a random effects model is that it can produce efficient estimates with finite sample sizes compared to other approaches.

The software used in this work is NLOGIT, developed by Econometric. Inc. To deal with the data that involves repeated analysis (i.e., the panel data form), the software recommends using a RPL estimator to develop models. In RPL models, the data are fit using maximum simulated likelihood estimation (not maximum likelihood estimation), i.e., the finite sample set is analyzed, and the experiment condition is simulated based on the number of repetitions coded. The simulation helps in the development of efficient models that reflect actual needs. This approach is also called mixed-logit modelling, as it considers both fixed and random effects. Halton sequences were used here to generate points in the parameter space for simulations. Random-parameter logit models consume more time for model estimation than conventional models.

5.7.2.1 Model development

Stacked data for the first road segment was converted to comma-separated values format as the software prefers this format to import the data. Inside the RPLOGIT command, the choice variable was taken as the dependent variable. The independent variables should be assigned under two subcommands: 'Rhs' for variables that vary across the choices (attributes) and "Rh2" for variables that do not change across the choices (individual-specific variables). The simulations are performed based on the start values generated using Multinomial LOGIT (MNL).

The modeling was carried out for three routes. Route I: Aluva junction to Aroor Kumbalam Bridge, Route II: Thoppumpady to Kundanoor Thevara Bridge, and Route III: Nayarambalam to Vallarapadam ICTT, which were selected as explained in section 3.4.2. A total of 12000 observations collected from 1000 individuals were used for model formation in Route I, the longest route with a large population, and 6000 observations each in the case of Routes II and III. In the process of developing the NLOGIT model for each route, initially, the start values were estimated by the software. The initial estimates for the Route II model are shown in Table 5.18.

Then, initial iterations were performed to improve the starting values estimated by multinomial logistic regression. The replication for the simulation estimator was fixed at 100, which is sufficient to obtain reasonable estimates. Table 5.19 shows the estimates of the final Route II model.

The main difference between the estimates is that the start values are based on maximum likelihood estimation, while the final model is based on maximum simulated likelihood estimation. Also, the final model considers various effects to derive the parameters. Table 5.20 shows the different fitness criteria for the estimated Route II models.

All attributes used are significant at a 95% confidence interval in both the initial and final models. Apart from the attributes, marital status and accident history became significant at 95% in the initial model and the simulated model, whereas, in the case of Routes I and III, only the attributes appeared to be significant in the initial and final models. The final model gives a better R squared value (0.219) than the initial model shown in Table 5.20.

Table 5.18: Initial values estimated by MNL model for Route II

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-0.003	0.001	-2.327	0.022
Travel cost	-0.004	0.001	-4.632	0.000
Critical accidents rate	-0.027	0.013	-2.137	0.125
Married	-0.46	0.129	-3.538	0.000
Accident history	0.32	0.129	2.524	0.002

Table 5.19: Final estimates by RPL model for Route II

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-0.006	0.002	-4.117	0.000
Travel cost	0.000	0.000	-2.790	0.000
Critical accidents rate	-0.003	0.001	-2.941	0.040
Married	-0.589	0.155	-4.647	0.000
Accident history	0.454	0.133	3.413	0.002
Standard deviation	2.674	0.225	8.711	0.000

Table 5.20: Goodness of fit measures for Route II

Constant-only model	
Log-likelihood function	-675.934
Multinomial logit model- Start values	
Log-likelihood function	-658.358
Info. Criterion: Akaike Information Criterion (AIC)	1.25140
Info. Criterion: Bayesian Information Criterion (BIC)	1.25941
McFadden Pseudo R-squared	0.02600
McFadden adjusted R-squared	0.02518
Random parameters logit model-Final model	
Log-likelihood function	-529.473
Info. Criterion: AIC	1.14182
Info. Criterion: BIC	1.17015
Chi squared	277.367
Prob. [Chi-Squared > value]	0.00000
McFadden pseudo-R-squared	0.21667
McFadden adjusted R-squared	0.21601
Restricted Log-likelihood (RLL*) (No Coefficients)	-678.084
McFadden pseudo-R-squared*	0.21969
McFadden adjusted R-squared*	0.21904

McFadden recommends a value between 0.2 and 0.4 for better model fitness. The probability of exceeding the chi-squared value is less than the significance levels, i.e., the alternate hypothesis that adding independent variables improves the model is accepted. The Akaike and Bayesian criterion values are lower for the final model, indicating a lower prediction error than the constant-only and the MNL models. The random parameters model gives the standard deviation of the estimates, which is an essential factor for analyzing the individual's characteristics. The random parameters model gives the standard deviation of the estimates, which is an essential factor for analyzing the individual's characteristics. The standard deviation is also significant, with a t-value of 8.711 in the final model, confirming that there is unobserved heterogeneity among the individuals here, and a random-effects model gives better estimates than the base models. The log-likelihood values (absolute) of the final model are lesser than the initial ones, i.e., the final random-effects models provide a better fit to the data.

The tables showing the initial estimates, final estimates, and the goodness of fit criteria of the Route I and Route III models are given in the Appendix IV. In the case of Routes I and III, only the attributes appeared to be significant in the initial as well as final models.

5.7.2.2 Interpretation of the model

Understanding the model results and the trend associated with the generic and alternative-specific variables is imperative. The final model for the users of Route II, i.e., Thoppumpady to Kundanoor Thevara bridge, gives significant estimates for travel time, travel cost, critical accidents rate, marital status, and accident history. The variables gender, age, and income, which usually show significance in choice decisions, became insignificant in the model. This might be because of the negative tendency of the respondents to disclose their actual values. The attributes, or mode-specific variables, show parameters consistent with the expectations. The travel time (-0.003), travel cost (-0.004), and critical accidents rate (-0.027) show negative utility as the increase in these variables decreases the utility.

The parameter estimate of marital status shows that married people show negative utility (-0.457) towards riskier ones. It might be because of the assurance of the safety of the family as a responsible person. The respondents with accident histories show a positive coefficient (0.325) for riskier roads, which is consistent with the results obtained by

Antoniou (2014). Even after experiencing accidents, their attitude towards the safer alternative is low, possibly because of the misinterpretation of the risk associated with the alternative routes or their lack of confidence in their driving skills. While on Routes I and II, only attributes travel time (0.0102, 0.0097), travel cost (-0.0014, -0.0015), and critical accidents rate (-0.0027, -0.0061) were significant in the final model, which might be the same reason as in the first part, i.e., the discrepancy in the socio-economic factors given by the respondents. The attributes, or generic variables, show negative signs consistent with the expectations.

5.7.2.3 WTP, VSL, and Accident Cost Estimation

The main objective of this study is to estimate the WTP values for the critical trip settings of Ernakulam city. The WTP estimates can be obtained from the final models of the corresponding road segments using the MRS between risk and monetary parameters. Here, critical accidents rate and travel costs are the risk and the economic parameters, respectively. In this study, the risk and the cost parameters were treated as non-random, so a WTP value can be estimated by dividing the risk parameter by the cost parameter. Table 5.21 shows the WTP values for the considered trip settings.

Table 5.21: WTP values for the three routes

Trip setting	Variable	Coefficients	WTP
Aluva junction to Aroor Kumbalam bridge	Critical Accidents rate	-.0027	1.974
	Travel cost	-.0014	
Thoppumpady to Kundanoor Thevara bridge	Critical Accidents rate	-.0033	7.499
	Travel cost	-.0004	
Nayarambalam to Vallarapadam ICTT	Critical Accidents rate	-.0061	4.029
	Travel cost	-.0015	

The WTP is estimated using the MRS, using Eq 5.17. If 'u' represents the utility, then estimates of travel cost and critical accidents rate (ca) can be described as u/rupees and u/ca/trip, i.e., the estimates correspond to the unit change in that predictor variable.

$$WTP = \frac{\text{Risk estimate } (u/\text{ ca / trip })}{\text{Cost estimate } (u/\text{ Rupees })} \tag{5.17}$$

The WTP values to avoid a critical accidents rate obtained from the coefficients of predictor variables are 1.97, 7.49, and 4.03 INR per person trip, i.e., to avoid an accident involving a fatality or severe injury, a road user is willing to pay an average value of INR 1.97, 7.49 and 4.03 for Routes I, II, and III, respectively.

These routes fall under the urban classification and have identical traffic conditions. The primary distinction is the risk associated with each trip. The first and third routes were relatively longer and riskier than the second route, though riskier. The WTP values of the first route were lower than those of the second and third. Route I is one of the most essential roads in the city of Ernakulam and is in close proximity to the Vyttila bus terminal, Metro stations, Lulu Mall, and numerous other centres. This route has a Tollbooth at one of its endpoints, which may discourage people from spending more on safety. In addition, only a small portion of roads are routinely used for daily purposes outside of work and school, so the risk exposure of Route I is lower despite its relatively high risk. In addition, the traffic scenario on that route leads people to believe that it is less dangerous. Long journeys are typically less frequent than relatively short journeys for those who live nearby. Compared to Route I, Routes II and III are exclusively used by people who live in the surrounding areas; as a result, people may be more aware of the dangers that exist on those routes and be willing to pay more for their safety.

The essential WTP calculation parameters are travel cost and the number of road accidents. The WTP per person per trip is calculated by dividing the critical accidents rate (CA) parameter by the Travel cost (TC) parameter (Le et al. 2011; Antoniou 2014). The lowest WTP value of road accidents for vehicles found in this study is Rs. 1.974 per person per trip. The value of avoiding a road accident has been assessed based on the average daily vehicular traffic count. The average number of people commuting along the routes in both directions is calculated to be 31,700 based on an unpublished NATPAC study considering an average occupancy of 2.35 passengers per vehicle. The per capita trip rate was obtained from the comprehensive mobility plan of Ernakulam city as 1.04. Hence, VSL was calculated as follows. VSL = 31700*1.04*365* (1.974/person/trip) = INR 2,37,53,137 = 2.4 crore. This value is comparable with the value obtained by Mohan (2002), considering the consumer price index. In order to calculate the accident cost of each year, the number of fatalities and grievous injuries are to be multiplied by the VSL and VSI, respectively. In this case, also, VSI is calculated as 13% of VSL for grievous injuries and 1% of VSL for minor injuries (Perkins et al. 1998). The estimated VSL of Ernakulam city road users is INR 2.4 crore. The accident cost of fatalities and injuries is found to be in the range of INR 566.89 crore to INR 850.31 crore annually from 2018 to 2021, as shown in Table 5.22.

Table 5.22: Estimated Accident Cost-WTP (DCE)

Year	Accident Severity	No. of accidents	Accident cost (Crore)	Total cost (Crore)
2018	Fatal	131	311.17	831.34
	Grievous	1651	509.81	
	Minor	436	10.36	
2019	Fatal	144	342.05	850.31
	Grievous	1617	499.31	
	Minor	377	8.95	
2020	Fatal	98	232.78	566.89
	Grievous	1067	329.48	
	Minor	195	4.63	
2021	Fatal	134	318.29	723.02
	Grievous	1289	398.03	
	Minor	282	6.70	

5.8 SUMMARY

In this chapter, two different SP approaches, namely CV and DCE, were discussed. The results obtained from CV and DCE varied hugely in the case of VSL (approximately INR 38 lakh and INR 2.4 crores, respectively) as well as the accident cost (INR 176 crores and INR 743 crores, respectively). The VSL value obtained in this method is quite high and impractical for a developing country, though it is in line with the VSL obtained by Haddak et al. (2016) in the case of a developed country. The WTP-CV payment card approach indirectly reveals that accident costs depend mainly on the percentage risk reduction and population size rather than the number of fatalities and injuries. SEM analysis revealed that the WTP-CV approach is influenced by several socio-economic factors, risk perception, and driving behavior characteristics. Among these factors, the "never drink and drive" trait was found to have the greatest impact on WTP. The WTP-DCE was estimated using parameter estimates obtained from NLOGIT modeling. The model indicated that WTP is primarily influenced by attributes such as travel time, travel cost, and accident rate rather than socio-economic parameters. This could be attributed to the population's unfamiliarity with such an approach.

CHAPTER 6

HYBRIDISATION OF HC AND WTP APPROACHES

6.1 GENERAL

The accident costing method implemented by developing nations is typically the Human Capital (HC) method, although few nations have attempted to adopt the Willingness to Pay (WTP) method recently, as already discussed in Chapter 2. HC method focuses mainly on the monetization of production loss of victims, i.e., the monetary value of goods and services that the individual might have produced if he/she was not involved in an accident, regardless of whether they were actually employed. As the WTP approach is solely based on the respondent's perception, it can be considered the most suitable method to assess the intangible costs, although it is sometimes underestimated. Introducing a new hybridized approach can resolve the disadvantages of adopting any single methodology. The proposed hybrid methodology suggests revising conventional HC method cost components to address the existing limitations, including the Value of Statistical Life (VSL) and Value of Statistical Injury (VSI) concepts for Pain, Grief, and Suffering (PGS). To estimate VSI, which is a percentage of VSL, it is necessary to classify the injuries based on their severity. Hence, Maximum Abbreviated Injury Scale (MAIS) is introduced. The proposed methodology also enables the estimation of individual accident costs.

6.1.1 Scaling of grievous injury based on MAIS

Precise information on the injury is required to assign MAIS scores to injuries. The only data available for the study are the First Investigation Report (FIR) details, which give a generic or vague description of the injury. As there is no mechanism to update the victim's condition from post-medical examination, the FIR lacks a detailed medical description of the injury. Each case was awarded an MAIS score with the assistance of road safety experts and physicians specialized in trauma and emergency care. This was cross-referenced with the Abbreviated Injury Scale (AIS) dictionary, which provides the specific injury coding method.

In this study, MAIS 1-2 scores are considered minor injuries, whereas MAIS 3-5 values are considered serious injuries, similar to International Road Assessment Programme (iRAP). After assigning an MAIS score to each case in the data, it is requisite to determine the proportion of cases with different MAIS scores.

6.1.2 VSL to VSI

The VSL is calculated using the WTP method, which is the value of one statistical life. Conventionally, VSI is taken as 13% of VSL for serious injuries and 1% for minor injuries in many countries (Perkins et al. 1998; Wijnen 2021a). These values must be tailored to suit the accident statistics, road conditions, and crash severity distribution in a developing country like India. This study adopts the relation between MAIS scores and VSI/VSL percentages, as shown in Table 2.1.

As the distribution of MAIS scores in the data is available, using the weighted average method, a suitable fraction of VSI/VSL is found for both minor and grievous injuries. This can be adopted to estimate the value of PGS. The remaining components of the accident cost, which include Lost Productivity cost, Medical cost, Administration cost, and Vehicle Damage cost, are to be revised from the existing methodology of the HC approach.

6.2 REVISION OF HC APPROACH COST COMPONENTS

Conventionally, in the HC method, Lost Productivity cost, Medical cost, and Vehicle Damage cost are determined initially, and then the other components, like Administration cost and Human cost (PGS cost), are derived as the percentage of those mentioned above. The subsequent subsections detail the improvements made to the various cost components.

The revisions adopted in the various cost components of the conventional HC approach are discussed in the following subsections. The estimated accident costs based on the new methodology are also explained in detail.

6.2.1 Revision of Lost Productivity Cost

The loss of productivity due to fatality was calculated using Eq 4.1 as used in most HC studies for the victims of pre-retirement age.

Lost Productivity for Fatality (after retirement): As the conventional equations account for lost productivity only considering the retirement age, it is necessary to acknowledge the lost productivity of fatalities after retirement age. Even though people disengage from the active labor force or directly paid work, it is common for retired people to get involved in many unpaid works and services like volunteering, domestic, and caring. The average life expectancy for males and females is considered, and the difference between the life expectancy and the age at which the death happened is taken as the life years lost. Lost productivity is taken as the product of life years lost and average notional income set by the Honorable High Court of Kerala.

Lost Productivity for Grievous/Minor Injury: Future productivity loss for road injuries is calculated based on the number of days lost by the victim due to the injury. The average number of days victims are not able to work in case of minor and grievous injuries are found from surveys. The average wage per day is calculated using the notional income set by the Honorable High Court of Kerala in MACA No.3777/2019 and MACA No.3798/2019. The product of the number of days unable to work and the average daily income gives the total lost productivity.

Lost Productivity for Bystanders: This category often goes unacknowledged. In case of grievous injury, the victim often requires external help for even basic needs for a certain number of days. The number of days bystander is required is found from surveys as half of the days the victim was unable to work. The average wage per day is calculated from the notional income set by the Honorable High Court of Kerala.

6.2.1.1 Revised Lost Productivity Cost

The preliminary information required to calculate the lost productivity, gathered from various official sources and reports, was outlined in Table 4.1. Relying on the decisions of the Honorable Apex Court in Ramachandrappa vs Manager, Royal Sundaram Alliance Insurance Company Limited [(2011) 13 SCC 236] and Syed Sadiq vs Divisional Manager, United India Insurance Co. Ltd. [(2014) 2 SCC 735], and also the decisions of the Honorable High Court of Kerala in MACA No.3777/2019 and MACA No.3798/2019, considering the year of accident and the socio-economic conditions prevailing over the period of the accident, the notional income of the petitioner can be fixed as Rs.11,500 per month and is increased at the rate of 500 per year. The revised lost productivity cost, including the lost productivity of victims of post-retirement age and that of caregivers, is given in Table 6.1.

Table 6.1: Estimated Lost Productivity Cost (Crore INR)-Hybrid Approach

Injury Severity	2018	2019	2020	2021
Fatal	41.75	45.57	28.94	38.34
Grievous	8.54	8.92	8.54	8.92
Minor	0.45	0.41	0.46	0.41
Total	50.74	54.89	37.93	47.66

The variation of the revised lost productivity cost with the cost obtained by adopting the conventional HC method (refer to Table 4.7) is 1.06 times. The fatal and grievous accidents' costs are 1.05 and 1.16 times, respectively, revealing the cost increase due to the exercise.

6.2.2 Revision of Medical Cost

The collected medical bills that were initially used to calculate the average cost of hospitalization for injuries have now been categorized based on their MAIS score. The average medical cost is then estimated for each MAIS score. The resulting value is multiplied by the number of cases registered under each MAIS category. As MAIS 1 and 2 are considered minor injuries, and MAIS 3 - 5 are considered grievous injuries, the total medical cost is determined using Eqs 6.1 and 6.2.

$$\text{Total medical cost for minor injuries} = (\text{Total medical costs for MAIS 1 injuries}) + (\text{Total medical costs for MAIS 2 injuries}) \qquad (6.1)$$

$$\text{Total medical cost for grievous injuries} = (\text{Total medical costs for MAIS 3 injuries}) + (\text{Total medical costs for MAIS 4 injuries}) + (\text{Total medical costs for MAIS 5 injuries}) \qquad (6.2)$$

6.2.2.1 Revised Medical Cost

The revised medical cost considering their MAIS score is shown in Tables 6.2 and 6.3.

Table 6.2: Estimated Medical Cost (INR) based on MAIS-Hybrid Approach

MAIS Score	Average Medical Cost	No. of cases	Total Medical Cost (Crore)
1	19,450	363	0.71
2	55,600	1,046	5.82
3	1,60,000	3,600	57.60
4	2,85,000	1,327	37.82
5	4,80,000	570	27.36
6	1,800	412	0.07
Grand Total			129.38

Table 6.3: Estimated Total Medical Cost (Crore INR) for the study period

Year	Medical Cost
2018	39.99
2019	36.37
2020	24.35
2021	28.66
Grand Total	129.38

The revised medical cost is 1.53 times greater than the cost obtained by adopting the conventional HC method (refer to Table 4.7), as the injuries were precisely scaled according to their severity. Generally, MAIS 6 is assigned as currently untreatable cases, but in this methodology, only fatalities are being considered in the MAIS 6 category, as the medical cost considered for fatal cases is a smaller value compared to other cases.

6.2.3 Revision of Vehicle Damage Cost

Vehicle damage is generally a definite outcome of Road Traffic Accidents (RTAs) that may or may not necessarily have a fatal or injured victim. Vehicle damage cost is calculated using the severity of the accident, the count of involved vehicles per accident, and the average damage for each vehicle. Conventionally, vehicle damage cost is calculated as the product of the average vehicle damage cost and the number of vehicles involved in the accident. The average vehicle damage cost is found in surveys done in garages and workshops. The revision in the vehicle damage cost included a detailed approach in addressing the type of collision patterns, separately for the vehicles of various costs and the total cost estimation based on that.

From the surveys, it was inferred that the vehicle damage cost for front, side, and rear-end collisions can be expressed as a fraction of the total cost of the vehicle. These fractions were calculated based on the average cost of vehicles commonly found on Indian roadways, as well as data collected from authorized and unauthorized garages and insurance surveyors. The average price of the vehicles commonly used on Indian roads is shown in Table 6.4. The average cost of vehicles has been calculated using the weighted mean approach, which accounts for the number of vehicles sold within each vehicle segment and their corresponding costs. The number of vehicles sold within each vehicle segment (eg: hatchback, sedan, SUV, etc.) was derived from the 2019 Automobile Market Report published by the Indian Automobile Manufacturers Association. The average cost of vehicles in each segment was obtained from market research and automobile industry reports such as the Market Research Firm Annual Report 2019.

The FIR details from the District Crime Records Bureau (DCRB) clearly depict the type of collision, i.e., front, side, or rear collision, and, therefore, the total number of cases that could be found. The product of the number of cases falling under each collision and the average vehicle damage cost of each will give the total vehicle damage cost.

Table 6.4: Average Vehicle Price (INR)

Vehicle	Price (INR)
Scooter	1,00,000
Motorcycle	1,50,000
Car	10,00,000
3-Wheeler	3,00,000
Bus	20,00,000

6.2.3.1 Revised Vehicle Damage Cost

Table 6.5 represents a sample vehicle damage cost for cars in 2018. The estimated vehicle damage cost by the hybrid approach is, on average, 4.99 times the vehicle damage cost calculated using the conventional HC approach (refer to Table 4.7).

The total estimated vehicle damage cost from the Hybrid method based on injury severity (Minor. Grievous, Fatal, and Property Damage Only (PDO)) is given in Table 6.6.

Table 6.5: Estimated Vehicle Damage Cost (INR)-Car - 2018

Type of Collision	Factors Adopted-Collision	Minor $*10^5$	Factors Adopted -Injury	Grievous or Fatal $*10^5$	Total Average cost			
					Minor $*10^5$	Grievous $*10^5$	Fatal $*10^5$	PDO $*10^5$
Front	0.5	3.5	0.7	7.0	49.0	350	38.5	85.3
Rear	0.5	2.5	0.5	5.0	5.0	450	95.0	224.0
Side	0.5	2.0	0.4	4.0	8.0	392	38.0	154.7
Un-known	0.5	2.7	0.5	5.3	37.3	1466.7	221.3	229.3

Table 6.6: Estimated Vehicle Damage Cost (Crore INR)-Hybrid

Year	Fatal	Grievous	Minor	PDO	Total
2018	2.26	39.74	6.45	9.76	58.19
2019	2.79	37.46	5.80	5.89	51.95
2020	1.53	22.72	2.39	3.33	29.96
2021	2.11	31.21	3.49	3.43	40.24

6.2.4 Revision of Administration Cost

Conventionally, administration costs are a certain percentage of human and vehicle damage costs. The administrative system dealing with the RTA cases has gone much beyond the time of introducing the conventional HC approach ideology. Employees of the police, court, and insurance office who are involved in an RTA case are identified. A survey was undertaken to determine the average hourly rate and the number of hours each employee spends working on RTA cases. The total administrative cost of minor, grievous, and fatal injury is determined by multiplying the number of hours employees spend in these sectors by their hourly wage.

6.2.4.1 Revised Administration Cost

The estimated administrative costs for the police, court, and insurance services are given in Tables 6.7, 6.8, and 6.9.

Table 6.7: Police Administrative Cost (INR)

Staff	Time Effort	Hourly Wage	Total Amount
ACP	1	398	398
Police Inspector	18	341	6,138
Police Sub Inspector	38	284	10,792
ASI/Head Constable	16	227	3,632
PCR Vehicle Driver	6	142	852
PCR Operator	15	142	2,130
Body Vehicle Driver	1	142	142
Grand Total			24,084

Table 6.8: Insurance Administrative cost (INR)

Staff	Time Effort	Hourly Wage	Total Amount
Surveyor	10	260	2,600
Office Assistant	1	390	390
Officer	2	650	1,300
Manager	1	800	800
Accounts Officer	1	500	500
File Keeper	1	190	190
Grand Total			5,780

Table 6.9: Court Administrative cost (INR)

Staff	Time Effort	Hourly Wage	Total Amount
Judge	4	734	2,202
Bench clerk	3	287	861
Typist	2	205	410
Clerk	2	205	410
Steno	2	246	492
Office assistant	3	137	411
Grand Total			5,520

In case of minor accidents, the court administration cost is excluded, and the sum of the police administration and insurance administration costs calculated as INR 29,864 is considered, whereas, in case of fatal and grievous injury accidents, the court administration cost is also included, and is estimated as INR 35,384. The total estimated administration cost obtained by adopting the hybrid methodology is given in Table 6.10 for the study period. The revised administration cost is found to be 9.24 times that estimated using the conventional approach (refer to Table 4.7).

Table 6.10: Total estimated administration cost (Crore INR)-Hybrid

Year	Fatal	Grievous	Minor	PDO	Total
2018	0.46	5.84	1.05	0.23	7.58
2019	0.51	5.72	0.91	0.23	7.37
2020	0.35	3.78	0.47	0.45	5.05
2021	0.47	4.56	0.68	0.58	6.29

6.2.5 Revision of PGS Cost

The PGS cost, also referred to as human cost in the conventional HC approach, was about 16% of the total estimated accident cost, which underestimated the mental trauma of the victims and the families involved. In the revised PGS Cost, the concepts of VSL and VSI are incorporated. To estimate the VSL, from which the human costs are derived, the VSL obtained from the WTP approach is used in this study. In case of a fatal accident, the whole VSL value is taken as the cost of PGS. In cases of grievous or minor injuries, VSI is taken as a fraction of VSL. The VSL for a fatality is found from the WTP approach as INR 38 lakh. The VSI is calculated based on the scale of the injuries. The VSI for grievous and minor injuries is determined, as explained in Section 3.7.

6.2.5.1 Revised PGS Cost

Using the concept of weighted average, the VSI for grievous injuries is obtained as 19.45%, and that for minor injuries is obtained as 3.56%. The details used for calculating the same are given in Tables 6.11 and 6.12.

Table 6.11: Determination of VSI (INR)-Minor Injuries

MAIS	No. of cases	% of total cases	VSI (in Lakh)	Weighted Average-VSI	VSL (in Lakh)	VSI/VSL
1	363	25.76	0.11	1.36	38.08	3.56
2	1046	74.24	1.79			

Table 6.12: Determination of VSI (INR)-Grievous Injuries

MAIS	No. of cases	% of total cases	VSI (in Lakh)	Weighted Average-VSI	VSL (in Lakh)	VSI/VSL
3	3600	65.49	4.00	7.41	38.08	19.45
4	1327	24.14	10.13			
5	570	10.37	22.58			

The total year-wise estimated PGS Cost is given in Table 6.13. This cost component accounts for 53% of the total accident cost, giving due importance to the victim and the affected family.

Table 6.13: Estimated year-wise PGS Cost (INR)

Year	Total no. of accidents	MAIS	No. of each MAIS accidents	VSI	Cost of MAIS-scored accidents (INR)	Total PGS Cost (Crore INR)
2018	2351	1	147	11,424	16,79,328	156.43
		2	344	1,78,980	6,15,69,120	
		3	1314	3,99,850	52,54,02,900	
		4	300	10,12,954	30,38,86,200	
		5	171	22,58,203	38,61,52,713	
		6	75	38,08,100	28,56,07,500	
2019	2193	1	172	11,424	19,64,928	165.07
		2	368	1,78,980	6,58,64,640	
		3	972	3,99,850	38,86,54,200	
		4	429	10,12,954	43,45,57,266	
		5	129	22,58,203	29,13,08,187	

Year	Total no. of accidents	MAIS	No. of each MAIS accidents	VSI	Cost of MAIS-scored accidents (INR)	Total PGS Cost (Crore INR)
		6	123	38,08,100	46,83,96,300	
2020	1230	1	11	11,424	1,25,664	122.05
		2	95	1,78,980	1,70,03,100	
		3	604	3,99,850	24,15,09,400	
		4	300	10,12,954	30,38,86,200	
		5	116	22,58,203	26,19,51,548	
		6	104	38,08,100	39,60,42,400	
2021	1544	1	33	11,424	3,76,992	139.56
		2	239	1,78,980	4,27,76,220	
		3	710	3,99,850	28,38,93,500	
		4	298	10,12,954	30,18,60,292	
		5	154	22,58,203	34,77,63,262	
		6	110	38,08,100	41,88,91,000	

6.2.6 Total Estimated RTA Cost-Hybrid Method

A pictorial representation of the total estimated cost during the study period is shown in Fig. 6.1. A detailed analysis of the proportion of various accident cost components estimated using the hybrid approach reveals that the PGS (human) cost accounts for the maximum share (about 56%) of the total cost. By using the hybrid approach, it is clear that the underestimation of the PGS cost component is fixed. The lost productivity cost accounts for about 17% of the total cost in contrast to 54% in the conventional HC method, which justifies itself as not being focused only on monetizing lost productivity. The vehicle damage cost is obtained as 16% of the total cost, which is also due to the price hike in the automobile industry in the recent past. The medical cost, the second major share in the conventional HC method, accounts for only 12% of the total cost. As in the conventional HC method, administration costs hold the least share, though it is increased to about nine times as the detailed costs of each service are considered.

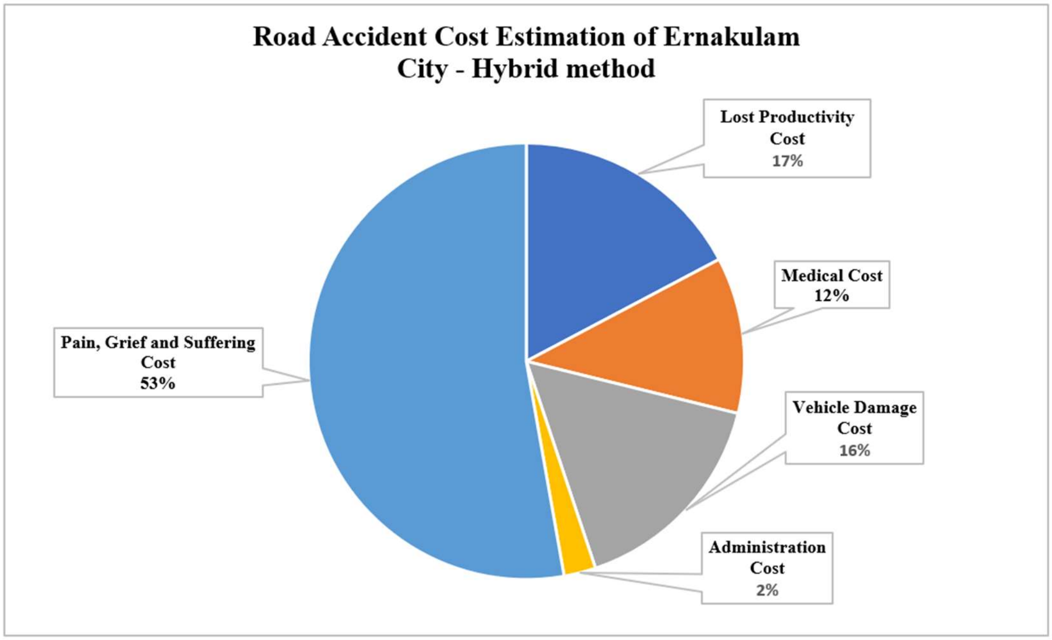

Figure 6.1: Total estimated cost (Hybrid) expressed as a percentage of total cost

The total estimated cost using the Hybrid method for the study period is given in Table 6.14.

Table 6.14: Estimated year-wise Total Cost (Crore INR)-Hybrid

Year	2018	2019	2020	2021
Lost Productivity Cost	50.74	54.89	37.93	47.66
Medical Cost	39.99	36.37	24.35	28.66
Vehicle Damage Cost	58.20	51.95	29.96	40.24
Administration Cost	7.58	7.37	5.05	6.29
Pain, Grief, and Suffering	156.43	165.07	122.05	139.56
Total Cost	312.94	315.65	219.34	262.41

The total estimated cost ranges from INR 219.34 crores to INR 315.65 crores, which can be averaged to INR 277.6 crores. This is higher than that obtained by adopting HC and WTP-Contingent Valuation (CV) but lower than that obtained while adopting WTP-Discrete Choice Experiment (DCE).

6.2.7 Accident Cost Prediction

The Hybrid method for the RTA cost estimation can also be used to predict the individual RTA cost using the economic concept of the Time Value of Money. This concept uses the Future Value equation, which considers compound interest over time to account for the future value of money. Interest, inflation, and risk rates are the three important variables in cost estimation and financial analysis. In particular, when projecting expenses or evaluating investments, each uniquely impacts how money's worth is determined over time.

The inflation rate is a percentage of the annual price increase for goods and services, affecting purchasing power. It plays a crucial role in cost prediction, as it affects the future value of money by reducing the currency's purchasing power over time. For instance, an item currently costing INR 100 will cost INR 102 in a year if the annual inflation rate is 2%. The interest rate is a yearly percentage of the principal representing the expense of borrowing money or the incentive for saving. It is important for cost estimation, estimating future returns on investments and loans, and figuring out loan payback terms. If INR 1000 is invested, INR 1050 can be anticipated after compound interest at a rate of 5% each year. Compared to a risk-free alternative, investors seek an additional return known as the risk rate or premium to offset the risk associated with their investment. As it accounts for possible risks and discounts future cash flows in project valuations and assessments, it is essential to cost prediction and investment analysis calculations. Given an investment with a risk rate of 2% and a risk-free rate of 3%, the projected total rate of return would be 5%. Investors demand this higher return in exchange for taking on more risk (Mankiw 2017).

The inflation rate is most suitable among these to address all the cost categories in the Hybrid method (Pineda Sandoval et al. 2023). This was reconfirmed with the discussion with economic experts. The scenario and the details of the cost components were explained to the experts, and trials of RTA cost prediction were carried out using the above three rates as per their advice. The expert believes that inflation rates are the most suitable for the RTA cost estimation. The cost prediction uses the future value equation (Khan and Jain 2008) in Eq 6.3.

$$FV = PV(i_r + 1)^{n_y} \tag{6.3}$$

where, FV denotes the Future Value of money, PV denotes the Present Value of money, n_y is the number of years, and i_r is the Inflation rate.

A Python program was developed to estimate the individual accident cost using the hybrid approach for the present and future, incorporating the economic concept of inflation. The program could be useful to find the total cost of any type of accident in the present year, where one can specify the type of accident, type of vehicle involved, the kind of collision that occurred, injuries suffered, etc. The input details of different accident severity scenarios were provided to the program to obtain the estimated RTA cost for different years. One such sample is shown in Table 6.15.

For example, consider the case of a 45-year-old male who was grievously injured as a result of a road accident and had multiple bone fractures. The brand new Maruti Suzuki Swift car he drove underwent a side collision during the crash. The side of the vehicle was damaged. He had to spend 5 days in the hospital with bystander support. The doctor prescribed him a rest of 30 days at home, requiring further bystander support of 15 days. The doctor diagnosed him with a permanent disability of 20% due to a shoulder joint injury. His per-day income was ₹2500. The loss due to this accident was estimated at INR 47,42,000 in the year 2023.

If the same accident takes place in the year 2025, the estimated RTA cost can be predicted using Eq. 6.3, where, PV = INR 47,42,000, $i_r = 0.058$, and $n_y = 2$, then the estimated RTA cost in the year 2025, FV, will be obtained as INR 53,08,024.

The RTA cost is predicted for a further five years until the year 2028 as shown in Table 6.15. The economic concept of Time Value of Money indirectly conveys that time will account for all the differences in the cost scenarios while considering the inflation rate for the accident costing.

Similar estimation and prediction are possible for road accidents differing in severity, i.e., minor injury and fatal accidents. The RTA cost for various injury types of grievous injury accidents, e.g., head injury, spinal injuries, rib injuries, bone fractures, multiple injuries, etc, can be estimated using this program for the present as well as future years.

Table 6.15: Estimated Present and Future RTA Cost – A sample calculation

Sl No.	Year	No. of years	Present RTA Cost (INR)	Inflation rate	Future RTA Cost (INR)
1	2023	0	47,42,000	0.058	47,42,000
2	2024	1			50,17,036
3	2025	2			53,08,024
4	2026	3			56,15,889
5	2027	4			59,41,611
6	2028	5			62,86,225

The variation in the inflation rate must be addressed with time. In conclusion, it makes sense to utilize the time value of money equation to anticipate accident costs since it offers a more thorough and precise financial analysis. It takes time's effect on money's value into account, ensuring that future expenses are suitably discounted to their current value to provide a realistic evaluation.

This program provides an interface for laymen to comprehend the severity of an accident, making it a useful aid for road accident awareness programs. For insurance professionals, accident cost prediction software is a priceless instrument that considerably facilitates accurate risk assessment and equitable premium calculation. This software plays a critical role in expediting claims processing, spotting possible fraud, and offering valuable information for prudent underwriting procedures. Precisely projecting future financial obligations, guaranteeing adequate reserve distribution, and augmenting client interaction via customized offerings are among their primary functions. These technologies also allow insurers to adhere to legal requirements, plan strategically, and make judgments based on solid data analytics. An individual can also use this program to calculate an approximation of his/her loss resulting from an accident and can, therefore, be used to determine how much the court-awarded compensation is covering for his/her loss.

6.3 SUMMARY

This chapter explains the concept of hybridization in detail, addressing the shortcomings of the HC and WTP approaches. The revision of specific cost components is described in depth. The RTA cost for each year of the study period is computed using the Hybrid method and compared to the conventional HC method. The calculation of each cost component was revised to account for the modifications. Considering the human pain and suffering, the PGS cost (53%) constitutes a much larger proportion of the Hybrid method's total cost than the conventional HC method (16%). Even after accounting for the lost productivity of post-retirement age victims and careers, the lost productivity accounts for only 17% of the total cost, demonstrating that this method does not rely solely on monetization of lost productivity. The administration cost (2%) is evaluated in depth in light of the current services provided. The estimated accident cost ranges from INR 219.34 crore to INR 315.65 crore, which can be averaged to INR 277.60 crore. This method also reveals that the RTAs impose a significant socio-economic burden (2.82% of Gross Domestic Product (GDP)) on Ernakulam city from 2018 to 2021.

The concept of predicting individual RTA costs for a future year incorporating the economic concept of inflation is also explained in this chapter. A Python program was developed to estimate the individual accident cost using the hybrid approach for both present and future dates.

CHAPTER 7

COMPARISON OF ESTIMATED RTA COSTS AND COURT COMPENSATION

7.1 GENERAL

This chapter aims to objectively present the data collected during the research process and critically analyze and interpret those findings in the context of the objectives. This chapter provides a detailed discussion on comparing the estimated costs obtained by adopting the Human Capital (HC), Willingness to Pay(WTP), and Hybrid approaches and the accident cost- Motor Accidents Claims Tribunal (MACT) compensation comparison.

7.2 COMPARISON OF ESTIMATED ACCIDENT COSTS

The Road Traffic Accident (RTA) costs obtained using the four methods (HC, WTP-Contingent Valuation (CV), WTP-Discrete Choice Experiment (DCE), and Hybrid) are being discussed with the help of Tables 7.1 and 7.2. Though the concept of WTP cannot be compared to other Road Traffic Accident (RTA) costing methods, it is being accepted as an accident costing technique in many developed and developing countries. Hence, this study is compelled to draw a comparison between these methods. Also, few previous studies compared the WTP methods with other costing approaches. While adopting the HC, WTP-CV, Hybrid, and WTP-DCE methods, the estimated accident cost was about INR 98 crores, 176 crores, 268 crores, and 743 crores, respectively.

The estimated accident cost is the lowest on adopting the HC approach and the highest on adopting the WTP-DCE method. It varies between 1.01% and 7.55% of the Gross Domestic Product (GDP). A huge difference can be noticed between the two different approaches of WTP, which makes this approach debatable. The total cost obtained by adopting the Hybrid method falls between that of the WTP-CV and WTP-DCE methods.

Table 7.1: Estimated year-wise Total Cost (INR)-A comparison

Year	Estimated total accident cost in crores			
	HCA	WTP-CV	HYBRID	WTP-DCE
2018	103.05	173.90	312.94	831.33
2019	105.59	175.08	315.65	850.31
2020	98.98	176.27	219.34	566.89
2021	85.71	177.45	262.34	723.02
Average	98.33	175.68	277.58	742.89
% of GDP	1.01	1.78	2.82	7.55

Table 7.2: RTA cost ratios from different methods

Methods	Average of yearly RTA Cost Ratio
WTP-CV/HC	1.99
Hybrid/HC	2.73
Hybrid/WTP-CV	1.53
WTP-DCE/HC	7.57
WTP-DCE/WTP-CV	4.23
WTP-DCE/Hybrid	2.77

The WTP-CV to HC ratio is 1.99, revealing that the WTP is approximately twice that of HC, which aligns with Bougna et al. (2022). The total cost of adopting the Hybrid method is 2.73 times those obtained using the HC method. The total costs by WTP-DCE are 4.23 times that by WTP-CV, which reveals that the costs obtained from adopting different methods within the same approach vary largely; hence, the reliability of adopting this approach is questionable. The average total costs obtained using the WTP-DCE method are 7.6, 4.2, and 2.8 times the HC, WTP-CV, and Hybrid approaches. The Hybrid method is 2.7 and 1.5 times the HC and WTP-CV methods, respectively. This comparison eliminates ambiguity regarding the selection of distinct approaches for various economies.

The HC method was found to be a direct method focused mainly on the monetization of lost productivity without considering the pain, grief, and suffering of the victim and their family. The HC method also required a revision in its cost components to incorporate the injury severity scaling and contribution of post-retirement age victims and caregivers. Due to its limitations, the WTP method is better for determining the WTP value and Value of Statistical Life (VSL) of the population than in accident costing. The significant limitations of the WTP method noticed in this study are:(i) Huge differences in the VSL obtained while adopting CV and DCE methods; (ii) The notable fact that the accident cost estimated in the CV method is concentrated on percentage risk reduction and population rather than the number of fatalities and injuries; (iii) The overestimated VSL and accident cost while adopting WTP-DCE, considering the economy of the country; (iv) The inefficiency in estimating the individual accident cost as a component-wise estimate rather than a VSL value, which is difficult for the layman to comprehend; and (v) The insufficiency in incorporating the injury scaling concept in a broader perspective, to make it applicable to different economies. Thus, the Hybrid method was introduced and analyzed for its ability to overcome the shortcomings of the above-said methods. This method calculates the cost of pain, grief, and suffering (PGS) by including the injury scaling concept (Maximum Abbreviated Injury Scale - MAIS). This method is component-wise, making it simpler to comprehend than WTP. It considers the lost productivity of victims of post-retirement age and the caregivers.

The estimated total accident cost using the Hybrid method lies between those calculated using the WTP-CV and WTP-DCE methods, making it plausible and acceptable for developing nations.

7.2.1 Comparison of Estimated Accident Costs from Expert Opinion Survey

The underlying principle of the Hybrid method was conclusively affirmed through a detailed analysis of the data derived from the responses in the Expert Opinion Survey. There were 30 valid responses received from the questionnaire distribution across the various sectors of the road stakeholder experts. The respondent composition had 6 samples (20%) from the road safety experts (scientists), 6 samples (20%) from the medical experts, 4 samples (13.33%) from the legal experts, 4 samples (13.33%) from the insurance officers and planners, and 10 samples (33.33%) from the academicians in the field of road safety. Respondents had ample experience in their fields. The sample size necessary for research of this nature, classified as a non-statistical method, is not governed by any fixed guideline. Azmi and Ram (2023) researched accident victim characteristics assessment involving only 27 experts. Given this context, it was determined that having 30 respondents for the study was sufficiently representative.

A briefing about the set objectives and the costing methods was provided as an introduction to the survey. The questionnaire included five accident scenarios of varying severity: one fatal, three grievous injuries (of different intensity), and a case of minor injury (See Appendix V). The basic details, such as the victim's age and income, were kept constant in all the cases. The vehicle used by the victim was varied only in the case of minor accidents to specify the injury to the victim. In the grievous injury cases, different collision types of vehicles were considered. The number of days of hospitalization, bystander support, and the percentage of disability were also specified in the cases of grievous injury. The RTA costs estimated by adopting HC, WTP-CV, WTP-DCE, and Hybrid approaches were provided as the options for all the questions. The RTA costs estimated using the Hybrid method were the second highest in all the cases. For the purpose of clarity and to avoid confusion and bias, the cases of different severity were given in a mixed manner.

In the case of a fatal accident, 60% of the respondents chose the RTA cost estimated by adopting the Hybrid method, 36.67% of respondents chose that by WTP-DCE, and 3.33% chose the option obtained by adopting WTP-CV method, as shown in Fig. 7.1. The respondents who selected the RTA cost estimated by adopting WTP-DCE might have considered the value of life and hence would have chosen the highest estimate among the provided options.

In the case of minor injury accident, 66.67% of the respondents chose the RTA cost estimated by adopting the Hybrid method, 20% of respondents chose that by WTP-CV, and 6.67% each chose the option obtained by adopting WTP-DCE method and HC method, as shown in Fig. 7.2. The respondents who chose WTP-CV would have underrated the accident cost as it is a minor injury accident. Among the 66.67% of respondents who chose the Hybrid method, 23.33% were academicians, 16.67% were medical experts, 13.33% were legal experts, and 6.67% each were road safety scientists and planners.

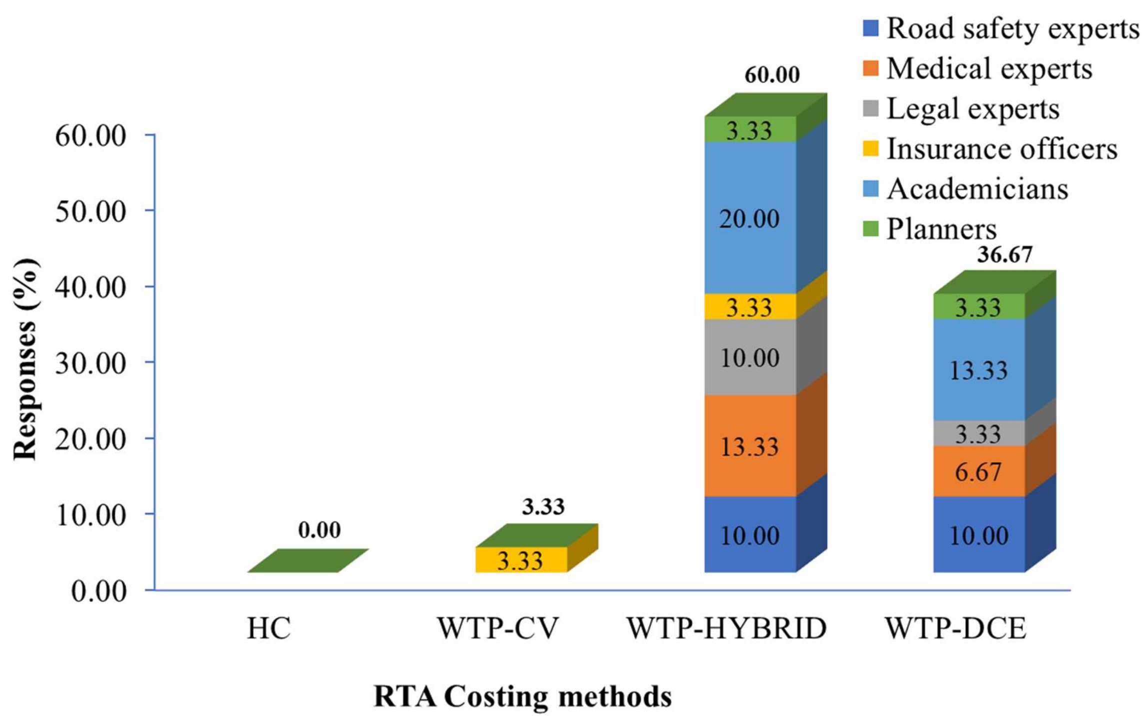

Figure 7.1: Case 1: RTA cost for Fatal Accident

In both fatal and minor accidents, the majority of the experts aligned with the RTA cost estimated using the Hybrid method.

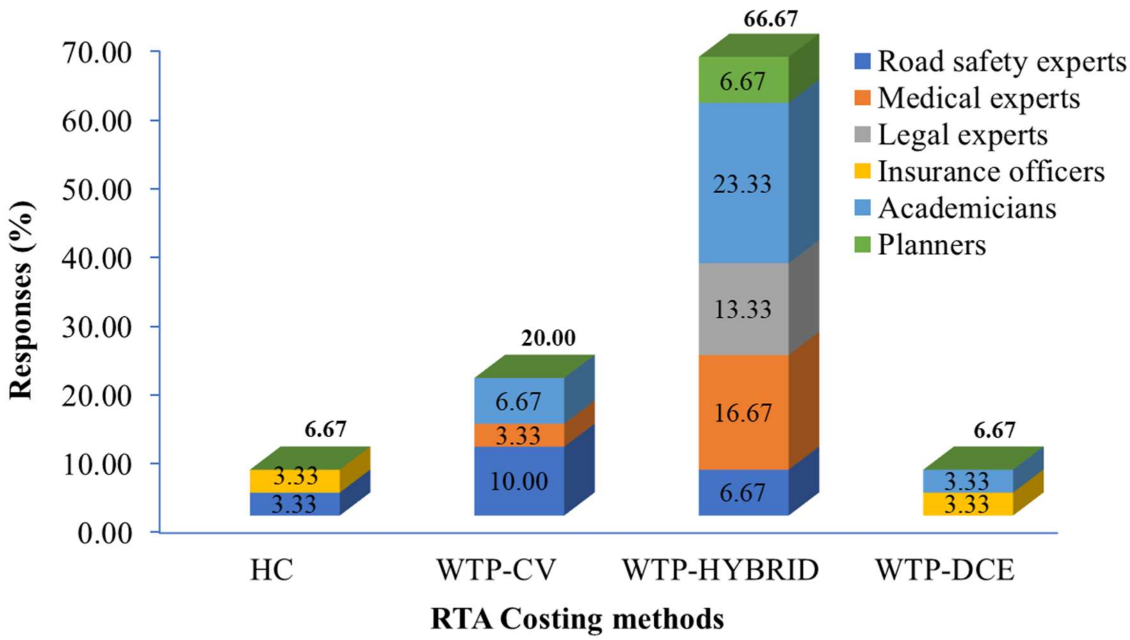

Figure 7.2: Case 2: RTA Cost for Minor Accident

For accidents resulting in different types of grievous injuries, the bystander requirement, rest period, vehicle collision types and permanent disability were presented to the respondents. The various cases presented and the responses received are explained below.

Case 3(a): The victim underwent multiple injuries, including head, spine, and bone fractures from a head-on collision damaging the front of the vehicle, 45 days of hospitalization with bystander support, a rest period of 60 days at home, and required further bystander support of 30 days.

In this case, 63.33% of the respondents chose the RTA cost estimated by adopting the Hybrid method, and 16.67% each chose the options obtained by adopting WTP-DCE and WTP-CV methods, as shown in Fig. 7.3. Among the 63.33% of respondents who chose the Hybrid method, 16.67% were medical experts, 13.33% each were legal experts and academicians, 10% were road safety scientists, 6.67% were insurance officers and 3.33% were planners.

Case 3(b): The victim underwent multiple bone fractures from a side collision damaging the side of the vehicle, requiring 5 days of hospitalization with bystander support, a rest period of 30 days at home and required further bystander support of 15 days.

In this case, 83.34% of the respondents chose the RTA cost estimated by adopting the Hybrid method, and 16.67% chose the HC method, as shown in Fig. 7.4. 83.34% was the highest percentage obtained among all the scenarios, supporting the grievous injury scaling incorporated in the Hybrid method.

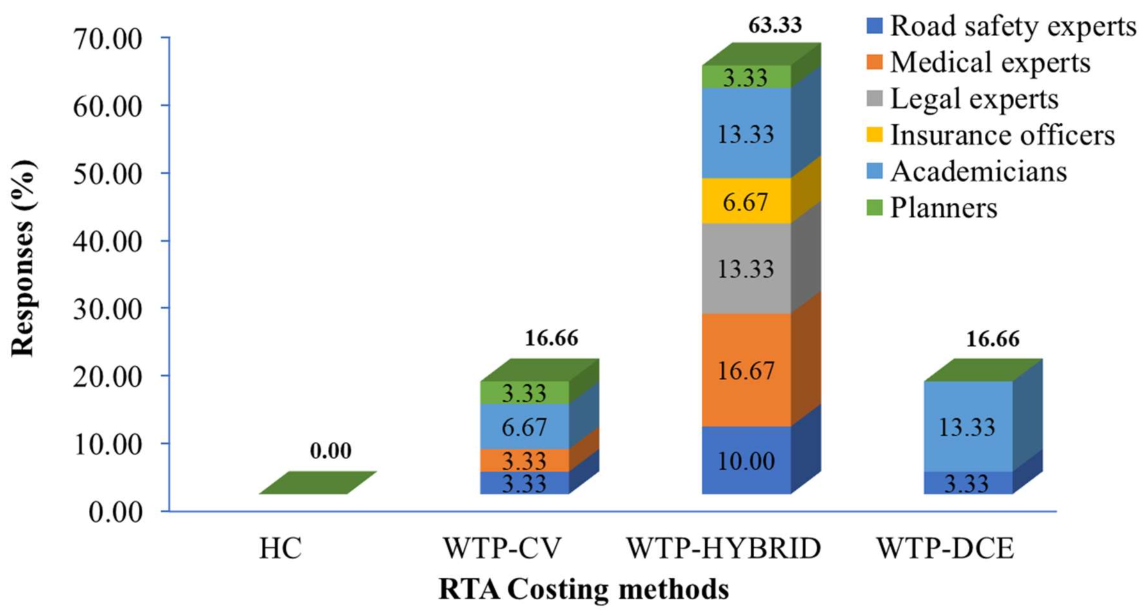

Figure 7.3: Case 3(a): RTA Cost for First Grievous Injury Accident

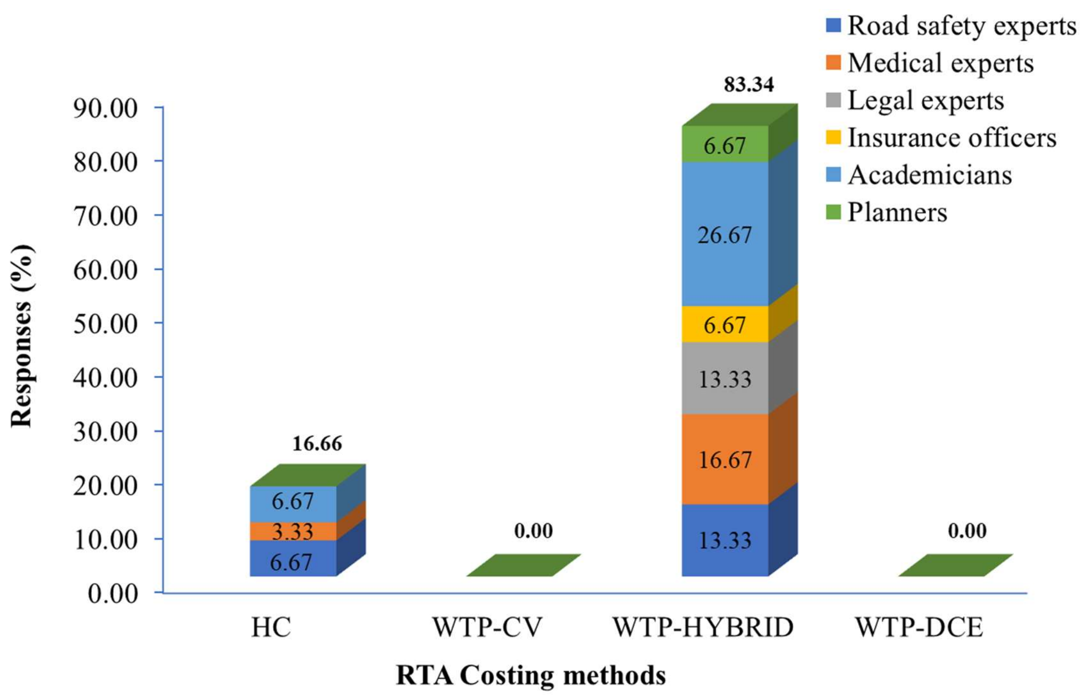

Figure 7.4: Case 3(b): RTA Cost for Second Grievous Injury Accident

Among those who chose the Hybrid method, the respondents comprised of 26.67% of academicians, 16.67% of medical experts, 13.33% each of legal experts and road safety experts, and 6.67% each of insurance officers and planners.

Case 3(c): The victim sustained multiple bone fractures in a head-on collision damaging the front of the vehicle resulting in five days of hospitalization, further 60 days of rest period with an additional fifteen days of bystander support. The victim was also diagnosed with a permanent disability of 20% as a result of a shoulder joint injury.

As shown in Fig. 7.5, 74.45% of respondents opted the RTA cost estimated by using the Hybrid method, 8.89% opted the alternatives obtained by using WTP-CV and WTP-DCE each, and 6.67% chose the estimates adopting the HC method. The 74.45% of respondents who chose the Hybrid method option comprised 22.22% of academicians, 16.67% of medical experts, 13.33% of legal experts, 11.11% of road safety experts, and 5.56% each of insurance officers and planners.

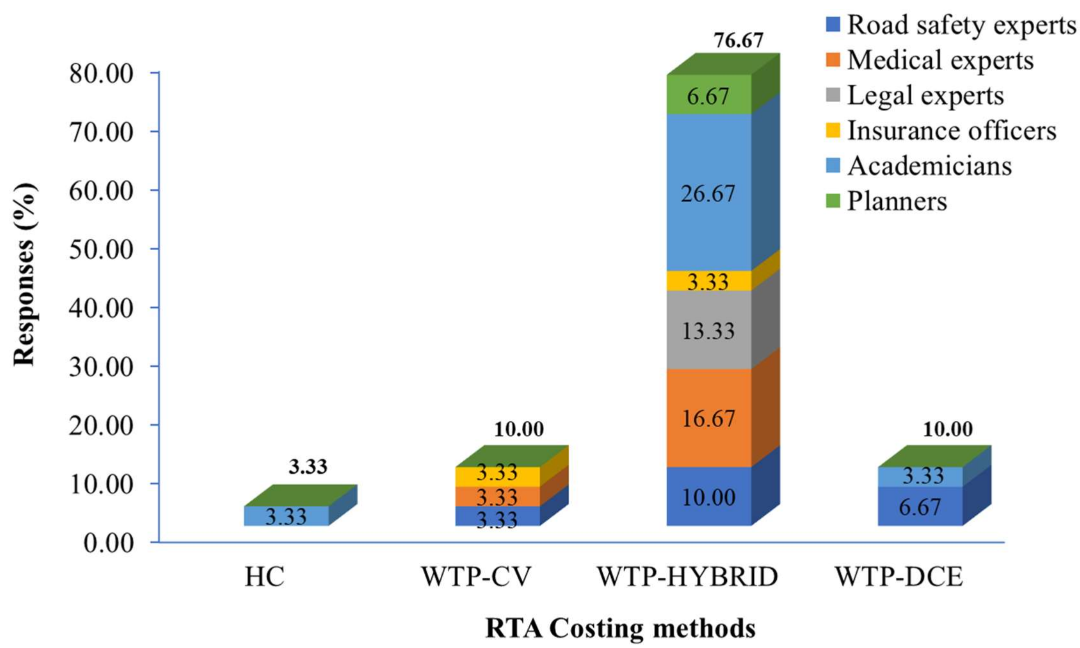

Figure 7.5: Case 3(c): RTA Cost for Third Grievous Injury Accident

In all three cases of grievous injury accidents, as in the cases of fatal and minor injury accidents, the majority of the experts o supported the RTA cost estimation using the Hybrid method, hence asserting the applicability of this method.

7.3 COMPARISON OF RTA COST ADOPTING HYBRID METHOD WITH COURT COMPENSATION

Evaluation of the direct and indirect socio-economic costs of the outcomes of road traffic crashes is important. This allows measurement of the burden that road traffic crash injury imposes on society and highlights the return on investment in road safety and the relative benefits and costs of different policy options in allocating resources. Along with this, it is important to evaluate the compensation provided. To provide speedier remedies to the victims of accidents by motor vehicles, MACT has been constituted. MACT Courts deal with claims relating to the loss of life/property and injury cases resulting from motor accidents after evaluating various factors like severity of the injury, age, income of the deceased, etc.

7.3.1 Compensation calculation and development of prediction program

The following subsections are a detailed explanation of the MACT compensation calculation in case of injuries and fatalities. This methodology is adopted when developing the compensation calculation program using Python. The user is prompted to enter the basic personal and injury details like age, year of the accident, accident severity, personal income, number of dependents, etc. It gives the amount probably to be awarded by the court under different heads.

7.3.1.1 Compensation in cases of death

Three facts need to be established by the claimants for assessing compensation in the case of death.

a) Age of the deceased
b) Income of the deceased
c) The number of dependents

It is necessary to reiterate that the multiplier method is logically sound and legally well-established. Some cases have proceeded to determine the compensation based on aggregating all future earnings for the period the life expectancy was lost, deducting a percentage towards future life uncertainties, and awarding the resulting sum as unscientific compensation.

In accordance with the formula established by Lord Wright in Davies method (Davies V. Powell Duffryn Associated Collieries Ltd., (1942) AC 601), the loss must be determined by calculating the deceased's monthly income, deducting the amount spent on the deceased, and then calculating the loss to the deceased's dependents. The annual dependency assessed in this manner is then to be multiplied by the use of an appropriate multiplier.

To have uniformity and consistency, Tribunals should determine compensation in cases of death by the following well-settled steps:

Step 1: Ascertaining the multiplicand

The income of the deceased per annum should be determined. Generally, the actual income of the deceased, less income tax, should be the starting point for calculating the compensation. Out of the said income, a deduction should be made regarding the amount the deceased would have spent on himself by way of personal and living expenses. The balance, which is considered to be the contribution to the dependent family, constitutes the multiplicand.

Step 2: Deduction for personal and living expenses

Claimants will obviously tend to claim that the deceased was very frugal, did not have any expensive habits, and was spending virtually the entire income on the family. In some cases, it may be so. No claimant would admit that the deceased was a spendthrift, even if he was one. It is also very difficult for the respondents in a claim petition to produce evidence to show that the deceased was spending a considerable part of the income on himself.

Therefore, it became necessary to standardize the deductions to be made under the head of personal and living expenses of the deceased. Table 7.3 shows the fraction of income that should be reduced considering the number of dependents.

Table 7.3: Fraction of income to be deducted for personal expense

Dependants	**2 to 3**	**4 to 6**	**More than 6**
Married	One-third	One-fourth	One-fifth
Bachelor	One-half		

Step 3: Addition to income for future prospects

The court held that the future prospects of advancement in life and career should also be sounded in terms of money to augment the multiplicand (annual contribution to the dependants) and that where the deceased had a stable job, the court can take note of the prospects of the future and it will be unreasonable to estimate the loss of dependency on the actual income of the deceased at the time of death. The future prospects concerning the injured' s age are given in Table 7.4.

Table 7.4: Future prospects with respect to the age of the injured

Permanent job (salaried)	Addition made	Self-employed	Addition made
Below 40 years	50%	**Below 40 years**	40%
40-50 years	30%	**40-50 years**	25%
50-60 years	15%	**50-60 years**	10%

Step 4: Ascertaining the multiplier

Regarding the age of the deceased and the period of active career, an appropriate multiplier should be selected. This does not mean ascertaining the number of years he/she would have lived or worked but for the accident. Concerning several imponderables in life and economic factors, the court has identified a table of multipliers with reference to age. The multiplier should be chosen from Table 7.5 with reference to the age of the deceased as per the Supreme Court case Sarla Verma (Smt.) and Ors Vs. Delhi Transport Corporation and Anr., (2009) 6 SCC 121.

Step 5: Loss of dependency

The annual contribution to the family (multiplicand), when multiplied by such multiplier, gives the 'loss of dependency' to the family and can be calculated by adding future prospects to the net income of the deceased and by subtracting personal expenses This amount is then multiplied with a suitable multiplier from the table.

Step 6: Other expenses

Medical expenses- The tribunal will award all medical expenses with adequate proof and documents not covered by insurance. Now, the court has affixed an amount of 40000 per dependent as loss of consortium with a 10% increase every three years. Loss of estate is around 15000, and funeral expenses are currently affixed as 15000, with a 10% increase every three years.

Table 7.5: Multipliers chosen by the court according to age

Age of the deceased	Multiplier
Upto 15 yrs	18
15 to 20 yrs	18
21 to 25 yrs	18
26 to 30 yrs	17
31 to 35 yrs	16
36 to 40 yrs	15
41 to 45 yrs	14
46 to 50 yrs	13
51 to 55 yrs	11
56 to 60 yrs	9
61 to 65 yrs	7
Above 65 yrs	5

7.3.1.2 Compensation in cases of injuries

Loss of income- The injured person must show proof that he is employed and submit proof of income to the court. He/she also needs to show that he was not able to work for a period of time due to the accident. The court calculates the loss of income as the product of the number of months he could not work and the person's monthly income.

If the person is not employed or cannot prove his/her income, the court sets a notional income, which was Rs.1500 in 2018. With each year, this amount is increased by Rs. 500. The same is followed in the case of housewives, which seems inadequate as the service and role played by them are immense.

- Bystander expense- A nominal amount of Rs 250 per day is fixed as an attendee charge, and it is multiplied by the number of days the patient required a bystander.

- Loss of earning capacity- In case of grievous injuries, the doctor proves if the injured have any permanent disability. This might reduce his productivity and prevent him/her from continuing his job as effectively as before. In some cases, considering the job requirements, he/she may become unsuitable to continue even with a small percentage of disability.
- Transportation charges- In most cases, transportation to hospitals multiple times to treat the injured can make up to a huge amount. The court awards the injured an amount for this, considering the distance of the hospital and where the injured person resides.
- Pain and suffering- Even though it is impossible to assess the monetary value of the pain and suffering of a person, the court awards an amount ranging from around INR 30,000 to 2,00,000 depending upon the injury's severity and the person's age. To ascertain this value in the compensation calculator program, the relationship was obtained from the collected verdicts between the number of days the victim was unable to work and the compensation awarded.
- Loss of amenities- These compensate for an injury that leaves victims with disabilities that tarnish general activities and satisfaction of lives but allow reasonable mobility to the victims, for instance, fractures that lead to recurring pain.
- Medical expenses, extra nourishment, and expenses for future treatment not covered under medical insurance can also be claimed through MACT.

To validate the program, data were collected from lawyers from different parts of Kerala. Data from the court verdicts were extracted and transferred to an Excel sheet to obtain the program's inputs. The minimum eligible compensation for each case is obtained from the program by entering the required inputs. This is compared with the actual compensation awarded by the court.

7.3.2 Comparison of Cost and Compensation

It has been reported that the compensation provided by the MACT has been inadequate for many cases, and appeals have been raised in the court. There have been many modifications and landmark judgments from the court regarding the compensation calculation. Studies about compensation will help to point out the shortcomings and underestimation or overestimation of compensation awarded by the MACT. To compare the costs incurred and the compensation awarded by the court, about 120 samples of verdicts by the court were taken. With the help of available inputs in the verdict, the total cost incurred was found using the Cost Calculator Python program. Another Python program was developed incorporating the aspects of MACT compensation. The development of such a tool will give a layman a fundamental understanding of MACT compensation calculation and the amount to which he/she is entitled. For the same 120 cases, the compensation that is probable to be awarded by the MACT is calculated using the compensation calculator program. This compares accident costs and compensation awarded, giving insight into the disparity between cost and compensation. Percentage error was found for each case, and the average percentage error obtained was 12.25%. The difference between the cost and compensation amounts was determined to compare these two aspects. Table 7.6 shows a sample of such a comparison.

In most cases, the results indicate that the cost and compensation differences are significant. The compensation awarded by the court is predicated primarily on the evidence presented to the court and the legal reasoning put forward by the lawyers and adopted by the judge. An accident cost calculator can help the judges and the lawyers assess each accident's cost and the loss incurred by the victim in detail. A person not at fault in RTA is eligible for compensation for their losses. As the study makes clear, the cost-compensation relationship must be analyzed, and appropriate measures must be taken to enhance the quality of life of an RTA victim.

Table 7.6: Comparison of cost and Court compensation

Age of victim	Absence from work (Months	Bystander support (days)	Disability (%)	Estimated total cost (INR)	Compensation by Court (INR)	% Difference
20	8	50	9	17,55,009	8,08,280	53.94
22	10	5	18	20,58,337	12,98,042	36.94
22	4	24	0	13,56,938	2,80,200	79.35
26	12	100	42	57,00,587	40,69,000	28.62
29	8	40	29	41,97,440	24,34,200	42.01
53	6	30	0	14,48,609	5,82,000	59.82
56	5	50	10	9,58,565	4,93,700	48.50
58	-	14	100	55,94,111	46,47,000	16.93
58	6	20	20	29,80,191	7,47,700	74.91
65	11	1400	98.18	44,92,397	28,50,990	36.54
68	12	100	25	29,36,225	10,01,000	65.91

7.4 SUMMARY

A detailed comparison of HC, WTP (CV and DCE), and the newly developed Hybrid approaches to accident costing is carried out. The total estimated accident cost adopting the Hybrid method falls between that calculated using the WTP-CV and WTP-DCE methods, justifying it to be realistic and acceptable for a developing country. The concept of the Hybrid method was conclusively affirmed through an expert opinion survey. In this survey, more than 60% of experts preferred the RTA cost estimated using the Hybrid method over other methods. The court compensation awarding procedure was studied in detail to develop a Python program to estimate the approximate compensation to be awarded by the court in each accident case. MACT lawyers can also use this to estimate the amount to be claimed for a traffic accident victim in court (with outcomes). The estimated RTA cost and court compensation were compared. The dissemination of the findings from this research to the general public will enhance social awareness about the financial consequences of RTAs and the associated compensation awarded by the court, thereby enlightening society on the economic burdens arising from such accidents.

CHAPTER 8

CONCLUSIONS

Road Traffic Accident (RTA) cost estimates vary significantly among countries, and these figures are greatly influenced by the methodology used to calculate them (Wijnen et al. 2017). This study draws the following conclusions from analyzing the Human Capital (HC), Willingness to Pay (WTP), and Hybrid approach in road accident cost estimation.

8.1 CONCLUSIONS

- The conventional HC approach is focused on monetizing lost productivity (49%), giving much less concern to the pain, grief, and suffering cost component (16%). Also, the lost productivity of post-retirement age victims and caregivers is neglected. The administration cost (1%) is not considered elaborately to account for the current services provided.
- To rectify the shortcomings of the HC method, the calculation of each cost component was revised. The notional income fixed by the Court was adopted as the income for post-retirement age victims, considering the service they provided to society. The lost productivity of the caregivers was also accounted for in this study.
- The WTP approach is found to be more suitable for estimating the WTP of the respondents as well as VSL rather than estimating the accident cost in developing countries. The component-wise calculation of accident cost is impossible while adopting the WTP approach.
- Two different stated preference approaches, Contingent Valuation (CV) and Discrete Choice Experiment (DCE), were included in this study. The results obtained from CV and DCE varied hugely in the case of Value of Statistical Life (VSL) (approximately INR 38 lakh and INR 2 cores, respectively) and the accident cost (INR 176 crores and INR 743 crores, respectively). The VSL obtained in the WTP-

CV approach is a lower bound estimate, which could be adopted as the pain, grief, and suffering component for fatality in the Hybrid approach. The CV method provides a dependable value of the VSL, as it elicits WTP more directly than the DCE method. Also, the VSL obtained in the WTP-DCE approach is a very high estimate, which is not justifiable considering the country's economy.

- The WTP-CV payment card approach reveals indirectly that the accident cost depends solely on the percentage risk reduction and population rather than the number of fatalities and injuries. The WTP-CV is found to be affected by a few socio-economic, risk perception, and driving behaviour characteristics through Structural Equation Modelling (SEM) analysis. Among them, the never drink and drive character influencing good driving behaviour was revealed to affect the WTP the highest.
- The WTP-DCE approach provided a very high estimate of VSL and accident cost, justifying its suitability to be adopted in developed countries rather than developing countries. The WTP-DCE was estimated using the parameter estimates obtained from the Multinomial LOGIT (MNL) model. The model revealed that the WTP mostly depended upon attributes such as travel time, travel cost, and accident rate rather than socio-economic parameters.
- The Hybrid approach addresses the limitations of the above two methods. This method does justice to the pain, grief, and suffering cost component by adopting the concept of VSL and injury scaling using Maximum Abbreviated Injury Scale (MAIS). Considering the economy of the country, using the weighted average approach, the Value of Statistical Injury (VSI) for grievous and minor injuries were obtained as 19.4% and 3.6%, respectively, which can be adopted wherever the same socio-economic characteristics exist.
- An expert opinion survey was conducted to assert the applicability of the hybrid approach for assessing the RTA costs at various severity levels. The results showed a notable trend in every scenario presented, with over 60% of the experts aligned

with the cost estimates derived from the Hybrid method compared to those from alternative methods.

- An individual road accident cost calculator is developed using Python based on the Hybrid method. The program can be used to calculate the present and future costs of a road accident as the concept of inflation is incorporated into it. A court compensation calculator is also developed using Python based on the collected verdicts of Motor Accidents Claims Tribunal (MACT) cases, and it was validated with an error of 12%. These programs can be used for a cost-compensation comparison by layman and law professionals. These can also be used to improve social awareness in the field of road safety.

The computed estimate for the city might be regarded as the lower bound of the expenses. This is because the analysis focused on key cost items and omitted numerous cost categories, such as infrastructure damage and traffic congestion charges. Also, the actual number of accidents might be greater than the reported ones, giving due consideration to the chance of underreporting.

8.2 LIMITATIONS

- As the scope of the research is limited to the city limits of Ernakulam, the particulars used in the study are region-specific.
- This study does not account for underreporting. Past studies comparing crash data and hospital data in India have shed light on the fact that there is a huge underreporting of accidents. This study directly uses the accident statistics provided by the District Crime Records Bureau (DCRB).
- The present study considered the daily income of the post-retirement victims and jobless people as a minimum for the lost productivity calculation, which could be considered as an underestimation with regard to the service provided by them to the society.

- WTP values were considered the same for the whole study period as the factors affecting WTP did not change considerably during the period of study.
- Assigning MAIS scores accurately can be done only if a detailed medical description of the injury is available. In this study, MAIS scores are assigned based on the medical details provided in the FIR.
- As the MACT court verdicts for the collected FIRs were not yet available, identical MACT court judgements from the study area were used.

8.3 FUTURE DIRECTIONS

- The present study was limited to the city limits of Ernakulam, Kerala state, South India. The study can be extended to areas with different socio-economic characteristics for generalization.
- The present study revealed that the population was unfamiliar with the concept of WTP; this can be remedied by educating the population further about the approach in future studies.
- Due to the lack of data, the present study could not consider certain cost components, such as infrastructure damage and traffic congestion. Further research involving these components can enhance the Hybrid method in the RTA cost estimation.
- The present study focused on enhancing the consideration for human pain and suffering instead of monetizing lost productivity; however, additional research on the various cost components could enhance the methodology.
- Further research based on the Hybrid concept in various countries can lead to a unified global approach for RTA accident costing.

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APPENDICES

APPENDIX I

I.A QUESTIONNAIRE SURVEY TO VICTIMS INVOLVED IN RTA

Dear Sir/Madam,

I am Sumayya Naznin P H, Research Scholar, Department of Civil Engineering, National Institute of Technology Karnataka, under the guidance of Dr. A.U. Ravi Shankar, Professor, Department of Civil Engineering, NITK. As a part of my project work, I need to collect some information from the road accident victims of Ernakulam City. Kindly cooperate with the project.

The data collected will be kept confidential and will be solely used for academic purposes only. Thanks in advance,

Sumayya Naznin P H,
Research Scholar,
Department of Civil Engineering, NITK.
Email: sumayyanazninph.187cv506@nitk.edu.in

SECTION-I

Name:

Location:

Gender of respondent

- o Male
- o Female

Age of respondent

- o <18 years

- 18 -25 years
- 26 – 35 years
- 36 – 45 years
- 46– 60 years
- >60 years

Occupation:

What is your current personal monthly income (INR)?

- <15000
- 15000 - 30000
- 30001 – 50000
- 50001 - 75000
- 75001 - 100000
- >100000

SECTION-II

Injury severity

- Non-injury accident
- Minor injury accident
- Grievous injury accident
- Fatal accident

Injury type (Eg: Head, Chest, etc.):

Which hospital did you visit for treatment?

How many days did you spend in the hospital for the treatment?

How many days did you spend at home without working after getting discharged from the hospital?

How many days were you in need of full-time bystander support?

How much money did you spend on in-hospital treatment?

How much money did you spend on extra medicines?

Have you received any compensation from the court? If yes, please specify the amount.

I.B QUESTIONNAIRE SURVEY TO GARAGES

Garage Name:

Garage Location:

Year:

Side Crash

1) **Number of side crash cases**

2) **Vehicle type in each case**

2W Scooter	2W Motorcycle	4W Car	3W Auto	Heavy Vehicle

3) **Number of days to repair in each case**

4) **Repair charges in each case**

Charges for new parts	
Service cost	
Taxes if any	

Head on Head crash

1) **Number of head-on-head crash cases**

2) **Vehicle type in each case**

2W Scooter	2W Motorcycle	4W Car	3W Auto	Heavy Vehicle

3) **Number of days to repair in each case**

4) **Repair charges in each case**

Charges for new parts	
Service cost	
Taxes if any	

Rear crash

1) **Number of rear crash cases**

2) **Vehicle type in each case**

2W Scooter	2W Motorcycle	4W Car	3W Auto	Heavy Vehicle

3) **Number of days to repair in each case**

4) **Repair charges in each case**

Charges for new parts	
Service cost	
Taxes if any	

Right angled crash

1) **Number of right-angled crash cases**

2) **Vehicle type in each case**

2W Scooter	2W Motorcycle	4W Car	3W Auto	Heavy Vehicle

3) **Number of days to repair in each case**

4) **Repair charges in each case**

Charges for new parts	
Service cost	
Taxes if any	

****Can you share with us if any bills concerning the above vehicle type and crash type are in your records?***

**For 4W, Parts Damaged in the front may include Windshield, A/C condenser, Radiator, Fan, Intercooler, Body Panels, Bumper, Headlights, Bonnets, Fenders, etc.*

**For 2W, Parts Damaged in the front may include Wielding, Front mudguard, Fork assembly, Headlight assembly, Wind glass, Fairing, Handlebar, Petrol tank etc.*

**For 4W, Parts Damaged in the back may include Deck, Deck glass, Body panels, Rear bumper, Rear tail lamps, etc.*

The below table was used for surveying insurance surveyor officers, garage workers, and some automobile showrooms.

Type of vehicle	Average price of vehicle in Indian road	Minor damage			Major damage		
		Front collision	Side Collision	Rear collision	Front collision	Side Collision	Rear collision
Scooter							
Motorcycle							
3 Wheeler							
4 Wheeler							
Bus							

I.C DATA COLLECTION FOR ADMINISTRATIVE COST

The following table was used to collect information regarding officers involved in each case and their hourly salary. This survey was done among employees of police, insurance, and court.

Staff involved	**Time Effort**	**Hourly Wage**	**Total Amount**
Grand Total			

I.D QUESTIONNAIRE SURVEY TO HOSPITALS

Hospital Name:

Hospital Location:

Year:

<u>Brought Dead cases</u>

Hospital charges in each case

Ambulance cost	
Medicines cost	
Test charges if any	
Mortuary charges	
M L C Charge	
Covid True Nat Test	

<u>Death after hospitalization cases</u>

Injury type identified in each case

Head	Chest	Abdominal	Spine	Bone fracture	Poly trauma

If Poly trauma, category of injury

Head trauma	Chest trauma	Abdominal trauma	Spinal trauma	Vascular trauma	Complications of previous trauma

Days of hospitalization in each case

Initial payment to the hospital

Registration charges	
Procedure charges	
Material charges	
Investigation charges	

Hospital charges in each case

Ambulance cost	
Admission cost including doctor's expenses	
Nursing charges	
Surgery cost	
ICU cost	
Medicine cost	
Test charges if any	
Mortuary charges	
Room charges & lab charges if any	

<u>Grievous injury cases</u>

Injury type identified in each case

Head	Chest	Abdominal	Spine	Bone fracture	Poly trauma

If Poly trauma, category of injury

Head trauma	Chest trauma	Abdominal trauma	Spinal trauma	Vascular trauma	Complications of previous trauma

Days of hospitalization in each case

Initial payment to the hospital

Registration charges	
Procedure charges	
Material charges	
Investigation charges	

Hospital charges in each case

Ambulance cost	
Admission cost (including doctor's expenses)	
Nursing charges	
Cost of surgery and that of surgical items used	
ICU cost	
Medicine cost	
Test charges	
Room rent	
Lab charges	
Monitoring charges if any	

Minor injury cases

Injury type identified in each case

Head	Chest	Abdominal	Spine	Bone fracture	Poly trauma

If Poly trauma, the category of injury

Head trauma	Chest trauma	Abdominal trauma	Spinal trauma	Vascular trauma	Complications of previous trauma

Days of hospitalization in each case

Initial payment to the hospital

Registration charges	
Procedure charges	
Material charges	
Investigation charges	

Hospital charges in each case

Ambulance cost	
Admission cost(including doctor's expenses)	
Nursing charges	
Medicine cost	
Test charges	
Room rent	
Lab charges if any	

Can you share with us if any bills with respect to the above injury type are there in your records.

I.E NUMBER OF VEHICLES INVOLVED IN ACCIDENTS

Table I.1 Number of vehicles involved in accidents in 2018

Vehicle type	Injury Severity			
	Fatal	Grievous	Minor	Non-Injury
Scooter	23	471	433	24
Motorcycle	43	812	201	44
Car	17	513	151	130
Autorickshaw	9	159	40	11
Bus/Truck	17	107	42	53
Total	**109**	**2062**	**867**	**262**

Table I.2 Number of vehicles involved in accidents in 2019

Vehicle type	Injury Severity			
	Fatal	Grievous	Minor	Non-Injury
Scooter	30	451	98	20
Motorcycle	65	712	155	33
Car	24	435	122	88
Autorickshaw	10	152	37	12
Bus/Truck	20	128	36	36
Total	**149**	**1878**	**448**	**189**

Table I.3 Number of vehicles involved in accidents in 2020

Vehicle type	Injury Severity			
	Fatal	Grievous	Minor	Non-Injury
Scooter	17	380	66	3
Motorcycle	26	511	67	7
Car	16	273	60	53
Autorickshaw	8	102	25	4
Bus/Truck	7	51	14	12
Total	**74**	**1317**	**232**	**79**

Table I.4 Number of vehicles involved in accidents in 2021

Vehicle type	Injury Severity			
	Fatal	**Grievous**	**Minor**	**Non-Injury**
Scooter	33	460	87	5
Motorcycle	52	633	127	10
Car	22	397	95	53
Autorickshaw	6	126	28	0
Bus/Truck	9	70	16	13
Total	**122**	**1686**	**353**	**81**

APPENDIX II

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA

WILLINGNESS TO PAY ELICITATION SURVEY

Dear Sir/Madam,

I am Sumayya Naznin P H, Research Scholar, Department of Civil Engineering, National Institute of Technology Karnataka, under the guidance of Dr. A.U. Ravi Shankar, Professor, Department of Civil Engineering, NITK. As a part of my project work, it is intended to collect data regarding the attitude of road users towards the cost of road accidents. The last part of the survey is elicitation of your willingness to pay. Any doubts while filling out the form will be cleared to you as this requires a thoughtful response. Kindly fill out the form and cooperate with the project. The data collected will be kept confidential and will be solely used for academic purposes only.

Thanks in advance,

Sumayya Naznin P H,

Research Scholar,

Department of Civil Engineering, NITK.

Email: sumayyanazninph.187cv506@nitk.edu.in

PART I: PERSONAL INFORMATION

Please choose the appropriate option because the correct response to each question has an impact on the study. (*Required)

Gender *

Male ○ Female ○ Other ○

Age (years)*:

<18	○	18-25	○	26-35	○
36-45	○	46-60	○	>60	○

Marital status *

Married	○	Single	○

Education *

10^{th} or below	○	Plus 2	○
Graduate	○	Postgraduate & above	○

Employment status *

Student	○	Private Job	○		
Government Job	○	Own a business	○		
Housewife	○	Retired	○	Unemployed	○

Monthly personal income (Rupees) *: ______________________________

HOUSEHOLD INFORMATION

Homeownership status? *

Family owns	○	Personally owned	○

Rented ○ Other ○

Number of household members, including yourself *

1 ○ 2 ○

3 ○ 4 ○

≥5 ○

Number of children living in the household? *

1 ○ 2 ○

3 ○ 4 ○

≥5 ○

Number of dependents in the household? *

1 ○ 2 ○

3 ○ 4 ○

≥5 ○

What is your current household monthly income? *

≤15,000 ○ 15,001-30,000 ○

30,001-50,000 ○ 50,001-75,000 ○

75,001-1,00,000 ○ ≥1,00,001 ○

Number of 2 wheelers owned by household? *

0 ○ 1 ○

2	○	≥3	○

Number of 4 wheelers owned by household? *

0	○	1	○
2	○	≥3	○

PART-II: TRAVEL BEHAVIOUR

Trip purpose*

Work	○	Education	○
Other	○		

Riding Frequency (How often do you travel through the road stretch) *

Daily	○	Weekly	○
Monthly	○	Occasionally	○

Driving experience*

Yes	○	No	○

Operating speed (km/hr) *

30-40	○	40-60	○
60-80	○	>80	○

Safety preference *

	Never	Rarely	Sometimes	Frequently
Safety belt/helmet	○	○	○	○
Cell phone driving/ Inattentive	○	○	○	○

Drunk and drive	○	○	○	○
Obey traffic rules	○	○	○	○

Condition of the vehicle *

Very bad	○	Bad	○
Satisfactory	○	Good	○
Very good	○		

PART-III: ACCIDENT HISTORY AND RISK PERCEPTION

Description

1: A **Non-injury** is the one which causes property damage.

2: A **Minor-injury** is any injury which is neither fatal nor grievous – for example, a sprain, bruise or cut which is not judged to be severe, or slight shock requiring roadside attention.

3: A **Grievous injury** is one which does not cause death less than 30 days after the accident, and which is in one (or more) of the following categories:

an injury for which a person is detained in hospital as an in-patient.

Or

any injury for which a person required ICU admission.

Or

any of the following injuries .... (whether or not the person is detained in hospital): fractures, concussion, internal injuries, crushing, severe cuts and lacerations, severe general shock requiring treatment. Or any injury causing death 30 or more days after the accident.

4: A **Fatal accident** is one which causes death less than 30 days after the accident.

Do you have any accident experience/history? *

- ○ Personally experienced
- ○ Family member has experienced
- ○ Friend has experienced
- ○ None

Please specify the degree of injury that you experienced or witnessed*

- ○ Non-injury accident
- ○ Minor injury accident

○ Grievous injury accident

○ Fatal accident

CHOICE OF ALTERNATIVE

Choose the alternative to safeguard yourself from being injured *

○ I would choose to use a safety device

○ I would choose an alternative route which has less risk of being injured

SAFETY DEVICE CHOICE

Since you have chosen the option of using a safety device. We would like to know how much you value your safety while travelling.

Choose the vehicle that you use more frequently *

2-wheeler	○	Car	○
Tanker	○	Auto	○
Private bus	○	KSRTC bus	○
Truck	○	Other	○

PART-IV: CV USING PAYMENT CARD

Which of the following would you choose *

○ Helmet A, it has the probability of 10 people out of 1,00,000 being injured each year.

○ Helmet B, it has the probability of 5 people out of 1,00,000 being injured each year.

What is the maximum amount of extra money that you would spend for Helmet B? *

NOTE: *Helmet B = Helmet A + Extra money*
Cost of helmet A = ₹1023

Choose maximum price that you would pay extra (per year) for the risk reduction			
₹ 0	₹ 33	₹ 299	₹ 1,068
₹ 3	₹ 43	₹ 385	₹ 1,281
₹ 5	₹ 65	₹ 470	₹ 1,495
₹ 9	₹ 86	₹ 555	₹ 1,708
₹ 13	₹ 129	₹ 640	₹ 1,922
₹ 18	₹ 171	₹ 769	₹ 2,135
₹ 22	₹ 214	₹ 854	> ₹ 2135
₹.......(Any other amount not mentioned above)			

Imagine that you were asked to install a speed control device in your car, using this safety device, the probability of being injured in a road accident would be reduced by 50% each year. *

Please estimate the amount that you are willing to pay to rent this safety device annually.

Choose maximum price that you would pay extra (per year) for the risk reduction			
₹ 0	₹ 33	₹ 299	₹ 1,068
₹ 3	₹ 43	₹ 385	₹ 1,281
₹ 5	₹ 65	₹ 470	₹ 1,495
₹ 9	₹ 86	₹ 555	₹ 1,708
₹ 13	₹ 129	₹ 640	₹ 1,922
₹ 18	₹ 171	₹ 769	₹ 2,135
₹ 22	₹ 214	₹ 854	> ₹ 2135
₹.......(Any other amount not mentioned above)			

Which of the following roads do you use more often/ more familiar?

- ○ Road 1: Aluva - Aroor Kumbalam Bridge (via Edappally junction, Kundannoor Junction)
- ○ Road 2: Thoppumpady - Kundannoor Thevara Bridge (via Kattipparambu, CIFT Junction)
- ○ Road 3: Nayarambalam Bridge – Vallarpadam ICTT (via Goshree Junction, Mulavukadu)

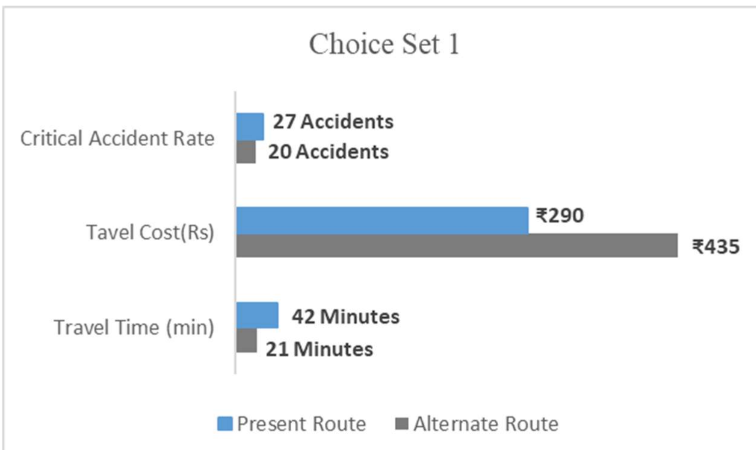
If the respondent selects Road 3, he/s will be provided the section for that particular road

Road 3: Nayarambalam Bridge – Vallarpadam ICTT (via Goshree Junction, Mulavukadu)

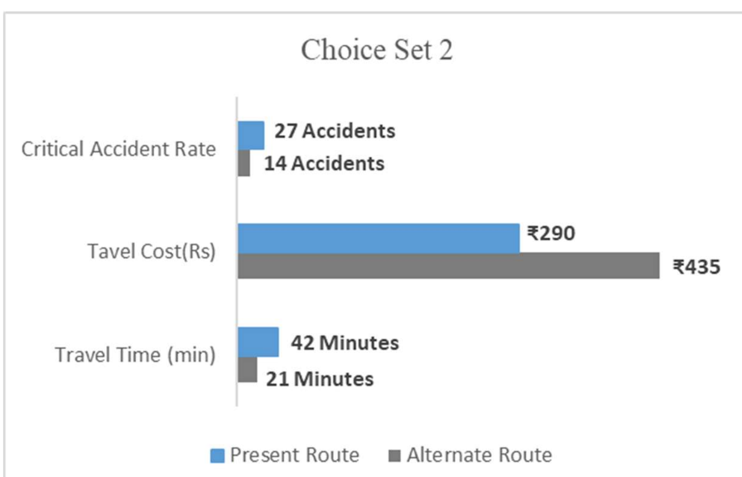
PART V: CHOICE EXPERIMENT

Imagine that you are making a trip from Nayarambalam Bridge – Vallarpadam ICTT (via Goshree Junction, Mulavukadu), (23 Km). The average values of travel time, travel cost, and the safety associated with the journey along the present route and some alternate routes are given below. Please select the one you would choose for travel. Six choice sets are presented below. Please read the data carefully and mark the one you would choose for travel

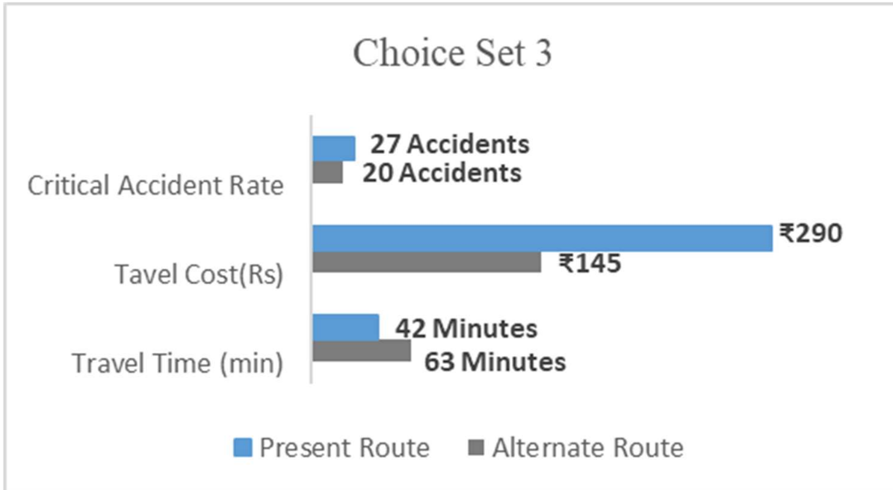
- **Choice set-I**



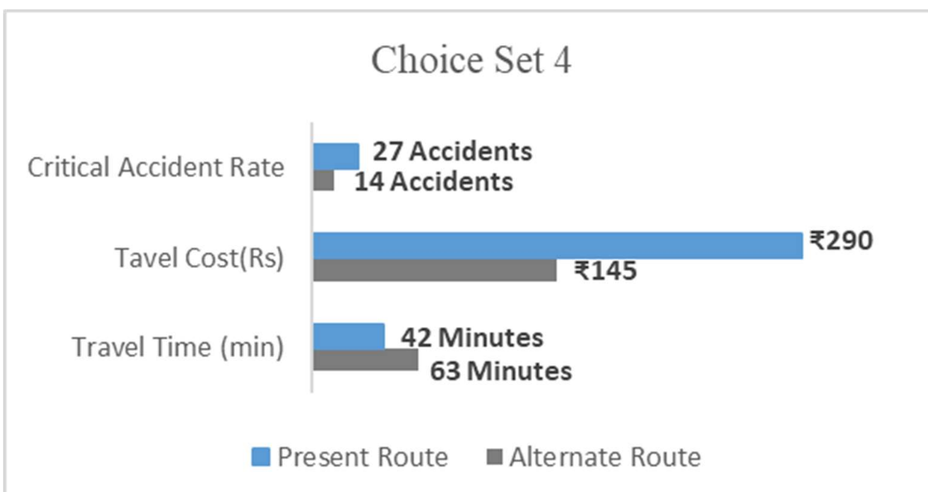
- **Choice set-II**



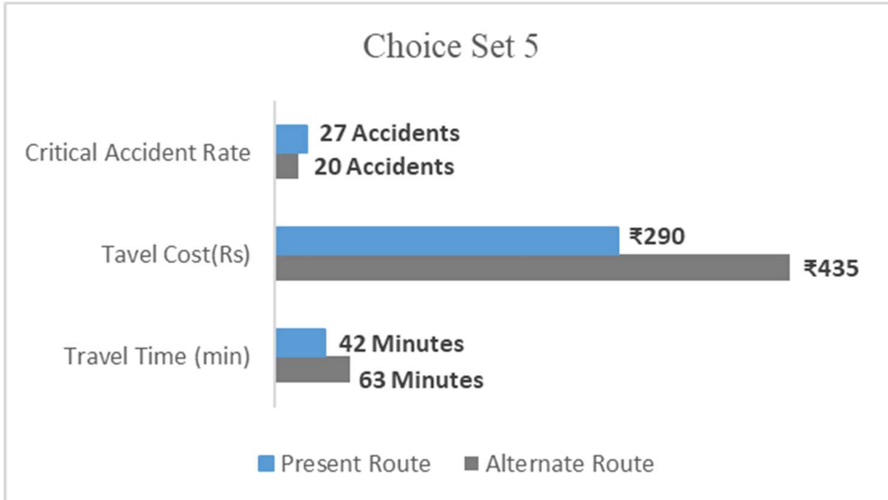
- **Choice set-III**



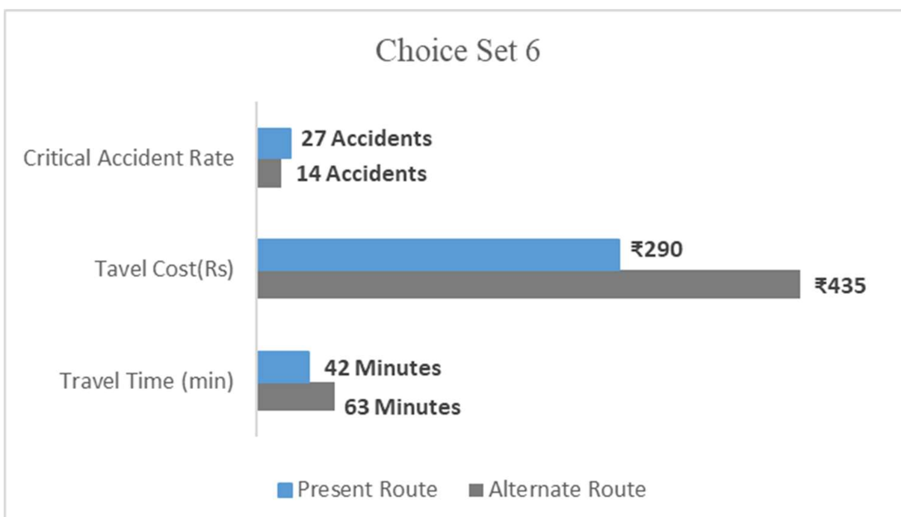
- **Choice set-IV**



- **Choice set-V**



- **Choice set-VI**



APPENDIX III

DETERMINATION OF COST/KM FOR 2W AND CARS

Table III.1: Travel cost estimation for car users

Avg. Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Maintenance Cost	Fuel Cost	Total Cost (Per Km)
3600	Tata Tiago XZ	Petrol	113.25	18	100000	5000	3	0.3333	1.3889	1.1325	3
3600	Alto 800	Petrol	113.25	25	500000	10000	8	1.6667	2.7778	4.5300	9
3600	Beat	Petrol	113.25	30	450000	5000	7	1.5000	1.3889	3.7750	7
3600	Bmw 3 series	Petrol	113.25	17	320000	30000	2	1.0667	8.3333	6.6618	16
3600	Fiat Punto	Petrol	113.25	14	1000000	35000	3	3.3333	9.7222	8.0893	21
6000	Dewoo matiz	Petrol	113.25	12	40000	20000	3	0.1333	3.3333	9.4375	13
6000	Duster	Petrol	113.25	11	1000000	4500	5	3.3333	0.7500	10.2955	14
6000	Honda City	Petrol	113.25	26	1330000	35000	5	4.4333	5.8333	4.3558	15
9000	Altroz	Petrol	113.25	18	1000000	3800	0.5	3.3333	0.4222	6.2917	10
9000	Baleno	Petrol	113.25	42	1400000	42000	11	4.6667	4.6667	2.6964	12

Avg. Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Maintenance Cost	Fuel Cost	Total Cost (Per Km)
9000	Baleno delta	Petrol	113.25	17	860000	20000	3	2.8667	2.2222	6.6618	12
9000	Ford Figo	Petrol	113.25	14	900000	10000	6	3.0000	1.1111	8.0893	12
9000	Honda Jazz	Petrol	113.25	16	800000	10000	4	2.6667	1.1111	7.0781	11
12000	Chevorlet Cruze	Petrol	113.25	13	350000	35000	3	1.1667	2.9167	8.7115	13
12000	Chevrolet sail	Petrol	113.25	22	900000	10000	10	3.0000	0.8333	5.1477	9
12000	Duster	Petrol	113.25	14	1100000	75000	4	3.6667	6.2500	8.0893	18
12000	Fiat Linea T-get	Petrol	113.25	15	1000000	50000	7	3.3333	4.1667	7.5500	15
12000	Ford Figo Aspire 1.5 AT	Petrol	113.25	12	915000	5000	6	3.0500	0.4167	9.4375	13
18000	Ford Ecosport	Petrol	113.25	15	1300000	10000	3	4.3333	0.5556	7.5500	12
18000	Ford Figo	Petrol	113.25	17	678000	5000	7	2.2600	0.2778	6.6618	9

Avg. Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Mainte nance Cost	Fuel Cost	Total Cost (Per Km)
18000	Hyundai Eon	Petrol	113.25	17	420000	30000	10	1.4000	1.6667	6.6618	10
18000	Maruti ciaz	Petrol	113.25	13	1300000	25000	6	4.3333	1.3889	8.7115	14
18000	Maruti Suzuki WagonR	Petrol	113.25	27	120000	5000	2	0.4000	0.2778	4.1944	5
21000	Alto lxi	Petrol	113.25	20	400000	50000	10	1.3333	2.3810	5.6625	9
21000	Dzire	Petrol	113.25	22	1000000	18000	3	3.3333	0.8571	5.1477	9
21000	Dzire vdi	Petrol	113.25	23	925000	50000	3	3.0833	2.3810	4.9239	10
21000	I20	Petrol	113.25	14	110000	4000	2	0.3667	0.1905	8.0893	9
21000	Maruti Suzuki Ritz	Petrol	113.25	18	800000	10000	10	2.6667	0.4762	6.2917	9

Table III.2: Travel cost estimation for Two-wheelers

Avg Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Maintenance Cost	Fuel Cost	Total Cost (Per Km)
3600	Honda DIO	petrol	113.25	50	1000	70000	1	0.7000	0.2778	2	3
3600	Access 125	petrol	113.25	93	8000	169600	2	1.6960	2.2222	1	5
3600	Access125	Diesel	86.74	35	5000	67000	1	0.6700	1.3889	2	5
3600	Honda Activa	petrol	113.25	40	15000	264700	3	2.6470	4.1667	1	8
3600	Activa 125	petrol	113.25	40	5000	150000	1	1.5000	1.3889	3	6
6000	Access 120	petrol	113.25	50	5000	85000	1	0.8500	0.8333	2	4
6000	Activa 125 3G	petrol	113.25	30	10000	100000	1	1.0000	1.6667	4	6
6000	Activa Honda 125	petrol	113.25	30	1000	85000	1	0.8500	0.1667	4	5
6000	Active 3 g	petrol	113.25	40	800	55000	1	0.5500	0.1333	3	4
6000	Bajaj Discover	petrol	113.25	30	2500	55000	1	0.5500	0.4167	4	5
9000	Activa 125	petrol	113.25	40	2000	58000	1	0.5800	0.2222	3	4
9000	Activa i	petrol	113.25	50	2000	15000	1	0.1500	0.2222	2	3
9000	Bajaj pulser 150	petrol	113.25	44	10000	15000	1	0.1500	1.1111	3	4
9000	Bullet standard 350	petrol	113.25	30	6000	80000	1	0.8000	0.6667	4	5
9000	Duke 200	petrol	113.25	70	6000	360000	2	3.6000	0.6667	2	6

Avg Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Maintenance Cost	Fuel Cost	Total Cost (Per Km)
9000	Yamaha Ray Z	petrol	113.25	44	1200	58000	1	0.5800	0.1333	3	3
12000	Activa 3 G	petrol	113.25	40	17000	64000	1	0.6400	1.4167	3	5
12000	activa 6g	petrol	113.25	30	5000	90000	1	0.9000	0.4167	4	5
12000	Bajaj Pulsar 180	petrol	113.25	40	3000	25000	1	0.2500	0.2500	3	3
12000	Enfield bullet classic 350	petrol	113.25	35	8000	160000	1	1.6000	0.6667	3	6
12000	Honda activa	petrol	113.25	40	4000	80000	1	0.8000	0.3333	3	4
12000	Ntorq	petrol	113.25	45	50000	100000	1	1.0000	4.1667	3	8
12000	R15v2	petrol	113.25	40	2000	110000	1	1.1000	0.1667	3	4
12000	RE 350	petrol	113.25	40	10000	134000	1	1.3400	0.8333	3	5
12000	Royal Enfield Classic 350	petrol	113.25	40	2000	150000	1	1.5000	0.1667	3	4
12000	Royal Enfield continental GT 650	petrol	113.25	26	5000	388000	1	3.8800	0.4167	4	9
12000	Royal Enfield Himalayan	petrol	113.25	20	5000	250000	1	2.5000	0.4167	6	9
12000	Royal Enfield Himalayan	petrol	113.25	30	5000	250000	1	2.5000	0.4167	4	7

Avg Travel Distance (Km)	Vehicle Model	Fuel Used	Fuel Price (Per Lit.)	Mileage (Km/Lit)	Maintenance Cost (Per Year)	Capital Cost (Rupees)	Vehicle Usage (Years)	Capital Cost	Maintenance Cost	Fuel Cost	Total Cost (Per Km)
12000	Royal enfield interceptor	petrol	113.25	18	20000	400000	1	4.0000	1.6667	6	12
12000	Yamaha Ray-Z	petrol	113.25	50	6000	55000	1	0.5500	0.5000	2	3
12000	Yamaha RX 135	petrol	113.25	30	4000	35000	1	0.3500	0.3333	4	4
18000	Fz	petrol	113.25	40	2700	82000	1	0.8200	0.1500	3	4
18000	Fz150	petrol	113.25	35	6000	93000	1	0.9300	0.3333	3	4

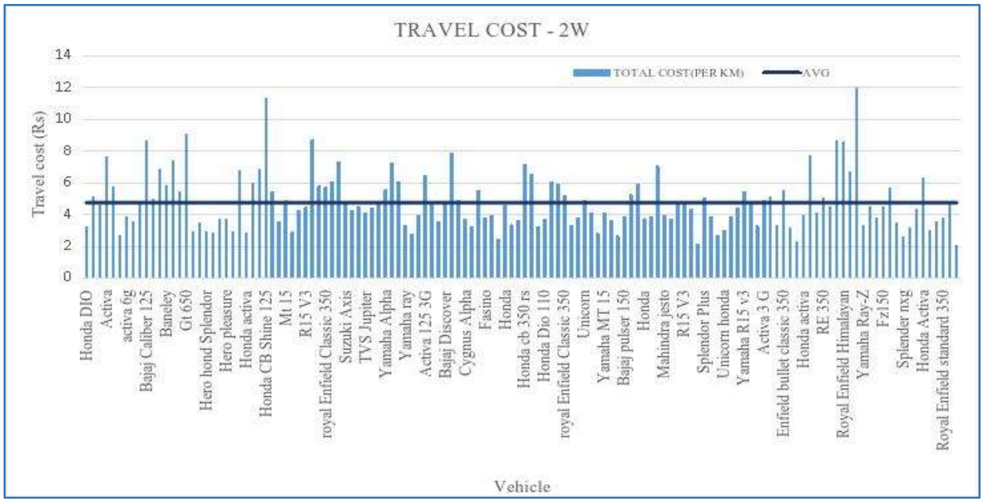


Figure III.1: Cost per kilometre for two-wheelers

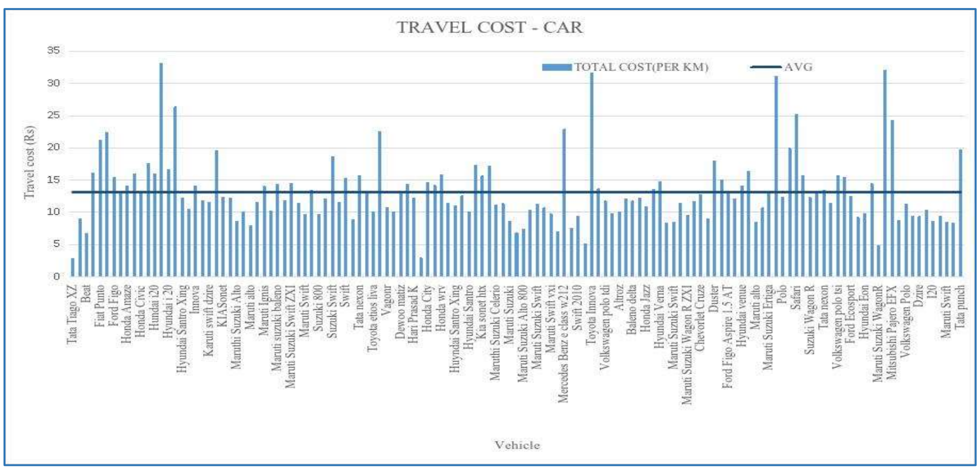


Figure III.2: Cost per kilometre for car users

Table III.3: Public transport fares

Public Buses:	
Bus Type	***Minimum Fare (Rs.)***
City/Ordinary	*10*
City fast	*10*
Fast passenger/LSFP	*14*
Superfast passenger	*19*
Super express	*28*
Super deluxe/semi sleeper	*38*
Luxury/hi-tech/ac	*55*
Volvo	*56*
Multi axle Volvo	*100*
Auto-Rickshaw:	
Distance	***Auto rickshaw Fare (Rs.)***
Minimum (2 km)	*30*
For every 0.5 km increase	*15*

APPENDIX IV

NLOGIT MODELS FOR ROUTES I AND III

Road segment-I

Table IV.1: Start values estimated by MNL model: Route I

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-.0.004	0.0004	-8.171	0.000
Travel cost	-0.002	0.0003	-4.646	0.000
Critical accidents rate	-0.003	0.0013	-2.384	0.000

Table IV.2: Final estimates by RPL model: Route I

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-0.0102	0.0011	-9.146	0.000
Travel cost	-0.0013	0.0002	-7.575	0.000
Critical accidents rate	-0.0027	0.0009	-2.988	0.000
Standard deviation	2.0977	0.2281	9.197	0.000

Table IV.3: Goodness of fit measures: Route I

Constant-only model	
Log-likelihood function	-654.937
Multinomial logit model- Start values	
Log-likelihood function	-612.362
Info. Criterion: AIC	1.212
Info. Criterion: BIC	1.216
McFadden Pseudo R-squared	0.065
McFadden adjusted R-squared	0.065

Random parameters logit model-Final model	
Log-likelihood function	-523.823
Info. Criterion: AIC	1.116
Info. Criterion: BIC	1.151
Chi squared	273.184
Prob.[Chi-Squared. > value]	0.0000
McFadden pseudo-R-squared	0.2003
McFadden adjusted R-squared	0.2001
Restricted Log-likelihood (RLL) (No Coefficients)	-655.421
McFadden pseudo-R-squared*	0.218
McFadden adjusted R-squared*	0.217

*(*based on RLL)*

Road segment-III

Table IV.4: Start values estimated by MNL model- Route III

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-0.0524	0.0023	-2.317	0.0132
Travel cost	-0.0033	0.0005	-4.632	0.0000
Critical accidents rate	-0.0131	0.0051	-2.586	0.0351

Table IV.5: Final estimates by RPL model- Route III

Variable	Coefficient	Standard error	t-value	p-value
Travel time	-0.0097	0.0023	-4.264	0.000
Travel cost	-0.0015	0.0002	-6.148	0.000
Critical accidents rate	-0.0061	0.0020	-2.993	0.047
Standard deviation	2.5734	0.4159	7.821	0.000

Table IV.6: Goodness of fit measures- Route III

Constant-only model	
Log-likelihood function	-523.754
Multinomial logit model- Start values	
Log-likelihood function	-568.348
Info. Criterion: AIC	1.304
Info. Criterion: BIC	1.312
McFadden Pseudo R-squared	0.085
McFadden adjusted R-squared	0.085
Random parameters logit model-Final model	
Log-likelihood function	-416.360
Info. Criterion: AIC	1.033
Info. Criterion: BIC	1.046
Chi squared	286.328
Prob. [Chi-Squared > value]	0.000
McFadden pseudo-R-squared	0.205
McFadden adjusted R-squared	0.205
Restricted Log-likelihood (RLL) (No Coefficients)	-525.072
McFadden pseudo-R-squared*	0.277
McFadden adjusted R-squared*	0.277

*(*based on RLL)*

APPENDIX V

AN EXPERT OPINION SURVEY ON ROAD ACCIDENT COSTING

The quantification of accidents and their associated parameters is necessary for the cost-benefit analysis of road safety infrastructures and, hence, to ensure the most efficient use of available resources in formulating road safety policies. Different countries use various methodologies for this estimation. Some methods adopt a component-wise accident cost estimation under the heads of lost productivity cost, medical cost, vehicle damage cost, administration cost, and human (pain, grief, and suffering) cost. In contrast, others consider the accident cost in terms of the Value of Statistical Life (VSL).

The following are a few scenarios of road traffic accidents. The costs are calculated using different methods. Kindly choose the most realistic values of the accident cost for the given scenarios.

Case 1

A 45-year-old male passed away as a result of a road accident. The person was brought dead to the hospital. He was driving a brand new Maruti Suzuki Swift car during the crash. The vehicle was a total loss. Estimate the loss due to the accident.

a) 28,69,000
b) 38,00,000
c) 48,76,000
d) 2,40,00,000

Case 2

A 45-year-old male underwent a minor road accident and had abrasions and contusions. He was traveling in a Honda Activa scooter during the crash, which skidded on its side. The side of the scooter was damaged. He had to spend 7 days at home even though the Doctor did not prescribe it. His per-day income was ₹2500. Estimate the loss due to the accident.

a) 65,000
b) 38,000

c) 96,000

d) 2,40,000

Case 3 (a)

A 45-year-old male was grievously injured as a result of a road accident and had multiple injuries, including head, spine, and bone fractures. He was driving a brand new Maruti Suzuki Swift during the crash, which underwent a head-on collision. The front of the vehicle was damaged. He had to spend 45 days in the hospital with bystander support. The doctor prescribed him a rest of 60 days at home and required further bystander support of 30 days. His per-day income was ₹2500. Estimate the loss due to the accident.

a) 4,20,000

b) 4,94,000

c) 19,02,000

d) 31,20,000

Case 3 (b)

A 45-year-old male was grievously injured as a result of a road accident and had multiple bone fractures. He was driving a brand new Maruti Suzuki Swift car during the crash, which underwent a side collision. The side of the vehicle was damaged. He had to spend 5 days in the hospital with bystander support. The doctor prescribed him a rest of 30 days at home, requiring further bystander support of 15 days. His per-day income was ₹2500. Estimate the loss due to the accident.

a) 3,02,000

b) 4,94,000

c) 11,89,000

d) 31,20,000

Case 3 (c)

A 45-year-old male was grievously injured as a result of a road accident and had multiple bone fractures. He was driving a brand new Maruti Suzuki Swift car during the crash, which underwent a side collision. The side of the vehicle was damaged. He had to spend 5 days in the hospital with bystander support. The doctor prescribed him a rest of 30 days at home, requiring further bystander support of 15 days. The doctor diagnosed him with a permanent disability of 20% due to a shoulder joint injury. His per-day income was ₹2500. Estimate the loss due to the accident.

a) 3,02,000
b) 4,94,000
c) 47,42,000
d) 31,20,000

LIST OF PUBLICATIONS

JOURNAL

1. Naznin, P. H. S., Gidugu, S., Cyril, A. and Shankar, A. U. R. (2023). "Human Capital Approach for Road Accident Costing in an Indian City", *European Transport*, 94, DOI: https://doi.org/10.48295/ET.2023.94.5

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1. Naznin, P. H. S., Anandu, V. G., Panackel, L. S. and Ravi Shankar, A. U. (2023). "Estimation of Willingness to Pay for Reducing Road Accident Risk Using Route Choice Model", in *Proceedings of SECON 2022*, *Lecture Notes in Civil Engineering*, Springer, Cham.,1075-1086, DOI: https://doi.org/10.1007/978-3-031-12011-4_91.
2. Naznin, P.H.S, Katrawath, D, Sabu,R.M and Ravi Shankar, A. U. (2023). "Determination of factors affecting the Willingness to Pay elicited by Contingent Valuation Payment Card Method using Structural Equation Modeling", *International Conference on Sustainable Infrastructure: Innovations, Opportunities, and Challenges (SIIOC 2023)*, April 20-21, 2023 Department of Civil Engineering, National Institute of Technology Karnataka, Surathkal (Accepted for publication).

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