IDENTIFICATION OF FACTORS CONTRIBUTING TO TRAFFIC FATALITIES IN THE UNITED STATES

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Identifications of Factors Contributing to Traffic

Fatalities in the United States

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

Traffic accidents not only cause injuries and deaths but also result in significant property and economic losses. With annual 40,000 lives lost in United States and $80 billion in economic losses, research in minimizing accidents is a major priority. This research identified and ranked factors that reduce traffic fatalities and determined their relative importance.

A total of 93 factors were identified and ranked into seven major categories through a systematic literature review. A questionnaire was sent to the State Departments of Transportation, and the responses were coded and analyzed using a relative importance index, rankings and percentages. The systematic literature review and survey results indicated that agencies should direct resources toward the highest-ranking factors to achieve better safety performance. Efforts should be made to improve infrastructure and influence road-user behavior towards safer habits. Laws and policies are vital to maintaining good road-user behavior, which could leads to lower traffic fatalities.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SD…………………………… Science Direct

WOS………………………….Web of Science

ASCE………………………... American Society of Civil Engineers

USA…………………………..United States of America

IRB………………………….. Institutional Review Board

NHTSA………………………National Highway Traffic State Administration

FARS………………………....Fatality Analysis Reporting System

NASS…………………………National Automotive Sampling System

GES…………………………...General Estimates System

DVC…………………………..Deer-Vehicle Crashes

TSC…………………………...Traffic Safety Consciousness

ANT…………………………..Accident Notification Time

EMS…………………………..Emergency Medical Service

QI…………………………… Quality Indicators

GDP…………………………..Gross Domestic Product

IV……………………………..Intravenous Catheters

TM …………………………...Trauma Management

SPI……………………………Safety Performance Indicators

GDL…………………………..Graduated Driving License

AHLS ………………………...Active Hood Lift System

ADAS ……………………….. Advanced Driver Assistance Systems

SLR…………………………..Systematic Literature Review

EMT…………………………. Emergency Response and Trauma Care Advancements

DOT…………………………..Department of Transportation

NCADD………………………National Council on Alcoholism and Drug Dependence

CDC…………………………..Centers for Disease Control and Prevention

FHWA…………………………Federal Highway Administration

WHO………………………….World Health Organization

FY…………………………......Fiscal Year

GIS……………………………Geographical Information System

LTV……………………….......Light Truck Vehicle

SUV……………………………Sports Utility Vehicles

RII……………………….........Relative Importance Index

CHAPTER 1. INTRODUCTION

1.1. Background

Over the past several decades, roughly 40,000 people have died each year in traffic accidents in the United States (Kittelson, 2010). Despite this high fatality rate, society has tolerated this trend without much public outcry. According to data from the National Highway Traffic Safety Administration (NHTSA), the United States has experienced a steady decline in the number of highway fatalities since 2005. While a significant decline in fatalities from 2005 to 2011 occurred, NHTSA's Fatality Analysis Reporting System (FARS) data for 2012 shows that 33,561 people lost their lives in traffic accidents—a 3.3% increase from 2011 (Fig 1.1 and 1.2). In 2012, an estimated 2.36 million people were injured in motor vehicle accidents, compared to 2.22 million in 2011, according to NHTSA's National Automotive Sampling System (NASS) General Estimates System (GES); this is an increase of 6.5%.(Fig 1.3). While there have been several statistically significant decreases in the estimated number of people injured annually; this is the first statistically significant increase since 1995 (Fig 1.4). As the economy continues to recover and more people take to the roads, this trend could increase over the next few years. The fatality, injury, and property-damage-only crashes have significant economic costs. The National Highway Traffic Safety Administration (NHTSA) estimated the economic costs for motor vehicle accidents in 2010 at more than $277 billion, or the equivalent of over $900 for every person living in the United States. NHTSA's estimate of economic costs includes productivity losses, property damage, medical costs, rehabilitation costs, travel delays, legal and court costs, emergency services, insurance administration costs, and costs to employers (NHTSA, 2010).

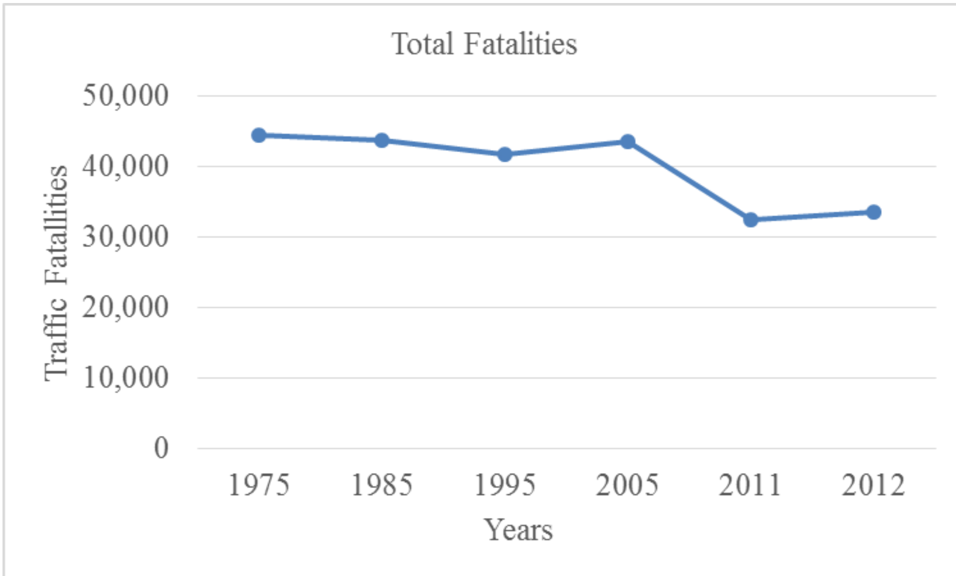

Fig 1.1: The number of traffic fatalities from 1975–2012 (Source: National Highway Traffic Safety Administration (NHTSA), June 2012 "Traffic safety facts, 2012 DATA")

Fig 1.2: The percentage change from 1975–2012 (Source: National Highway Traffic Safety Administration (NHTSA), June 2012 "Traffic safety facts, 2012 DATA")

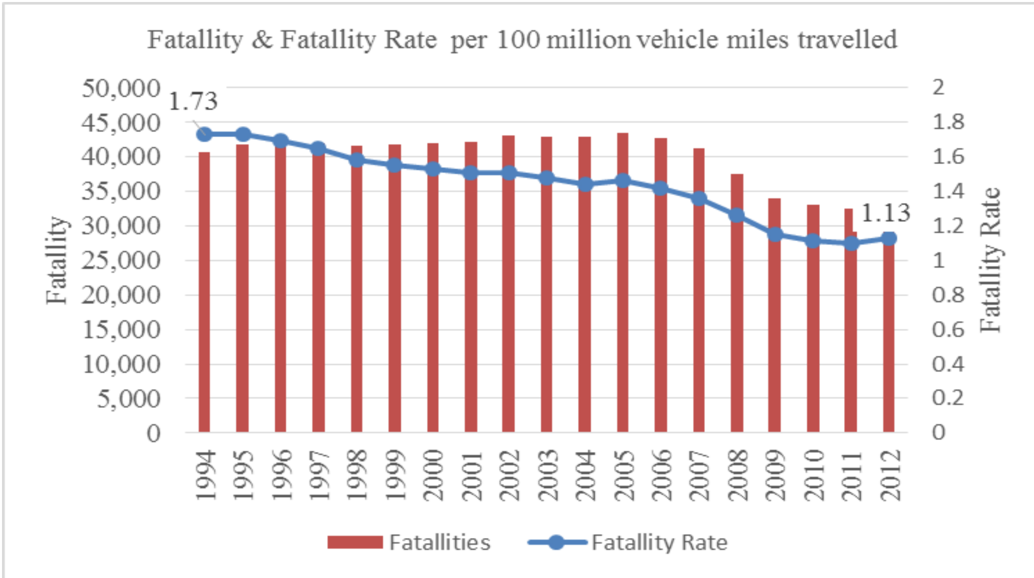

Fig 1.3: The number of fatalities and the fatality rate per 100 million vehicles traveled by year (Source: NHTSA, Traffic Safety Facts. Retrieved from: http://www-nrd.nhtsa.dot.gov/)

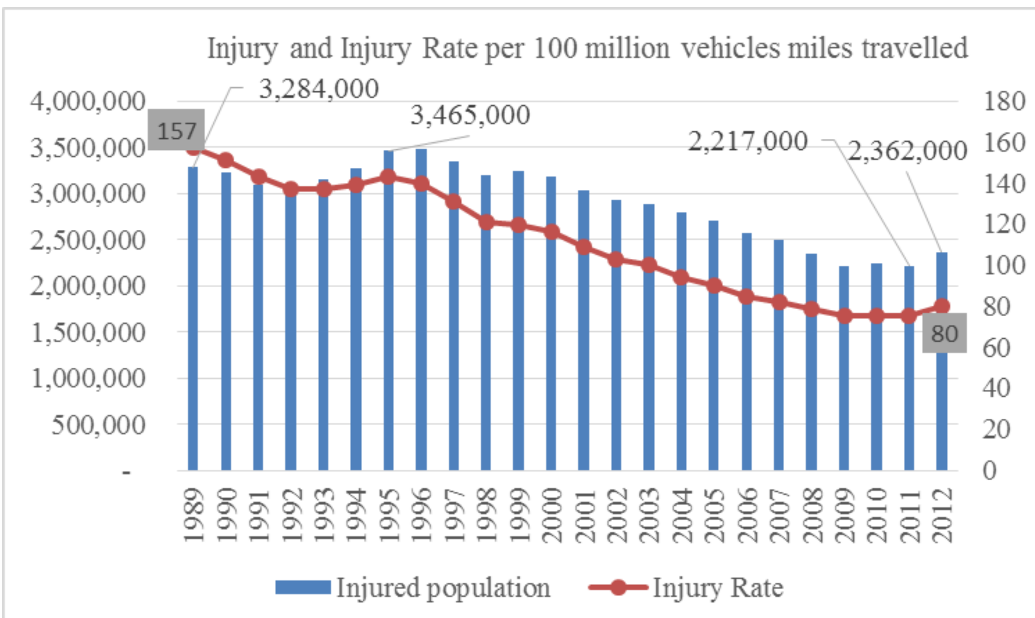

Fig 1.4: The number of people injured and the injury rate per 100 million vehicles miles traveled by year (Source: NHTSA, Traffic Safety Facts. Retrieved from: http://www-nrd.nhtsa.dot.gov/)

1.2. Research Problem

In recent years, there have been numerous state and federal level efforts to improve the traffic safety situation in this country. With the passage of Reauthorization of Federal Transportation Funding, Moving Ahead for Progress in the 21^{st} Century (MAP-21), all states are now required to increase focus on safety performance targets, especially those involving fatalities and serious injuries. In spite of implementation of traffic laws, technological advances, and improved traffic education systems, the number of traffic fatalities has not decreased substantially. This indicates that although efforts are being made in the right direction, there is a lack of overall understanding of all the contributing factors and their interaction with each other. Decision makers need to understand how various factors have affected highway fatality trends in order to implement the programs that make the best use of funds and personnel and to make progress toward meeting the safety performance targets. While many agencies are tasked with addressing transportation safety, each approaches the challenge of traffic crashes from a different perspective. For example, transportation officials are often tasked with identifying ways to improve the safety of the overall transportation system. By comparison, a police department focuses on enforcing laws and regulations to ensure that users of the transportation system are not placed in harm's way by the actions of other individuals in motor vehicles. Lastly, public health officials focus on how to prevent injuries or how to treat injuries when they occur. Although different, each of these perspectives is critical to understanding the breadth of perspectives that can be brought to a discussion of traffic safety.

Various explanations have been offered to account for the significant reduction in crashes in recent years. Factors, such as increased safety belt usage, safer vehicles, better roads, increased funding for safety infrastructure improvements, the economic downturn, changes in teen licensing laws, enhanced enforcement efforts, and others, have been identified as possible contributing factors to the downward trend in accidents. To date, no comprehensive analysis of past research in traffic fatalities and factors contributing to the decline of fatalities has been performed. Without such a study of contributing factors accounting for the decline in accidents, it is difficult for highway safety professionals to know where best to direct their efforts and resources. Research is needed to provide information that helps optimize the allocation of safety resources in a more informed manner. This type of research will assist states in determining where to effectively apply their capital, operating, and human resources to continually reduce fatalities. This study is focused on studying and analyzing the factors contributing to traffic fatalities. This study investigated correlations between accidents and factors ranging from driver behavior to vehicle and road designs. The purpose of the study was to investigate and document the factors contributing to the traffic fatalities and to the decline in traffic fatalities respectively. This way, it will provide the comprehensive information to the state DOTs/safety personnel for helping them to develop more informed policies, structure, and decisions.

1.3. Research Objectives

The objective of this research investigation was to perform a systematic literature review to provide a detailed analysis of the relative influence of the types of factors that contribute to the recent national decline in the number of highway fatalities in the United States. The study was also aimed at conducting research surveys of state DOTs to ascertain their prospective of factors contributing to traffic fatalities in the US This research would help transportation agencies and other safety stakeholders to optimize resource allocation and strategic decision making to further reduce highway traffic fatalities. The primary objective of this research was to determine the potential factors that played an important role in decreasing traffic fatalities directly or indirectly. The types of factors to consider include, but are not limited to, the following:

A) Road-user behavior,

B) Infrastructure,

C) Emergency response and trauma care advancements,

D) Policy enforcement,

E) Socio-economics and demographics,

F) Systems operations and management,

G) Vehicle safety advancements.

The objectives of the research are:

i. To conduct a systematic literature review to ascertain the various factors affecting traffic fatalities in the US transportation industry.

ii. To conduct a research survey of factors affecting traffic fatalities, code the data and use the Relative Important Index (RII) with statistical methods to analyze the data.

iii. To use the results of the research to make recommendations for decreasing traffic fatalities or "Zero fatalities."

1.4. Research Contributions

The research investigated factors affecting traffic fatalities directly or indirectly in the United States. The results of this research would assist transportation agencies and other traffic safety stakeholders in optimizing resource allocation and strategic decision making to further reduce highway traffic fatalities. Understanding these factors is helpful for transportation agencies and other safety stakeholders who work on research and policies aimed at minimizing fatalities. For achieving the goal of reducing fatalities to minimal or zero levels, extra attention needs to be given to road design. The research study provided information on factors that cause traffic fatalities directly and indirectly.

1.5. Research Structure

This research consists of five chapters and appendices (IRB Approval and Survey Questionnaire).

Chapter 1 discusses the background, provides figures, and states the research problem and the objectives.

Chapter 2 discusses the use of systematic literature review method to collect, compile and analyze previous studies on traffic safety and fatalities located in three major databases, namely Science Direct, Web of Science, and American Society of Civil Engineers. It also lists various factors contributing to the decline of traffic fatalities directly or indirectly in the United States.

Chapter 3 discusses the research methodology used; including a discussion of the research survey methodology.

Chapter 4 discusses the analysis methods and statistical methods used for the study, as well as the results obtained from the survey.

Chapter 5 discusses the conclusions, recommendations, and suggestions for future research.

CHAPTER 2. SYSTEMATIC LITERATURE REVIEW

2.1. Introduction

This chapter is a systematic literature review of the factors that have directly/ indirectly contributed to traffic fatalities in United States. Basically, literature review identifies the findings in this matter, which has been performed worldwide.

A systematic literature review was conducted of the traffic fatalities and injuries in the United States of America. This literature review reports on the findings from peer-reviewed publications published in three major databases. A discussion is provided on the importance of the factors responsible for the decline or increase in traffic fatalities. During the literature review, some research findings were found to conflict with one another. This is sometimes due to differences in the type of data being used by different researchers and the incompatibility of data sources used, even from within the same country (Sheikh, 2009). Research into traffic fatalities is conducted in many countries. Many of the studies are reviewed in this chapter in order to provide valuable information on the importance of traffic fatalities analysis.

Thousands of people are killed and injured on roads worldwide every year. People walking, driving, or biking on the roads do not have a guarantee that they will reach their destination safely, and their families might have to pay the price in terms of lost lives, medical expenses, lost wages and property damages.

2.2. Literature Review

A literature review provides a foundation for research progress and is based on a “historical perspective of the respective research area and are in depth accounts of independent research endeavors” (Mentzer and Khan, 1995). In the search for factors contributing to a decline in traffic fatalities, a systematic literature review was conducted. A systematic review provides a detailed summary of relevant current literature to a research question. The first step of a systematic review is to conduct a thorough search of the literature for relevant research. The methodology section lists the databases and citation indexes searched, such as Web of Science (WOS), Science Direct (SD), and the American Society of Civil Engineers (ASCE). Next, the titles and the abstracts of the identified articles were checked against pre-determined criteria for relevance. This list depended on the research problem.

2.2.1. Literature Review Approaches

In order to identify the factors that have accounted for a reduction in traffic fatalities, it was necessary to review existing research on traffic accidents, reasons for traffic fatalities by organizations and countries, and the most frequently cited research. It is vital that the study be inclusive and not be limited to United States but all regions of the world, where research has been performed. There are lessons to be learned from the experiences of other countries. The strategies, techniques and lessons learnt by these countries could be implemented to reduce traffic fatalities. The mistakes they have made could also be avoided. In addition, the impacts of certain factors such as culture, socio-economic, population, economic changes etc. could be understood in detail if diverse studies from different countries are included in the literature review. This research work contributes to the advancement of construction management as well as transportation engineering in the following ways:

a) Identifies the factors contributing to the traffic fatalities from primary research studies from three different search engines.
b) Analyzes and documents the factors.
c) Extraction, analyses, and synthesizing the factors.

In order to achieve these objectives, a systematic literature review (SLR) approach was used. An SLR is a literature review that follows a rigorous, transparent, and reproducible process to identify, select, appraise, analyze, and synthesize, in a systematic and comprehensive way, research evidence on a specific research topic (Cook et al. 1997; Transfield et al. 2003) by documenting all the steps followed. According to Denyer and Neely (2004), SLR must have a section on the methodology used and provide a description of the procedure used to conduct the study. To perform this study, first a series of keywords related to traffic fatalities, road accidents, and road safety were extracted from the review questions and then search criteria were established. Secondly, the search engines (ASCE, WOS and SD) were selected for use because of their high acceptance by the academic community and worldwide electronic database availability. Figure 2.1 shows the steps followed in the systematic literature review.

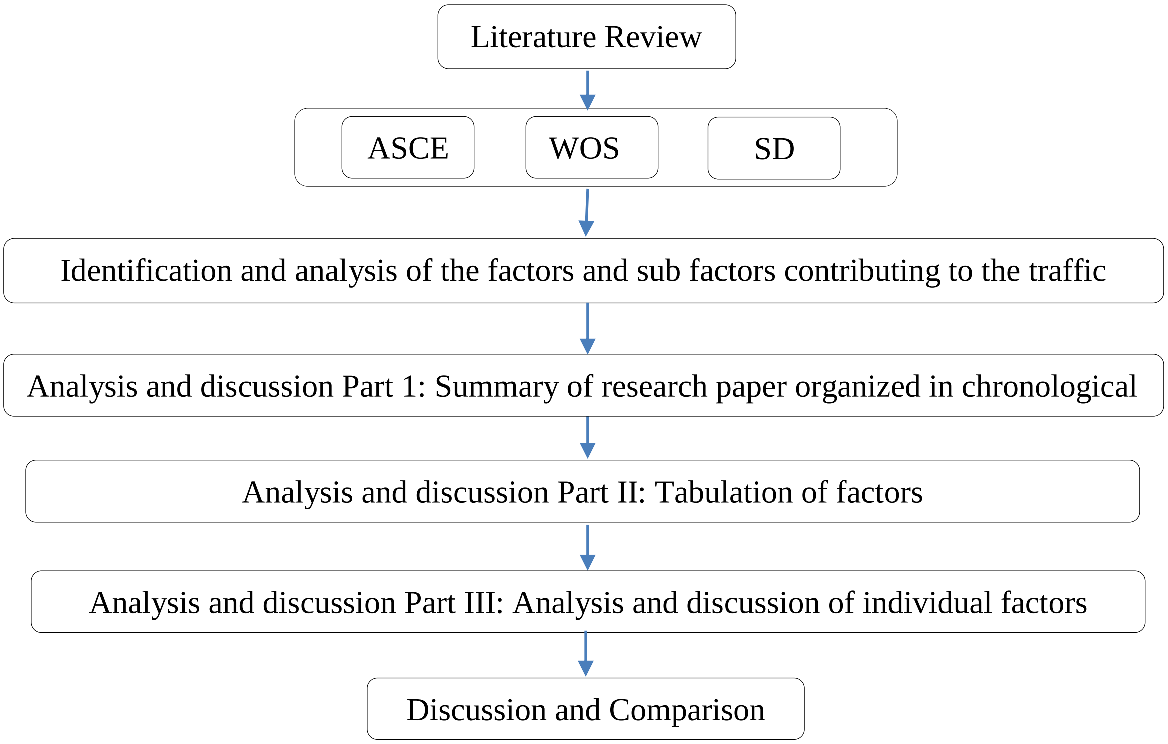

Fig 2.1: Systematic Literature Review process

In order to conduct a systematic literature review (SLR), the research evaluated existing journals and publications on traffic fatalities, road accidents, road safety and so forth on the three search engines. These databases were used because of their acceptance by the academic community. Relevant data was extracted from research papers, and then a survey questionnaire was developed and sent to all the transportation agencies in the United States. The following factors were listed in the articles as directly or indirectly contributing to the decline/increase in traffic fatalities in the United States and in other countries. A review of these publications shows that the experiences of other countries are not much different from that of the United States. The existing literature is summarized below:

A) Road-user Behavior:

1. Janssen (1994) conducted a field experiment to study the effects of seatbelt legislation on the reduction of traffic fatalities. In an instrumented-vehicle study, Janssen found that habitual seatbelt wearers, who were offered incentives for safe driving, did not show considerable improvement in driving behavior over the study period. On the other hand, the non-seatbelt wearers showed an increase in risky behavior, such as increased speed and close following after being asked to wear seatbelts. The study suggested that there was change in driver behavior but not as expected, i.e., in the safe direction.
2. Solnick et al. (1995) studied 18,000 hit-and-run cases reported by the Fatal Accident Recording System for the 1989–1991 period. They found that drivers that are younger, intoxicated, and male or have previous records are more likely to flee the scene of an accident compared to their counterparts. Drivers tend to flee in cases when they are likely to be punished or when it is easier to do so.

3. Since 1959, Norway has banned driving under the influence of illegal or prescribed drugs. Police conduct clinical tests of drivers suspected of driving under the influence. Christophersen and Mørland (1997) in their study of the Norwegian Road Traffic Act found that although the frequency of drugged drivers apprehended in Norway was ten times higher than most other countries, it was not necessarily because of a higher number of drugged drivers but as a result of drug specific laws and the level of attention to the problem in Norway.
4. Traffic accident caused by animals is a major safety concern for countries, such as the United States wherein an estimated 500,000 annual incidents are related to deer (deer-vehicle crashes or DVCs). Haikonen and Summala (2001) found that traffic accidents involving deer occurred mostly one hour after sunset. Crash rates due to for white-tail deer peaked in fall whereas for moose, the peak period was in the summer. By carefully studying the nature and timing of these accidents, drivers are able to adjust their behavior, speed, and hour of driving to avoid accidents with these animals.
5. Karl et al. (2001) in their study stated that driver behavior can be modified by passenger feedback. In his study, two drivers and their single respective passengers participated. For each driver, repeated in-car observations were made of four unsafe driving behaviors. Two of these were sequentially targeted in the behavioral intervention that involved the passengers providing informational feedback to their driver. Both drivers showed a marked improvement across the targeted behaviors.
6. Tay et al. (2002) in their article identified speeding as a major cause of accidents, but at the same time they stated that speeding is increasingly becoming a socially acceptable traffic violation. This sheds light on the fact that personal and social perception resulting

in traffic rules violations may diminish the role of traffic safety regulations in reducing accidents and fatalities. Education, awareness, and emphasis on traffic safety regulations should be the focus of long-term traffic safety agenda.

7. Chang and Yeh (2006) compared the single-vehicle crashes in motorcyclists and non-motorcycle drivers resulting in fatalities. Although there were similarities between the two in terms of demographics and driving hours, they found that the difference in fatality rates between the two groups was linked to vehicle type, speeding, and driving impairments. This indicates a possible link between vehicle type and driver behavior. Also, that today's road designs, management systems, and safety measures may be subconsciously biased towards certain types of motor vehicles.
8. A controlled virtual environment (VE) test was conducted by Schwebel et al. (2006) to study personality aspects in predicting risky driving behavior. They studied three main characteristics: sensation-seeking, thoroughness, and anger/hostility. Sensation seeking was found to be the best predictor of self-reported driving violations.
9. Engeland et al. (2007) conducted a study in Norway regarding the risks of traffic accidents caused by the use of prescribed drugs by drivers. Their study found that not only did the use of prescription drugs increase the risk of accidents, such risks were even higher during the first seven days of usage of the drugs. This study suggests that more attention needs to be paid in devising policies and warning systems to avoid such traffic accidents.
10. Driving under the influence (DUI) and speeding are common but serious traffic violation behaviors around the world. Li et al. (2007) analyzed a five-year traffic accident data of Hualien County in eastern Taiwan to assess the fatal crashes caused by drivers under the influence and speeding. The data showed that half of the deaths were caused by either DUI

and/or speeding. Li et al. also found that such risky behavior (DUI and speeding) was more common in the rural areas as compared to the urban areas. The study recommended that road safety campaigns and traffic education help curb such behavior and reduce traffic fatalities.

11. Chiron et al. (2008) studied the relationship between work fatigue and road accidents with road crash-related injuries in employees of French electric and gas companies. They were able to determine a relationship between work type and work fatigue as indicators of road crashes. Their study could be used to prevent accidents by controlling work fatigue at work places.
12. Cellphone distractions are risky but eating/drinking while driving also has an equally negative effect on a driver's ability to focus and drive safely. Young et al. (2008) used driving simulators and found that a driver's ability to drive safely reduced substantially with increased eating and drinking.
13. Among the serious traffic violations, speeding is of a major concern for law enforcement and safety agencies. In a study of speeding violations in China, Hu et al. (2009) found that speeding violations are a function of traffic volume and were likely to happen on certain roads and/or times sections. Their study can be utilized to identify high-risk road sections as well as the time accidents are likely to occur and implement law enforcement and controls accordingly. This will not only reduce traffic crashes but also substantially reduce law enforcement-related costs.
14. Cellphones are considered as one of the major reasons for distractions, accidents, and fatalities. However, Loeb et al. (2009) in their study of effects of cellphone use on pedestrian fatalities found that pedestrian fatalities increased when cellphones were first

introduced, but decreased as cellphone numbers approached a critical threshold. But this trend has reversed and pedestrian fatalities continue to increase with the increase in cellphone numbers and usage.

15. Traffic intervention systems are aimed towards providing higher levels of safety; however, not all the interventions are effective. Novoa et al. (2009) evaluated the effectiveness of various intervention systems using before-during-after effects of the implementation of such systems. The study revealed that the most effective interventions are the ones that are not dependent on a road user's behavior or their knowledge of safety issues. Interventions are solely dependent on education are the least effective.
16. Pannaluri and Santhi (2009) studied the crash history and risk groups in India, which has seen a dramatic increase in the number of vehicles since 1995. Their study found that in an urban setting, motorized two-wheelers, pedestrians, and bicyclists posed the highest risk, whereas in an urban setting, heavy vehicles were the major risk factors. Recommendations were proposed to improve traffic reporting system, rigorous enforcement of laws, vehicle maintenance rules, driver behavior and infrastructure.
17. Tay et al. (2009) developed a logistic regression model to identify the factors that might affect the occurrence of hit-and-runs in fatal crashes in California. They concluded that roadway functional class, routes, traffic flow, types of roadway sections, speed limit, traffic control devices, functioning of traffic control devices, lighting conditions, roadway alignment, and roadway profile are important determinants that engineers can target to reduce hit-and-runs in fatal crashes. In addition, they confirmed that traffic enforcement should be performed on weekends and during the nighttime.

18. Wahlberg and Dorn (2009) studied work absence behavior as an indicator of traffic crash in professional drivers. They studied British and Swedish sample data and found absence as an indicator of general health and subsequently crash predictability. They also proposed that absence records of professional drivers can be used by companies and government agencies to identify risky drivers while promoting health and wellness.
19. Mao et al. (2010) in their study of traffic accidents in a rural area of China found that the probability of traffic accident increases with decreases in traffic safety consciousness (TSC). Demographics and driving skill contributed to traffic safety consciousness. In their article, they reported that motor vehicle drivers were responsible for more than 90% of traffic accidents in China. They recommended that a combination of traffic safety education and improvement in safety facilities be used to standardize traffic safety management and reduce the number of crashes and fatalities.
20. Brookhuis et al. (2011) studied the effect of alcohol intervention programs (Alcohol Free on the Road) on the behavior and alcohol law compliance by young drivers. It was found that the drivers who attended the program showed greater awareness and lesser involvement in alcohol-related accidents. However, this was not true for the drivers who did not attend the program, suggesting that such intervention programs are effective.
21. Based on 2003–2007 Ohio state motorcycle accident data, Eustace and Hovey (2011) concluded that excessive speed and intoxicated while riding should be a major focus of enforcement. They also found that the fatality and/or severity of crashes increase if the driver is female, riders are not wearing helmets, and when driving on horizontal curves and graded segments. Their study showed that the combination of driver behavior and infrastructure can impact fatalities and injury severity in motorcycle riders.

22. Gjerde et al. (2011) did a case study on 204 drivers injured in southeastern Norway during the period of 2003–2008. Cases from single vehicle accidents (N = 68) were assessed separately. As controls, 10,540 drivers selected in a roadside survey in the same geographical area during 2005–2006 were used. Blood samples were collected from the cases and oral fluid (saliva) samples from the controls. Samples were analyzed for drugs and alcohol. The result was that drugged driving other than alcohol has a major impact on traffic fatalities. As per the data collected, they analyzed the use of amphetamine and heroin use. They concluded that the use of such drugs increased drastically in Norway compared to most other countries. This is because of differences between national road traffic laws and the level of attention given to the problem, and not to national differences in the prevalence of drugged driving.
23. Similar to the study by Hu, Sun and Liu in 2009, Yao et al. (2011) in their study, focused on the factors effecting two-wheeler accidents in China. Their results were identical and suggested that gender, behavior control, risk and utility perception played major roles in the probability of red light infractions and subsequent accidents. Driver behavior and social norms are increasingly becoming factors contributing to traffic fatalities.
24. Apart from accident and fatality rates, the overall traffic safety situation of a country should be determined using a holistic approach that encompasses road-user behavior, awareness and education, infrastructure, and law enforcement. Hassan et al. (2012) conducted a similar study in the United Arab Emirates and provided recommendations to improve the deficiencies associated with the above-mentioned factors.
25. MacLeod et al. (2012) studied 48,000 pedestrian deaths in United States between 1998 and 2007 and found that such accidents were more common in the early morning hours under

poor light conditions and on the weekends. Their study also showed alcohol use and invalid licenses were common reasons for these hit-and-run cases. However, they recognized that more information about drivers involved in such hit-and-run cases will be required to further analyze the relationship.

26. Technology is meant to make life easier and safer but the use of handheld media devices disapproves this. Schwebel et al. (2012) designed a study to test the impact of the use of handheld devices on pedestrian safety. Their study clearly indicated that pedestrian's using handheld devices are more likely to get into accidents than undistracted pedestrians, and it is critical that policy makers start evaluating ways to mitigate such accidents.
27. Recently, a large number of studies was dedicated to alcohol consumption and driving safety but few focused on the use of drugs. Callaghan et al. (2013) studied drug related accidents and fatality rates in California from 1990 to 2005 and found that drug-related fatality rates were similar in males and females. Also, individuals with alcohol and drug-related disorders were at high risk of motor vehicle accidents. It is evident that more interventions are required with a primary focus on drug use.
28. Dultz et al. (2013) studied accidents involving vulnerable road users (pedestrians and cyclists) struck by motor vehicles in New York City from 2008 to 2011. They used the accident data, interviews, and imaging to study the demographic and behavioral aspects of the vulnerable users and motorists. It was found that non-compliance with laws and regulations was a major cause of such accidents, and traffic safety must be focused on it accordingly.
29. One of the important factors in traffic accidents is sleep deprivation among drivers. Komada et al. (2013) studied traffic accidents related to sleep disorders and sleep

deprivation, as well as discussed advances in detecting sleepiness and thus avoiding such accidents.

30. Liu (2013) compared the fatality rates of vulnerable road users, pedestrians, and two-wheel users in China with those in developed countries. Liu found that the higher fatality rates in China were linked to driver behavior. In developed countries, traffic rules are strictly applied, which discourage drivers from breaking rules and taking risks, whereas in China, vulnerable drivers were more likely to take risks. Liu drew a direct correlation between traffic management, traffic rule implementation, and fatality rates. The study shows that traffic fatalities can be reduced by enforcement of stricter traffic rules. Although the study is fairly conclusive, it does not account for other factors, such as volume, infrastructure, traffic accident response systems, etc.
31. Sleep-related accidents are avoidable but they remain a major cause of traffic accidents. Lucidia et al. (2013) studied sleep-related risk factors and found that young and inexperienced drivers are more susceptible whereas non-urban roads have more sleep-related accidents.
32. Petrie et al. (2013) studied the effect of alcohol consumption on crime rates and traffic accidents in rural Australia. They found a positive correlation between risky alcohol use and crime and traffic accidents and suggested that reducing the population levels of those drinking at risk of acute harm or improving the drinking settings can reduce traffic fatalities.
33. Ren (2013) analyzed road traffic accidents caused by human error and concluded that human error is a major reason behind such accidents.

34. Smith et al. (2013) studied the relationship between ambulatory persons distracted by cellphone and traffic fatalities. Their study showed that female drivers and younger drivers are more likely to be involved in accidents caused by cellphone-related distractions. They recommended implementing policies to address cellphone usage as well as tools and applications to warn distracted drivers.
35. Alcohol and distracted driving are major causes of traffic accidents and fatalities, and the fatality rates continue to grow. Wilson et al. (2013) studied the effect of alcohol use and distracted driving in traffic fatalities. They emphasized the negative effects of this trend on policies to counter distracted driving.
36. Brown et al. (2014) studied behavioral adaptation by drivers to changing road conditions and road environment complexity. Their tests using a driving simulator showed that experienced drivers (5–10 years of experience) adapted more easily to driving in changing environments than non-experienced (1–5 yrs.) drivers.

SUMMARY: The driver behind the wheel is the best resource to avoid traffic accidents. But the same driver can become high-risk if he/she does not practice safe driving behavior. Based on numerous studies on this aspect of road safety, the most common types of unsafe behavior are speeding and driving under the influence of alcohol and/or drugs. In 2012, 10,322 people lost their lives in alcohol-impaired driving crashes in the United States, which accounted for 31% of the total fatalities. Other common types of unsafe behavior include the lack of use of restraint and safety devices, such as seatbelts and helmets. Driving when tired, sleepy, or highly emotional can also lead to risky behavior on the road. Males were found to be more prone to risky behavior as compared to females, whereas younger drivers were involved in more accidents as compared to their older counterparts.

A driver's respect for traffic rules and adherence to traffic laws are also major contributing factors; accounting for traffic accidents and fatalities. Accidents involving cellphone use and other distracting devices are also on the rise, but these are often underreported, mainly because the person who can typically confirm the use is the driver.

B) Infrastructure

1. Golob and Recker (2003) in their study of relationships of accidents with traffic flow, weather and lighting conditions found strong indications that accident severity is a function of traffic volume and not speed. They determined from their multivariate statistical analyses of South California freeway accident data that although weather was related to type of accidents, controlling for weather and lighting conditions, traffic volume influenced accident severity more than traffic speed. This is in contrast to the study done by Wang and Ison (2010) who proposed that congestion may not be directly responsible for accident severity.
2. Jones et al. (2003) studied and found that geographical variations, such as population size and age, road length, number of cars, per capita income, traffic counts, and material deprivation are important indicators of mortality and morbidity rates in traffic accidents. The study was based of traffic data on England and Wales, and it demonstrated the importance of geographical approach rather than more conventional road sections studies.
3. In a study of infrastructure changes, such as addition of lanes, change in lane widths, etc., and its effect on traffic fatalities, Noland (2003) found that there was no direct correlation between such changes and traffic fatalities. He suggested that factors such as age, use of alcohol, seatbelt use, medical technology, etc., played a far more important role than the infrastructure itself.

4. Road and infrastructure improvements are carried out with a premise of easing traffic-related issues and reducing fatalities. In a study of 14 years of traffic data from all 50 states conducted by Noland (2003), it was found that there infrastructure development was not a factor in the reduction of traffic fatalities. In fact, demographic changes such as seatbelt use, changes in age cohorts, improvement in medical technology, etc., were more effective when it comes to reduction in traffic fatalities.
5. Liu and Chu (2005) in their study of highway accidents highlighted the role of worse communication markets, safety unawareness for drivers, road administration, and prolonged highway maintenance played in such accidents. Based on their case studies of accidents in the Yunnan province of China, they recommended that driver education, safety control, and emergency rescue should be the top priority for highway administration.
6. Noland et al. (2005) studied the relationship between congestion and traffic safety using London traffic data. Although it is generally accepted hypothesis that congestion reduces the severity of crashes due to reduced speeds, the results of the study were inconclusive. There were indications of interactions between road infrastructure and congestion that could have contributed to road safety but there were no conclusive results.
7. Donnell and Mason (2006) studied the frequency of median barrier accidents on Pennsylvania interstate highways and found that although median barrier selection is a systematic approach, it is still archaic, as it was developed in the 1970s and it has generally remained unchanged. Since then, traffic volumes and speed limits have changed, which demand subsequent change in the selection criteria for such barriers. They were able to

develop methodologies that could be used in barrier selection and placement resulting in reduced collisions and fatalities.

8. There are a limited number of studies conducted on the collision of vehicles with infrastructure elements, such as traffic signal poles. Elmarakbi et al. (2006) carried out a study focused on traffic light poles and found that steel poles embedded directly into the soil provided flexibility and subsequently more protection to the vehicle occupants involved in head-on crashes with the pole. More studies need to be carried out to determine design and selection of traffic infrastructure hardware.
9. Haynes et al. (2007) in a study of road curvature and its relationship with accidents using road-network data from England and Wales indicated that the curvature was not a contributing factor in traffic fatalities. In fact, the number of collisions was negatively correlated to road curvature and at the district scale, road curvature was protective.
10. Xing et al. (2007) proposed a novel vision of using location-centric storage (LCS) and communications system to provide zero-delay warning to motorists. The system is based on advanced sensing and wireless communication. Based on theoretical and simulation studies, it concluded that LCS is a promising roadway warning system that is able to reduce traffic fatalities.
11. Jones et al. (2008) in their study of traffic accident casualty data from an English and Welsh local authority district found that geographic variations, such as size, age, and structure of the population, traffic counts, road classification, road curvatures, road length, and urban road percentage, were significant variables in predicting fatalities. They argued that geographical approaches can provide contextual associations, which might be missed by conventional studies of road sections and accidents.

12. In an analysis of traffic data from the 8019 census wards of England, Chao et al.(2009) found that increases in road traffic speeds resulted in a higher number of fatalities but found that road curvature was negatively associated with road accidents. This contradicts some other studies on road curvature, which found that road curvature resulted in an increase in accidents as higher cognitive skills were required to drive on such roads.

13. In general, traffic congestion has been directly linked to the number and the severity of crashes. However, a study conducted by Wang and Ison (2010) on the London M25 revealed that there may not be a direct relationship between congestion and the severity of crashes. They proposed that there are other underlying contributing factors, such as flow, driver behavior, road geometry, and vehicle design, which affect the severity of crashes. Their study suggests that factors contributing to accidents and crashes may not be fully attributable to one or a couple of factors. All factors need to be studied in conjunction with each other to be able to draw relevant conclusions and suggest suitable solutions.

14. Shakil et al. (2011) in their study of street patterns (grid-iron, warped parallel, loops and lollipops, and mixed patterns) found that loops and lollipop designs have a higher probability of accidents involving vulnerable road users but a lower probability of accident-related fatalities. An obvious inference can be drawn that reduced speeds in such patterns results in lower fatalities. However, user behavior (skill level, casual driving etc.) in such closed street patterns may explain the higher frequency of accidents.

15. In a study based on data from different countries worldwide, Jamroz (2012) was able to identify the effects of infrastructure and systems on the Road Fatality Rate (RFR). He

found that the mobility of the population, traffic density, and the proportion of paved roads, motorways, and express roads contributed to traffic fatalities.

16. The effects of infrastructure and traffic regulations have been studied in isolation. However, in a unified approach, Albalate et al. (2013) studied these factors in combination in an attempt to understand successful strategies in reducing traffic fatalities. In their study of infrastructure characteristics and regulatory changes in Spain, they demonstrated the importance of infrastructure spending in combination with traffic regulations in reducing traffic fatalities.

17. In their study of safety countermeasures and crash reduction in New York City, Chen et al. (2013) found a significant improvement in traffic safety due to the implementation of a holistic approach by New York City between 1990 and 2008. They deduced that signal-related countermeasures, along with traffic calming measures, had resulted in an improvement in road safety and a reduction in injuries. This provides interesting insight into the approach and the strategies that need to be considered while designing roads and implementing safety measures.

18. Cohen et al. (2013) in a field study of guardrails at roundabouts and their effect on pedestrian behavior found that at roundabouts with no guardrails, pedestrians were more likely to break the law and cross at non-designated places than at the roundabouts with guardrails. This observation shows how important road safety measures are in reducing traffic violations and subsequent accidents.

19. In most of the cases, driving in the wrong direction always led to traffic fatalities or severe injuries and it was a major factor in road accidents. Conesa et al. (2013) proposed a paradigm based on the exchange of information between vehicles and the infrastructure

nodes placed on the highway in order to detect vehicles driving in the wrong direction. The 70 test was performed on 7 users who participated by using different vehicles in different ways. It resulted in positive results which had a 100% success ratio.

20. In their research, Gkritza et al. (2013), studied deer-vehicle crash data for the State of Iowa to evaluate the correlation between deer-vehicle crash frequency and roadway and environmental factors. They collected crash data from state police and maintenance records and applied statistical binomial regression methodologies to assess safety improvement measures. Their study indicated that deer-vehicle crashes accounted for 13% of all crashes in the state, and such crashes occurred in both urban and rural settings. They were also able to identify 25 segments for deer-vehicle crash countermeasures, which included countermeasure implementation, as well as crash trend monitoring.

21. Horizontal curves are important in a road network and are known to contribute towards run-off accidents and lane changing crashes. In their *Journal of Transportation Engineering* article published in Sep, 2005, Othman and Lanner (2013) provided critical inputs on curve designs, the selection of countermeasures, and safety devices for such road sections. Their findings were based on real traffic data and environments. The study highlighted that in order to reduce accidents and fatalities, it is imperative that quantitative characteristics of the curves such as radii, geometry, curve direction and other structure be studied along with qualitative characteristics such as driver skills and behavior, vehicle responsiveness, lateral acceleration, and the dynamic limits of the vehicles.

22. Rangel et al. (2013) discovered that there was a link between economic incentives incorporated in highway toll contracts and road safety improvements. They found that although contractors and toll operators had no control over the road infrastructure itself,

adding such incentives to the contracts did have a favorable effect on the reduction of traffic accidents and injuries. A natural inference can be that such incentives motivate the contractors to be more actively involved in traffic management, communications, and reporting.

23. Road safety barriers are key design features in road safety systems, especially in cases of run-off crashes and their impact on accidents. Soltani et al. (2013) studied transition barrier systems and found that such barriers not only provided directional control for traffic but also provided safety during and after impacts. Based on their study they were able to propose better road barrier systems that would help reduce severe injuries suffered by vehicle occupants.

24. Yannis et al. (2013) evaluated the importance of street lighting, especially in the night time, on road accidents by using existing police recorded accidents in Greece. They developed a model that allowed the investigation of the influence of road lighting and other parameters, such as weather conditions, accident type, and vehicle type, on the number of casualties and injuries. They concluded that more road lighting contributes to less road accidents and severe injuries. It was discovered that nighttime lighting has a great impact in improving traffic safety. Identifying the effect of lighting on road safety benefits road safety policy decision makers in designing and implementing appropriate road safety measures (infrastructure improvement, safety campaigns and so on).

SUMMARY: Proper and adequate infrastructure is crucial in keeping roads safe for all users (drivers and pedestrians). It is a known fact that poor lighting, inadequate visibility, improper designs, and inefficient traffic administration can all lead to high traffic fatality rates. This is further bolstered by the fact that countries with poor infrastructure have higher traffic fatality rates, as compared to countries with advanced infrastructure. Bad weather conditions, poorly lit roads, a lack of street lighting, and the absence of warning systems are all responsible for higher numbers of traffic accidents. Proper consideration of design factors, such as lane widths, the number of lanes, road curvature, median selection, loops/lollipops/four-way roads, entry/exit ramps, speed limits and so forth, also contribute towards road safety. Using barrier systems, guardrails at intersections, signalized road crossings, ample road-crossing time, properly marked road signs, and signals all help reduce traffic accidents involving non-vehicular road users. Other infrastructure-related factors that need special consideration to enhance road safety is road administration and management.

C) Emergency Response and Trauma Care Advancements

1. Meng et.al (1991) conducted an uncertainty analysis of accident notification time (ANT) and emergency medical service (EMS) as two random variables in work zone traffic accidents. The analysis showed that ANT was a more effective variable in reducing mortality rates rather than EMS response times. They also recommended that work zone activities should be planned so as to avoid poor weather and light conditions.

2. Vanbeeck et.al (1991) studied the influence of socio-demographic factors, as well as direct factors in regional traffic accident mortality in the Netherlands. The study showed that per-capita income is a strong indicator; however, availability of advanced trauma care in the region was also one of the strongest indicators of traffic mortality rates. The study emphasized the importance of an advanced trauma center in early diagnosis and treatment of head injuries and the lowering of mortality rates.

3. Cooper et.al (1998) conducted a quality assessment of emergency and trauma management at a Level I trauma center (TC) and other hospitals in Victoria, Australia. The study concluded that Level I TCs had lower deaths and less preventable deaths, as compared to other hospitals, such as specialist teaching, metropolitan, or regional hospitals. The study suggests that hospitals with 24-hour trauma services system are more likely to reduce the frequency of preventable deaths.
4. Schmucker et.al (1998) in their study on traffic crashes and fatalities in developing countries found that these countries account for less than half of motorized vehicles but more than 90% of annual worldwide fatalities. As developing countries may not have appropriate or advanced emergency response and trauma care systems, it is imperative that developed countries provide support to developing countries in reducing global traffic accidents and fatalities.
5. Stelfox et al. (1998) reviewed literature on quality indicators (QI) used for evaluating the qualities of trauma care in order to decide whether or not these QIs were relevant. The study concluded that there was no strong evidence to show that these QIs were strong indictors of the quality of trauma centers and more studies are required to select pertinent indicators.
6. Nathens et al. (2000) studied the effect of organized trauma care system, such as trauma triage protocols, inter-hospital transfers, organizations of trauma centers, and quality assurance on motor vehicle crash mortality rates. The study found that with the implementation of organized mature systems, the mortality rates caused by traffic accidents declined.

7. Becker et.al (2003) studied the risk of injury and death of emergency responders and civilians in ambulances and emergency vehicles, such as fire trucks and police cars. Their study showed that the percentage of fatal crashes was higher when the occupants of the vehicle were unrestrained and/or proper siren/lights were not deployed.
8. Noland and Quddus (2004) in their analysis of traffic-related fatalities as a function of medical care and technology, found that improvement in medical technology is inversely related to the traffic fatalities. Their study was carried out in Great Britain, which has one of the best medical technologies and lowest levels of traffic-related fatalities in the world.
9. Lagarde et al. (2005) in their study of French middle-aged workers and pensioners found that men and women who took pain-related medication were at higher risk of getting into serious traffic accidents. Their study showed a correlation between serious traffic accidents and the medical condition of the driver.
10. Bystanders can also play a major role in mitigating the adverse impact of a serious traffic accident. In a controlled experiment, Ertl and Christ (2007) used personal digital assistants (PDAs) to test a group helping accident trauma victim scenarios. The test group that had access to PDAs with audio-visual instructions to assist the victims performed much better than the control group that did not have access to any such devices. They showed that untrained helpers can significantly alter the outcome for victims of traffic accidents.
11. Perez-Nunez et.al (2007) studied the economic impact of road fatalities in Belize from a human capital and economic cost perspective. The study showed that the economic impact of such premature road fatalities was equivalent to 1% of the country’s GDP. This clearly indicated the necessity of identifying issues and improving the country’s trauma response infrastructure.

12. Sanchez-Mangas et.al (2007) researched the relation between emergency medical response time and the probability of death arising from traffic accidents in Spain. The analysis of road accident data showed that a 10 minute reduction in response time could reduce the mortality probability by almost 30%. This result is significant in understanding the importance of emergency responses in reducing traffic fatalities.
13. Gonzalez et.al (2008) studied the relationship between emergency medical services (EMS) time and fatality rates, more specifically the pre-hospital time spent on inserting intravenous catheters (IV). The study found that on-scene IV insertion was more common on rural roads rather than urban roads. The study suggested that this increased EMS time used in IV insertion in rural areas may be linked to higher vehicular fatality rates.
14. Kleweno et.al (2008) used a case study of a 25-year-old male who sustained serious injuries in a motor vehicle accident to demonstrate that rapid response time and advanced trauma systems are absolutely critical in saving lives of people who have suffered from complex injuries due to traffic accidents.
15. A lack of medical service facilities and immediate treatment of persons involved in accidents can increase fatality rates. (Li et al. 2008). In their study of rural accidents, as compared to urban accidents, Li et al. concluded that the absence of intelligent systems and the use of restraints led to higher traffic fatalities. They recommended that emergency systems, campaigns for using restraints, enforcing the use of helmets and seatbelts, and speed control be priority for reducing such accidents.
16. McDermott et al. (2010) stated in his paper that advanced trauma services in Victoria are required to reduce traffic fatalities. They proved this by taking the existing fatalities data in trauma services and comparing it with the new trauma systems. They identified the

inadequacies within the individual trauma services and in association with representatives of these services, they developed appropriate countermeasures to address the problems.

17. In an another study of emergency care systems, David et al.(2013) found that shorter EMS response times were beneficial in reducing mortality rates in severe traffic accidents. Their study model highlighted the importance of the "golden hour" in EMS care coupled with timely transport to a hospital in reducing mortality rates.

18. Victoris et al. (2013) studied the trauma management (TM) system of 21 European countries to develop road safety performance indicators (SPI's). Their study was based on the consensus in the professional literature that a reduction in accident victims can be achieved by having a well-equipped TM system. In their study, they were able to categorize and group countries with low and high TM SPIs. Their study emphasized the importance of two types of medical treatment the initial EMS and permanent medical facilities with special focus on availability, composition, staff, transportation units, response time, and availability of trauma beds in hospitals.

SUMMARY: In general, avoiding traffic accidents in the first place is of primary importance in reducing fatalities, but despite the best efforts, it is not always possible to avoid accidents. Post-accident responses such as accident notification, emergency response, on-site immediate treatment, trauma care, and permanent hospital treatments are all significant. Short accident notification and response times are very crucial in saving the lives of accident victims. Emergency response and treatment within the first hour after the accident, also known as the "golden hour," is vital in reducing the probability of death. Time spent at the accident site, treatment provided to the victims, time taken to move the victims to trauma centers, safety measures while transporting the victims, and the quality of treatment provided at trauma centers work together to influence the outcome of accidents. Many times civilian bystanders with certain assistance devices and/or training have also proven to be effective in saving lives. It is imperative to mention that it is not only the presence of response and care systems that is critical but the quality, administration, and management of such services are important.

D) Policy Enforcement

1. Law enforcement is a basic necessity if states are to control traffic fatalities. Harper (1991) reviewed the impact of semi-automatic monitoring systems in improving detection in traffic law programs. He concluded that taking into account the existence of core technology, tentative conclusions can be drawn as to the likely benefits and disadvantages of such systems.
2. Ruhm (1996) studied the impact of seemingly unrelated factors—beer taxes and alcohol control policies—on traffic fatality rates and found that higher taxes and controls on alcohol resulted in a reduction in traffic fatalities. This study signifies the importance of policies, direct and indirect, in control of traffic accidents and fatalities.
3. Young and Likens (2000) in their study on the relationship between traffic fatalities and alcohol regulations found that beer prices and taxes were statistically insignificant. This is in contrast to the study conducted by Ruhm in 1996, who suggested that beer policies and taxes were negatively related to accidents. Young and Likens found other policies such as seatbelt laws, the minimum legal drinking age, and dram-shops laws to have more of an impact on reducing fatalities.

4. Koushki et al. (2003) studied the impact of safety belt use on the number and type of road accidents fatalities and injuries in Kuwait. In their study they found that the use of seatbelts had a positive effect on reducing traffic fatalities and multiple injuries.
5. Welki and Zlatoper (2007), using 1973–2000 annual Ohio data, found that highway safety regulation enforcements are effective in reducing motor vehicle fatalities. The study also showed that fatalities increased with improved economic conditions, higher alcohol consumption, higher speed limits, rural road driving, and increases in young and old drivers.
6. Traynor (2009) studied the 1999–2003 Insurance Institute for Highway Safety data for 48 US states and found that restrictive graduated teen licensing and DUI policies significantly reduce traffic fatality rates. This supports the general consensus that policy enforcements impact traffic safety; however, Traynor did not find a statistically significant relationship between seat belt enforcement policies and fatality rates. These two results seem to be counter intuitive but do not dismiss the importance of policies and enforcements.
7. Manzano et al. (2011) studied the impact of strict legal reforms in Spain on road fatalities. Their study showed that immediately before the reform was passed and after it was implemented, there was a fall in traffic fatalities in Spain. This supports the general consensus that stricter traffic rules and regulations are pivotal in reducing traffic related fatalities.
8. Chang et al. (2012) analyzed a comprehensive set of nine traffic policies and their effect on fatality rates. Using a panel GLS model and holding regional effects and state-specific time effects constant, they found that zero-tolerance laws and hikes in beer taxes as the most effective policies in reducing alcohol related fatalities. This is in contrast with some

other similar studies that found the correlation between tax policies and fatality rate to be zero.

9. French et al. (2012) investigated the effect of universal helmet laws (UHLs) and other policies on reducing motorcycle fatalities, especially for out-of-state riders. They found that states without such laws and policies attract risky riders, increasing fatalities and accidents. This effect was more prominent for out-of-state riders from states that enforced such laws.
10. Lyon et al. (2012) studied the effect of different levels of graduated drivers licensing (GDL) on teenager driving fatalities and crashes. Their study found that with increases in strict permitting stages, the crash risks decreased, and vice-versa. This is in alignment with other studies that emphasize stricter implementation of rules and laws.
11. In a study conducted by Carpenter et al. (2013), non-compliance of GDL laws was found to be associated with higher accidents and fatality rates in teenagers between 15and 17 years old. This is consistent with the studies conducted by Lyon, Pan, and Li. (2012). The likely reasons found in such fatal accidents were alcohol, seatbelt nonuse, and weekend driving.
12. Traffic enforcement is equally as important as road designs and safety measures when it comes to controlling driver behavior and traffic accidents. Stanojevic et al. (2013), in their study of Northern Kosovo (where traffic enforcement is minimal) and Serbia (where there is higher levels of traffic enforcement), found that regions with enforcements have drivers following traffic rules and regulations and they are less prone to accidents and fatalities.

SUMMARY: Traffic laws and the strict implementation of the law have repeatedly proven to be effective deterrents to traffic violations, accidents, and related fatalities.

Traffic laws and regulations largely define how users act and react while travelling and using the roads and other infrastructure. Strict laws pertaining to alcohol use, drugs, legal driving ages, driver's license issuance policies, traffic safety education, and the use of seatbelts, restraining, and safety devices are all essential parts of overall traffic safety. Countries with stricter rules and enforcement policies are known for lower fatality rates, as compared to the countries with less traffic rules and/or implementation mechanisms. These days, countries are focusing on and implementing effective laws such as zero-tolerance in order to improve traffic safety performance.

E) Socio-economics and Demographics :

1. Apart from the cost of human life, traffic fatalities are also responsible for socio-economic costs, such as loss of income, property loss, emergency response costs, and other incidental costs. Chin (2002) in his study of accident related costs found that the cost of each fatal accident was equivalent to approximately $172,000. Due to the high costs involved, it is imperative that driver education, safe speed limits, clear road signs, and improved road management systems be emphasized.
2. Young drivers are involved in highly fatal and single-vehicle crashes. Using sequential binary logistic regression models, Dissanayake and Lu (2002) found that the use of alcohol or drugs, ejection from a vehicle, rural settings, road curvature, and gradient played critical roles in accidents involving young drivers. It was also found that gender and the use of restraints determined the severity of such crashes; however, they did not find substantial evidence to link such accidents to weather, residential location, or physical conditions. The study clearly indicated the focus areas for road safety education and traffic management.

3. Khattak et al. (2002) studied the aging driver population in the United States in order to determine the factors related to severity of accidents involving drivers 65 years of age and older. They studied 1990–1999 crash data from the state of Iowa and found that the severity of accidents increased if alcohol was involved. Also, vehicle type played a role in the severity of accidents. In fact older people driving farm vehicles were involved in more severe accidents than the rest of their age group. This study is helpful in understanding the types of accidents involving elderly people and formulating traffic rules and regulations to address them.
4. Clark and Cushing (2004) used rural and urban traffic mortality data for 1998–2000 from the Federal Highway Administration to determine the effect of population density on mortality rates. They used linear regression models and concluded that population density was directly related to higher mortality rates in urban areas but had an inverse effect in rural areas. They also deduced that the state trauma system in rural areas did not substantially affect mortality rates.
5. Koptis and Cropper (2005) studied the traffic fatality rates of 88 countries from 1963–1999 using linear and log-linear models to forecast traffic fatalities. Their study revealed that globally, road death rates will increase by 66% over the next twenty years. Although this forecast is applicable to developing countries like India and China, the trend may be in reverse in developed countries such as the United States.
6. Laws, policies, and rules are as good as they are enforced and complied with by the public. Similarly, Lode and Klara (2007) analyzed the 1996–2002 data from 15 European Union countries and found that social willingness to comply with laws significantly affects the

traffic fatality rates. Corruption levels, traffic exposure, economic growth, speed, and alcohol contributed towards driver behavior and traffic fatality.

7. In a study conducted by Melinder (2007), it was found that socio-cultural characteristics, such as religion and wealth, play a role in traffic accidents. Based on the relation of religion and wealth to traffic accidents, Melinder categorized countries in three religion-based and five wealth-based categories.

8. Paulozzi et al. (2007) carried out a cross-sectional regression analysis of mortality rates in 44 countries using economic factors as predictors. They found that motor vehicle crashes was higher in countries with low per capita income, whereas in countries with high per-capita income vehicle crashes were lower.

9. Traynor et al. (2008) evaluated the relationship between economic conditions and traffic fatalities using cross-sectional time-series models and found that a significant non-linear relationship existed between the two factors. Alcohol abuse, population density, the presence of interstate highways in rural areas, and teen drivers also played a major role in traffic fatalities.

10. Gaygisiz et al. (2010) studied traffic fatality related data from 46 different countries in relation to cultural values and governance quality. It was concluded that improvements in the quality of governance and institutions resulted in improvements in traffic safety.

11. The minimum legal drinking age (MLDA) is an important socio-legal policy that helps reduce traffic fatality rates across the country and globally. Lovenheim and Slemrod (2010) studied traffic fatality data using GIS and micro-data to substantiate and further support this policy. Their study is consistent with the general consensus that lowering MLDA substantially increases traffic accidents and fatality rates involving teenagers.

12. Michael et al. (2011) reviewed the effects of sleep disorders and common ailments, such as asthma, arthritis, chronic fatigue syndrome, on driving performance and road accidents in their article. They emphasized the cost effects and importance of addressing the role of sleep disorders and medical related conditions in road accidents.
13. Simon et al. (2011) in a study of traffic accidents in Christchurch, New Zealand, found that crash rates were not necessarily related to morning rush hour or the "school run." They suggested that policies that target traffic safety should be geographically uniform rather than focused on the immediate vicinity of schools.
14. In a study of drivers 65 and older, Sun et al. (2011) identified gender, use of seatbelts, vehicle type, and light conditions to be contributing factors. They also found that the severity of accidents increased at intersections, especially those without control and safety devices. Thus, in order to reduce accidents and/or the severity of accidents, it is important that intersections be better controlled and managed using traffic control devices. Even though the study focused on a certain demographic, the implementation is applicable to all ages and gender groups.
15. Li et al. (2012) studied the effects of congestion-charge on road accidents in the central London charging zone. It was found that such charges imposed upon drivers reduced car accident rates but resulted in increases in two-wheeler accidents. Their study implies that such charges affect the selection of vehicle but not necessarily the driver behavior.
16. Mohamad et al. (2012) studied the three ergonomic principle "human-machine-environment" in their paper with emphasis on children and youth. They suggested that developing countries should base their road safety models on the ones used by developed countries with special focus on education, enforcement, land use, and vehicle designs.

17. Nordfjærn et al. (2012) investigated cultural and socio-demographic predictors of accidents in Norway and three developing African countries. Their study revealed that male gender was the only significant predictor of accidents in these countries. An introverted and extroverted culture, density, and written culture were also found to be predictors of traffic accidents.

18. Road accidents are a direct function of traffic volume. In a study of the Fatality Analysis Reporting System (FARS) data for traffic fatalities between 1994 and 2005, it was found that the number of fatalities was linked with the sales volume of automobiles. Zhou and Wang (2012) were able to draw parallels between improvements in the economy, automobile sales, and traffic fatalities. This seems logical as an improved economy results in increased sales volume, as well as new drivers on the road. This may also be an indication of driver behavior, as a function of socio-economic conditions.

19. Srinivas et al. (2013), in their study of Mecklenburg County, Charlotte, found that demographics/socio-economic characteristics such as population, household units, and employment can be used to develop crash estimation models. The outcomes can be used in planning, policy making, and land use decisions in high risk traffic analysis zones (TAZs)

20. The long-time debate of men versus women drivers has been more of a coffee table discussion rather than a serious study by professionals. In a recent study of traffic data for Catalonia for 2004 and 2008 carried out by Elena et al. (2014), it was found that in accidents involving child pedestrians and young drivers, men are at a greater risk as compared to women. With respect to age groups, old female drivers have higher accident

risks. However, men are more prone to being involved in severe accidents and injuries. There is a correlation between age/sex and traffic accidents.

21. Yannis et al. (2014) researched the relationship between gross domestic product (GDP) changes and traffic mortality rates across 27 European countries using data spanning four decades (1975-2011). Their research revealed a positive relationship between the two, suggesting that improvements in GDP (and subsequent economic conditions) leads to higher motorization and mobility. This in turns leads to higher mortality rates and vice versa.

SUMMARY: Apart from loss of human life, accidents and traffic fatalities have a socio-economic aspect to them. Loss of income, property loss, emergency service costs, and other incidental costs are some of the economic impacts of traffic accidents. In a reverse relationship, the socio-economic conditions also impact traffic fatality rates. Studies show that developed countries have lower fatality rates, as compared to developing or under-developed countries. Traffic fatalities have also been found to increase in countries undergoing economic growth. Increases in earning capacity and higher GDP are directly related to increases in the number of vehicles on the road; which results in higher accident and fatality rates. Also, societies with high corruption levels, poor governance, and low exposure to traffic safety education have higher traffic violations and accident rates. Men and younger members of society also have a higher risk of accidents. Other factors, such as religion, personal wealth, and cultural values, correlate with traffic fatality rates.

F) System Operation and Management

1. De Winne (2005) developed a road safety management plan in Europe, aka Flanders Integrated Mobility Management Plan for taking precautions against traffic fatalities. It

was developed to increase traffic safety by using an integrated approach targeting the short and long term strategies, technological evolutions, traffic education, speed control measurements, influence by traffic lights, and the problem of black spots.

2. Garcia et al. (2006) carried out a research project to measure the impact of construction activities on rural interstate highways. The study found that construction activities lead to issues ranging from queuing to fatal accidents involving road users and construction workers. The research dealt with the use of GPS systems in analyzing the impact of construction work on traffic conditions.
3. Traffic control and guidance systems are critical in smooth traffic flow and safety. They become even more critical during emergency and evacuation situations. Zhang et al. (2007) proposed mixed integer nonlinear programming models (MINLP) that can be used to identify crucial intersections, maintain optimal traffic flow, best evacuation destination choices, and perform at a minimal cost. Numerical tests have shown that the proposed models perform reasonably well.
4. As indicated in different traffic-related studies, one of the major traffic violations is speeding. Speeding is an outcome of driver behavior and perception of safe driving speed by different drivers. There is a tendency to speed in certain locations and sections of the highway as well as farm roads. This was conclusively found in the studies conducted by Sun (2010) on the effectiveness of nighttime driving and posted speed limits. It was found that car drivers tend to speed on highways whereas truck drivers tend to speed on farm roads. This study is of interest to law enforcement agencies in identifying road sections requiring added surveillance.

5. The paper published by Jiang et al. (2012) titled, "Planning and Management to Prevent and Cure Traffic Accidents," explores the application of planning and management in improving bicycle traffic safety. Although this may be directly applicable in China, the implications are limited in the context of the United States where the use of electric two-wheelers is limited. However, the paper does emphasize the role of planning and management, which can be universally understood and implemented in reducing traffic accidents.

   SUMMARY: Traffic system operations and management are critical for traffic control and monitoring. They play a major role in planning and implementing safe practices aimed at ensuring smooth traffic flow and reducing issues ranging from queuing to fatal accidents. This includes a wide array of basic elements, such as traffic lights, road signs, speed limits, street lights, road markings, and toll booths, as well as more complicated management and operations issues, such as traffic detectors, lane closures, road construction, and infrastructure improvements. It is necessary for traffic planners and operators to be able to identify congestion and high-risk zones so that they can plan and design traffic systems targeted at mitigating associated risks. Extensive research and planning of traffic systems, including the integration of advanced technology within the system, can play an important role in traffic safety.

G) Vehicle Safety Advancements

1. A breakdown in communications between traffic control devices and drivers often leads to crashes at highway-railroad grade crossings. Noyce et al. (1998) in their study of such accidents proposed that enhanced systems, such as vehicle-activated strobe lights and

supplemental signs, can be used to reduce accidents at such intersections. The advanced systems appear to be useful in increasing awareness and caution by drivers.

2. Air-bags and seatbelts are the most common and effective safety features used in cars, however, not a lot of studies focus on correlating the use of these devices with facial injuries. This is important because head and facial injuries are serious and more often lead to fatalities. Murphy et al. (2000) did a study of accident data from the Pennsylvania Trauma Outcome Study Database and found that use of these devices, either individually or in combination, decreased the incidence of facial fractures and lacerations in motor accidents.
3. Although seatbelts and airbags have saved numerous lives and injuries to vehicle occupants, occasionally they have also resulted in injuries and even deaths. In order to address this issue, NHTSA made policy changes and introduced new advanced airbag rules for all vehicles sold in the United States. Anishetty and Little (2001) in their study reviewed such technologies and proposed new regulations and strategies to enhance occupant protection.
4. Sances et al. (2003) in their study of laminated side door windows and sunroofs during rollover scenarios found that such laminations were unlikely factors contributing to head and neck injuries. In fact, such laminations contain the driver and passengers within the vehicle hence avoiding serious injuries.
5. Intelligent transport systems (ITS), such as driver assistance and traveler information systems, have the potential of improving road safety and addressing specific causes of accidents. Spyropoulou et al. (2003) investigated such ITS systems and suggested that

these solutions are useful but can also lead to over-reliance by users. Behavioral adaptation risk, acceptability, and implementation of such systems can be challenging to drivers.

6. Wang et al. (2003) suggested that safety warning systems using high precision digital road maps and vehicle status sensory techniques can be used to improve road safety without having to add or improve road infrastructure. The systems warns drivers in advance and enable them to avoid accidents.
7. With the increasing number of car ownership, environmental, and resource problems will soon force manufacturers to make changes in the design, methods, materials, and technology of future cars. Honnery (2004) suggested that safety and technology will be key to the next generation of cars.
8. Braitman et al. (2007) in their study of changes in vehicle type and fatality rates found that the use of sport utility vehicles (SUVs) has increased over the last couple of decades but fatality rates have declined. This trend can most likely be attributable to advanced safety features, higher vehicle weight, and a reduction in alcohol-impaired driving. Although the effects are encouraging, the same may not be true in two-vehicle collision scenarios where the occupants of other cars are at higher risks of injury.
9. Fujiwara and Suto (2008) in their study of traffic fatalities in Japan found that the introduction of countermeasures reduced fatalities but distracted driving, and failure to follow warning systems continued to be a major cause of traffic accidents. Their study and subsequent recommendations found human errors, improper driving habits, and failure to confirm to warning information system as causes of traffic accidents.
10. Oh et al. (2008) used data analysis and simulation experiments to demonstrate that active hood lift systems (AHLS) prevent fatal injuries in pedestrian-vehicle collisions. AHLS

work by absorbing the impact energy by lifting the hood and preventing pedestrians heads from hitting the hood. Although this system focuses on a particular type of accident, the methodology used to quantify safety benefits can be used in evaluating other technologies as well as establishing safety policies.

11. Allen et al. (2009) in their study proposed that advanced driver assistance systems can be used to warn drivers of unintended lane departures and prevent accidents. A combination of navigation, detection, and ranging systems can be used as standard features in vehicles to enhance vehicle navigation and safety. Although promising, these systems face challenges in terms of lane mapping, surveying limitations, and instrument precision.
12. Bohman et al. (2011) carried out in-depth study of accidents where a rear-seated, belt-restrained child suffered head injuries. The analysis revealed that seatback contact and side-interior contact were two major reasons for head injuries. The study provides insight into the types and patterns of injuries which can be used to improve vehicle and device designs.
13. Seatbelts are an integral part of contemporary vehicle designs and standards. But they are as effective as their use and design. Chen and Zhang (2011) in their study of vehicle models, seatbelts, and occupants using PC-Crash software indicated a strong link between the use of seatbelts and occupant injury severity. Even though seatbelts cannot directly contribute towards reduction in accidents and collisions, they (and similar safety apparatus) can substantially mitigate injury severity and reduce fatalities.
14. Accidents in urban areas involving vulnerable road users (VRAs) are often attributed to a driver's failure to observe VRUs, reduced visibility, and awareness. Habibovic et al. (2011) studied the potential of using advanced driver assistance systems (ADAS) to warn drivers

in advance and prevent such accidents. The study also focused on deriving functional sensors, collision detection, and interface systems.

15. With advancements in technology, an increasing number of safety devices and features are now being installed in new vehicles. Becic et al. (2012) used similar systems in a simulated environment experiment to evaluate the effectiveness of assist systems. The experiments revealed that advanced driver assistance systems installed within the vehicle can benefit drivers and result in higher safety performance. An older driver seems to benefit more than younger drivers, hence suggesting the need for transitioning such systems to the inside of a vehicle.
16. Public transport systems are important in reducing traffic volumes and providing safety. Cafiso et al. (2012) carried out a study of crash data related to buses in the European Union and found that start inhibition, automatic doors, bus materials, and the interior of a bus are top safety features for passengers. Brake assistance and vehicle monitoring systems were also found to be effective.
17. Improvements in technology and advanced designs are key contributing factors in avoiding accidents and fatalities. Lee and Lin (2012) in their study of transit bus side crashes found that by installing side view video systems on transit buses, blind zones can be reduced by 43% to 64%. They found that such systems provided better distance/depth perception and improved lane change maneuvers. Their study was based on controlled driving tests, measurements of blind zones, and survey feedback from 28 participating drivers.
18. Ortepp et al. (2012) suggested that ADASs have played a major role in reducing traffic accidents in roads outside built-up areas in Germany. Infrastructure-based driver assistance systems are effective, but they require a high level of technical and financial inputs.

19. Westhofen et al. (2012) proposed a cooperative traffic safety system that would use transponders and cameras to predict upcoming collision risks. These systems prevent accidents by predicting collisions, providing advanced warnings and even autonomous braking maneuvers. The experimental study using real-life scenarios confirmed excellent performance and the potential of active safety systems.
20. Head-on collisions, especially involving vehicles travelling in the opposite direction of a highway, results in a high number of casualties. Driver error, alcohol and drug induced errors, and insufficient infrastructure are often the cause of drivers driving on the wrong side. Conesa et al. (2013) proposed that the exchange of information between vehicles and infrastructure nodes on the highway can be used to detect such vehicles.
21. Romo et al. (2013) in their research on factors leading to collisions in the same direction of multilane highways found that the probability of collisions is associated with vehicle attributes. They focused on analyzing collisions of passenger cars and trucks and found that drivers behave differently in these vehicles. Their study provided a better understanding of driving behavior and the implications of policies between car and truck driving.

SUMMARY: Automotive industry professionals and policy makers are increasingly focusing their efforts on safer vehicle designs and intelligent transportation systems. New vehicles are now equipped with advanced designs, navigation, detection, ranging and sensor systems. Improvements are being made to vehicle safety features such as advanced air-bags and seatbelt designs, laminated glass, crash warning, automatic braking, autonomous driving, blind spot detection, driver distraction warning etc. Apart from installing advanced systems within a vehicle, manufactures and traffic operators are also focusing on ways of improving communications between the driver and traffic systems. Intelligent transportation systems now allow vehicles to communicate with other vehicles on the road. Driver assistance, warning systems and traveler information systems are all part of the advancement in vehicle and traffic safety systems.

2.2.2. Summary of SLR Process

The SLR was performed by searching a combination of ASCE, WOS, and SD. The technical articles were extracted from these web search engines based on their relevance to the research objectives. The procedure involved reading the abstracts or entire paper if the abstracts were not clear. Once a document was obtained, it was analyzed to identify the factors contributing to traffic fatalities and then the data was entered into a designed form for each search engine and categorized into seven main factor headings; a) Road-user behavior; b) Infrastructure; c) Emergency response and trauma care advancements (EMT); d) Policy enforcements; e) Socio-economic and demographic; f) System operations and managements; and g) Vehicle safety advancement. A number of sub-factors were listed under each major factor. Several papers were reviewed during this study and 175 papers were selected and subjected to the SLR process. The selected and analyzed articles covered a quarter of a century from 1990 to 2014. In these research studies, different authors/agencies from different countries have developed models and performed different analyses on the impact of various individual factors on traffic fatalities in the countries involved. A review of the literature revealed what factors contributed to the increase or decrease in traffic fatalities. In the literature, the causes of traffic fatalities were attributed to different factors. In order to achieve the objectives the factors identified were organized into tables (Tables 2.1- 2.7). The count data for sub factors is the number of times a factor occurred in the literature. In the second step, a total of 99 sub factors were identified and ranks were assigned to the counts.

The factor with the highest count was ranked as 1, the second highest as 2 and so on. (See Table 2.8)

Table 2.1: Road User Behavior

Factors			**Road User Behavior**																
Sources/Sub factors			**Alcohol**	**Dieting**	**Cell phone**	**Speed**	**Stress**	**Music**	**Drugs**	**Road rage**	**Sleep disorders**	**Driving experience**	**Health**	**Intermittent driving record**	**Passenger feedback**	**Hit and Run**	**Deer Crash**	**Pedestrian behavior**	**Count**
		Year																	
1	Janssen.W.	1994										x							1
2	Solnick & Hemenwa.	1995														x			1
3	Christophersen & Mørland.	1997	x						x										2
4	Haikonen & Summala.	2001															x		1
5	Eric M. & Peter.	2002				x													1
6	Tay et al.	2002					x												1
7	Chang & Yeh	2006				x													1
8	Schwebel, et al.	2006							x	x									2
9	Engeland, et al.	2007																	0
10	Yin-Ming Li	2007	x			x									x				3
11	Chiron, et al.	2008					x												1
12	Young, et al.	2008		x															1
13	Hu, et al.	2009				x													1
14	Loeb & Clarke.	2009			x														1
15	Novoa, et al.	2009								x									1
16	Tay, et al.	2009														x			1
17	Wåhlberg & Dorn.	2009												x					1
18	Huang & Ma.	2010																x	1

Table 2.1: Road User Behavior (Continued)

Factors			Road User Behavior																
Sources/Sub factors			**Alcohol**	**Dieting**	**Cell phone**	**Speed**	**Stress**	**Music**	**Drugs**	**Road rage**	**Sleep disorders**	**Driving experience**	**Health**	**Intermittent driving record**	**Passenger feedback**	**Hit and Run**	**Deer Crash**	**Pedestrian behavior**	**Count**
		Year																	
19	Mao, et al.	2010										x							1
20	Brookhuis, et al.	2011	x																1
21	Eustace, et al.	2011	x						x			x							3
22	Elvik,R.	2011											x						1
23	Gjerde, et al.	2011	x						x										2
24	Xu, et al.	2011											x						1
25	Yao, et al.	2011										x							1
26	Hassan, et al.	2012										x							1
27	MacLeod, et al.	2012														x			1
28	Schwebel, et al.	2012			x			x											2
29	Callaghan, et al.	2013	x						x										2
30	Dultz, et al.	2013								x									1
31	Komada, et al.	2013									x								1
32	Lucidia, et al.	2013									x								1
33	Liu, D.	2013								x		x							2
34	Petrie, et al.	2013	x																1
35	Ren, Y.	2013										x							1
36	Wilson, et al.	2013	x																1
37	Rudin-Brown, et al.	2014										x							1
Count			8	1	2	4	2	1	5	4	2	8	2	1	1	3	1	1	

Table 2.2: Infrastructure

Factors			Infrastructure															
Sources/Sub factors			Developed transition road safety barrier system	Improvement in lane width for Arterial and Collector roads	Changes in geometric design	Street network structure	Placement of median barrier	Street pattern	Geographical variation	Road safety indicators	Safety countermeasures	Guardrails at roundabouts	Detectors for wrong direction vehicle	Congestion mitigator	Improvement in roadside hardware	Road transition	Identifying the effect of lighting conditions/weather	Count
		Year																
1	Golob & Recker	2003															x	1
2	Noland,R.B	2003		x														1
3	Noland, R.B.	2003			x													1
4	Noland & Oh	2004			x													1
5	Noland & Oh	2004			x	x												2
6	Noland & Quddus	2005												x				1
7	Donnell & Mason	2006					x											1
8	Elmarakbi, et al.	2006													x			1
9	Haynes,at al.	2007			x													1
10	Lu & Wevers	2007			x													1
11	Liu & Ye	2007			x		x								x			3
12	Jones, et al.	2008							x									1
13	Jones, et al.	2008			x			x										2
14	Jiao, et al.	2009												x				1
15	Wang, et al.	2009			x							x						2
16	Quddus, et al.	2010			x									x				2
17	Rifaat, et al.	2011						x										1
18	Chen, et al.	2013									x							1
19	Conesa, et al.	2013				x							x					2
20	Caliendo & De Guglielmo	2013														x		1
21	Gkritza, et al.	2013			x										x			2
22	Othman, et al.	2013			x													1
23	Rangel, et al.	2013								x								1

Table 2.2: Infrastructure (Continued)

Factors			Infrastructure															
Sources/Sub factors			Developed transition road safety barrier system	Improvement in lane width for Arterial and Collector roads	Changes in geometric design	Street network structure	Placement of median barrier	Street pattern	Geographical variation	Road safety indicators	Safety countermeasures	Guardrails at roundabouts	Detectors for wrong direction vehicle	Congestion mitigator	Improvement in roadside hardware	Road transition	Identifying the effect of lighting	Count
		Year																
24	Rangel, et al.	2013								x								1
25	Soltani, et al.	2013	x															1
26	Yannis, et al.	2013															x	1
27	Moeinaddini, et al.	2014				x												1
Count			1	1	1 1	3	2	2	1	2	1	1	1	3	3	1	2	

Table 2.3: Emergency response and trauma care advancements

Factors			Emergency Response and Trauma Care Advancements							
Sources/Sub factors			Intelligent Emergency Medical System in rural Area	Campaigns for helmets and seat belt	Better quality bystander first-aid by using internet compatible mobile device	Improved medical care and technology in Industrialized countries	Improvement in Trauma Management	Increase the advanced trauma care	Improvement in EMS response time	Count
		Year								
1	Vanbeeck, et al.	1991						x		1
2	Cooper, et al.	1998					x			1
3	Nathens, et al.	2000					x			1
4	Noland,R.B.	2003				x				1
5	Noland,et al.	2004				x				1
6	Ertl,L & Christ,F.	2007		x	x					2
7	McDermott, et al.	2007					x			1
8	Gonzalez, et al.	2008	x							1
9	Kleweno, et al.	2008				x				1
10	Li, et al.	2008	x							1
11	McDermott ,et al.	2010					x			1
12	Sanchez-Mangas, et al.	2010							x	1
13	Stelfox, et al.	2010					x			1
14	Gitelman, et al.	2013					x			1
15	Meng & Weng.	2013							x	1
Count			2	1	1	3	6	1	2	

Table 2.4: Policy enforcements

Factors			Laws & regulation - Policy enforcement									
Sources/Sub factors			Safety belt law	Traffic enforcement	Implication of automatic policing	Graduated driver licensing laws	Police enforcement on speed	Increase enforcement	Driving under influence/Teen Drinking	Helmet law	Teen licensing	Count
		Year										
1	Harper.J.G	1991			x							1
2	Ruhm.C.J.	1996							x			1
3	Vaa.T	1997					x					1
4	Dee.T.S	1999							x			1
5	Young & Likens.	2000							x			1
6	Koushki, et al.	2003	x									1
7	Welki & Zlatoper.	2007						x				1
8	Traynor.T.L.	2009	x	x		x			x	x		5
9	Welki & Zlatoper.	2009						x				1
10	Chang,et al.	2012							x			1
11	French, et al.	2012								x		1
12	Lyon, et al.	2012				x						1
13	Carpenter & Pressley.	2013				x						1
14	Stanojević, et al.	2013		x								1
Count			2	2	1	3	1	2	5	2	0	

Table 2.5: Socio-economics and demographics

Factors			Socio economics & demographics																				
Sources/Sub factors			Gender	Age	Corruption	Governance quality	Temporal variations	Race	Economic conditions/ development	Driving experience	GDP changes	Legal age drinking restrictions	Congestion charging	Population density in rural and urban area	Medical condition/sleep disorder	Socio cultural characteristics	School run time/peak hours	Social attitude	Land use characteristics	Education	Safety based Incentives	Pedestrian crossing	Count
		Year																					
1	Miyamoto, K.	2001																		x			1
2	Chin, A.	2002		x												x				x			3
3	Dissanayake & Lu.	2002	x	x																			2
4	Khattak, et al.	2002	x	x																			2
5	Clark & Cushing.	2004												x									1
6	Martin,et al.	2004	x	x																			2
7	Roudsari, et al.	2004	x	x																			2
8	Kopits & Cropper.	2005							x														1
9	Vereeck & Vrolix	2007																x					1
10	Melinder,K.	2007														x							1
11	Paulozzi, et al.	2007							x														1
12	Traynor,T. L.	2008							x														1
13	Germeni, et al.	2009	x	x																			2
14	Chen, G.	2010							x					x									2
15	Gaygısız, E.	2010				x																	1
16	Sichelschmidt , et al.	2010																				x	1
17	Zhao, et al.	2010										x				x		x					3

Table 2.5: Socio-economics and demographics (Continued)

Factors			Socio economics & demographics																				
Sources/Sub factors			Gender	Age	Corruption	Governance quality	Temporal variations	Race	Economic conditions/ development	Driving experience	GDP changes	Legal age drinking restrictions	Congestion charging	Population density in rural and urban area	Medical condition/sleep disorder	Socio cultural characteristics	School run time/peak hours	Social attitude	Land use characteristics	Education	Safety based Incentives	Pedestrian crossing	Count
		Year																					
18	Lovenheim, & Slemrod.	2010										x											1
19	Hilton, et al.	2011							x														1
20	Kingham, et al.	2011															x						1
21	Michael, et al.	2011 a													x								1
22	Miliaa, et al.	2011 b	x	x				x								x							4
23	Sukhai, et al.	2011					x																1
24	Sun, et al.	2011		x																			1
25	Wells & Beynon.	2011			x											x							2
26	Jones & Lucas.	2012														x							1
27	Li, et al.	2012											x										1
28	Li,et al.	2012											x										1
29	Masuri, et al.	2012		x																			1
30	Nordfjærn, et al.	2012	x	x																x			3
31	Rangel, et al.	2012																			x		1
32	Voigtmann, et al.	2012																				x	1
33	Zhou & Wang.	2012									x									x			2

Table 2.5: Socio-economics and demographics (Continued)

Factors			Socio economics & demographics																				
Sources/Sub factors			Gender	Age	Corruption	Governance quality	Temporal variations	Race	Economic conditions/ development	Driving experience	GDP changes	Legal age drinking restrictions	Congestion charging	Population density in rural and urban area	Medical condition/sleep disorder	Socio cultural characteristics	School run time/peak hours	Social attitude	Land use characteristics	Education	Safety based Incentives	Pedestrian crossing	Count
		Year																					
34	Anthikkat, et al.	2013		x																			1
35	Factor, et al.	2013														x							1
36	Grimm & Treibich.	2013	x																				1
37	McAndrews,e t al.	2013	x	x																			2
38	Sukhai, & Jones.	2013					x		x							x							3
39	Srinivas, et al.	2013																	x				1
40	Sun, et al.	2013							x														1
41	Rudin-Brown, et al.	2014								x													1
42	Santamariña-Rubio,et al.	2014	x																				1
43	Yannis,et al.	2014									x												1
Count			10	12	1	1	2	1	7	1	2	2	2	2	1	8	1	2	1	4	1	2	

Table 2.6: System operation and management

Factors			System operation and management																			
Sources/Sub factors			Budget	Vision & strategy	Evaluation & reporting	Speed cameras	Controlling signal timing for emergency vehicle	Advanced Intelligent Transportation Systems	Fatigue Detection Technology	Improvement of route segments by using GIS	Car pooling	Safety monitoring system	Integrated speed management plan in residential areas	System dynamics	Traffic police deployment system	Integrated mobility management plan	GPS up gradation showing construction work	Improvement in traffic Control system during	Speed limit on highway	Strict road Administration	Proper management & Planning for Electric Bicycler	Count
		Year																				
1	Chang & Paniati.	1990																	x			1
2	Newstead , et al.	2001													x							1
3	Murphy, et al.	2005														x						1
4	Garcia, et al.	2006															x					1
5	Liu & Ye.	2007																		x		1
6	Gomes, et al.	2008								x												1
7	Spyropou lou, et al.	2008						x														1
8	Sun, D	2010																	x			1
9	Gundogd u.I.B.	2010								x												1
10	Rojas-Rueda,et al.	2012									x											1
11	Fries, et al.	2012						x														1
12	Goh & Love et al.	2012												x								1
13	Jiang, et al.	2012																			x	1
14	Qin & Khan.	2012					x															1
15	William, et al.	2012										x										1
16	Dawson, et al.	2013							x													1
17	Tazul , et al.	2013											x									1

Table 2.6: System operation and management (Continued)

Factors			System operation and management																			
Sources/Sub factors			Budget	Vision & strategy	Evaluation & reporting	Speed cameras	Controlling signal timing for emergency vehicle	Advanced Intelligent Transportation Systems	Fatigue Detection Technology	Improvement of route segments by using GIS	Car pooling	Safety monitoring system	Integrated speed management plan in residential areas	System dynamics	Traffic police deployment system	Integrated mobility management plan	GPS up gradation showing construction work	Improvement in traffic Control system during emergency	Speed limit on highway	Strict road Administration	Proper management & Planning for Electric Bicycler	Count
		Year																				
18	Papadimitriou& Yannis.	2013	x	x	x																	3
19	Zhang, et al.	2013																x				1
20	Pauw, et al.	2014				x																1
Count			1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	1	2	1	1	

Table 2.7: Vehicle safety and advancements

Factors			Vehicle safety advancements													
Sources/Sub factors			Increase in LTV with time	Vehicle configuration, mass, components and types	Efficacy of safety policy	Advances to front row passive safety system for unrestrained rear seat passenger	Advances in active safety system	Deployment of digital vehicle technology	Advanced Driver Assistance System	Active Hood Lift System	Location centric storage based on roadway sensor networks	Advanced traveler Information systems	Warning Information Sytem	Side View Video System	Safety Belt	Count
		Year														
1	Wong & Wu.	1998			x											1
2	Murphy, et al.	2000				x										1
3	Wang, et al.	2003						x								1
4	Abdel-Aty & Abdelwahab.	2004	x													1
5	Ballesteros, et al.	2004		x												1
6	Honnery, D.	2004		x												1
7	Xing, et al.	2007									x					1
8	Fujiwara, et al.	2008											x			1
9	Nirula & Pintar.	2008		x												1
10	Oh, et al.	2008								x						1
11	Spyropoulou, et al.	2008							x			x	x			3
12	Tolouei & Titheridge.	2009		x												1
13	Bohman, et al.	2011				x										1
14	Chen, et al.	2011													x	1
15	Habibovic & Davidsson.	2012					x									1

Table 2.7: Vehicle safety and advancements (Continued)

Factors			Vehicle safety advancements													
Sources/Sub factors			Increase in LTV with time	Vehicle configuration, mass, components and types	Efficacy of safety policy	Advances to front row passive safety system for unrestrained rear seat passenger	Advances in active safety system	Deployment of digital vehicle technology	Advanced Driver Assistance System	Active Hood Lift System	Location centric storage based on roadway sensor networks	Advanced traveler Information systems	Warning Information Sytem	Side View Video System	Safety Belt	Count
		Year														
16	Lin, et al.	2012												x		1
17	Ortlepp & Bakaba.	2012							x							1
18	Bose, et al.	2013				x										1
19	Romo, et al.	2013		x												1
Count			1	5	1	3	1	1	2	1	1	1	2	1	1	

Table 2.8: Ranking of factors as per their occurrence in existing research

Factors	Count	Rank as per count	Remarks
Age	12	1	
Changes in geometric design	11	2	
Gender	10	3	
Alcohol	8	4	
Driving experience	8	4	
Socio cultural characteristics	8	4	
Economic conditions/ development	7	5	
Improvement in trauma management	6	6	
Vehicle configuration, mass, components and types	5	7	

Table 2.8: Ranking of factors as per their occurrence in existing research (Continued)

Factors	Count	Rank as per count	Remarks
DUI/teen drinking	5	7	
Drugs	5	7	
Speed	4	8	
Road rage	4	8	
Education	4	8	
Advances to front row passive safety system for unrestrained rear seat passenger	3	9	
Improved medical care and technology in industrialized countries	3	9	
Hit and run	3	9	
Street network structure	3	9	
Congestion mitigator	3	9	
Improvement in roadside hardware	3	9	
Graduated driver licensing laws	3	9	
Intelligent EMS in rural area	3	9	
Cell phone	2	10	
Safety belt law	2	10	
Traffic enforcement	2	10	
Helmet law	2	10	
Increase enforcement	2	10	
Sleep disorders	2	10	
Health	2	10	
Stress	2	10	
Temporal variations	2	10	
GDP changes	2	10	
Legal age drinking restriction	2	10	
Congestion charging	2	10	
Population density in rural and urban area	2	10	
Pedestrian crossing	2	10	
Social attitude	2	10	
Improvement in EMS response time	2	10	
Advanced driver assistance system	2	10	
Placement of median barrier	2	10	

Table 2.8: Ranking of factors as per their occurrence in existing research (Continued)

Factors	Count	Rank as per count	Remarks
Identifying the effect of lighting conditions/weather	2	10	
Road safety indicators	2	10	
Advanced intelligent transportation systems	2	10	
Improvement of route segments by using GIS	2	10	
Speed limit on highway	2	10	
Music	1	11	
Intermittent driving record	1	11	
Passenger feedback	1	11	
Dieting	1	11	
Deer crash	1	11	
Pedestrian behavior	1	11	
Medical condition/sleep disorder	1	11	
School run time/peak hours	1	11	
Land use characteristics	1	11	
Corruption	1	11	
Governance quality	1	11	
Safety-based incentives	1	11	
Race	1	11	
Driving experience	1	11	
Geographical variation	1	11	
Safety countermeasures	1	11	
Guardrails at roundabouts	1	11	
Detectors for wrong direction vehicle	1	11	
Developed transition road safety barrier system	1	**11**	
Improvement in lane width for arterial and collector roads	1	11	
Road transition	1	11	
Active hood lift system	1	11	
Location centric storage based on roadway sensor networks	1	11	
Advanced traveler information systems	1	11	
Deployment of digital vehicle technology	1	11	

Table 2.8: Ranking of factors as per their occurrence in existing research (Continued)

Factors	Count	Rank as per count	Remarks
Efficacy of safety policy	1	11	
Increase in LTV with time	1	11	
Side view video system	1	11	
Safety Belt	1	11	
Campaigns for helmets and seatbelt	1	11	
Better quality bystander first-aid by using internet compatible mobile device	1	11	
Increase the advanced trauma care	1	11	
Budget	1	**11**	
Vision & strategy	1	11	
Evaluation & reporting	1	11	
Speed cameras	1	11	
Warning information system	1	11	
Controlling signal timing for emergency vehicle	1	11	
Fatigue detection technology	1	11	
Carpooling	1	11	
Safety monitoring system	1	11	
Integrated speed management plan in residential areas	1	11	
System dynamics	1	11	
Traffic police deployment system	1	11	
Integrated mobility management plan	1	11	
GPS up gradation showing construction work	1	11	
Improvement in traffic control system during emergency evacuation	1	11	
Strict road administration	1	11	
Proper management & planning for electric bicycler	1	11	
Police enforcement on speed	1	11	
Implication of automatic policing	1	11	

Results obtained from the tables show that the highest number of publications was published by SD journals with a total count of 86, followed by WOS and ASCE with the count of

58 and 31 respectively. Table 2.9 and Fig 2.2 represent the number of research contributions as part of the literature, according to the publication type.

Table 2.9: Number of publications from the three database

	Web Search Engine	**Number of Research**
1	ASCE	31
2	SD	86
3	WOS	58
	Total	**175**

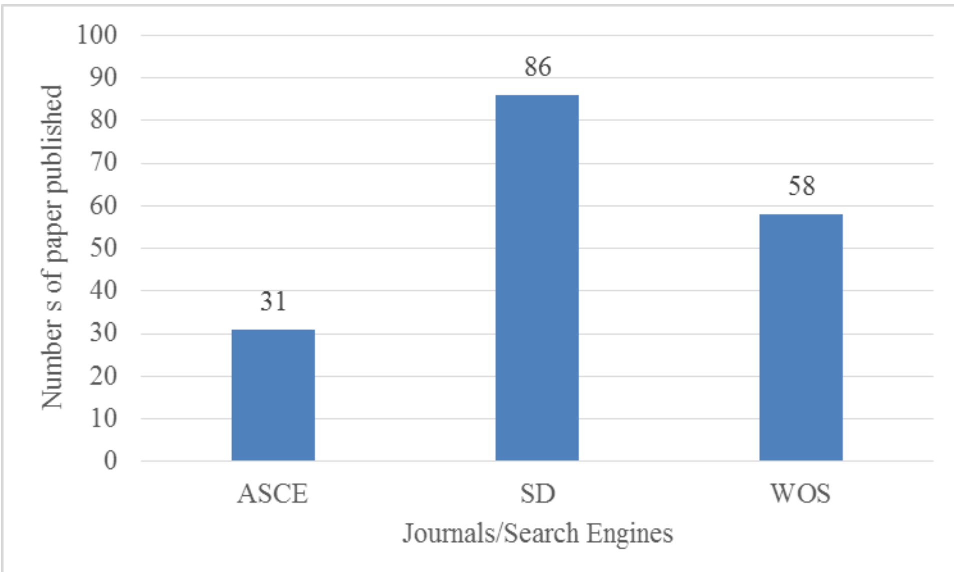

Fig 2.2: Number of papers published vs databases/repositories

Further analysis was performed to illustrate the increase in publications over the last two and a half decades. The distribution of the reviewed papers by publication year shows that there were only four papers published from 1990 to 1994, 10 papers in 1995 to 1999, 23 papers in 2000 to 2004, 46 papers in 2005 to 2009 and 92 papers in 2010 to 2014. The distribution of papers published over time is reflective of the growing concerns over traffic safety, and subsequent efforts by various researchers and professionals to document the factors contributing to traffic fatalities. It is an indication of heightened awareness, in both public and private sectors, towards traffic fatalities and the growing need to formulate effective solutions and policies to reach the goal of zero fatalities. Table 2.10 and Fig 2.3 depict the increase in number of publications over a quarter of century (1990–2014).

Table 2.10: Number of papers published over the years (1990–2014):

Years	Number of papers published
1990-1994	4
1995-1999	10
2000-2004	23
2005-2009	46
2010-2014	92

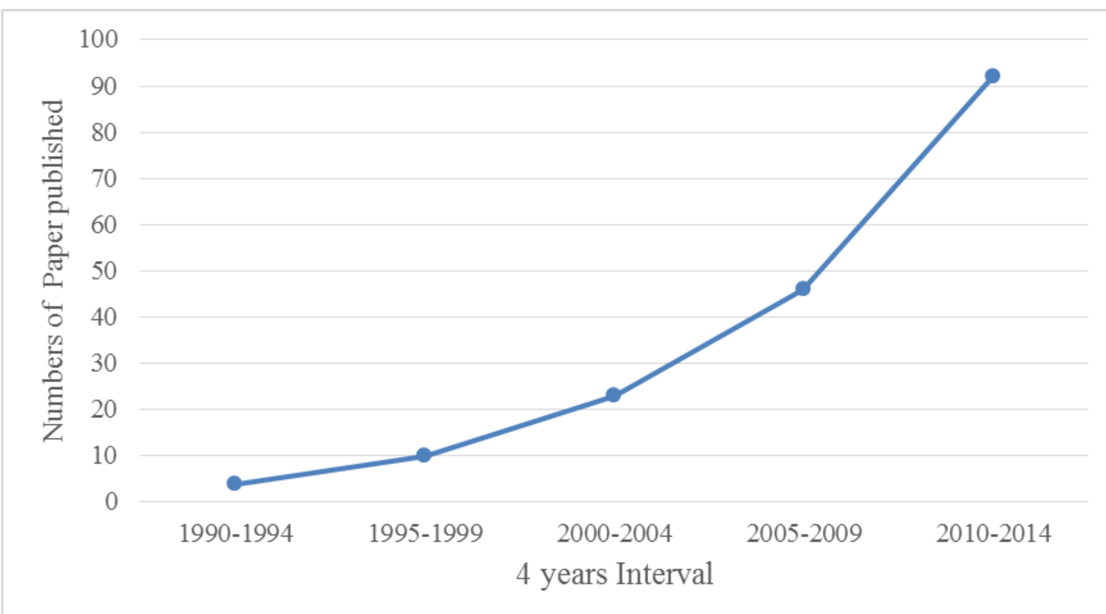

Fig 2.3: Number of publications over a quarter of century (1990–2014)

2.2.3. Analysis of Individual Factors

As mentioned in Tables 2.1 to 2.7, the factors were identified by conducting a search in the three major databases. A total of 175 papers were identified which has been published on the factors contributed to the traffic fatalities, road accidents, road safety and others, out of which the sub factors have been discussed in total of 221 times and then tabulated as shown in Table 2.11. The significance of a factor is dependent on the number of times the factor occurred in the literature. The percentage distribution of sub factors by publications count has shown in Fig 2.4. The socio-economic and demographics had the highest level of influence. The research shows that a number of research studies have been performed on socio economic and demographics and road-user behavior factors. However other factors like emergency response and trauma care advancements and policy reinforcements have not been given the same attention. (See Table 2.11 and Fig 2.4)

Table 2.11: Factors Classification of occurrence in literature review

Factors/Sub factors	**No of Papers**	**%**
Road User Behavior	46	20.81
Infrastructure	35	15.84
Socio Economic and Demographics	63	28.51
Vehicle Safety Advancements	20	9.05
Emergency Response and Trauma Care Advancements	17	7.69
System Operations and Managements	22	9.95
Policy Enforcements	18	8.14
Total	**221**	**100.00**

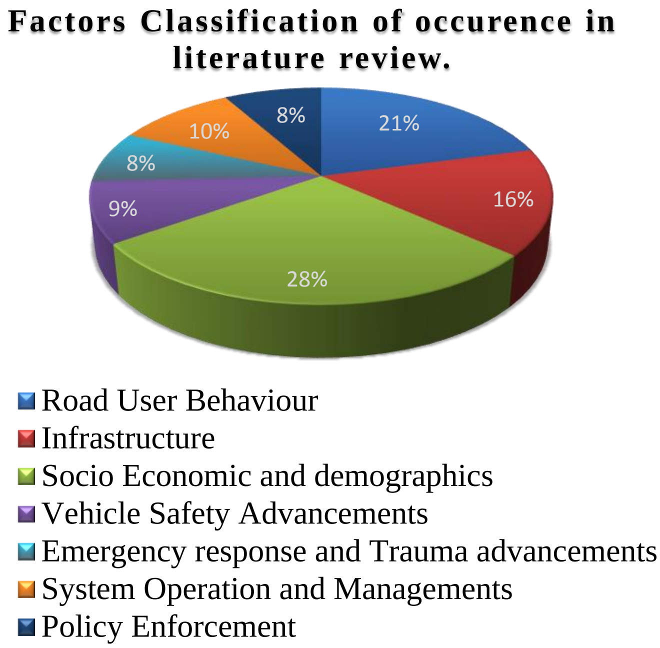

Fig 2.4: Percentage distribution of the sub factors by publications count

2.2.4. Discussion

There has been considerable research conducted over the past twenty-five years focused on traffic fatalities. From the literature survey, it can be deduced that socio-economic and demographics factor were considered to be the most prevalent factors; followed by road-user behavior and then infrastructure (Table 2.11 and Fig 2.4).

Upon comparing the different factors, it can be concluded that SD had the highest literature review for the road user behavior, system operation and managements and vehicle safety advancements when compared to WOS and ASCE. WOS has the highest literature review on infrastructure, ER and trauma care advancements and policy enforcements as compared to SD and ASCE. It has discovered that there have not been enough publications on policy enforcements in ASCE. The same is true or vehicle safety advancements. Table 2.12 and Fig 2.5 show the data collected on all factors from all search engines.

Table 2.12: Types and number of factors by different research facets

Factors	WOS	SD	ASCE
Road User Behaviors	8	25	13
Infrastructure	13	11	11
ER & Trauma care advancements	11	6	0
Policy Enforcements	0	18	0
Socio-Economics & Demographics	28	24	11
System Operations and Managements	5	13	4
Vehicle safety advancements	9	7	4
Total	**74**	**104**	**43**

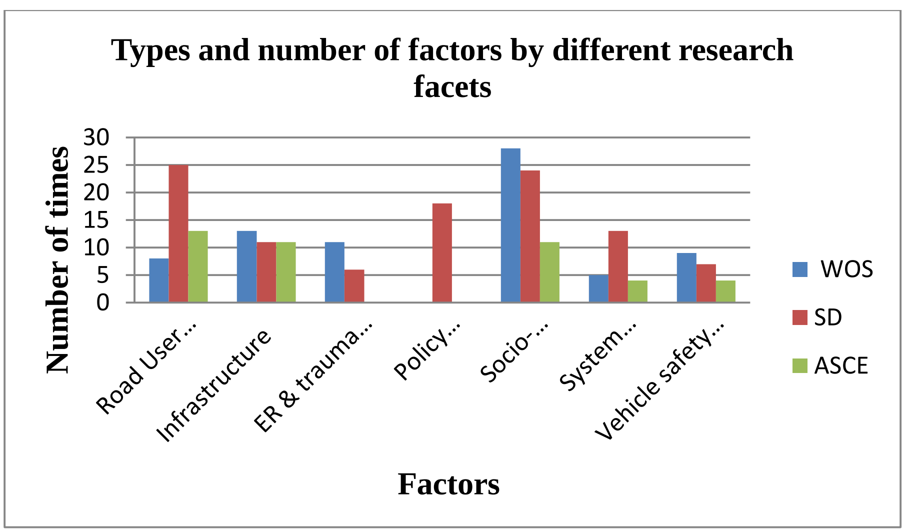

Fig 2.5: Types and number of factors by different research facets

Along with the data collection on existing research, it can be concluded from Table 2.13 and Fig 2.6 that more research has been focused on traffic fatalities in Science direct over the years and it has been significantly increased in recent years as compared to WOS and ASCE. Initially, 1990-1994 had the same amount of literature review due to the low effect and less safety awareness. But as the year's passed, traffic fatalities started getting more attention and were ultimately developed into the goal of zero fatalities.

Table 2.13: Number of papers published from the different databases over the years

Years of Paper Publication	**ASCE**	**WOS**	**SD**
1990-1994	1	2	1
1995-1999	0	1	6
2000-2004	5	10	11
2005-2009	6	17	23
2010-2014	19	28	45
Total	**31**	**58**	**86**

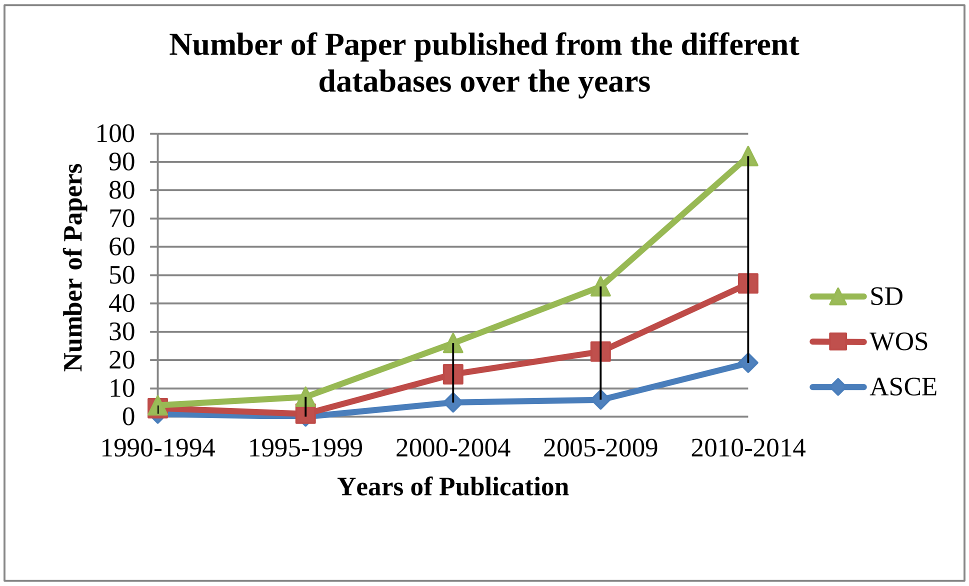

Fig 2.6: Number of papers published from the different databases over the years

2.2.5. Statistical Validity of the Factors

From the literature review, a total of 99 factors were identified. These factors were mentioned in Table 2.1- 2.7. In Table 2.8, each factor was ranked as per the number of times it occurred in the literature from the databases. From the results, it was apparent that “age” has been researched the most (12 times) in previous studies. This shows the importance of the “age” factor. Thus, it was ranked as the first factor. A total of 31 factors were ranked as the least criterion. In order to design a good questionnaire statistical analysis was conducted to investigate the mean, standard deviation, kurtosis, skewness, histogram, and normality plots of the factors. A histogram plot is a graph showing the distribution of the data. The basic descriptive statistics and the Anderson-Darling statistic test were performed on the factors identified and mentioned in Table 2.1- 2.7 by using the Minitab Program 16.

2.2.6. Descriptive Statistics

Minitab 16 was used to analyze and rank as per the occurrence of the factors (Table 2.1.1-2.1.7.). The Minitab 16 was used to analyze as presented in Table 2.8. The mean for all the factors is 2.255, the standard deviation is 2.240, the kurtosis of 683 and skewness is 2.59 (which is closest to 3).The basic descriptive statistics shows that the factors have a high level of skewness at 2.59 and standard deviation at 2.240, which means that the distribution pattern of factors is positively skewed and indicate the greater variability of the factors that contributes to traffic fatalities. A histogram plot showing the factors that contributed to an increase or decrease of traffic fatalities is shown in Fig 2.7. This figure also shows it is positively skewed. A histogram is basically a pictorial way of showing the distribution of the data points.

Table 2.14: Descriptive statistics

Mean	2.255		Kurtosis	6.83
Standard Error	0.226		Skewness	2.59
Median	1		Range	11
Mode	1		Minimum	1
Standard Deviation	2.240		Maximum	12

2.2.7. Histogram of Count Data

Using the frequency and count data of factors reviewed in literature.

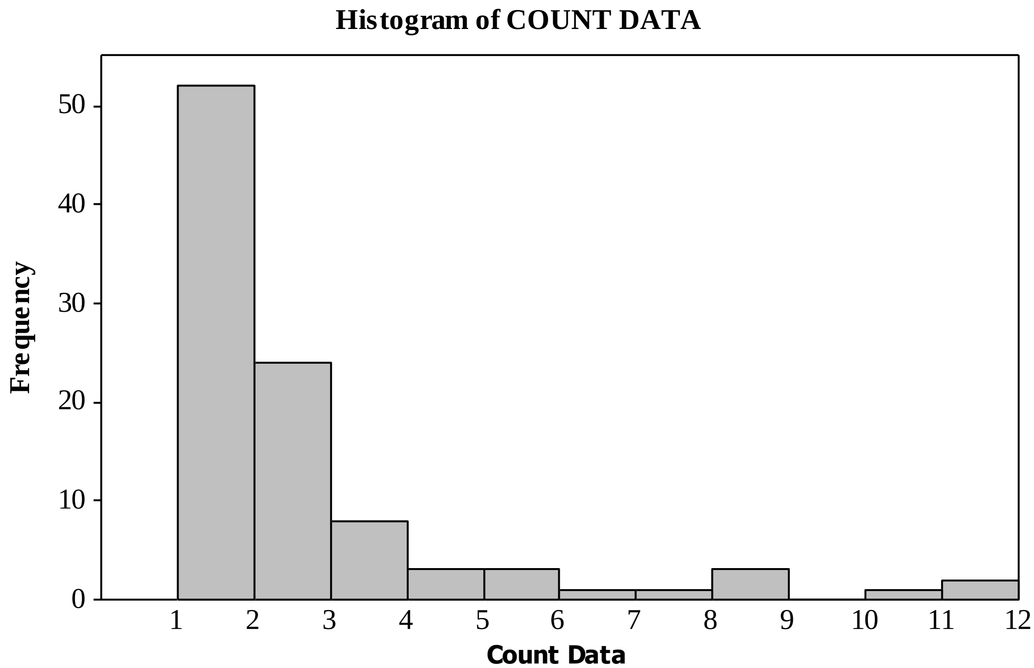

Fig 2.7: Histogram of count data

2.2.8. Normal Probability Plot

Generally, it is always presumed that data is normally distributed. In this case, normality is examined by plotting the data, checking for kurtosis (how sharp the peak is), or skewness (if more than half of the data is on one side of the peak) or calculating the Anderson-Darling (AD) statistic test using Minitab 16. The hypotheses for the Anderson-Darling test are H_0= the data follow a normal distribution and H_a =the data do not follow a normal distribution. The AD test was performed at the 95% confidence level and the ṗ-value was less that of the chosen α- level of 5%. Results from the AD test show that the factors have a high AD value of 13.878; therefore, the null hypothesis is rejected. It can be concluded that the data is not normally distributed. From the normality probability plot shown in Figure 2.8, the N value is more than 40, which indicates that it does not fall into the normal distribution.

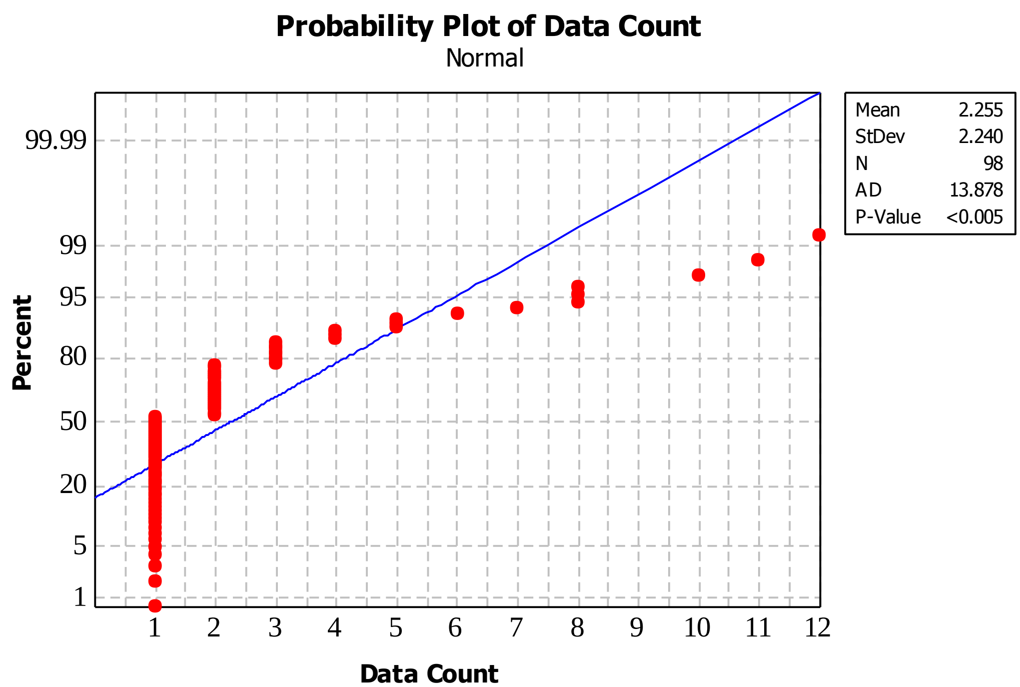

Fig 2.8: Probability plot

2.3. Summary of Literature Review

The frequencies/rates of traffic accidents and casualties have been increasing in recent years, particularly in terms of fatalities (killed) and serious injuries. In the above literature review, data was collected from different resources. The analysis of the data was performed to identify the factors contributing to traffic fatalities. The factors identified were road user behavior, infrastructure, emergency response & trauma care advancements, policy enforcements, socio-economic and demographics, system operation and managements, and vehicle safety advancements. Based on the comparison and analysis, it could be concluded that the more research needs to be done on socio-economic and demographics followed by road-user behavior.

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter provides the overall information about the research methodology used in this thesis. This thesis is aimed at identifying the factors that have directly or indirectly contributed to the reduction of traffic fatalities in the US in recent years. The methodology adopted to identify the factors of this thesis is listed as follows:

- A thorough literature review was performed and a number of factors that have contributed to the increase or decrease of traffic fatalities was identified. A total of 99 factors were identified, out of which 93 factors were finalized to be used in developing the survey questionnaire.
- A research questionnaire was designed and pilot tested. The final survey was then sent to IRB review and approval.
- The approved research survey was sent to all the DOT's in the US, including Puerto Rico, through emails and ordinary mails. A total of 50 surveys were sent.
- Data collection was done and then assessment of feedback from questionnaire survey was made. The survey results were coded and analyzed. Both qualitative and quantitative methods were used.
- The Likert scale was used during the analysis. The relative importance index (RII) was used for calculating the weight of each factor. The analysis is discussed in details in Chapter 4 on the basis of which conclusions and recommendations were drawn. The results of analysis is shown in Chapter 4, Table 4.10.The entire research approach has been summarized as shown in Fig 3.1 below:

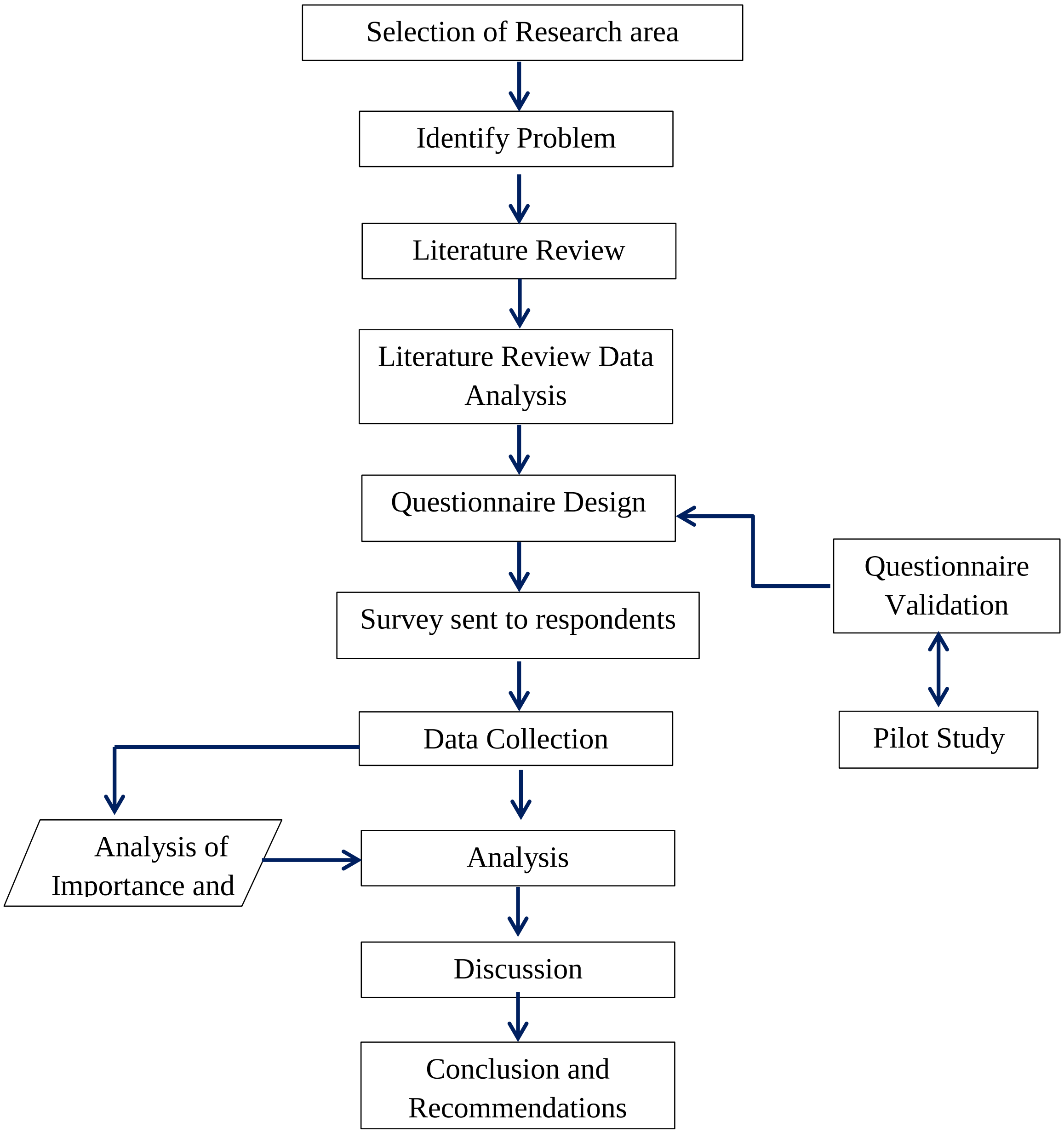

Fig 3.1: Research methodology flow chart

3.2. Research Approach

To achieve the objectives described, a research framework was developed to conduct the research. Firstly, the research problem was identified and objectives were developed. This was followed by a comprehensive literature review related to traffic safety, traffic fatalities, etc.

A systematic literature review was selected because it is one of the most widely used methodology in research as it tries to answer a research question by synthesizing quality data and evidence from published work. It is a systematic, empirical and scientific method accepted in all the fields including medical, healthcare, construction, industrial, electrical, international development and particularly for research students and others new to a discipline wherein previous researches can be leveraged to better understand and answer the question under research. This method is objective and transparent, and highly effective in the fields related to safety, strategy and policy making, including traffic safety. Traffic safety requires qualitative as well as quantitative analysis, for which systematic literature review is very suitable.

Through the systematic literature review and analysis, a total of 99 factors were compiled. These factors were organized into seven main categories as shown in Chapter 2. The factors were used to develop the research questionnaire. Then, the questionnaire was validated during the process of pilot study. Based on the comments and corrections, the questionnaire was modified. Then after accommodating all the corrections, a total of 93 factors were finalized for the questionnaire. The questionnaire was then sent to the IRB for review. Upon receipt of IRB approval, the survey was sent to the participants.

3.3. Survey Planning

The survey method was chosen to determine the factors contributing to the reduction of traffic fatalities in the US. The survey was designed using ordered categorical data and a Likert categorical scale to measure respondent's answers about the important factors consistent with previous research findings. The target respondents were selected as per the number of DOTs (Department of Transportation) in the United States. The United States has 50 states and 50 DOTs respectively, and respondents were selected on basis of the number of DOT's in the country. The research survey was sent to all the DOTs via email and the United States Postal Service mail. The purpose and approach used in the survey were fully explained to the respondents in the cover letter attached to the questionnaire. Guidelines were provided to the respondents in the cover letter to ensure that the procedure was followed properly to reduce errors. During the survey period, some oversights were provided to help ensure the process was consistent. The objective of the survey was to ascertain the opinion of the DOTs on the subject matter of the research.

3.4. Questionnaire Design and Its Content

The questionnaire design took into consideration the objectives of the study with the aim of answering the research questions. Special care was taken to phrase the questions in a language that was easily understood by the respondents. Through the literature review analysis, a total of 99 factors were compiled that were categorized further into seven major groups, namely road-user behaviors, infrastructure, emergency response and trauma care advancements, policy enforcements, socio-economic and demographics, system operations and management and vehicle safety advancements. These factors were listed in Chapter 2. These factors were analyzed and added to the questionnaire. It was tested and a total of 93 factors were selected for the final questionnaire. Along with the factors, some general questions, such as which agency and how many years of experience, were added to the questionnaire to obtain more information from the respondents. The questionnaire had to be simple, clear and understandable to respondents and at the same time they needed to be able to be interpreted well by the researchers. These questions helped in analyzing the survey results. Once the draft was finalized, it was sent to the IRB. After the final copy was approved by the IRB, it was sent to the target participants. The respondents were asked to indicate their level of preference from very low to very high. A sample of the IRB form and survey questionnaire is attached in APPENDICES A and B. The survey was used to investigate the respondents experience and attitudes towards the factors contributing to the reduction of traffic fatalities. The respondents were asked to state the impact of each factor in reducing traffic fatalities from their experience. The most impacted was stated as “very high” and the least impacted was stated as “very low” and no impact was stated as “not significant,” which means it does not contribute into reducing traffic fatalities. The respondents were asked to add any other factors that they think could be major reasons for reducing the traffic fatalities as “the other.”

3.5. Data Collection

The questionnaires were mailed and emailed to the respondents and were requested to be mailed back, emailed, or faxed. Over a period of two months, out of 50 participants, 9 (24%) responded. Table 3.1 shows the number of the survey responses received. The data was coded and analyzed. The scaling method was used as an alternative to asking questions by using simultaneously a number of observations on each respondent (Hannagan, 1986). The Likert scale of 1 to 6 was used to measure the respondent’s answers to the questions and convert the data from qualitative to quantitative. Although there are many forms of scaling, the Likert scale was adopted because it is the most commonly used (Bernard, 2000), simple to construct, permits the use of latent attitudes, and is likely to produce a highly reliable scale (Baker, 1997). When the Likert categorical scale is used for scoring, the category scale 6 is assigned to very high, 2 is assigned to very low and 1 is assigned to not significant respectively.

Table 3.1: Number of respondents and their positions held

Position of respondents	Organization	No of participants	No of respondents
Safety Engineer	State Department Agency (DOT's)	50	9 (18%)

3.6. Method of Evaluation/Data Analysis

The relative importance index (RII) method would be used to determine the relative importance of each factor affecting traffic fatalities. This method was selected because it calculates the weighted average of the participant's opinions and it depends on the different ranks given to the particular factors that contributed to the traffic fatalities. Based on the weights given to each factor, the importance index can be derived. The importance index is one of the major indicators (techniques) in technology foresight of surveys in Japan, Germany, Korea, China and other countries (Cheng 2002). This is used to assess or evaluate the relative importance among the items. For instance, Cheng (2002) used the importance index for ranking the 100 top research topics in various fields.

In relevant literature, there are many formulas for calculating importance index, such as in Kadir et al. (2005), Johnson and Le Breton (2004), Cheng (2002), and Lim and Alum (1995). For this evaluation, the importance index was derived for each factor by using a formula that is based on the work of Lim and Alum (1995). Many researchers have applied the formula in their research projects in particular in project management fields such as Alinaitwe et al. (2007) and Kadir et al. (2005).

The formula of the relative importance index that has been suggested in Lim and Alum (1995) is expressed as %:

$$Relative\ Importance\ Index\ (RII) = \frac{1(n1)+2(n2)+\cdots+6(n6)}{6(n1+n2+\cdots+n6)} * 100\ \%$$

Whereas,

n1 = number of respondents who answered “not significant”

n2 = number of respondents who answered “very low”

n3 = number of respondents who answered “low”

n4 = number of respondents who answered “moderate”

n5= number of respondents who answered “high”

n6 = number of respondents who answered “very high”

The relative importance index (RII) for this analysis is calculated by using the above formula. For this purpose, values of scores are ranked either very high, high, moderate, low, very low or not significant. The arrangement is done according to the compatibility of the number of n. The number of n is referred to the number of answers (factors) which have been provided by the respondents to the questionnaire. The difference is in the way of the respondents ranked their answers. As mentioned above, the respondents were asked to rank the selected factors by their priority in terms of very high, high, moderate, low, very low and not significant. Thus, in order to adopt the formula, the values of scores were coded into the six importance levels similar to the formula. In this case, a factor that has the highest score is assigned as very high, followed by the factor which has the second highest score is assigned as high. The factors which have the third highest and below are assigned into three importance levels: moderate, low, very low, or not significant.

The RII values ranged from 0 to 100%. The magnitudes/values of the percentage depicts the importance of the factor. As the RII increases the requirement for the factor to be considered in reducing traffic fatalities increases and become important. The RII values are then used to determine the rank for each factor contributing to the reduction in traffic fatalities.

3.7. Summary

The purpose of this chapter was to describe the research methodology employed in this study, explaining the sample selection, describing the procedure used in designing the questionnaire and collecting the data and providing an explanation of the statistical procedures used to analyze the data. The analysis, discussion, conclusion and further recommendations for future in detail are discussed in Chapter 4: Data Analysis and Discussion and Chapter 5: Conclusion and Recommendations.

CHAPTER 4. DATA COLLECTION, ANALYSIS, AND DISCUSSION

4.1. Introduction

In order to achieve the objectives of the study, one of the most important phases is collection, coding, and the analysis of survey data. Data collection is a procedure of obtaining crucial data records for a certain sample or population of observations (Bohrnstedt and Knoke, 1994). This research facilitates a discussion of the results of the survey described in Chapter 3. The total responses out of 50 were 9, which is 18%. Table 4.1 and 4.2 show the number of replies received from the DOTs and the years of experience of the respondents. The analysis was intended to provide an understanding of the research outcomes.

Table 4.1: Number of respondents and their position held

Position of respondents	Organization	No of participants	No of respondents
Safety Engineer	State Department Agency (DOT's)	50	9 (18%)

Table 4.2: Years of experience for respondents in their organizations

Years of Experience	Number of responses	Percentage of responses (%)
1–5 years	1	11.11
6–10 years	4	44.44
11–15 years	1	11.11
15–20 years	1	11.11
20–25 years	2	22.23

4.2. Individual Factor Analysis

As discussed in Chapter 3, the literature review resulted in discovering 93 factors that might contributed indirectly/directly to the reduction in traffic fatalities in the United States. These factors were classified into seven major groups namely road user behavior, infrastructure, emergency response and trauma care advancements, policy enforcements, socio-economic and demographics, system operation and managements, and vehicle safety advancements. The RII for the different groups was calculated and discussed in detail in this study.

4.2.1. Road-user Behavior

There were 16 sub factors identified under the road user behavior category. Table 4.3 shows the ranking of these factors according to their RIIs. Alcohol was ranked first in the road user group with an RII value of 48.15% and ranked eighth among all of the 93 factors that affect traffic fatalities (Table 4.10). Alcohol ranked the highest in terms of RII followed by driving experience, pedestrian behavior and driving speed. Driving record and passenger feedback was ranked last in RII rankings.

Table 4.3: Road-user behavior group ranking

ID	FACTOR	RII	RANKING
1	Alcohol	48.15%	1
2	Speed	46.30%	2
3	Driving experience	44.44%	3
4	Pedestrian behavior	44.44%	3
5	Drugs	37.04%	4
6	Cell phone	35.19%	5
7	Road rage	33.33%	6
8	Eating/drinking while driving	29.63%	7
9	Hit and run	27.78%	8
10	Stress	25.93%	9
11	Music (Distraction)	25.93%	9
12	Collision with deer	25.93%	9
13	Sleep disorders	24.07%	10
14	Health conditions	24.07%	10
15	Intermittent driving record	14.81%	11
16	Passenger feedback	14.81%	11

As per the National Council on Alcoholism and Drug Dependence, Inc (NCADD), 32% of traffic fatalities involve a drunk driver or pedestrian, resulting in about 13,000 deaths per year. However, this trend was reduced by 48.5% from 1982 (26,172 deaths) to 2006 (13,470 deaths) due to law enforcement, public awareness, and treatment/recovery (National Council on Alcoholism and Drug Dependence (2006).

Driving speed with a RII of 46.30% is ranked second among road-user behavior factors (Table 4.3) and ninth among all the factors (Table 4.10). Driving over the legal limits and/or at high speeds results in reduced vehicle control, lesser reaction times, and increased impact force. As per the National Safety Council, it is the third highest reason for traffic fatalities resulting in economic losses of $40 billion annually. Auto enforcements and high-visibility enforcements have been found to reduce speeding violations. Media, education, and awareness programs have also been found to be effective.

Driving experience and pedestrian behavior were both ranked third among the road-user behavior factors with RIIs of 44.44% each (Table 4.3). Both rank tenth in the overall RII ranking for all the factors (Table 4.10). As per the Centers for Disease Control and Prevention fact sheet, teenagers and new drivers account for 30% of fatal accidents and cause $19 billion in economic losses. Research suggests that the most comprehensive graduated drivers licensing (GDL) programs are associated with reductions of 38% and 40% in fatal and injury crashes, respectively.

As per CDC, in 2010, 4280 pedestrians were killed in traffic crashes in the United States, and another 70,000 pedestrians were injured. Education and awareness programs, strict law enforcement, infrastructure, visible and sufficient signs, and effective road designs have been found to reduce pedestrian fatalities and injuries.

Drug use ranked fourth in RII ranking for road-user behavior (Table 4.3) and 13th among all other factors (Table 4.10). An NHTSA study found that in 2009, 18 % of fatally injured drivers tested positive for at least one illicit, prescription, or over-the-counter drug. Prevention programs, parental monitoring, drug and substance abuse education, public awareness, and law enforcement are all important in reducing drug and substance abuse related traffic fatalities.

Use of cellphones is increasingly becoming one of the major reasons for traffic accidents and fatalities. As per the survey, cellphone use was ranked fifth under the road-user behavior category (Table 4.3) and 14th in the overall RII ranking (Table 4.10). Cellphone use leads to distracted driving, which is risky behavior in both low speed and high speed driving. The National Safety Council (2010, Jan 12) estimates that about 1.6 million crashes (28% of all crashes) can be contributed to distractions caused by cellphone use while driving. Law enforcement against cellphone use and public awareness can help reduce the fatalities related to cellphone and other hand-held devices.

Road rage ranks sixth among the road user behavior factors (Table 4.3) and 15th among all the factors (Table 4.10). The RII index for road rage is 33.33%. As per the US Highway Safety Office, tens of thousands of accidents occur every year due to road rage related incidents. Road rage related incidents can be reduced by public awareness of effects of emotions on driving and law enforcement.

Similar to cellphone use, eating and drinking also cause driving distractions and subsequent accidents. Eating and drinking with a RII of 29.63% was ranked seventh among the road user ranking (Table 4.3) and 17th in the overall RII ranking (Table 4.10). Some research has shown that eating and/or drinking is even more dangerous than using a cellphone while driving. A study done by the National Highway Traffic Safety Administration (NHTSA) concluded that those who eat and drive increase the odds of an accident by 80%. They also concluded that 65% of near miss accidents are caused by distracted drivers fussing with food and drinks. Although it is not illegal to eat or drink while driving, laws similar to cellphone use can be helpful in reducing traffic accidents.

Hit-and-runs, with a RII of 27.78%, is ranked eighth in the road user behavior group (Table 4.3) and 18th in the overall ranking (Table 4.10). Educating vulnerable road users, visible and sufficient signs/signals, law enforcement and awareness programs are effective in reducing hit and run fatality cases. At 25.93% RII, three factors—stress, music-related distraction and deer collisions were ranked ninth among road-user behavior (Table 4.3) and 19th among all 93 factors (Table 4.10). Stress and music are distractions for drivers that reduce awareness of surroundings, increases response time and more importantly, changes the driving attitude of the driver. On the other hand, deer collisions (and similar animal collisions) are related to geography, location and time of the day. Public awareness and law enforcement are some of the ways to tackle stress and music related accidents. Street lights, speed limits, proper signage, and infrastructure can help avoid vehicle-animal collisions, as these can be a problem in certain states.

The RII for sleep disorders and health conditions is 24.07% which ranks them tenth among road-user behavior category factors (Table 4.3) and 20th among all the factors (Table 4.10). The National Highway Traffic Safety Administration estimates that 2.5% of fatal crashes and 2% of injury crashes involve drowsy driving. In 2009, 2.5 % (832) of the fatalities that occurred on US roadways were due to involve drowsy driving.

Frequent check points, sufficient rest areas, affected driver identification, and intervention by enforcement agencies and driver awareness can be effective in avoiding sleep disorder related accidents. Certain health conditions such as poor vision, diabetes, strokes, Alzheimer’s disease, seizures, etc., can render the driver incapable to drive and cause fatal accidents. Driver awareness and laws enforcements can be crucial in reducing fatalities caused by health conditions.

Passenger feedback and intermittent driving records were ranked last among the road-user behavior (Table 4.3) and 25th among all factors (Table 4.10). The RII for both the factors was only 14.81%.

4.2.2. Infrastructure

Table 4.4: Infrastructure group ranking

ID	FACTOR	RII	RANKING
1	Safety countermeasures	59.26%	1
2	Placement of median barrier	55.56%	2
3	Improvement in roadside hardware	53.70%	3
4	Guardrails	53.70%	3
5	Changes in geometric design	46.30%	4
6	Effect of lighting conditions/weather	46.30%	4
7	Road safety indicators	35.19%	5
8	Congestion mitigation	33.33%	6
9	Street pattern	33.33%	6
10	Wrong way sensors	33.33%	6
11	Improvement in lane width for arterial and collector roads	33.33%	6
12	Developed transition road safety barrier system	29.63%	7
13	Street network structure	24.07%	8
14	Road transition	24.07%	8
15	Geographical variations	22.22%	9

A total of 15 factors were categorized under the infrastructure category with safety countermeasures ranked highest followed by median barrier and roadside hardware. Based on RII, geographical variations, street network structure, and road transition were ranked among the last.

Safety countermeasures ranked first among the infrastructure factors and with a RII of 59.26%, it ranks third among all of the 93 factors. Road safety countermeasures, such as road designs, corridor access management, road signs and signals, road diet, and road safety education, have been great effectiveness in improving safety. There can be a number of possible countermeasures but proper evaluation must be done to determine the safety measures that provide the greatest return for the amount invested.

Median barrier, with a rank of 55.56%, was ranked second among infrastructure factors and 4th among all other factors. As per 2003 FARS data, there were 366 fatal cross-median head-on crashes on US freeways. Also for every 200 freeway miles travelled, there was one crossover fatal accident. Design and placement of median barriers is important as they prevent head-on-collisions, which are the most severe and fatal of road accidents. Median barriers should prevent crossovers as well as mitigate injury to the occupants of the vehicle.

Improvements in roadside hardware and guardrails were ranked third among infrastructure factors and with a RII of 53.70%, rank fifth among all 93 factors. The main function of roadside hardware, such as traffic and work zone barriers, barricades, sign supports, bridge railings, and crash cushions, prevent vehicles from leaving the road. According to the FHWA data, in 2011, there were 15,307 fatal roadway departure crashes resulting in 16,948 fatalities, which was 51 % of the fatal crashes in the United States. Crash tests data and actual traffic crash data from various road safety organizations can help understand the effectiveness of roadside barriers in preventing fatalities. They can also help in the design, material selection, and placement of road safety hardware.

Guardrails along the road help contain and redirect drivers, as well as provide safe crossing locations for pedestrians. They not only protect vehicles from veering off the road but are also intended to prevent the vehicles from rolling over. Depending on speed, vehicle type, terrain, and road curvature, guardrails can be as simple as concrete barriers to high tensile cables. Since guardrails have their own inherent dangers, it is important that guardrails are used only when the road conditions impose higher danger than the guardrail itself.

Changes in geometric designs and weather/lighting conditions with a RII of 46.30% were ranked fourth in the infrastructure category and ninth overall. Road geometries, such as curvature,

curvature direction, grade, banking, and alignment, affect vehicle performance, as well as a driver's ability to safely navigate them. Sufficient visible warning signs, adequate sight distance, road departure prevention measures such as road barriers, and traffic control devices need to studied and designed to minimize traffic fatalities caused by these road geometries.

Poor weather and lighting conditions substantially affect both the performance of drivers and vehicles. The most effective way to prevent fatal conditions due to bad weather and lighting conditions is to avoid driving during such conditions. Since it not always possible to avoid driving during bad conditions, measures such as safe driving practices, driver education, advance warning signs and systems, and road and infrastructure maintenance are highly effective in reducing accidents and fatalities.

Road safety indicators was ranked fifth in the infrastructure category with a RII of 35.19% and it was ranked 14th among all other factors.

Congestion mitigation, street pattern, improvement in lane width for arterial and collector roads and wrong way sensors, with a RII of 33.33% were ranked sixth among the infrastructure and 15th among all 93 factors. Congestion results when traffic demand approaches or exceeds the available capacity of the system. This in turn results in lost time, additional fuel costs, emissions, and above all unsafe driver behavior resulting in accidents and even fatalities. Tolls, congestion charges, real-time travel information system, traffic incident management, traffic signal timing, road construction planning and management, and infrastructure development all contribute towards mitigating congestion and accidents.

The standard street pattern for roads in the US has been grid iron; however, in recent time hierarchy pattern, curvilinear design, loops, lollipops, distributary and disconnected networks have become more popular. Street pattern designs are crucial in urban areas and especially important to prevent vehicle-pedestrian crashes. Marks (1957) found that grid iron patterns resulted in eight times more crashes than limited-access patterns. Ben-Joseph (1995) found that grid communities have more accidents than loops and cul-de-sac communities.

Arterial and collector roads are an integral part of the urban road system and the freeway network system. Various studies have suggested varying lane numbers and width, however, it is important to consider the traffic volume, access points, and costs while deciding on arterial and collector lanes.

According to the FHWA and the NTSB data sheet, on an average about 350 people are fatally injured in wrong-way freeway accidents and from 1996 to 2000, about 1750 people were killed in wrong-way crashes. In spite of numerous signs improvements and highway striping, the problem continues to persist. Most of these accidents were caused by alcohol impairment and the inability of the driver to read signs. Some of the most effective countermeasures include alcohol ignition lock devices, wrong-way signs and reflectors, ramp designs, wrong way monitors and cameras, and wrong-way navigation alerts in vehicles.

Developed transition road safety barrier system, with a RII of 29.63%, was ranked seventh among the infrastructure factors and 17th among all other 93 factors. Transition barriers should be designed and installed based on type of transition, road type, grade, curvature, speed limit, and vehicle type and traffic volume.

Road transition and street network structure were ranked eighth among infrastructure factors and with a RII of 24.07% were ranked 20th among all other factors. Road transitions are essential to help drivers move from one traffic condition to other safely. Acceleration and deceleration lanes are the most common road transitions. Transition lane length, curvature, grade, turns, transition signage, and signals are all crucial in proper and safe road transitions.

Street network structure affects the travel patterns, traffic volume, speed and travel time (perceived and actual). Systematic street network structure also helps users predict the road course, which in turn controls behavior hence improving safety. Some calming measures include turns, curves, reduced street widths, speed bumps, signage, signals, and calming road environment.

Geographical variation, with a RII of 22.22%, was ranked 21st among all factors and ninth among infrastructure factors. Suburban and rural areas have higher fatality rates than cities and urban areas. Geographical variations are not given enough consideration while designing roads and road infrastructure. Elements such as land use, population characteristics, prevalent profession, and vehicle type used, road lengths, elevation, terrain, and even climate needs to be part of any road safety study and design.

4.2.3. Emergency Response and Trauma Care Advancements

Table 4.5: Emergency response and trauma care advancements group ranking

ID	FACTOR	RII	RANKING
1	Improvement in EMS(emergency medical	53.70%	1
2	Intelligent emergency medical system in rural areas	50.00%	2
3	Advances in trauma care	46.30%	3
4	Improvement in trauma management	40.74%	4
5	Improved medical care and technology in industrialized countries	35.19%	5
6	Better quality bystander first aid by using internet compatible mobile device	29.63%	6

Improvement in EMS response time was ranked first in the emergency response and trauma care advancement group (Table 4.5) and fifth among all the 93 factors for overall ranking (Table 4.10) with RII value of 53.70%. Sanchez-Mangas et.al (2007) researched the relationship between emergency medical response time and the probability of deaths arising from traffic accidents. An analysis of road accidents data showed that a 10 minutes reduction in response time could increase the mortality probability by almost 30%. This result is significant in understanding the importance of emergency response in reducing traffic fatalities. In a study of emergency care systems, David et al. (2013) found that a shorter EMS response time was beneficial in reducing mortality rates in severe traffic accidents. Their study model highlighted the importance of the golden hour in EMS care coupled with timely transport to a hospital in reducing mortality rates.

Intelligent medical systems in rural areas ranked second in the emergency response and trauma care advancement group (Table 4.5) and seventh among all the 93 factors for overall ranking (Table 4.10) with the RII value of 50% . Lack of medical service facilities and immediate treatment of the people involved in accidents can increase fatality rates. As per US DOT, 68.4% crash fatalities occurred on rural highways. Rural accident fatality rates are much higher than in urban areas; fatal crashes are more prevalent in rural areas, and mile-for-mile rural travelers are roughly 2.5 times more likely to be in a fatal crash. Li et al. (2008) recommended that emergency systems, campaigns for use of restraints, enforcements for use of helmets and seat belt, and speed control be priority to reduce such accidents.

The study shows the advances in trauma management was ranked third with RII value of 46.30% in EMR group (Table 4.5) and ninth among all of the 93 factors for overall ranking (Table 4.10) followed by improvement in trauma management with a RII value of 40.74%, which ranked 12^{th} among all the 93 factors. This shows rapid response time and advanced trauma system are absolutely critical in saving the lives of people who have suffered from complex injuries due to traffic accidents. Post-accident responses such as accident notification, emergency response, on-site immediate treatment, trauma care, and permanent hospital treatment are all of significance. Time spent at the accident site, treatment provided to the victims, time taken to move the victims to trauma centers, safety measures while transporting the victims and quality of treatment provided at the trauma centers work together to influence the outcome of the accident.

Improved medical care and technology in industrialized countries ranked fifth with a RII value of 39.19% followed by better quality bystander first aid by using internet compatible mobile device, which ranked last as 29.63% (Table 4.5). These factors were ranked 14th and 17th among all the 93 factors respectively (Table 4.10). Many times civilian bystanders with certain assistance devices and/or training have also proven to be effective in saving lives. It is important to mention that it is not only the presence of response and care system that are critical but the quality, administration and management of such services are equally important.

4.2.4. Policy Enforcements

Table 4.6: Policy enforcements group ranking

ID	FACTOR	RII	RANKING
1	Safety belt law	62.96%	1
2	Traffic enforcement	51.85%	2
3	Increase enforcement	51.85%	2
4	Graduated driver licensing law	50.00%	3
5	Speed enforcement	44.44%	4
6	Helmet and seat belts campaigns	44.44%	4
7	Driving under Influence/Teen drinking	42.59%	5
8	Implication of automatic policing	25.93%	6

Safety belt law ranked first in the policy enforcement group shown in Table 4.6 and second among all of the 93 factors in overall rankings with the RII value of 62.96% (Table 4.10). As per the survey results, this has been considered the major factor that has contributed tremendously to the reduction in traffic fatalities in every states of the United States. Drivers and passengers who buckle up are 50 % more likely to survive serious motor vehicle crashes and avoid injuries, making safety belts the least expensive and most effective way to lower employer costs due to crashes and injuries.(CDC, 2014). Seatbelts reduce serious crash-related injuries and deaths by about 50%. Air bags provide added protection but are not a substitute for seatbelts. Air bags plus seatbelts provide the greatest protection for adults. Safety belt laws differ from state to state, but there are adult belt use laws in 49 states and in the District of Columbia. Despite this, in 2011, 10,180 people not wearing safety belts were killed in motor vehicle crashes. Encouraging drivers to wear their safety belts will greatly increase their chances of surviving a traffic crash and is the easiest way to lower crash-related costs. As per the report of FARS, the overall safety belt use rate saved 11,949 lives in 2011. (NHTSA, 2010).

Traffic enforcement and increased enforcement were ranked second in the policy enforcement group (Table 4.6) and sixth among all of the 93 factors in overall ranking (Table 4.10). The RII value was 51.85%. Traffic enforcement and strict implementation of laws have repeatedly proven to be effective deterrents to traffic violations, accidents, and related fatalities. Traffic laws and regulations largely define how users act and react while travelling and using the roads and other transportation infrastructure. Countries with stricter rules and enforcement are known for lower fatality rates, as compared to the countries with lighter traffic rules and/or implementation. Now countries are focusing on and implementing effective laws such the zero-tolerance law in order to improve their safety performance.

Graduated driving license (GDL) law ranked third in the policy enforcement group with RII value of 50% (Table 4.6) and seventh among all the 93 factors in overall ranking (Table 4.10). Novice drivers have higher crash rates. GDL programs allow young drivers to safely gain driving experience before obtaining full driving privileges. GDL systems are proven to reduce teen crashes and deaths.

Table 4.6 shows that speed enforcement and helmet and seatbelt campaigns are ranked fourth among the Policy Enforcement group with a RII value of 44.44% and tenth among all the 93 factors (Table 4.10). Excessive speed is considered to be a major contributing factor to motor vehicle crashes and is thus an important focus of highway enforcement efforts. In the United States, the National Highway Traffic Safety Administration (NHTSA) reported that in 2003, speeding contributed to 30 percent of all fatal traffic crashes, in which 13,113 lives were lost. Moreover, the economic cost of these is estimated to be over 40 billion dollars per year. To reduce the numbers of crashes, automated speed enforcements have been implemented in most states, such as setting up speed traps operated by the police or automated roadside speed camera systems that may incorporate the use of an automatic number plate recognition system.

Driving under the influence ranked fifth among the policy enforcement group (Table 4.6) and 11th among all of the factors (Table 4.10). The RII index for DUI is 42.59%. Drunk driving is often a reason for major crashes and other larger problems, such as alcohol abuse and misuse. As per NHTSA, alcohol-impaired crashes cost more than an estimated $37 billion annually (NHTSA, 2012, Impaired Driving). In 2012, More than 10,000 people died in alcohol-impaired driving crashes—that is one every 51 minutes (NHTSA, 2012). The United States General Accounting Office (1987) reviewed and synthesized results from all 49 studies that had adopted MLDA 21 by 1986. They concluded that "raising the drinking age has a direct effect on reducing alcohol-related traffic accidents among youths affected by the laws, on average, across the states" and that "raising the drinking age also results in a decline in alcohol consumption and in driving after drinking for the age group affected by the law." All states in the US designate a per se blood or breath alcohol level as the threshold point for an independent criminal offense. A second criminal offense of driving "under the influence" or "while impaired" is also usually charged in most states, with a permissive presumption of guilt where the person's BAC is 0.08% or greater (units of milligrams per deciliter, representing 8 g of alcohol in 10 liters of blood).

The implication of automatic policing, such as cameras, speeding machines, and sensors to warn drivers, was ranked last in the policy enforcement group (Table 4.6) and 19th among all of the 93 factors with the RII value of 25.93 % (Table 4.10). Law enforcement is a basic necessity if states are to control traffic fatalities. Harper (1991) reviewed the impact of semi-automatic monitoring systems in improving detection in traffic law programs. He concluded that taking into account the existence of core technology; tentative conclusions can be drawn as to the likely benefits and disadvantages of such systems.

4.2.5. Socio-economics and Demographics

There are 17 factors under the socio-economic category. Table 4.7 represents the ranking of these factors. Pedestrian crossing/animal crossing was ranked first with RII of 40.74% followed by economic conditions/development and social attitude at 37.04% each. The lowest ranked among the socio-economic factors was race at 12.96%.

Table 4.7: Socio-economics and demographics group ranking

ID	FACTOR	RII	RANKING
1	Pedestrian crossing	40.74%	1
2	Economic conditions/development	37.04%	2
3	Social attitude	37.04%	2
4	Safety based incentives	33.33%	3
5	Age	31.48%	4
6	Education	27.78%	5
7	Socio cultural characteristics	25.93%	6
8	GDP changes	25.93%	6
9	Legal drinking age restriction	25.93%	6
10	Population density in rural and urban areas	25.93%	6
11	Gender	24.07%	7
12	Governance quality	22.22%	8
13	Medical condition	20.37%	9
14	Temporal variations	18.52%	10
15	School time/peak hours	18.52%	10
16	Congestion charges	14.81%	11
17	Race	12.96%	12

Pedestrian crossing, with a RII of 40.74%, was ranked 1st (Table 4.7) among the socio-economic factors and 12th among all factors (Table 4.10). As per the NHTSA and Insurance Institute for Highway Safety, there are about 5000 fatalities and another 64,000 injuries every year in the US (NHTSA, 2008, March 18). Pedestrian fatalities account for 11 % of motor vehicle fatalities. Properly designed and marked pedestrian crossings are important in reducing fatal accidents involving vulnerable users. Educational and community-based programs to educate both pedestrians and drivers have also helped reduce pedestrian collisions.

With RII of 37.04%, economic conditions and social attitude were ranked second among the socio-economic factors (Table 4.7) and 13th in the overall ranking (Table 4.10). Regional economic indicators, such as GDP, unemployment, per capita income, and household income, are correlated to traffic accidents. Social attitudes toward law enforcement, traffic rules, and the importance of safety affect driver behavior and, eventually, accident rates. While allocating resources and developing policies, policy makers should consider these factors.

Safety-based incentives with a RII of 33.33% were ranked third in socio-economic factors (Table 4.7) and 15th in the overall ranking (Table 4.10). Many countries and states have implemented economic incentive-based public private partnership (PPP) in road infrastructure and traffic safety. Although incentives do not directly influence traffic or road users, they do motivate operators and contractors to focus their resources on providing safer infrastructure and service (Rangel et al., 2008).

Age of the driver has an RII of 31.48% and was ranked fourth among the socio-economic factors (Table 4.7) and 16th among all the factors in the overall ranking (Table 4.10). As per the NHTSA, drivers in the 16–20 and 50+ age groups have higher fatality rates, as compared to drivers in the age group of 20–50 years.

Education was ranked fifth among the socio-economic factors, with a RII of 27.78% (Table 4.7) and 18th among all of factors (Table 4.10). According to a World Health Organization (WHO) survey, 1.24 million people worldwide die in traffic accidents each year, making traffic accidents the eighth leading cause of death. (WHO, 2013.) While the number of deaths due to traffic accidents has been decreasing slightly in Japan, North America, and Europe, it has been steadily increasing in emerging nations where traffic safety education and transportation infrastructure have not kept up with increases in the number of vehicles on the road. On a global scale, traffic fatalities continue to increase steadily and are expected to become the fifth leading cause of death by 2030 unless countermeasures are implemented. To achieve the goal of completely eliminating traffic casualties, developing safe vehicles is of course important, but it is also essential to educate drivers and pedestrians regarding traffic safety and to create a safe traffic environment.

Socio-cultural characteristics, GDP changes, the legal drinking age, and population density were ranked sixth in the socio-cultural category (Table 4.7). The RII for these factors was 25.93%; which ranks them 19th among all of 93 factors (Table 4.10). Socio-cultural factors was found to affect road-user behavior and overall safety by a study conducted by the United Nations Economic Commissions for Europe in its 2011 paper, "Cultural Differences and Traffic Safety," by Michael Cole Bryan E. Porter in his book, *Handbook of Traffic Psychology* (2011), suggested that drivers in different countries behave differently and these behaviors are driven by cultural, sociopolitical, national, and organizational factors.

An increase of 10% in GDP (GDP/capita <1600) in a low-income country resulted in an increase in traffic fatalities by 3.1%. However, there exists a negative relationship between GDP growth and traffic fatalities in rich countries. This reversal in relationship occurs when the per capita income ranges from $1500 to $1800. (Bishai et. al. 2006)

Increasing the minimum legal drinking age to 21 not only resulted in reductions in alcohol consumption but also in youth traffic fatalities. This has accounted for both reductions in alcohol availability to youth and punishment for alcohol use by youth as per the NHTSA (2012). This effect is further increased by zero-tolerance laws and awareness programs on the effects of alcohol on driving.

The NHTSA in its publication Traffic Safety Facts 2012 found that states with higher populations had higher traffic fatalities, which supports the relationship between population and traffic fatality rates. However, this trend reverses in rural areas, although with lower population density, rural areas report a higher number of fatalities as compared to urban areas. This is partly explained by the fact that drivers tend to speed on rural roads compared to urban roads, and urban areas are better equipped to handle accidents and trauma.

The RII for gender was 24.07%, which ranks it in the seventh position among socio-economic factors (Table 4.7) and 20th overall among all factors (Table 4.10). More males die in motor vehicle crashes than women, mainly because they are involved in risky driving behavior, such as speeding, alcohol consumption, and not using seatbelts. Also, crashes involving males are more severe than the crashes involving females. As per the IIHS data sheet from 1975 to 2012, male fatalities are 1.8% to 2.6 % higher than females.

Governance quality with a RII of 22.22% was ranked eighth among the socio -economic factor (Table 4.7) and 21st among all of 93 factors (Table 4.10). Governance quality as measured by six World Governance Indicators (WGI) effects on traffic fatalities. A direct relationship between quality of governance and traffic safety has been established (Gaygisiz, 2010).

Medical conditions with a RII of 20.37% were ranked ninth among socio-economic factors (Table 4.7) and 22nd among all of factors (Table 4.10). Drivers with medical conditions, such as vision and hearing impairment, cardiovascular diseases, diabetes, seizures, dementia and respiratory diseases, are at higher risk due to functional impairments, acute or chronic. If not managed properly, medical conditions can increase your crash risk. Even if you have one or more of these medical conditions, if you work closely with your doctor, you often can continue safe driving. Increased use of prescription and over-the-counter medications to treat temporary or chronic medical conditions also is common as you age. Some medications or combinations of medications can impact your ability to drive safely. Because of this, some states have made it illegal to drive while impaired by medications and other drugs. Knowing the facts, understanding the risks, and seeking help to properly manage your health will keep you safely behind the wheel and out of legal trouble (Driver Safety Information Medical Conditions and Traffic Safety, para. "https://www.dmv.ca.gov").

Temporal variations and school time/peak hours, with a RII of 18.52%, were ranked 10th among socio-economic factors (Table 4.7) and 23rd among all of 93 factors (Table 4.10). Temporal variations in deaths related to alcohol intoxication are generally high during festive days and weekends as compared to normal weekdays. Pia Makela et al. (2005) concluded that intoxication-related deaths peak during weekends and around festival days when alcohol is widely consumed in excess. Public awareness of the risks attached to alcohol use and driving should be increased.

Congestion charges with a RII of 14.81% ranked last among the socio-economic factors (Table 4.7) and 25th among all of factors. (Table 4.10) Congestion charges can potentially reduce traffic fatalities by reducing the traffic volume in the area where such charges are levied. Such charges will also encourage road users to take public transport, which further reduces the risks of fatal accidents.

4.2.6. System Operations and Managements

A total of 19 factors were categorized in the systems operation and management category. Available budget ranked the highest in the category followed by advanced intelligent transportation system and traffic police deployment system. Only available budget was ranked in the top ten among all 93 factors and nine factors ranked below 20 in the overall ranking.

Table 4.8: System operations and management group ranking

ID	FACTOR	RII	RANKING
1	Available budget	48.15%	1
2	Advanced intelligent transportation system	37.04%	2
3	Traffic police deployment system	37.04%	2
4	Vision and strategy	35.19%	3
5	Evaluation and reporting	35.19%	3
6	Controlling signal timing for emergency	29.63%	4
7	Speed limitation on highways	27.78%	5
8	Improvement of route segments by using GIS	25.93%	6
9	Speed cameras	25.93%	6
10	Integrated speed management plan in residential areas	25.93%	6
11	Fatigue detection technology	22.22%	7
12	Safety monitoring system	22.22%	7
13	GPS upgrade to show construction work	22.22%	7
14	Improvement in traffic control system during emergency evacuation	20.37%	8
15	Car pooling	16.67%	9
16	System dynamics	16.67%	9
17	Integrated mobility management plan	16.67%	9
18	Strict road administration	14.81%	10
19	Proper management and planning for electric bicyclers	14.81%	10

Budget availability defines the amount of resources used towards traffic infrastructure and management, which in turn influences overall traffic safety. With a RII of 48.15%, available budget was ranked first among the system operation and management category (Table 4.8) and fourth overall (Table 4.10). The FY2014 budget proposed marks $76.6 billion for Department of Transportation, a 5.5% increase from FY2012. A total of $2.4 billion will be directly used for highway safety improvement programs and investments in other programs will directly or indirectly help improve safety performance of US roads.

Advanced intelligent transportation system and traffic police deployment system, with a RII of 37.04%, were ranked second in this category (Table 4.8) and 13th among all other factors (Table 4.10). Advanced intelligent systems can be specific to the vehicle, mode of transportation, navigation or overall traffic management. These systems can be used as advanced warnings, number plate recognitions, traffic signal controls, and navigation systems, weather information systems, parking guidance, and automatic road enforcement.

One of the major ways to deter traffic violations and eventual fatalities is by deploying traffic police. The fear of punishment and other consequences improves driver's behavior. Apart from preventing accidents, efficient traffic police deployment can also help quickly address existing accidents, manage the flow of traffic at accident sites, prevent further accidents, and normalize traffic in the minimum possible time. To be most effective, traffic police deployment should be approached from both technological and organizational perspectives.

Vision and strategy, as well as evaluation and reporting, with a RII of 35.19% were ranked third among the systems operations and management category (Table 4.8) and 14th among all other factors (Table 4.10). Both of these factors emphasize the importance of proactively addressing traffic safety rather than simply responding to traffic events. The overall strategy of traffic safety organization should be zero accidents, injuries, or fatalities, followed by effective strategizing to achieve the vision. Such a vision may not be achievable immediately but the planning and implementation of strategies in a gradual and phased manner should prove effective.

Evaluation and reporting should be an integral part of the ongoing efforts by traffic organizations to achieve traffic safety. The evaluation of current infrastructure, systems, management, and performance followed be reporting should be able to highlight problem areas. Upon evaluation and reporting, resources can be focused towards solving the existing problems and devising effective road safety strategies.

Controlling signal timing for emergency vehicles was ranked fourth among the systems operations and management category (Table 4.8) and 17th overall (Table 4.10). According to NHTSA, in 1997, 15,000 accidents involving emergency vehicles while on duty resulted in 8000 injuries and 500 fatalities. Statistics also show that nearly 40% of fire fighters were killed in traffic accidents while in route to the scene of an accident. These accidents result in loss of human life, property damage, replacement costs, and legal liability costs for emergency response organizations. Emergency vehicle preemption or traffic signal preemption has evolved as the industry's leading technology in addressing such accidents by controlling traffic lights to allow safe passage for the vehicles.

Although speed limits are posted on almost all roads, speeding continues to remain one of the most common forms of traffic violations in United States. Speed limits on highways were ranked fifth among system operations and management (Table 4.8) and with a RII of 27.78% was ranked 18th overall. (Table 4.10) As per National Safety Council, one out of three fatal accidents involves speeding. (National Safety Council , 2014).The NHTSA's 2006 fatality data reported that 33% of speed related fatalities occurred on roads with a speed limit of 75 mph or less, 47% occurred on roads with a speed limit of 50 mph or less and 25% occurred on roads with speed limits of 35mph or less.(NSC, 2014) Although there are numerous ongoing studies and arguments, speed limits should be decided based on zone, traffic volume, road length, road conditions, geographic conditions, and advancements in vehicle designs.

Improvement of route segments using GIS, speed cameras, and an integrated speed management plan in residential areas, with a RII of 25.93% was ranked sixth in the category (Table 4.8) and 19th among all the 93 factors (Table 4.10). GIS technologies have been instrumental in controlling traffic flow and redirecting traffic in case of an event or incident. It helps the road users avoid routes that are congested, backed up, under construction, or hazardous. Not only does it result in saved travel time but also traffic safety. Speed cameras are used as monitoring, control, and law enforcement devices in traffic management systems. They have been found to be effective in reducing speeding, bus lane encroachments, red light infraction, and overall crashes by effecting road-user behavior. In a study conducted by the Washington DC Department of Transportation, speed cameras were found to have reduced crashes by as much as 20%. The 2010 Cochrane Review of speed cameras for the prevention of road traffic injuries and deaths also found a reduction in all crashes, injury crashes, injury severity, and fatalities.

Speeding in residential areas is a risk for vulnerable road users such as cyclists, children, and pedestrians. An integrated speed management plan in residential areas combines education, infrastructure improvement, and enforcement activities to reduce driving speeds on residential roads, calm traffic and improve road safety. Integrated speed management plan essentially works on the premise that reduced speed equates to reduced accidents (Islam and El-Basyouny, 2013).

Fatigue detection technology, safety monitoring system, and GPS-upgrades to show construction work were ranked seventh among systems operation and management factors (Table 4.8) and with RII of 22.22%, and ranked 21st overall (Table 4.10). Drowsy driving leads to thousands of vehicle crashes and fatalities every year. Apart from education and awareness programs, fatigue detection technology can prove pivotal in avoiding such accidents. They can be either vehicle mounted and warn drivers of drowsiness or integrated into the larger traffic management system to detect fatigued drivers. (NHTSA 2013).

Traffic monitoring systems and upgraded GPS systems can help track traffic in real time and help traffic managers and road users make real time decisions. GPS systems can help drivers avoid congested roads, construction zones, and reduce travel time while aiding traffic safety. Traffic monitoring systems can go one step further in recording, processing, and analyzing traffic data that can be used for planning, upgrading, and managing traffic in an efficient way.

Improvements in traffic control systems during emergency evacuation were ranked eighth in its category (Table 4.8) and with a RII of 20.37% ranked 22nd among all 93 factors (Table 4.10). Emergency evacuations can be challenging and a logistical nightmare. Efficient traffic control systems can help manage an emergency evacuation, reduce evacuation time, prevent accidents, and ultimately save lives. This includes extensive preplanning, setting up of evacuation zones and routes, control nodes, efficient communications and emergency evacuation public education programs.

Carpooling, system dynamics, and integrated mobility management plans with a RII of 16.67% were ranked ninth among systems operation and management category (Table 4.8) and 24th overall (Table 4.11). Carpooling helps reduce the number of vehicles and users on the road, which in turn eases traffic volume, reduces emissions, and effectively reduces the probability of human error resulting in fatal accidents. Internet sites and apps have proved to be particularly useful in promoting carpooling. System dynamics has been used to evaluate traffic in general as well as micro level issues, such as interactions between driver, infrastructure, and the vehicle. System dynamics can be used to formulate macro level policies (Goh, 2012). Integrated mobility management plans bring together transport, road users, and site-specific issues in a coordinated manner to manage traffic and road user demand. It should ensure reliable, efficient and affordable transport system.

Strict road administration and proper management and planning for electric bicyclers was ranked 25th among all 93 factors and last among systems operation and management category (RII – 14.81%).

4.2.7. Vehicle Safety Advancements

Table 4.9: Vehicle safety advancements group ranking

ID	FACTOR	RII	RANKING
1	Safety belt	64.81%	1
2	Airbag for unrestrained rear seat passengers	42.59%	2
3	Advanced driver assistance system	33.33%	3
4	Warning information system	31.48%	4
5	Efficacy of safety policy	31.48%	4
6	Vehicle configuration, mass, components and types	29.63%	5
7	Deployment of digital vehicle technology	27.78%	6
8	Advanced traveler information system	25.93%	7
9	Side view video system	22.22%	8
10	Location of safety warning system	18.52%	9
11	Increase in Light Truck Vehicle with time	18.52%	9
12	Active hood lift system	11.11%	10

Safety belts with a RII of 64.81%, was ranked 1st (Table 4.9) among the vehicle safety advancements group and 1st among all of the 93 factors (Table 4.10). This result shows how important safety belts are achieving the goal of “zero fatalities.” According to a report by the National Highway Transportation Safety Administration, safety belts prevent about 11,900 fatalities and 325,000 injuries every year, saving $50 billion in medical care, lost productivity, and other injury-related costs. Not wearing a safety belt results in 9200 avoidable deaths and 143,000 needless injuries nationally. The evidence is overwhelming that safety belts save lives and reduce the severity of injuries. The National Safety Council data shows that the safety belt use rate was 84 % in 2011, as compared to 58 % in 1994. Experts say safety belts have helped save an additional 11,949 lives in 2011 and more than 250,000 lives since 1975.However, 51% of fatalities where restraints were said to have been used were unrestrained. Passengers and pickup drivers are less likely to buckle up than other motorists, and men are less likely to use safety belts than women. An estimated 3384 additional lives could have been saved in 2011 if all vehicle occupants over age 5 wore safety belts.

Air bag for unrestrained rear seat passengers was ranked second with the RII value of 42.59% (Table 4.9) and 11th among all the 93 factors (Table 4.10). It is well documented that seatbelt usage effectively reduces the severity of motor vehicle occupant injuries and fatalities in roadway crashes. While rear-seat occupancy in motor vehicle travel has been disproportionately low (Trowbridge and Kent, 2009), recent research has emphasized that crash protection and safety measures need to focus on rear-seat passengers (Forman et al., 2009 and Mizuno et al., 2011). Current US traffic data on fatal crashes has shown that unbelted rear-seat passengers not only compromise their own safety in a frontal crash but also pose increased threat for fatal injury to front-seat occupants, such as the driver. Further, the results indicated that the source of increased threat to driver fatality is not only limited to the passenger seated directly behind the driver but additional unrestrained rear-seat passengers also contribute to this problem (NHTSA, 2012). To mitigate the increased risk posed by unrestrained rear-seat passengers, adoption of comprehensive seatbelt laws for all seating positions is necessary. As noted in the Introduction section, there are rear-seatbelt laws in only 17 out of the 50 states in the US. Also, to compliment the role of seatbelt laws, it is necessary to aggressively pursue national and state level campaigns to improve awareness among motor vehicle users regarding the importance of rear-seatbelt use. In the past, campaigning efforts such as Buckle Up in 1999 were largely responsible for improving the seatbelt usage rate by more than 81% in the first few months (NHTSA, 2013). It is expected that with effective legislation and awareness, rear-seatbelt use can be significantly improved, which will subsequently contribute to the safety of both, the rear-seat passengers as well as their front-row counterparts.

Advanced driver assistance system (ADAS) ranked third in the vehicle safety advancement group (Table 4.9) and 15th among all of the other 93 factors with an RII value of 33.33% (Table 4.10). ADAS technologies provide a driver with essential information, automate difficult or repetitive tasks and lead to an overall increase in car safety for everyone (Laukkonen 2014). Some of these technologies have been around for some time, and they have already proven to contribute to an improved driving experience and better overall road safety. A lot of ADAS are right on the cutting edge of emerging automotive technologies. Examples are adaptive cruise control, adaptive light control, automatic braking, automatic parking, blind spot detections, collision avoidance, intelligent speed adaptation, GPS navigation, hill descent control, and driver drowsiness detection (Laukkonen 2014). Some of these technologies are already being implemented and some will implement soon and contribute to traffic safety.

Warning system and efficacy of safety was ranked fourth in the vehicle safety advancements group (Table 4.9) and 16th among all of the 93 factors (Table 4.10). According to the World Health Organization (WHO), road accidents annually cause approximately 1.2 million deaths worldwide and one fourth of all deaths caused by injuries (WHO, 2012). Also, about 50 million people are injured in traffic accidents. If preventive measures are not implemented, road death could become the third-leading cause of death by 2020 (from ninth place in 1990). A study by the American Automobile Association (AAA) concluded that car crashes cost the US $300 billion per year (AAA, 2011). However, the deaths caused by car crashes are in principle avoidable. The US Department of Transportation states that 21,000 of the annual 43,000 road accident deaths in the US are caused by roadway departures and intersection-related incidents (DOT, August 2012). This number can be significantly decreased by deploying local warning systems through vehicular communications. Departing vehicles can inform other vehicles that they intend to depart the highway and arriving cars at intersections can send warning messages to other cars traversing that intersection. The main advantage of vehicular networks is safety improvements. There are several other benefits as well as vehicular networks that can help to avoid congestion and finding better routes by processing real time data. This in turn saves both time and fuel and has significant economic advantages.

Along with vehicle advancements, implementing policies such as safety belt laws, age limit and alcohol restrictions could help decreases causalities.

Vehicle configuration, mass, components, and types was ranked fifth in the vehicle advancement group with the RII of 29.63% (Table 4.9) and 17th among all of the factors (Table 4.10).Travel in private vehicles is one of the leading causes of death in the US. According to the US Department of Transportation, 34,080 people died in crashes in 2012, and 94% of those deaths occurred on highways. Research has shown that passenger fatality rates and vehicle weight are closely related. The heavier the vehicle is, the less likely its occupants would be injured in case of an accident, but the more likely those in other vehicles will be hurt. SUVs and light trucks are on average heavier and thus pose a greater threat to those in other vehicles. In addition, because of factors, such as differences in bumper height, they are significantly more likely to cause fatalities in the vehicles they strike. The use of sport utility vehicles (SUVs) has increased during the last couple of decades and fatality rates have declined. This trend is most likely attributable to advances in safety features, higher vehicle weight, and reduction in alcohol-impaired driving. Although the effects are encouraging, the same may not be applicable in two-vehicle collision scenarios where the occupants of other cars are at higher risks of injury.

Deployment of digital technology was ranked sixth in the vehicle advancement group with an RII of 27.78% (Table 4.9) and 18th among all of the factors (Table 4.10). Although currently seatbelts and airbags are widely used, there are still more than 40,000 people killed annually in the United States in traffic accidents. Recent research indicates that deploying a safety warning system using high precision digital road maps and a combination of various vehicle status sensory techniques, with or without a minimum requirement of additional road infrastructure, can help to reduce and achieve a goal of zero fatalities. For example, an automotive short-range radar (SRR) systems, which can constantly monitor the area around a vehicle to detect obstacles such as other vehicles, pedestrians or static obstacles. SRR systems are similar to current parking assistants but with a longer range. They are aimed at warning drivers in advance of potential collisions and alert them to pedestrians or obstacles in blind spots.

Advanced traveler information system (ATIS) was ranked seventh in the vehicle advancement group with an RII of 25.93% (Table 4.9) and 19th among all of the factors (Table 4.10). A book written by Hyejung Hu (2009) found that ATIS is useful for making travel decisions and it reduces stress and travel time. It was shown that ATIS significantly reduces the amount of time spent on arrivals in peak periods with most studies reporting reductions in the number of stops, travel time, and vehicle miles. Along with this, ATIS has other benefits in terms of the environment, energy, and fuel consumption. Better ATIS results in changes in routes and travel time and it reduces vehicle emissions and fuel consumptions as well as fatalities (Jensen. et al., 2000 and Jeannotte, 2001). As per the FHWA, the data from the ITS Deployment Analysis System

(June, 2001) indicates that there is reduction in fatalities of 3.2% during peak periods due to the use of an ATIS. Not only are travel times reduced using ATIS but ATIS stress reduces related to congestion and uncertainty.

Side/rear view video system was ranked eighth in the vehicle advancement group with an RII of 22.22% (Table 4.9) and 21st among all of the factors (Table 4.10). In larger vehicles, such as tractors, trailers and buses, sometimes it is difficult to see the people behind the vehicle while reversing. To overcome this problem, NHTSA made a rule that trucks weighing more than 10,000 pounds need to be equipped with side/rear view object detection systems. These alert drivers to persons and objects directly behind the vehicle, which further reduces backing related deaths and injuries.

Location of safety warning system and increase in LTV with time was ranked ninth in the vehicle advancement group with the RII of 18.52% (Table 4.9) and 23rd among all of the factors (Table 4.10). Safety warning systems based on sensor networks were developed to provide zero delay safety warnings to motorists. These sensors detect events recorded at multiple designated locations such as passing by drivers can be alerted to potential dangers on traffic delays through the wireless communication among sensors deployed at the highway and the vehicle. This manages the propagation and storage of an event record are determined by the event location and the time needed to clear the road for the event. The closer to the event location, the larger the number of sensors storing the event; the longer the time needed to clear the road for the event, the farther away the record is propagated, and the longer time the record is stored in the database. The application of sensor networks has not been explored because sensor network technology is still a new development. However, sensors have already been used in highway and traffic data collection for real-time management and control of traffic.

The rapid growth in light truck vehicle (LTV) sales, including minivans, sport utility vehicles (SUVs), and light-duty trucks, has been associated with an overall increase in collisions or traffic deaths in the United States. The research by Abdel-Aty and Abdelwahab (2004) investigated the number of annual fatalities that result from angle collisions, as well as collision configuration (car-car, car-LTV, LTV-car, and LTV-LTV). The analysis uses the Fatality Analysis Reporting System (FARS) crash databases covering the period 1975–2000. The results showed that fatalities in angle collisions will increase in the next 10 years, and that they are affected by the expected increase in the percentage of LTVs in traffic.

Active hood lift System (AHLS) for pedestrian was ranked tenth in the vehicle advancement group with the RII of 11.11% (Table 4.9) and 27th among all of the factors (Table 4.10). Active hoods Lift Systems (AHLS) prevent fatal injuries in pedestrian-vehicle collisions. AHLS work by absorbing the impact energy by lifting the hood and preventing a pedestrian head from hitting the hood. Although this system focusses on a particular type of accident, the methodology used to quantify safety benefits can be used in evaluating other technologies, as well as establishing safety policies.

4.3. Overall Factors Contributing to the Decline According to RII Values

The results in Table 4.10 show the overall ranking of 93 factors that have contributed to the decline in traffic fatalities in US, identified in this study by using the survey approach and analyzing the responses.

Table 4.10: Overall ranking of factors according to RII values

Factors	RII	Overall Ranking
Safety belt	64.81%	1
Safety belt law	62.96%	2
Safety countermeasures	59.26%	3
Placement of median barrier	55.56%	4
Improvement in roadside hardware	53.70%	5
Guardrails	53.70%	5
Improvement in EMS(emergency medical system)response time	53.70%	5
Traffic enforcement	51.85%	6
Increase enforcement	51.85%	6
Intelligent emergency medical system in rural areas	50.00%	7
Graduated driver licensing law	50.00%	7
Alcohol	48.15%	8
Available budget	48.15%	8
Speed	46.30%	9
Changes in geometric design	46.30%	9
Effect of lighting conditions/weather	46.30%	9
Advances in trauma care	46.30%	9
Driving experience	44.44%	10
Pedestrian behavior	44.44%	10
Speed enforcement	44.44%	10
Helmet and seat belts campaigns	44.44%	10
Airbag for unrestrained rear seat passengers	42.59%	11

Table 4.10: Overall ranking of factors according to RII values (Continued)

Factors	RII	Overall Ranking
Driving under Influence/Teen drinking	42.59%	11
Pedestrian crossing	40.74%	12
Improvement in trauma management	40.74%	12
Drugs	37.04%	13
Economic conditions/development	37.04%	13
Social attitude	37.04%	13
Advanced intelligent transportation system	37.04%	13
Traffic police deployment system	37.04%	13
Cell phone	35.19%	14
Road safety indicators	35.19%	14
Improved medical care and technology in industrialized countries	35.19%	14
Vision and strategy	35.19%	14
Evaluation and reporting	35.19%	14
Road rage	33.33%	15
Safety based incentives	33.33%	15
Congestion mitigation	33.33%	15
Street pattern	33.33%	15
Wrong way sensors	33.33%	15
Improvement in lane width for arterial and collector roads	33.33%	15
Advanced driver assistance system	33.33%	15
Age	31.48%	16
Warning information system	31.48%	16
Efficacy of safety policy	31.48%	16
Eating/drinking while driving	29.63%	17
Developed transition road safety barrier system	29.63%	17
Vehicle configuration, mass, components and types	29.63%	17
Better quality bystander first aid by using internet compatible mobile device	29.63%	17
Controlling signal timing for emergency vehicles	29.63%	17
Hit and run	27.78%	18
Education	27.78%	18

Table 4.10: Overall ranking of factors according to RII values (Continued)

Factors	RII	Overall Ranking
Deployment of digital vehicle technology	27.78%	18
Speed limitation on highways	27.78%	18
Stress	25.93%	19
Music (Distraction)	25.93%	19
Collision with deer	25.93%	19
Socio cultural characteristics	25.93%	19
GDP changes	25.93%	19
Legal drinking age restriction	25.93%	19
Population density in rural and urban areas	25.93%	19
Advanced traveler information system	25.93%	19
Improvement of route segments by using GIS	25.93%	19
Speed cameras	25.93%	19
Integrated speed management plan in residential areas	25.93%	19
Implication of automatic policing	25.93%	19
Sleep disorders	24.07%	20
Health conditions	24.07%	20
Gender	24.07%	20
Street network structure	24.07%	20
Road transition	24.07%	20
Governance quality	22.22%	21
Geographical variations	22.22%	21
Side view video system	22.22%	21
Fatigue detection technology	22.22%	21
Safety monitoring system	22.22%	21
GPS upgrade to show construction work	22.22%	21
Medical condition	20.37%	22
Improvement in traffic control system during emergency evacuation	20.37%	22
Temporal variations	18.52%	23
School time/peak hours	18.52%	23
Location of safety warning system	18.52%	23
Increase in Light Truck Vehicle with time	18.52%	23
Car pooling	16.67%	24
System dynamics	16.67%	24
Integrated mobility management plan	16.67%	24

Table 4.10: Overall ranking of factors according to RII values (Continued)

Factors	RII	Overall Ranking
Intermittent driving record	14.81%	25
Passenger feedback	14.81%	25
Congestion charges	14.81%	25
Strict road administration	14.81%	25
Proper management and planning for electric bicyclers	14.81%	25
Race	12.96%	26
Active hood lift system	11.11%	27

4.4. Group Ranking of RII Values

Group ranking according to the respective factors is shown in Table 4.11. It was calculated by taking into consideration the average RII value for all the factors that have contributed to the decline of traffic fatalities in the US. Policy enforcements factors was the top group of factors with an average RII of 46.76%, and socio-economics and system operation was at the bottom with an average RII value of 26.02%. As seen in Table 4.10, safety belt use and safety belt laws were on the top two crucial factors which have contributed to the decline in traffic fatalities in the US.

Table 4.11: Group ranking of RII values

ID	FACTOR	RII	RANK
1	Policy enforcements	46.76%	1
2	Emergency response and trauma care advancements	42.59%	2
3	Infrastructure	38.89%	3
4	Road user behaviour	31.37%	4
5	Vehicle safety advancements	29.78%	5
6	Socio economics and demographics	26.03%	6
7	System operations and managements	26.02%	7

Traffic law enforcement includes all police activities relating to the observation of traffic violations and policing activities, such as warning, reporting, summonsing, and arresting. Whenever possible, the form of enforcement used should be designed to educate those who have violated the law and others who may be influenced by their example so that such unlawful and unsafe driving behavior will not be repeated (Weston. P, 1978). As per Table 4.11, implementation of laws has been considered to be the most effective way to reduce traffic fatalities so far. Traffic laws and regulations largely define how users act and react while travelling and using roads and other highway infrastructure. Strict laws pertaining to alcohol use, drugs, legal driving age, driving license issuance policy, traffic safety education, use of seatbelts, restraining and safety devices, etc., are all essential parts of the overall traffic safety. It is true that enforcement impacts are immediately felt by the road users. Effects of long-term measures of public health policy, traffic education, and road engineering take years to change driving habits and driving conditions. Countries with stricter rules and enforcements are known for lower fatality rates as compared to the countries with lighter traffic rules and/or implementation.

4.5. Descriptive Statistics and Analysis

The statistical analysis shown in Table 4.12 used Minitab 16 software to find the mean for the categorical variables resulting from the research survey. The mean relative importance index was 0.4709(47%) for the policy enforcements, 0.4259(42%) for the emergency response and trauma care advancements group, 0.3889(39%) for the infrastructure group, 0.3137(31%) for the road-user behavior group, 0.2978 (30%) for the vehicle safety advancements group, 0.2603 (26%) for the socio economics and demographics group and 0.2602 (26%) for the system operations and managements group. The results showed that policy enforcement has a higher RII than all the other factors. The result also showed that the standard deviation of the mean was varying from 0.09 to 0.12 for all the categories.

Table 4.12: Descriptive statistics output from Minitab 16

Var	Category	Mean	St dev	Variance	Minimum	Median	Maximum	Skewness	Kurtosis
RII	Policy enforcements	0.4709	0.1141	0.0130	0.2593	0.5000	0.6296	-0.84	1.92
	Emergency response and trauma care advancements	0.4259	0.0915	0.0084	0.2963	0.4352	0.5370	-0.30	-1.28
	Infrastructure	0.3889	0.1248	0.0156	0.2222	0.3333	0.5926	0.33	-1.34
	Road user behavior	0.3137	0.1051	0.0110	0.1481	0.2870	0.4815	0.16	-0.87
	Vehicle safety advancements	0.2978	0.1378	0.0190	0.1111	0.2870	0.6481	1.47	3.36
	Socio economics and demographics	0.2603	0.0792	0.0063	0.1296	0.2593	0.4074	0.24	-0.60
	System operations and managements	0.2602	0.0914	0.0084	0.1481	0.2593	0.4815	0.77	0.19

4.6. Statistical Analysis of Relative Importance Index

The individual RII value plot shown in Figure 4.1 and the box plot in Figure 4.2 indicate that each category has a different mean relative importance index. The individual value plot in Figure 4.1 indicates that the RII distribution for all categories varies a lot.

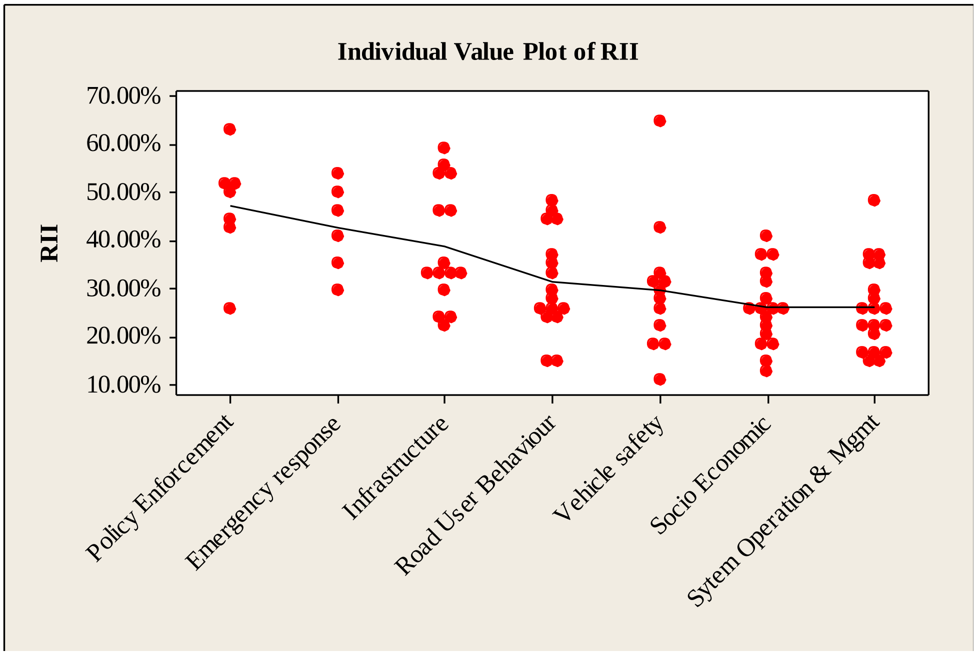

Fig 4.1: Plot of relative importance index values

1) **Policy Enforcement**: This individual plot indicates that this factor has the highest mean and so it has highest impact. But if we look closely, this factor has minimum number of data points, i.e., 7. With such a small sample, mean alone cannot be a true representation of the data. Also, due to the presence of one outlier, we cannot be certain that mean is the true average or center of gravity of the responses. As seen from the descriptive data in the above table, standard deviation of this factor is on the higher end of the scale, i.e., 0.1141. This shows the presence of considerable variation in the responses, which makes it difficult to draw the conclusion.
2) **Emergency response:** Individual plot gives the perfect representation of this data. The variance is less (0.09); however, once again the number of data values are low, i.e., 6
3) **Infrastructure**: Good size of data points; however, high variation.
4) **Road user**: Good size of data points, comparatively less variation. Could be a candidate for factor with strong impact
5) **Vehicle safety**: Good number of data points, but very high variation and presence of outlier. Not a true representation of central tendency.
6) **Socio-economic and system operations:** Good number of data points. Lowest variation (0.07 and 0.09), no outliers.

The order or ranking of factors with respect to their impact and number of good data points would be:

1) Socio-economics
2) System operations
3) Road user
4) Infrastructure

5) Vehicle safety

6) Emergency response

7) Policy enforcement

The above ranking shows that socio-economic factors, as per the analyses, will have greater impact and needs to be given close attention as compared to system operation factors. It has been shown the more influence and care has been given towards the policy enforcement so far but other factor which has been given less priority will have greater impact as per the analysis. It is also apparent from the research that lot of research has been done in policy enforcement. However, other factors have to be given equal attention.

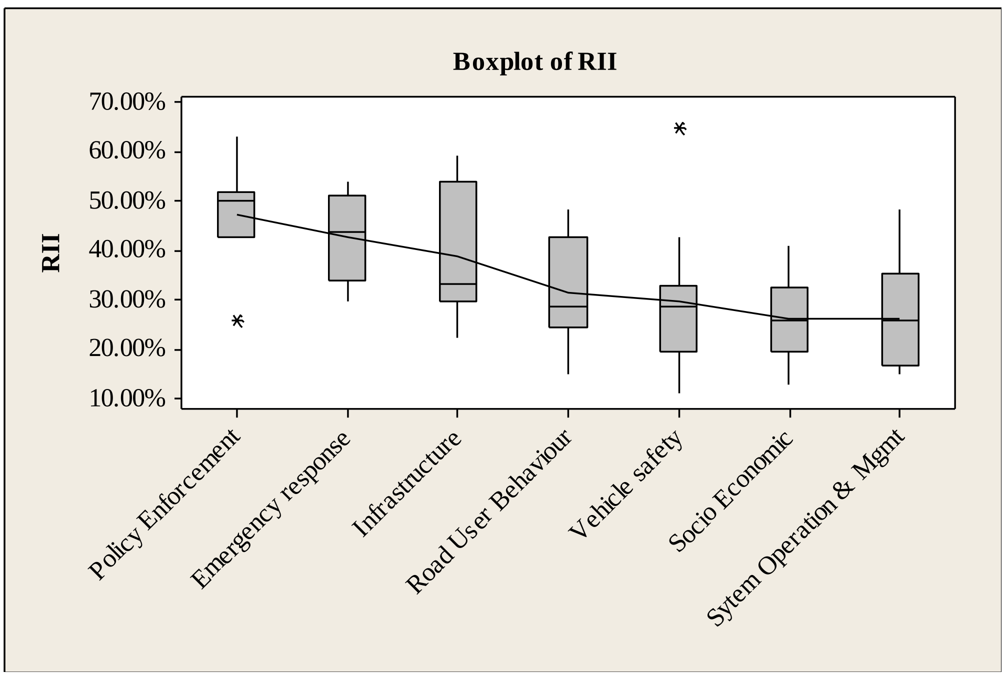

Fig 4.2: Box plot of relative importance index of group categories of factors

The box plot in Figure 4.2 is the methodology of descriptive measures and is based on quartiles of the RII values (shown in Fig 4.3).

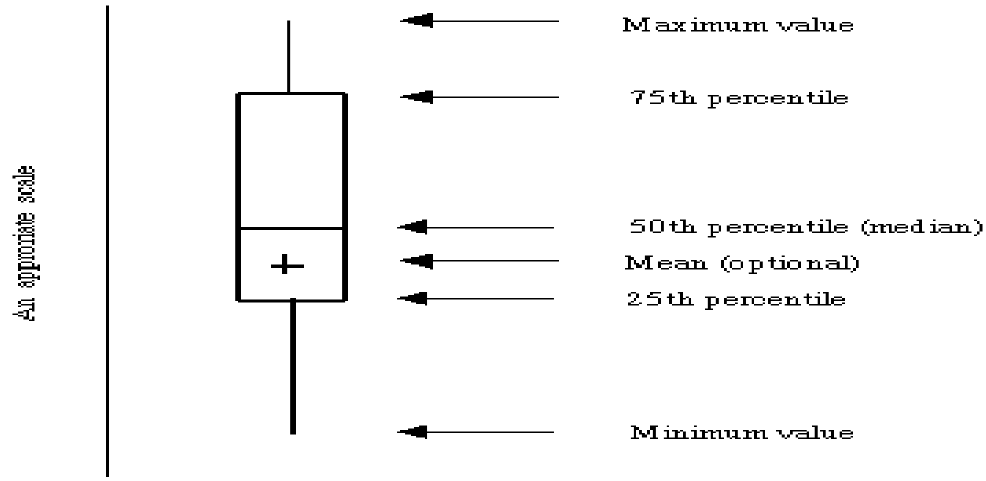

Fig 4.3: Box plot interpretation

The box plot shows that all RII values have different interquartile ranges except the two observations which are the outliers. As seen in the individual value plot and in the box plot, the means for each category of respondents are different. The mean RIIs were as follows:

1) **Policy enforcement:** Shows an outlier. All the four sections, i.e. median, lower whisker, higher whisker and interquartile range are all different from each other. This shows that many survey participants have variable views. And so, this could not be trusted as the factor with true impact. High range (63-26 = 37) and so high variation within the responses.
2) **Infrastructure**: The plot shows that the distribution is right skewed, with more data values on the higher end. The calculated range though is high (60-22 = 38) showing high variation among the responses.
3) **Road-user behavior:** Low variation (48-15= 33) with no outlier. Good number of responses. Thus, descriptive data represents the true responses. Good candidate for factor with strong impact.
4) **Socio-economic and system operation:** Good number of data points, low ranges (41-13=28 and 48-15= 33) and thus low variation among responses with no outliers.

5) **Emergency response and trauma care:** Box plot gives the perfect representation of this data. The range is less (54-30 = 24), but once again number of data values are low, i.e. 6

6) **Vehicle safety and its advancements:** High range (65-11 =54) and thus high variation among the responses due to an outlier.

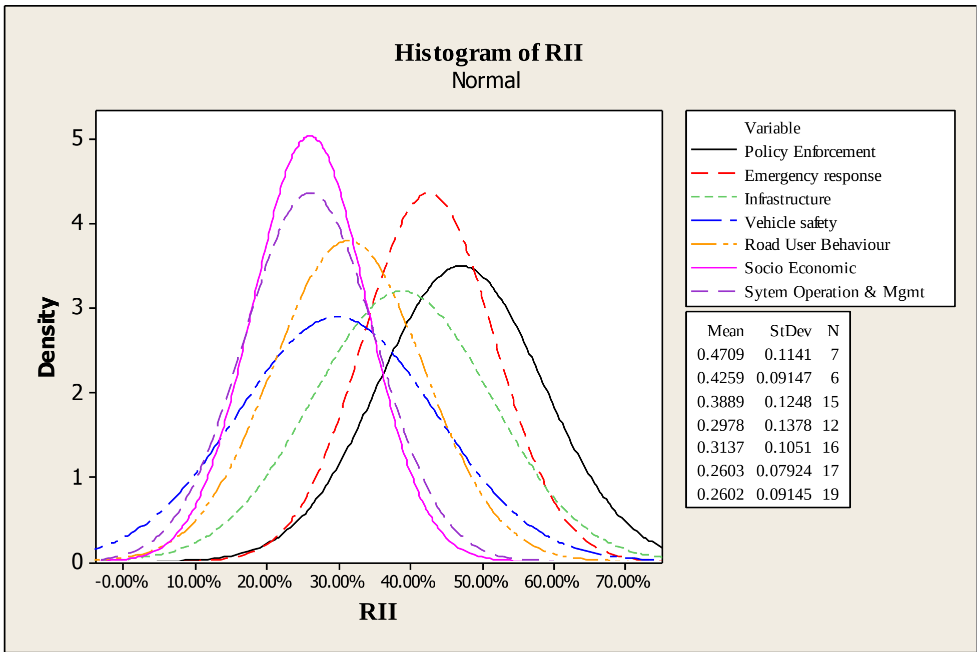

Fig 4.4: Histogram of relative importance index of group categories of factors

The group RII histogram, shown in Figure 4.3, indicates that all the categorical factors were different in their mean RIIs with a different RII spread. It was determined that neither group had a smaller or larger difference in the mean and the distribution. Wider distribution increases the probability of containing the true value. However, there is a difference in finding the precise value and finding the accurate value. Wide distribution though increases the probability of containing the true value, also increases the variability on the other hand. Thus, for such distributions, sample size becomes a critical factor to derive the results. Since policy enforcement has high variability, wider distribution, and low sample size. It cannot be trusted as a factor with major impact. On the other hand, socio-economic and system operations distribution has low variability, narrow distribution, and high sample size. This shows that these two factors have highest impact.

CHAPTER 5. CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH

5.1. Conclusions

Traffic safety is an important agenda for all traffic operations and management agencies. Accidents and crashes not only cause loss of valuable lives but also results in significant property and economic losses. With 40,000 lives lost every year in the United States, coupled with an economic loss of approximately $80 billion, research geared towards the minimization of traffic crashes is of utmost priority for state and federal transportation agencies. In spite of implementation of traffic laws, technological advances and improved traffic education systems, the number of traffic fatalities has not decreased substantially. It is critical that we understand the reasons that lead to fatal crashes and deduce effective solutions to address the problem. This indicates that although efforts are being made in the right direction, there is a lack of overall understanding of all contributing factors and their interaction with each other. Decision makers need to understand how various factors have affected highway fatality trends in order to implement the programs that make the best use of funds and personnel and to make progress toward meeting the safety performance targets. While many agencies are tasked with addressing transportation safety, each approaches the challenge of traffic crashes from a different perspective. For example, transportation officials are often tasked with identifying ways to improve the safety of the overall transportation system. By comparison, a police department focuses on enforcing laws and regulations to ensure that users of the transportation system are not put in harm's way by reckless actions or reckless individuals in motor vehicles. Lastly, public health officials focus on how to prevent injuries or how to treat injuries when they occur. Although different, each of these perspectives is critical to understanding the breadth of perspectives that can be brought to a discussion of traffic safety. This research study is a step forward in the right direction and could lead to the understanding and reduction in traffic fatalities. This research study is an attempt to identify the contributing factors to the traffic safety.

This study investigates all possible factors researched through a systematic literature review from three different databases (Web of Science, Science direct and ASCE) of referenced literature and a structured questionnaire approaches. The research study reached out to various US DOT using a structured questionnaire that asked specific questions about traffic fatalities. The questionnaire basically was a vehicle to collect data, information and opinions of various DOTs on the topic of traffic fatallities safety. More specifically, the questionnaire sought information about factors that would help reduce traffic fatalities.

A total of 175 research papers and publications (from the US and international sources) from three databases were used in the current research studies. *Science Direct* published the highest number of papers (86) followed by *Web of Science* (58) and *American Society of Civil Engineers* (31). The study found that there has been significant increase in the number of research papers on traffic safety since 1990's. A total of four papers were written during 1990–1994, seven during 1995–1999, 26 during 2000–2004, 46 during 2005–2009 and 92 during 2010–2014.This clearly shows an interest in traffic fatalities across the globe. There is also a secondary reason for an increase in awareness and prioritization of traffic safety by the state, federal, private, and public organizations. Among the research papers selected for study, it was discovered that the highest number of papers were associated with socio-economic and demographic factors (RII-28.51%), followed by road-user behavior (RII-20.81%), infrastructure (RII-15.84%), system operations and management (RII-9.95%), vehicle safety advancements (RII-9.05%), policy enforcement (RII-8.14%), and emergency response and trauma advancements (RII-7.69%). The study of these papers resulted in the identification of 221 sub-factors that have been studied over a quarter of century. The published papers reflect primary inclination of the researchers towards non-infrastructure factors. Road-user behavior continues to remain a major interest category, whereas emergency response was studied the least.

A total of 93 factors were considered for the study and were categorized into seven different groups: road-user behavior, infrastructure, socio-economics and demographics, vehicle safety and its advancements, policy enforcement, emergency response and trauma care advancements and system operation and managements. The target groups in this study were all the US DOTs. A total of 50 questionnaires were distributed and 9 questionnaires (18% response rate) were returned. The survey results are subjected to analysis, and the ranking of factors is calculated using the relative important index. The basic ideas of the research are to study the various factors affecting traffic fatalities.

This study analyzed the responses from DOTs and coded the data and ranks them as per the responses to each individual factor for providing the comprehensive understanding of the problem while attempting to suggest possible solutions. The study then applied statistical analysis on the DOT responses and research papers to provide conclusions and recommendations.

The top 10 factors (in the order of RII ranking) that were considered to reduce traffic fatalities were the use of safety belt (64.81%), safety belt law (62.96%), safety countermeasures (59.26%), placement of median barrier (55.56%), improvement in roadside barrier (53.70%), guardrails (53.70%), improvement in emergency medical system (53.70%), traffic enforcement (51.85%), increase in traffic enforcement (51.85%), intelligent emergency medical system in rural areas (50.00%), graduated driver licensing law (50.00%), alcohol (48.15%), available budget (48.15%), speed (46.30%), changes in geometric design (46.30%), effects of lighting conditions/weather (46.30%), advances in trauma care (46.30%), driving experience (44.44%), pedestrian behavior (44.44%), speed enforcement (44.44%), and helmet and seat belt campaigns (44.44%). These factors are primarily related to road user behavior, traffic infrastructure, traffic management and law enforcement. Factors related to technology and policy were typically given lesser priority and ranked lower in the ranking system.

The use of safety belt has been identified as the main factor that can help reduce traffic fatalities. This study clearly shows that traffic organizations should direct their resources towards these high-ranking factors to be able to achieve a considerable reduction in traffic fatalities. Efforts should be made to improve infrastructure as well as influence road-user behavior towards safer driving practices. Law and policy enforcement is very important in maintaining a good road user behavior which in turn could lead to lower traffic fatalities.

5.2. Recommendation

The problem is that all the studies and research efforts are focused on one or two factors contributing to traffic fatalities. In view of the narrow approach, traffic safety agencies are having problems directing their resources in the right direction. They did not have one single database where they could look at all the factors contributing to traffic fatalities. As a result insufficient and inefficient efforts were being made to resolve the traffic safety issues. In this work an attempt has been made to solve this problem by carrying out a detailed study and research of all factors that contribute towards traffic fatalities increase or decrease. An effort has been made to gather this highly dispersed data points, ranked them in terms of their importance and provided a one-stop snapshot of all the factors. This will help traffic safety agencies understand the importance of the various factors and accordingly deploy their responses.

DOT responses and research papers provide valuable insight into the factors that can alleviate traffic fatalities; however, they are not precisely aligned in their focus on traffic safety factors.

Although efforts from traffic organizations and research groups have helped reduced traffic fatality rates, the problem is still prevalent and requires more comprehensive approach. An approach that will combine the real life practical experiences with advanced studies to provide efficient, cost effective and sustainable solutions. In addition, policies, programs, laws, and studies that have worked in the past or other parts of the world should be taken into account while making efforts to reduce traffic fatalities

5.3. Future Research

The present studies are typically focused on one or a couple of factors leading to reduction in traffic fatalities and improvements in traffic safety. There is a need to carry out research studies, which are all-inclusive and approach traffic safety in a holistic fashion. Also, DOTs and other organizations should invest in researches to collect and analyze quality traffic data that would lead to safer policies, law, infrastructure, management and public programs. Technology has proven to be highly effective when it comes to improving standards. This is equally true for traffic safety and management, hence there is need to place greater emphasis in integrating technology into traffic systems and infrastructure. And since human factor place a crucial role in traffic safety, it is essential that interaction of humans and environment be studied at greater depths.

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APPENDIX A. IRB APPROVAL FORM

NDSU NORTH DAKOTA STATE UNIVERSITY

February 25, 2014

FederalWide Assurance FWA00002439

Dr. Eric Asa
Construction Management & Engineering

Re: IRB Certification of Exempt Human Subjects Research:
Protocol #**EN14192 , "Identification of Factors Contributing to the Decline of Traffic Fatalities in the United States"**

Co-investigator(s) and research team: **Dharminder Kaur**

Certification Date: 2/25/14 Expiration Date: 2/24/17
Study site(s): **varied**
Funding: **n/a**

The above referenced human subjects research project has been certified as exempt (category # 2) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*). This determination is based on the revised protocol (received 2/21/14).

Please also note the following:

- If you wish to continue the research after the expiration, submit a request for recertification several weeks prior to the expiration.
- Conduct the study as described in the approved protocol. If you wish to make changes, obtain approval from the IRB prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
- Notify the IRB promptly of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
- Report any significant new findings that may affect the risks and benefits to the participants and the IRB.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB standard operating procedures.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.
Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb

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APPENDIX B. SURVEY QUESTIONNAIRE

Identification of Factors Contributing to Traffic Fatalities in the U.S.

Research Intent

Dear Participants,

This research is conducted by Dharminder Kaur, under the direction of Dr. Eric Asa; an Associate Professor in the Department of Construction Management and Engineering at the North Dakota State University, Fargo, North Dakota.

According the National Highway Traffic Safety Administration (NHTSA), the United States has experienced continuous decline in the number of highway traffic fatalities since 2005; with a dramatic decline beginning in 2007. Highway deaths fell to its lowest level in decades (since 1949) in 2011. Even though there was a significant decline in fatalities from 2005 to 2011, highway deaths increased to 33,561 in 2012; which was 1,082 more fatalities than in 2011. In spite of the decline in deaths on US roads, highway fatalities and serious injuries remain a significant threat to public health. A number of reasons have been offered to account for the significant reduction in crashes in recent years. Examples of factors that might have contributed to the decline in highway fatalities are increased safety belt usage, safer vehicles, better roads, increased funding for safety infrastructure improvements, the economic downturn, changes in teen licensing laws, enhanced enforcement efforts and others. A comprehensive analysis of crash data, information and contributing factors need to be performed to determine the relative impact of various factors. The results of the research would be useful for decision makers and would help optimize the allocation of limited safety resources, especially within the recent years where the decrease in fatalities has not been so dramatic.

The purpose of this research survey is to collect information/data that will enable us analyze (and rank) the relative influence of factors that have contributed to the recent national decline in the number of highway fatalities in the United States. This survey is intended to collect information/data from DOT's, affiliated entities, academia and consultants in the United States.

You are being kindly requested to participate in this research study. It would take 20-25 minutes to complete the entire survey. The survey is based on filling out and making check marks in associated boxes. Your participation is voluntary, and you may change your mind or quit participating at any time; with no penalty to you. However, your assistance would be highly appreciated in making this a meaningful study. We encourage you to take your time to complete the enclosed survey and return it by fax to 701.231.7431 or email to Eric.Asa@ndsu.edu or dharminder.kaur@my.ndsu.edu.

Thank you for taking part in this research. If you have questions about your rights as a participant, or to report a problem, contact NDSU Institutional Review Board (IRB) office at ndsu.irb@ndsu.edu or 701.231.8908 or toll free 1.855.800.6717. If you wish to receive a copy of the research or have questions about this research or your participation in this study, please email Dr. Eric Asa, at Eric.Asa@ndsu.edu or dharminder.kaur@my.ndsu.edu.

Your participation is highly appreciated.
Sincerely,

Eric Asa, Ph.D, Associate Professor and Director, Computational and Sustainable Infrastructure Laboratory (CSI Lab).

SURVEY QUESTIONNAIRE: FACTORS

FACTORS CONTRIBUTING TO TRAFFIC FATALITIES.

According to a recent literature review conducted by us, the following factors might have directly or indirectly contributed to the decline in traffic fatalities in the United States. Please indicate the significance of each factor by placing an X in the appropriate boxes. Please add other factors that are not presented in this survey at the bottom of each group of factors. You can further expand any group of factors beyond the two additional factors by inserting new rows and cutting and pasting. Comments and remarks relating to each factor should be entered in the last (Remarks) column.

VL = very low L = low M = moderate H = high
VH = very high NS = not significant

	VL	L	M	H	VH	NS	Remarks
1.Road user behavior							
• **Alcohol**	☐	☐	☐	☐	☐	☐	
• **Driving experience**	☐	☐	☐	☐	☐	☐	
• **Drugs**	☐	☐	☐	☐	☐	☐	
• **Speed**	☐	☐	☐	☐	☐	☐	
• **Road rage**	☐	☐	☐	☐	☐	☐	
• **Hit and run**	☐	☐	☐	☐	☐	☐	
• **Cell phone**	☐	☐	☐	☐	☐	☐	
• **Sleep disorders**	☐	☐	☐	☐	☐	☐	
• **Health conditions**	☐	☐	☐	☐	☐	☐	
• **Stress**	☐	☐	☐	☐	☐	☐	
• **Music (Distraction)**	☐	☐	☐	☐	☐	☐	
• **Intermittent driving record**	☐	☐	☐	☐	☐	☐	
• **Passenger feedback**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Eating/drinking while driving**	☐	☐	☐	☐	☐	☐	
• **Collision with deer**	☐	☐	☐	☐	☐	☐	
• **Pedestrian behavior**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2(Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
2. Socio-economic and demographics							
• **Age**	☐	☐	☐	☐	☐	☐	
• **Gender**	☐	☐	☐	☐	☐	☐	
• **Socio cultural characteristics**	☐	☐	☐	☐	☐	☐	
• **Economic conditions/developm ent**	☐	☐	☐	☐	☐	☐	
• **Education**	☐	☐	☐	☐	☐	☐	
• **Temporal variations**	☐	☐	☐	☐	☐	☐	
• **GDP changes**	☐	☐	☐	☐	☐	☐	
• **Legal drinking age restriction**	☐	☐	☐	☐	☐	☐	
• **Congestion charges**	☐	☐	☐	☐	☐	☐	
• **Population density in rural and urban areas**	☐	☐	☐	☐	☐	☐	
• **Pedestrian crossing**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Social attitude**	☐	☐	☐	☐	☐	☐	
• **Medical condition**	☐	☐	☐	☐	☐	☐	
• **School time/peak hours**	☐	☐	☐	☐	☐	☐	
• **Governance quality**	☐	☐	☐	☐	☐	☐	
• **Safety based incentives**	☐	☐	☐	☐	☐	☐	
• **Race**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
3. Infrastructure							
• **Changes in geometric design**	☐	☐	☐	☐	☐	☐	
• **Street network structure**	☐	☐	☐	☐	☐	☐	
• **Congestion mitigation**	☐	☐	☐	☐	☐	☐	
• **Improvement in roadside hardware**	☐	☐	☐	☐	☐	☐	
• **Placement of median barrier**	☐	☐	☐	☐	☐	☐	
• **Street pattern**	☐	☐	☐	☐	☐	☐	
• **Effect of lighting conditions/weather**	☐	☐	☐	☐	☐	☐	
• **Road safety indicators**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Geographical variations**	☐	☐	☐	☐	☐	☐	
• **Safety countermeasures**	☐	☐	☐	☐	☐	☐	
• **Guardrails**	☐	☐	☐	☐	☐	☐	
• **Wrong way sensors**	☐	☐	☐	☐	☐	☐	
• **Developed transition road safety barrier system**	☐	☐	☐	☐	☐	☐	
• **Improvement in lane width for arterial and collector roads**	☐	☐	☐	☐	☐	☐	
• **Road transition**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
4. Vehicle safety and advancements							
• **Vehicle configuration, mass, components and types**	☐	☐	☐	☐	☐	☐	
• **Airbag for unrestrained rear seat passengers**	☐	☐	☐	☐	☐	☐	
• **Advanced driver assistance system**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Warning information system**	☐	☐	☐	☐	☐	☐	
• **Active hood lift system**	☐	☐	☐	☐	☐	☐	
• **Advanced traveler information system**	☐	☐	☐	☐	☐	☐	
• **Location of safety warning system**	☐	☐	☐	☐	☐	☐	
• **Deployment of digital vehicle technology**	☐	☐	☐	☐	☐	☐	
• **Efficacy of safety policy**	☐	☐	☐	☐	☐	☐	
• **Increase in Light Truck Vehicle with time**	☐	☐	☐	☐	☐	☐	
• **Side view video system**	☐	☐	☐	☐	☐	☐	
• **Safety belt**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
5. Emergency response and trauma care							
• **Improvement in trauma management**	☐	☐	☐	☐	☐	☐	
• **Improved medical care and technology in industrialized countries**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Intelligent emergency medical system in rural areas**	☐	☐	☐	☐	☐	☐	
• **Improvement in EMS(emergency medical system)response time**	☐	☐	☐	☐	☐	☐	
• **Better quality bystander first aid by using internet compatible mobile device**	☐	☐	☐	☐	☐	☐	
• **Advances in trauma care**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
6. System operation and management							
• **Advanced intelligent transportation system**	☐	☐	☐	☐	☐	☐	
• **Improvement of route segments by using GIS**	☐	☐	☐	☐	☐	☐	
• **Speed limitation on highways**	☐	☐	☐	☐	☐	☐	
• **Available budget**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Vision and strategy**	☐	☐	☐	☐	☐	☐	
• **Evaluation and reporting**	☐	☐	☐	☐	☐	☐	
• **Speed cameras**	☐	☐	☐	☐	☐	☐	
• **Controlling signal timing for emergency vehicles**	☐	☐	☐	☐	☐	☐	
• **Fatigue detection technology**	☐	☐	☐	☐	☐	☐	
• **Car pooling**	☐	☐	☐	☐	☐	☐	
• **Safety monitoring system**	☐	☐	☐	☐	☐	☐	
• **Integrated speed management plan in residential areas**	☐	☐	☐	☐	☐	☐	
• **System dynamics**	☐	☐	☐	☐	☐	☐	
• **Traffic police deployment system**	☐	☐	☐	☐	☐	☐	
• **Integrated mobility management plan**	☐	☐	☐	☐	☐	☐	
• **GPS upgrade to show construction work**	☐	☐	☐	☐	☐	☐	
• **Improvement in traffic control system during emergency evacuation**	☐	☐	☐	☐	☐	☐	
• **Strict road administration**	☐	☐	☐	☐	☐	☐	

	VL	L	M	H	VH	NS	Remarks
• **Proper management and planning for electric bicyclers**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	
	VL	**L**	**M**	**H**	**VH**	**NS**	**Remarks**
7. Policy Enforcement							
• **Driving under Influence/Teen drinking**	☐	☐	☐	☐	☐	☐	
• **Safety belt law**	☐	☐	☐	☐	☐	☐	
• **Traffic enforcement**	☐	☐	☐	☐	☐	☐	
• **Increase enforcement**	☐	☐	☐	☐	☐	☐	
• **Graduated driver licensing law**	☐	☐	☐	☐	☐	☐	
• **Implication of automatic policing**	☐	☐	☐	☐	☐	☐	
• **Speed enforcement**	☐	☐	☐	☐	☐	☐	
• **Helmet and seat belts campaigns**	☐	☐	☐	☐	☐	☐	
• **Other 1(Please specify)**	☐	☐	☐	☐	☐	☐	
• **Other 2 (Please specify)**	☐	☐	☐	☐	☐	☐	

If there are reports you might want to share with us, please feel free to send them.

The following are organizational questions:

1. What organization do you work for?

   ☐State Department Agency (DOT) ☐ Public Agency ☐Academia

   ☐Consultant ☐other (state) Click here to enter text.

2. How many years of experience do you have in transportation safety?

Please send the completed survey and copies of any other reports documenting the contribution of the various factors to the reduction in traffic fatalities to:

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Department of Construction Management and Engineering, NDSU Dept. 2475
P.O. Box 6050, Fargo, ND 58105-6050

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WE APPRECIATE YOUR RESPONSE – THANK YOU