Prediction of Road Crash Fatalities for Pakistan using Aggregate Data

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Beenish Akbar Khan
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National Institute of Transportation (NIT)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences & Technology (NUST)
Sector H-12, Islamabad, Pakistan
(2013)

Certified that the contents and form of thesis titled “Prediction of Road Crash Fatalities for Pakistan using Aggregate Data” submitted by Beenish Akbar Khan have been found satisfactory for the requirement of the degree.

Supervisor: ______________________________

Associate Professor (Dr. Anwaar Ahmed, PhD)

To my parents,
and my dear brother – an unfortunate victim
of road traffic crash who is not among us

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LIST OF ACRONYMS

UN	United Nation
WB	World Bank
TRL	Total Road length
PRL	Paved Road Length
RCI	Road Crash Injuries
RTC	Road Traffic Crashes
RCF	Road Crash Fatalities
OLS	Ordinary Least Squares
GDP	Gross Domestic Product
GOP	Government of Pakistan
VRUs	Vulnerable Road Users
ADB	Asian Development Bank
SIP	Social Indicator of Pakistan
GBD	Global Burden of Disease
NDC	National Data Coordinator
WHO	World Health Organization
ESP	Economic Survey of Pakistan
MOC	Ministry of Communication
PTPS	Pakistan Transport Plan Study
SAARC	South Asian Association for Regional Cooperation
LIMDEP	Limited Dependent Models
MAPE	Mean Absolute Percentage Error

NRSS	National Road Safety Secretariat
NTRC	National Transport Research Center
GNI	Gross National Income
JICA	Japan International Cooperation Agency
NH&MP	National Highway and Motorway Police
OECD	Organization Economic Cooperation and Development
GB&AJK	Gilgit Baltistan and Azad Jammu Kashmir
FPHTP	Fatalities per Hundred Thousand Population
FPHTRV	Fatalities per hundred Thousand Registered Vehicles
FPMVKMT	Fatalities per Million Vehicle Kilometre Travelled

ABSTRACT

Nations around the globe continue to face the challenges posed by alarming increase in number of road crash fatalities (RCF) and injuries. About 1.24 million people die every year in road traffic crashes worldwide and approximately 20 to 50 million suffer from non-fatal injuries. Reliable estimates of road crash fatalities of a country, is a vital element needed for road safety improvement efforts. Pakistan with a diverse road network and vehicle fleet has high road crash fatality rate. Reliability of current annual road crash fatality estimates for Pakistan becomes highly questionable due to lack of reliable data and use of inappropriate methodologies used in past studies. The present study aimed to predict RCF for Pakistan using two different data sets and different model specifications. First set of models used police reported annual number of RCF for Pakistan while the second set of models used data obtained from international organizations like World Health Organization (WHO) and International Road Federation (IRF). RCF were predicted from year 2014 to 2040 and results were compared with national and international estimates. Overall, 21,095 RCF were predicted for year 2014, compared to approximately 30,000 annual fatalities predicted by WHO (2013) and 5,323 (2012) reported by police. Analysis of the results indicated that use of police reported data results into under prediction, while methodology adopted by WHO over predicts the annual road crash fatalities for Pakistan. The study also carried out a detailed comparison of RCF rates of Pakistan with other regional countries and international trends. This study also presents a comprehensive documentation and discussion of state of road safety and related factors for Pakistan. The road crash fatality estimates can be used by National Highway Authority and Ministry of Communication as an input for formulation of multipronged road safety improvement policy for Pakistan.

CHAPTER 1. INTRODUCTION

1.1 Background

In recent years road traffic crashes (RTC) have emerged as a serious global challenge than may be expected. According to the World Health Organization (WHO) “Global Status Report on Road Safety - 2013”, nearly 1.24 million people die each year on world’s roads and approximately 20 to 50 million sustain non-fatal injuries due to road traffic crashes [WHO, 2013]. Fatalities and injuries resulting from road traffic crashes not only have immeasurable impact on the families of victims but also constitute a major public health challenge. The issue is of more serious nature in low- and middle-income countries where rapid motorization has taken place in recent past without adequate traffic management and safety strategies. Approximately 90% of the worlds’ RCF occur in low and middle income countries even though they account for only 48% of the world’s registered vehicles [WHO, 2004]. RCF and road crash injuries (RCI) are expected to increase by 65% in next 20 years unless there are new efforts to improve the current state of road safety around the globe. In recent past an overall downward trend in RCF has been observed in high income countries where only 10% of the world RCF occurs [WHO, 2004]. RCFs are predicted to increase by 83% in developing countries and are expected to decrease by 27% in developed countries [Kopits and Cropper, 2003]. WHO predicts that, if current trends continue and efforts are not undertaken to improve road safety situation, especially in low-and middle-income countries, road traffic injuries will become overall the fifth leading cause of death by year 2030, which is already the leading cause of death for young people aged 15–29 years [WHO, 2009].

RTC are human tragedy, as these incur huge socio-economic cost in terms of injuries and untimely death. RTC not only cause economic loss by pushing many families more deeply into poverty by the loss of working member, but also are huge burden on health care services. Recent estimates indicate that RTC cost approximately 1-3% of a country’s gross domestic product (GDP) [WHO, 2009]. Road safety has become an issue of national and global concern as its negative impact is not only felt by the individuals of all ages and groups but national and international economy as well.

Good transportation infrastructure benefits both individuals and society by facilitating safe and efficient movement of people and good and by providing accessibility to a wide range of socio economic services. Pakistan is a developing country of South East Asia region having the sixth largest population in the entire world (180.71 million as of 2012) [ESP, 2012]. Although, Pakistan has experienced a slow economic growth in recent past but road infrastructure has improved at a reasonable pace. Length of paved road increased from 148,000 Kilometer (Km) in 2002 to approximately 180,000 Km in 2012 [ESP, 2012]. Overall there has been 0.38% growth in road infrastructure in past one decade. However, in Pakistan vehicle population has grown at mush faster pace as compared to population, economy and road infrastructure. Motorized vehicle population has increased from about 5.3 million in year 2002 to 11 million vehicles of all type in year 2012 [ESP, 2012]. The dominate vehicle groups are: motor cycles (53%), motor cars (33%), tractors (9.3%), buses (1.2%), trucks (2.12 %) and Rickshaws (0.86%). In last decade there has been approximately 110%, 150%, 45% and 30% increase in motorcycles, passenger cars, trucks and buses respectively [NTRC, 2011].

The rapid motorization, increase in proportion of vulnerable road users and expansion of road infrastructure has brought with it higher number of RTC. Pakistan is facing a serious issue of RCF and injuries and RTC cost Pakistan's economy about Rs 100 billion per annum [Baguley and Jacobs, 2000; Ahmad, A., 2007]. RCI are the second leading cause of disability, the fifth cause of overall healthy life-year losses and the eleventh cause of premature fatality in Pakistan [Hyder and Morrow, 2000; Hyder et al., 2006]. Past studies provide different estimates of RCF and RCI with wide variations. According to NTRC, in year 1999 approximately 1.4 million RTC occurred in Pakistan that resulted in 7,000 fatalities [NTRC, 1999]. Studies by Ghaffar et al., [2004] and Fatmi et al., [2007] found that approximately 1,500 individuals per 100,000 population sustain injuries due to RTC in Pakistan annually. Ahmed (2007) estimated that two million crashes occurred in the Pakistan in the year 2006 and 0.418 million were of serious nature. However, recent data suggested that these figures could be four to ten times higher than those reported officially [WHO, 2009]. WHO, “Global Status Report on Road Safety” – 2009 estimated that there were approximately 52,537 annual RCF in Pakistan, however the latest estimates by same organization indicate that there are approximately 30,130 annual RCF in Pakistan. As per the official data collected through National Highway and Motorway Police (NH&MP), and provincial police there were total of 5,323 RCF in Pakistan in year 2012. This dichotomy between reported and estimated number of fatalities is a reflective of extent of underreporting of fatal crashes in Pakistan, and highlights the importance of need for renewed efforts to provide reliable estimates for RCF in Pakistan.

1.2 Problem Statement

Since fatalities due to road crashes are amenable to remedial measures, therefore it is possible to observe drop in annual number of fatalities of any country if multipronged road safety improvement policy is adopted. Reliable estimate of annual fatalities due to road crashes is the cornerstone of all road safety activities in a country. Before starting any remedial measure, it is necessary to understand the magnitude and dimensions of the problem due to RTC. In case of Pakistan, data on annual road crash fatalities is available from two sources:

- Police Reported Data. The data on fatal accidents is collected by NH&MP in their area of jurisdiction and provincial police in respective Thana and reported to their respective Headquarters at national/provincial levels [NRSP, 2007]. The data obtained from police sources is highly unreliable, incomplete and without any international accepted standards [NRSP, 2007].
- International Organization. Different international organizations like IRF, World Bank, WHO and Asian Development Bank publish data on RCF at regular interval. The previous studies that attempted to estimate the annual RCF produced a wide range of estimates. For example the WHO’s “Global Status Report on Road Safety – 2009” estimated that there were approximately 52,537 annual RCF in Pakistan in year 2010, however a more recent report by the same organization indicates that there are approximately 30,130 annual RCF in Pakistan.

Both the data sets have their issues and limitation and it is highly unlikely that reliable estimates for annual RCF can be obtained. Data collected through police record will result into serious underestimation of fatalities, as there is no systematic way of recording, reporting and storing the road crash data. In case of RCF, estimates obtained from international sources there is wide range of estimated fatalities and details of methodology used for estimation are not reported/covered in published reports. In order to get reliable estimate of annual RCF, the adopted methodology should use: (1) a detailed data set that uses information on fatalities, population, gross national income, road infrastructure, registered vehicles and traffic laws and their enforcement (2) model with appropriate function form, that has been used in present study.

1.3 Research Objectives

To overcome the road safety problems in Pakistan, there is a need to play our role at national level in halting and reversing the current national trends of RCF and RCI. Reliable estimation of annual RCF and RCI is the first step to get a clear understanding of the nature of the problem. In order to address the key aspects of identified problem, the objectives set forth for this research are:

- To synthesize the current state of road safety and associated factors in Pakistan.
- To identify RCF data issues in Pakistan.
- To carry out an international statistical comparison of road safety situation in Pakistan with other countries.
- To develop RCF prediction model for Pakistan using different data sets.

1.4 Overview of Study Approach

To accomplish the research objectives, a detailed methodology was devised and the following research tasks were outlined:

- Literature review of the previous research findings on the factors affecting the RCF, including both the international and national research efforts.
- Collection and collation of RCF data for Pakistan from different national sources/ organizations.
- Collection and collation of RCF data for different countries around the globe from WHO, IRF and WB data sources.

- Comparison of RCF rate of Pakistan with countries of South East Asia, Asia, middle income group countries and overall with all the countries of the globe.
- Estimation of statistical models on basis of different data sources (Pakistan specific data and data from international organizations).
- Comparison of estimated RCF obtained from developed models and reported data.

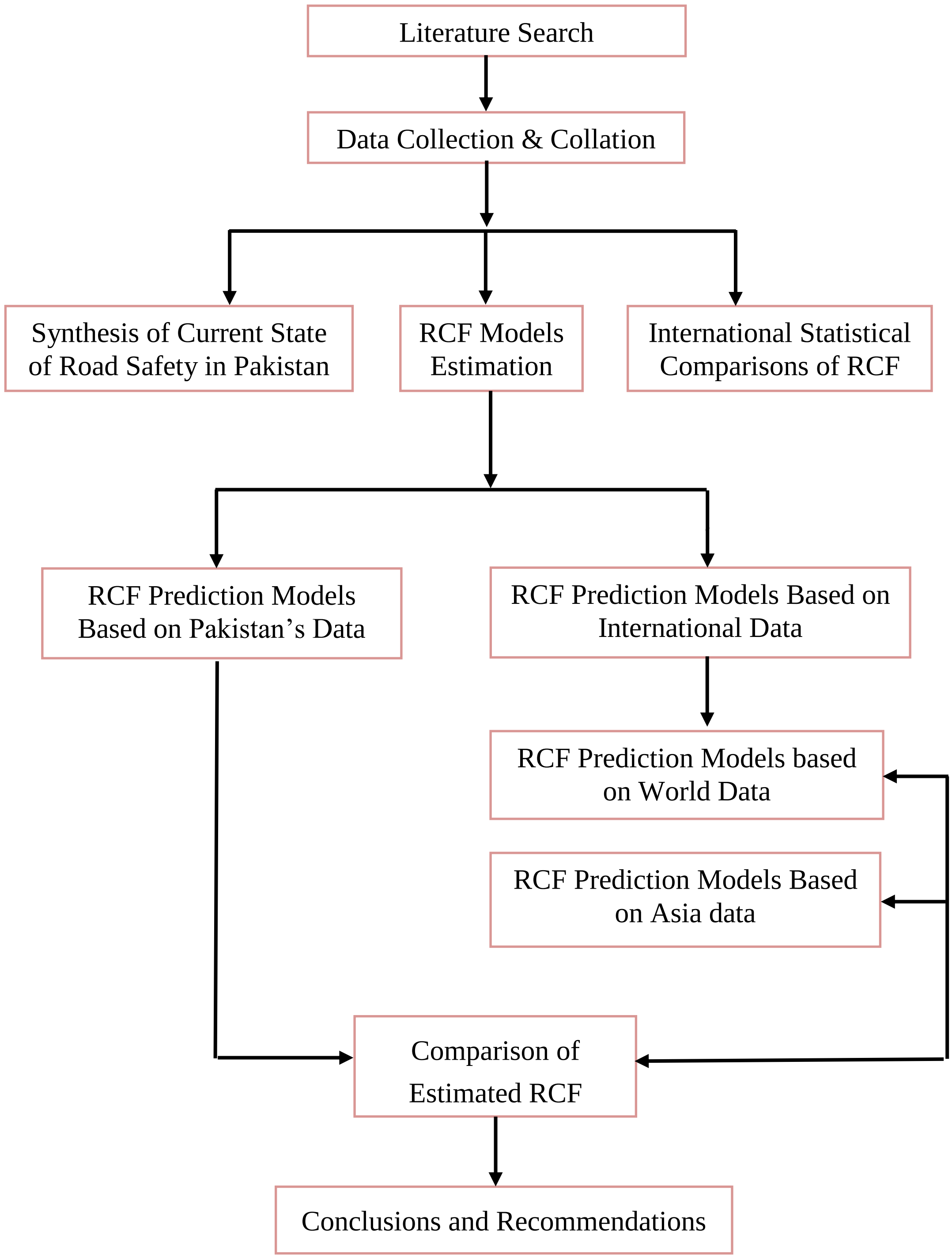

Figure 1.1 Overview of Study Approach

1.5 Thesis Organization

This research is organized into six chapters. The need for accurate estimation of RCF and study objectives are discussed in Chapter 1. Chapter 2 provides a literature review on RCF estimation. In Chapter 3 the current state of road safety in Pakistan is discussed. Population, vehicles fleet, roads infrastructure growth trends and past annual road crash fatalities in Pakistan are also discussed in Chapter 3. Chapter 4 covers the comparison of RCF rate of Pakistan with countries of South East Asia, Asia, middle income countries, and overall with all the countries of the globe. Chapter 5 describes the RCF prediction models. Lastly, the research summary, conclusions, and recommendations are presented in Chapter 6.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter summarizes several past RCF studies that were either carried out internationally or in Pakistan. This chapter first examines different methodologies used at international level for estimation of RCF using aggregate data. The discussion covers the importance of accurate data management, road safety laws implementation, and road safety awareness programs sponsored by the government, enhanced medical care and traffic management. Literature review covers multiple international and national RCF studies, where wide range of variables and methodologies were used.

Literature review revealed that RCF have a non-linear relationship with economic growth. In high-income countries, a proven set of interventions have contributed to the significant reductions in RCF and low-income counties like Pakistan are having the highest burden of RCF. The major issues faced by the developing countries are lack of medical services, higher number of vulnerable road user and under reporting of accidents. The RCF are significantly associated with the availability of a pre-hospital care system, governmental laws and policies and their enforcement level, road network density, vehicle kilometre travelled, alcohol usage, proportion of young males and speed limits.

Lastly the literature review highlights the road safety situation in Pakistan. There is no approved transport policy in Pakistan. The RCF have increasing trend due to low traffic safety awareness, negligence of traffic rules, overloading, bad road conditions, low standards of vehicle maintenance, violation of road safety law and increased motorization.

2.2 Road Crash Fatalities – Summary of International Research Efforts

Jacobs and Cuttings [1986] using cross-sectional data for twenty developing countries, estimated multiple regression model to investigate the factors affecting RCF.

RCF data for the year 1980 were used for analysis. Population per physician, vehicle ownership, road density, gross national product per capita, vehicle density and population per hospital bed were used as explanatory variables for model development by the authors. Study results revealed that the developing countries experienced increased fatality rates than the developed countries due to lack of medical services and under reporting of accidents.

Soderlund and Zwi [1995] examined the regional and worldwide road fatality trends by using cross-sectional data from eighty three countries for the year 1990 and multivariate regression methods. Road density, number of vehicles per capita, health expenditure as a percentage of GDP, ratio of mid-age to total population, fatality rates, population density, ratio of male to female fatality rates and GNP per capita were used as independent variables. Study results indicated that former Socialist East European countries and industrialized countries had the maximum traffic fatality rates. In case of underdeveloped countries, India and African countries exhibited higher number of fatalities. Author found a positive correlation between RCF per 100,000 populations and GNP per capita, whereas inverse effects were observed in road fatalities per l000 registered vehicles. Higher medical care expenditure and GNP per capita were found to be positively associated with reduced fatality rates. Greater RCF in the young and aged persons were linked directly with raised population density. Lack of information on location of traffic accident (urban vs rural) and details of individual who suffered as a result of accident (pedestrian vs car occupant) are the major limitation of this study.

Van Beeck et al., [2000] studied the relationship between RCF and economic growth for twenty one developed countries, using regression model. RCF data from year 1962-1996 were used for analysis. Study results revealed that RCF have a non-linear relationship with economic growth. RCF for developed countries were observed to start reducing at 14,000 $ per capita of their economic growth.

Bester [2001] studied the relationship between RCF, socio-economic and state of infrastructure for ninety countries, using stepwise regression model. RCF data from year 1994-1996 were used for analysis. Study results revealed that the RCF were significantly affected by human development index (HDI), road density and passenger car ownership.

Lassarre [2001] studied the relationship between RCF, vehicle kilometres driven and traffic regulation for ten European countries, using Harvey’s structural model. RCF data for year 1950-1990 were used for analysis. Study results revealed that the countries that insure higher road safety intervention implementation enjoyed higher success in lowering traffic fatalities.

Page [2001] using data for twenty one different European countries, developed multiple regression model to investigate the factors affecting RCF. RCF data from year 1980-1994 were used for the analysis. Vehicle fleet per capita, population levels, alcohol consumption, employment rate, percentage of young people, urban trips and high number of buses in the vehicle fleet were found to be directly associated with RCF. Study results revealed that generally RCF had decreasing trend over the time. Use of few variables for analysis and inability of study to investigate impact of climate are the major limitation of this study.

Noland et al., [2003] studied the relationship between the developments in medical care and RCF, for twenty two Organization Economic Cooperation and Development (OECD) countries, using fixed effect model [Hausman et al., 1984]. RCF data from year 1970-1996 were used for analysis. Population, GDP per capita, motor vehicles per capita, physician's per capita, average acute care days in hospital and infant mortality rates were used as explanatory variables for the model development by the authors. Study results revealed that improved medical technology can help in lowering the RCF.

Scuffham [2003] analysed the relationship between RCF and economic aspects in New Zealand, using Harvey structural time series model. RCF data from year 1970-1994 were used for analysis. Unemployment rate, vehicle kilometre travelled, proportion of young males in the population, income level, speed limit, proportion of motorcycles, real gross domestic product per capita, alcohol consumption per capita and seatbelt usage were used as explanatory variables for the model development by the author. Study found that increased vehicle kilometre travelled, alcohol usage, high proportion of young males and high speed limits result in increased RCF. One of the major issues of this study is that only few variables were used for analysis/ model development. Also this study failed to incorporate policy changes and variation of climatic conditions into proposed methodology.

Kumara and Chin [2004] studied the relationship between RCF, the level of development and socioeconomic conditions for forty-one Asia Pacific countries, using fixed effect negative binomial model. RCF data from year 1994-1996 were used for analysis. Population growth, GNP per capita, total length of road network and total number of registered vehicles were found to be directly associated with RCF. Study results revealed that generally RCF have decreasing trends over the time and RCF rate for pacific countries were 3.12 times higher than Asian countries.

Kopits and Copper [2005] analysed the association between RCF and income per capita for eighty eight countries using linear regression model. RCF data from year 1963-1999 were used for analysis. Study results revealed that RCF rapidly increased in developing countries up to a certain income threshold ($ 8600 per capita, 1985 constant $) and then become constant. Study predicted that for next twenty years total RCF are expected to rise up to 66% from their current level.

Bishai et al., [2006] using data for forty one different countries, developed fixed effect regression model to investigate factor affecting traffic fatalities. RCF data from year 1992-1999 were used for analysis. GDP, population, number of registered vehicles, kilometres of road network, traffic fatalities and injuries per annum, annual crashes, alcohol consumption and total natural fuel consumption were used as explanatory variables for model development by the authors. Rapid increase in RCF was observed in low income countries at the start of economic development, but as soon as income level reached certain income threshold ($8000 per capita), the traffic fatality rates become constant. Study results also revealed that in wealthy countries, in-spite of higher crash rates, fatality rates are low that may be attributed to enhanced level of medical services. Lack of complete/ accurate data for low income counties and failure to characterize level of development of individual countries were the major weak areas of the study.

Bhalla et al., [2007] studied the RCF with respect to four different scenarios; (1) high bus use (2) high car use (3) high scooter use and (4) a mixed use base case. Study results revealed that normally RCF have non-linear trend over the time for the high car scenario, whereas for remaining scenarios the RCF had increasing trend.

Paulozzi et al., [2007] studied the relationship between RCF, road user type, motor vehicles per thousand people and economic growth for forty four countries, using regression technique. RCF data from year 1996-2002 were used for analysis. Rapid increase in RCF was observed in low income countries where non-motorized exposure was high. Lack of complete data, focus on Europe and America only and failure to characterize the travel mode of the victim are the major weak area of this study.

Eksler et al., [2008] using data from twenty five different European countries, developed ecological Bayesian regression model to investigate factors affecting RCF. Population density and country (affiliation) were used as explanatory variable for model development by the authors. Study results revealed that population density has a positive effect on RCF. Study presented a ranking of European countries based on RCF. Scandinavian countries were found to be high in ranking (better road safety) compared to other countries.

Law et al., [2008] studied the relationship between RCF and income per capita for twenty five European countries, using fixed effect negative binomial regression model. RCF data from year 1970-1999 were used for analysis. Infant mortality rate, corruption, population age groups from 15 to 24 and total number of registered vehicles were found to be directly associated with RCF. While physicians per thousand capita, implementation of road safety laws, upgraded political institutions and percentage of population above 64 years of age were inversely associated with RCF.

Ahmed et al., [2009] using data for 178 countries, developed seemingly unrelated regression equation and ordinary least square (OLS) models to investigate relationship between road traffic safety, health service levels and motorization level. RCF data from year 2007-2008 were used for analysis. Fatalities per hundred thousand population, number of hospital beds per thousand population and number of registered vehicles per capita were used as response variable for model development by the authors. Study results revealed that income level of a country, the availability of a pre-hospital care system, governmental laws and policies and their enforcement level, road network density and speed limits are significantly associated with the levels of traffic safety, health care services and motorization level of a country.

Grimm and Treibich [2012] using data for twenty five Indian states, developed multivariate regression model to investigate factors affecting RCF. RCF data from year 1996-2006 were used for analysis. Aggregate income, road and health infrastructure, socio-demographic population infrastructure, enforcement of road traffic regulation and motorization stages were used as explanatory variables for model development by the authors. Study results revealed that increased motorization, urbanization and vulnerable road user’s growth especially pedestrians and two wheelers were the main cause of RCF. Table 2.1 summarizes the past international studies on RCF.

Table 2.1 Summary of Past International Research on RCF

Study	Data/Time of Study	Modelling Technique	Factors related to Road Traffic Safety
Jacobs and Cuttings (1986)	20 developing countries (1980)	Linear regression	GDP, population per hospital bed, road density, total number of vehicles
Soderlund and Zwi (1995)	83 countries (1990)	Linear regression	Road density, health expenditure, population density, surface area, income level, education level
Van Beek et al., (2000)	21 industrialized countries (1962-1996)	Linear regression	GDP per capita
Bester (2001)	93 countries (1994-1996)	Linear regression	Road density, human development index, GDP, car ownership
Lassarre et al., (2001)	10 European countries (1950-1990)	Harvey structural model	Vehicle kilometres of travel, traffic regulations (speed limits, seatbelt use, etc.)
Page (2001)	21 European countries (1980-1994)	Time series model	Population, percentage of young , fraction of buses in traffic stream, vehicle fleet, percentage of urban population, alcohol usage, percentage of population employed
Noland et al., (2003)	22 OECD countries (1970-1996)	Negative binomial	GDP, physicians per capita, infant mortality rate, no. of vehicles, population, average days of acute care in hospital
Scuffham (2003)	New Zealand (1970-1994)	Multivariate structure time-series model (STSM)	Distance travelled, unemployment rate, GDP, percentage of young males, speed limits at roads, alcohol consumption
Kumara and Chin (2004)	41 Asia- Pacific countries (1994-1996)	Negative binomial	Population, GDP, total length of roads, number of registered vehicles
Kopits and Cropper (2005)	88 countries (1963-1999)	Linear / log-linear regression	GDP per capita
Bishai et al., (2006)	41 countries (1992-1999)	Fixed effect regression	GDP, fuel consumption, alcohol use
Paulozzi et al., (2007)	44 countries (1996-2002)	Cross-sectional regression	Vehicles per 1000 population, GDP
Eksler et al., (2008)	25 European countries	Bayesian ecological regression	Population density
Law et al., (2008)	25 European countries (1970-1999)	Negative binomial	GDP, physician/ 1,000 population, infant mortality rate, motorcycles per capita, level of corruption, level of political rights

2.3 Road Crash Fatalities – Summary of National Research Efforts

Downing [1985] studied the relationship between RCF, traffic law enforcement and driver trainings for different cities of Pakistan. Driver's behavioural issues and experimental road markings were used as explanatory variables for model development by the author. Study results revealed that adaption of improved training courses for drivers, better law enforcement strategies and effective road marking may be attributed to reduce RCF in Pakistan.

Bishai et al., [2003] evaluated the impact of investment in road traffic safety for Pakistan and Uganda. Estimates of road traffic safety investment for both countries were obtained from government financial records, non-governmental organization sources and World Bank records. The study found that road traffic safety investment in Pakistan and Uganda was $0.07 and $0.09 per capita respectively in 1998. The study found that a significant drop in RCF is possible if road traffic safety expenditure is increased.

Hyder et al., [2006] carried out a thorough literature review to investigate health policies gaps regarding RTC. Study results revealed that generally there was no approved transport policy in Pakistan.

Shah et al., [2007] examined the pattern and factors affecting RCF for Sindh province. RCF data for the year 2004 were used for the analysis. Road user's type, age, place of occurrence, gender and motorization levels were used as explanatory variables for model development by the author. Study results revealed that generally RCF were positively associated with population, number of motor vehicles and motorization level. Lack of complete/accurate data and failure to characterize information on socio-demographic factor are the major weak area of this study.

Mir et al., [2010] used statistical analysis to investigate the disproportionate RCF of commercial vehicles for Rawalpindi city. Alcohol usage, vehicle maintenance, driver's behaviours, seatbelt usage and fatigue were used as explanatory variables for analysis by the authors. Study results revealed that marijuana usage, failure to use seatbelt and low standard of vehicle maintenance were the major causes of the RCF.

Hussain et al., [2011] investigated the traffic rules familiarity level and its association with RCF for Islamabad using random observational and survey analysis techniques. Author selected city main roads (highways with traffic flow of 50 vehicles per minute involving both heavy traffic vehicles and light traffic vehicles) and local streets for their study. The study found that: (1) majority of travellers lacked general traffic safety awareness (2) low level of helmets/seatbelt usage. Authors concluded that over speeding, poor vehicle condition, and underage driving were the major cause of RCF. Authors recommended that for reducing the RCF, there is need of enhanced traffic safety education, higher level of traffic law enforcement and better vehicles quality.

Bhatti et al., [2011] studied the relationship between RCF and highway work zone for Karachi city, using data from year 2006-2008. Road surface type, road user type, crash type and work zones were used as explanatory variables for this study by the author. Study results revealed that RCF rates were higher in the highway work zones than other zones. It was also concluded that opposite-direction crashes and traffic crashes involving pedestrians and on wet road surfaces were significantly associated with the highway work zone.

Nasr, [2011] using data for Pakistan, developed autoregressive integrated moving average time series models to analyse the road crashes trends and forecasted the RCF for Pakistan. RCF data from year 2000-2010 were used for the analysis. Road length, number of population in different regions of country, weather conditions, driver's skills and level of vehicle maintenance were used as explanatory variables for model development. Study results revealed that RCF have the positive association with the population of the country, number of vehicles on the road and road length, whereas negative association has been observed with passenger per traffic kilometre.

Bhatti et al., [2011] studied the relationship between RCF and traffic law enforcement for Karachi city. RCF data from year 2009-2010 were used for analysis. Vehicle type, age and gender were used as explanatory variables for analysis by the author. Study results revealed that no change in driver's behavior was observed after the strict implementation of road safety laws. Gulzar et al., [2012] using data for Pakistan, developed OLS regression models to analyze RCF for different provinces. RCF data for the year 2000-2010 were used for the analysis. Total vehicles involved in crashes were found to be directly associated with RCF. Study results revealed that Punjab had generally higher and consistent RCF than the other provinces. One of the major issues of this study is that only few variables were used for model development.

Tahir et al., [2012] investigated factors affecting RCF for Lahore city using gender, age, injury patterns and type of colliding vehicles as explanatory variables. RCF data from year 2005-2010 were used for analysis. Over speeding was observed to be the main cause of RCF.

Durrani et al., [2012] studied the relationship between the RCF and road safety attitudes and ticket fixing behaviours for Lahore city, using multivariate logistic regression models. Attitudes towards traffic rules compliance, traffic ticket history (number of tickets received during lifetime, their reason and whether they were involved in traffic ticket fixing), age at the time of first driving license, vehicle driven and whether trained from a driving school or not were used as explanatory variables for model development by the author. Study results revealed that generally RCF were higher in those individuals who had received a traffic signal violation ticket and being involved in traffic ticket fixing. Authors suggested that there is a need to improve driver licensing system, anti-ticket fixing polices, implementation of point demerit system and safety awareness.

Batool et al., [2012] studied the relationship between RCF, user's attitude towards the road safety and low safety standard in Pakistan, using survey analysis. Students, government officials and commercial driver were interviewed by the author. Study results revealed that RCF have increasing trend due to traffic rules negligence, road safety law violation, lack of skilled drivers, lack of timely implementation of traffic safety polices and increasing urbanization and motorization.

Khan and Tehreem [2012] determined the reasons of RCF in Pakistan. Study found that fewer training institutes, over loading, unskilled driving, road conditions and cell phone usage while driving are the major causes of RCF. Author suggested that there is a demand of road safety awareness program at the community level.

Hyder et al., [2000] examined the influence and magnitude of RCI in Pakistan. Author carried out a thorough literature review of past studies and used all available governmental data's since1956. Independent variables used in the analysis were: (1) vehicles per KM (2) motorization level (3) population density (4) traffic fatalities for the year 1956-1996. Major finding of the study are: (1) A gradual rise in RCF and injuries (2) merely 14.3% of the accidents were registered by the police which indicates a serious under-reporting issue (3) higher contribution of commercial vehicles to RCF and injuries.

Ghaffar et al., [2004] investigated factors affecting RCI in Pakistan. Household interview surveys were conducted for three months duration in the year 1997. Authors found that there was increased road traffic injury burden which implies a challenge for the health system in Pakistan. It was also concluded that traffic injuries were highest for young males, vendors, under 5 years school going children, urban populations and vehicle occupants. Lack of precise information about condition of injuries, and underreporting of crashes are the major study limitations.

Razzak and Laflamme [2005] investigated the accuracy of RCI data for Karachi city. Road traffic injury data from year 2003 were used for analysis. Injury type, fatality location, age, injury outcome and victim's gender were used as explanatory variables for analysis by the author. Study results revealed that RCI data have major limitations.

Shamim et al., [2011] analysed RCI of Karachi city using data from road traffic injury investigation program (RTIRP) for the year 2006-2009. Authors compared findings with other published road traffic injury data's from low/middle income countries with Karachi. Study result revealed that RCI of Karachi city were much lower than the other low/middle income countries. In case of Karachi city, RCI were found to be higher among young males, motorcycle users followed by pedestrians. Major finding of the study are: (1) uniform temporal trends of RCI (2) rear end collision as the major cause of RTI (3) external wounds is the major type of injury (4) mostly road traffic victims are rescued by volunteers and taken to a government hospital.

Razzak et al., [2011] studied the relationship between the RCI and healthcare budget for Karachi city. Road traffic injury data from year 2007-2008 were used for analysis. Authors found that the two wheelers and breadwinners accounted for the majority of RCI. Study results also revealed that the total healthcare costs on traffic accident victim were approximately 4.7 million US dollar, while the total economic lost due to work loss costs were 1.4 million US dollar. One of the major issues of this study was that there was no alternative method available to verify the reported costs, also there was a lack of complete/accurate data on treatment given in hospitals.

Bhatti et al., [2011] studied the variations in RCI reporting system of police, edhi ambulance service and hospital emergence departments for Karachi city. Road traffic injury data from year 2008 were used for analysis. Road user's types and outcome of accidents were used as explanatory variables for his comparative study. Study results revealed that RCI reporting system of police department required improvements.

Lateef [2011] using data for Karachi metropolis, performed spatial analysis to assess the patterns of RCF and injuries. RCF data from year 2008 were used for analysis. Road user's type, victim's demographic, injury severity, type of vehicle involved in crash, crash location details and time of day were used as explanatory variables for analysis by the author. Study results revealed that generally RCF and injuries were higher for young males, motorcyclists, pillion riders and accident occurring during dusk time of the day. It was also revealed that RTC mostly caused head injuries. Lack of accurate data and failure to incorporate accurate location of accident are the major weak area of this study.

Farooq et al., [2011] investigated patterns of RCI for Rawalpindi city. Road traffic injury data from year 2007-2008 were used for analysis. Gender, age, injury nature, injury severity and alcohol usage were used as explanatory variables for analysis by the authors. Major finding of the study were: (1) young males are main victim of RCI (2) most of the RCI are mild in nature (3) cuts and open wounds is the major type of injury (4) very few road traffic victims were under the influence of drugs. Lack of complete/accurate data is the major weak area of this study.

Table 2.2 presents the summary of past RCF and RCI studies carried out in Pakistan.

Table 2.2 National Research on RCF and RCI

Study	Location/Time of Study	Analysis Technique	Factors related to road traffic safety
Shah et al., (2007)	Sindh province (1991-2003)	Descriptive statistics and Pearson correlations	Gender, age, category of road user, place of occurrence, motorization level.
Mir et al., (2010)	Rawalpindi city (2005-2010)	Time location cluster sampling	Fatigue, sleep inadequacy, marijuana/ alcohol use, unsafe driving habits, vehicle maintenance and seat belt use.
Waseem et al., (2010)	Karachi and Lahore	Case-control study (questionnaire based)	Helmet usage of women pillion riders
Lateef (2011)	Karachi (2008)	Spatial pattern analysis (Geocoded databases)	Victim's demographics, location details, time of the day, means of transportation to hospital, type of vehicle involved in crash, injury Severity and road user type.
Razzak et al., (2011)	Karachi city (2007)	Stratified sampling	Road user group, age, gender, injury severity, household income, outcome of victim, hospital expenses paid, time spent in hospital and loss of work day.
Bhatti et al., (2011)	Karachi (2006-2008)	Comparative analysis	Crash type, road surface, road user type.
Farooq et al., (2011)	Rawalpindi city (2007-2008)	Standard surveillance method	Age, gender, injury severity, site, activity, nature of injury, alcohol abuse.
Bhatti et al., (2011)	Karachi - Hala road section (2008)	Comparative analysis of different data reporting system	Age, gender, road user group, crash and injury outcome.
Nasr (2011)	Pakistan (2000-2010)	ARIMA time series analysis	Weather conditions, driver's skills, condition of the vehicle, length of roads, population in the different regions of country and adherence to car insurance.
Gulzar et al., (2012)	Pakistan (2000-2010)	OLS regression	Number of vehicles involved
Tahir et al., (2012)	Lahore city (2005-2010)	Retrospective registry-based study	Age, gender, yearly breakdown of crashes, road user category, injury patterns, category of colliding vehicles.
Durrani et al., (2012)	Lahore city	Multivariate logistic regression	Age, traffic ticket fixing, vehicle type, professional status, learned driving, traffic safety Attitudes, years of education, number of years since licensed.

2.4 Chapter Summary and Conclusion

RCF have become one of the critical public health problem and challenge around the globe. Millions of people die every year while traveling and it expected to keep increasing in future unless there are new and focused efforts to improve the current state of road safety. The situation is improving in developed countries while it continues to deteriorate in low and middle income countries.

According to international studies, the major factors that are found to be associated with road crash fatalities are: road density, number of registered vehicles, population density, GDP, human development index, level of healthcare services, vehicle kilometres driven, traffic regulation, level of corruption, level of alcohol consumption, employment rate, and infant mortality rate. Research findings indicate that enhanced medical services, improved quality of public transport, proper implementation of road safety regulation and stricter enforcement of traffic laws/polices, higher level of road safety awareness, improved road design, strong multi-sectoral involvement in road safety and efficient accident reporting system are attributed to lower road fatality rate. The major limitations of international studies are: (1) lack of complete/accurate road crash fatality data (2) failure to consider appropriate variables for analysis (3) incorrect functional form of the mathematical model.

No effort has been made at national level to estimate the annual road crash fatalities for Pakistan. However, various studies have investigated factors associated with RCF and RCI. National studies show that the major factors that are significantly associated with road crash fatalities are: over speeding, under-age driving, fatigue, violation of seatbelt laws, weather conditions, cell phone use while driving and poor road maintenance. National research findings indicate that improve traffic law enforcement, effective road marking, proper seatbelt usage, improved vehicle maintenance standards, enhanced traffic safety education, improved driver licensing system, modern accidents reporting system, traffic safety awareness program and better healthcare system are expected to result in lower RCF.

CHAPTER 3. CURRENT STATE OF ROAD SAFETY IN PAKISTAN

3.1 Introduction

In this chapter, the current state of road safety in Pakistan is discussed. This chapter also provides detailed discussion on population, road network and vehicle fleet growth trends in Pakistan. In the later section, the past trends of RTC at national and provincial level are discussed in detail.

The Ministry of Communication (MOC) works as the lead policy making agency for transportation sector in Pakistan. In June 1974, National Transport Research Centre (NTRC) was founded under the planning and development division and later in November 1992 was transferred to the Communications Division. The major function of NTRC is to gather and manage the primary and secondary data across the Pakistan which includes road length, registered vehicles and accidents statistics etc. [Zia, Y., 2011]. In September 2000, the National Highway Safety Ordinance was passed to regulate transport especially on National Highways and Motorways [Hyder et al., 2006], as a result National and Highway Motorway police (NHMP) force has been provisioned. Due to efforts of NHMP major cutbacks have been observed in RCF on national highways and motorways [Ahmed, A., 2007].

In September 2006, National Road Safety Secretariat (NRSS) was founded to formulate and execute road safety plans, and to take preventive actions for road safety in Pakistan [Ahmed, A., 2007]. However, due to resource constraints and lack of political will NRSS was closed in 2008 [SPRSP, 2010]. Establishing road traffic injury research and prevention centre under the federal ministry of health was another significant step in road safety in Pakistan [Ahmed, A., 2007].

3.2 Population, Road Network and Vehicle fleet Growth in Pakistan

Pakistan is the sixth most populous country of the world with an estimated population of 178.9 million [PTPS, 2006]. Average population growth rate of Pakistan is approximately 1.55% whereas other Asian countries such as China, India and Iran have a growth rate of 1.31%, 1.25%, and 0.48% respectively [World Bank, 2012]. The population growth trends of Pakistan for the year 1981 – 2012 are given in Table 3.1.

Table 3.1 Population Growth Trends of Pakistan – Year 1981 - 2012

Year	Population	Year	Population
1981	84,254,000	1997	1,28,400,000
1982	87,400,000	1998	1,32,352,000
1983	89,900,000	1999	1,36,410,000
1984	92,400,000	2000	1,39,410,000
1985	94,900,000	2001	1,42,350,000
1986	97,500,000	2002	1,45,280,000
1987	1,00,100,000	2003	1,48,210,000
1988	1,02,700,000	2004	1,51,090,000
1989	1,05,400,000	2005	1,53,960,000
1990	1,08,000,000	2006	1,56,770,000
1991	1,10,800,000	2007	1,62,910,000
1992	1,13,600,000	2008	1,66,410,000
1993	1,16,500,000	2009	1,69,940,000
1994	1,19,400,000	2010	1,73,510,000
1995	1,22,400,000	2011	1,77,100,000
1996	1,25,400,000	2012	1,78,900,000

(ESP, 2000 page 139; SIP, 2011 Page 8)

Pakistan's economy has experienced ups and down in recent past; the early to middle 2000s was comparatively a period of rapid development whereas significant downfall was observed in year 2007. The average annual GDP growth rate of Pakistan for the year 2012 was observed at 3.7 % [ESP, 2012]. The GDP growth trends of Pakistan for the year 1981 – 2012 are given in Table 3.2.

Table 3.2 GDP Growth Trends of Pakistan – Year 1981 - 2012

Year	GDP per capita (US $)	Year	GDP per capita (US $)
1981	408	1997	536
1982	383	1998	522
1983	381	1999	510
1984	390	2000	491
1985	377	2001	461
1986	385	2002	499
1987	392	2003	549
1988	437	2004	622
1989	423	2005	687
1990	429	2006	780
1991	452	2007	870
1992	491	2008	866
1993	479	2009	915
1994	500	2010	1,002
1995	565	2011	1,182
1996	543	2012	1,290

(ESP, 2012)

Total length of road network in Pakistan is approximately 261,595 kilometres (Km) out of which 70% of roads are paved. Length of NHA network is 12,000 Km which is 4.6% of entire road network and carrying 80% of commercial traffic [ESP, 2012]. Currently the roads are the major mode of transportation in Pakistan and they are carrying approximately 96% of freight and 92% of passenger traffic [ESP, 2012]. The national highways are the backbone of Pakistan’s economy and approximately 10.5% of GDP is generated through transportation sector [PTPS, 2006; Ahmed, A., 2007; ABD, 2006]. In Pakistan the total length of roads was 95, 815 Km in year 1981, which has increased to 261,595 Km in 2012. This indicates a rapid growth in transportation sector which is a sign of infrastructure development and trade improvement. Total length of high type roads in Pakistan is approximately 181,940 Km and that of low type is approximately 79,655 Km. It implies a ratio of 70 to 30 for the two road types [ESP, 2012]. The road made up of bituminous concrete or cement concrete is a high type road. While the road having brick, stone, ordinary earth or gravel surface with drainage structures is a low type road [SIP, 2011]. The total length of high type roads has increased with the passage of time while the total length of low type roads has decreased. Length of roads by type in Km over thirty two year's period from 1981 to 2012 is summarized in Table 3.3.

Table 3.3 Road Network of Pakistan

Year	Road Length (Km)			Year	Roads Length (Km)		
	Total	High Type	Low Type		Total	High Type	Low Type
1981	95,815	52,839	42,976	1997	2,29,595	1,26,117	1,03,478
1982	1,01,573	55,035	46,538	1998	2,40,885	1,33,462	1,07,423
1983	1,03,573	56,083	47,490	1999	2,47,484	1,37,352	1,10,132
1984	1,11,916	60,927	50,989	2000	2,48,340	1,38,200	1,10,140
1985	1,18,471	63,307	55,164	2001	2,49,972	1,44,652	1,05,320
1986	1,26,243	67,429	58,814	2002	2,51,661	1,48,877	1,02,784
1987	1,33,953	71,368	62,584	2003	2,52,168	1,53,225	98,943
1988	1,42,941	75,516	67,425	2004	2,56,070	1,58,543	97,527
1989	1,51,449	79,352	72,132	2005	2,58,214	1,62,841	95,373
1990	1,62,345	83,205	79,140	2006	2,59,021	1,67,530	91,491
1991	1,70,823	86,839	83,984	2007	2,61,821	1,72,891	88,930
1992	1,82,709	95,374	87,335	2008	2,58,350	1,74,320	84,030
1993	1,89,321	99,083	90,238	2009	2,60,200	1,77,060	83,140
1994	1,96,817	104,001	92,816	2010	2,60,760	1,80,910	79,850
1995	2,07,645	111,307	96,338	2011	2,59,463	1,80,866	78,597
1996	2,18,345	118,428	99,917	2012	2,61,595	1,81,940	79,655

(NTRC, 2003 Page 10; ESP, 2012 Page 177)

Figure 3.1 shows annual change in length of roads by type. Increase in total roads length is observed on annual basis.

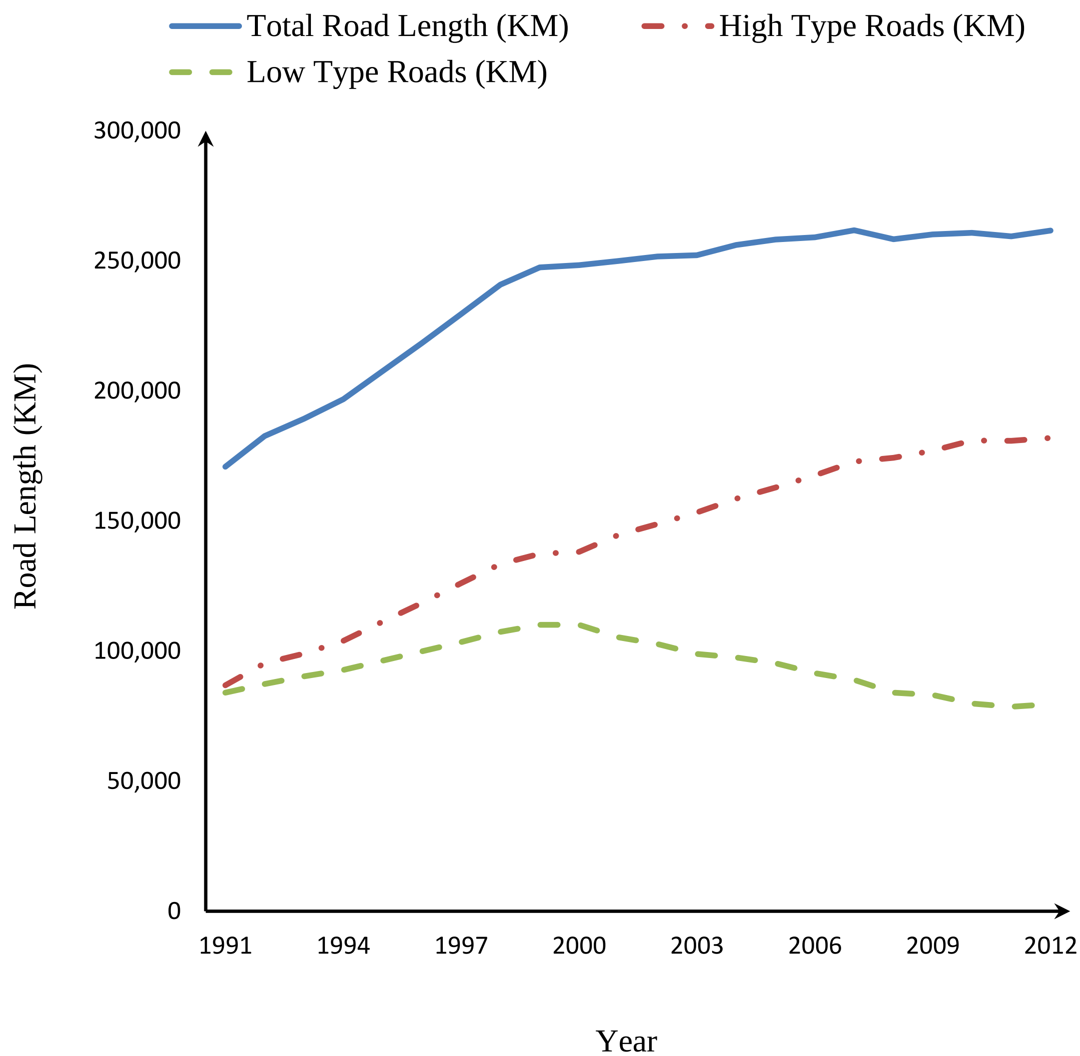

Figure 3.1 Lengths of Roads by Type (Km) for Year 1991- 2012

Roads length of four provinces categorized by low and high type roadways for the year 2002 to 2012 is given in Annexure - A. The ratio of low to high type roads varies across provinces. Figure 3.2 shows total roads length variations of four provinces for the year 2002 to 2012. Punjab has the highest length of road network followed by Sindh, Khyber Pakhtunkhwa (KPK), Baluchistan and Gilgit Baltistan and Azad Jammu Kashmir (GB&AJK). Baluchistan is the largest province by area, but it has only 13% of paved roads network. Punjab occupies the second place by area with 78% of paved roads. It has the highest population among provinces thus demands for greater travel [NTRC, 2005].

In Punjab and Sindh the road density is comparatively higher than other two provinces i.e. 0.51 and 0.57 km/km^2 respectively. On the contrary, road length per population is greatest in the Baluchistan (0.0037) and it is least in the Punjab (0.0011) while it has approximately same values for Sindh and KPK i.e. 0.0019 [PTPS, 2006].

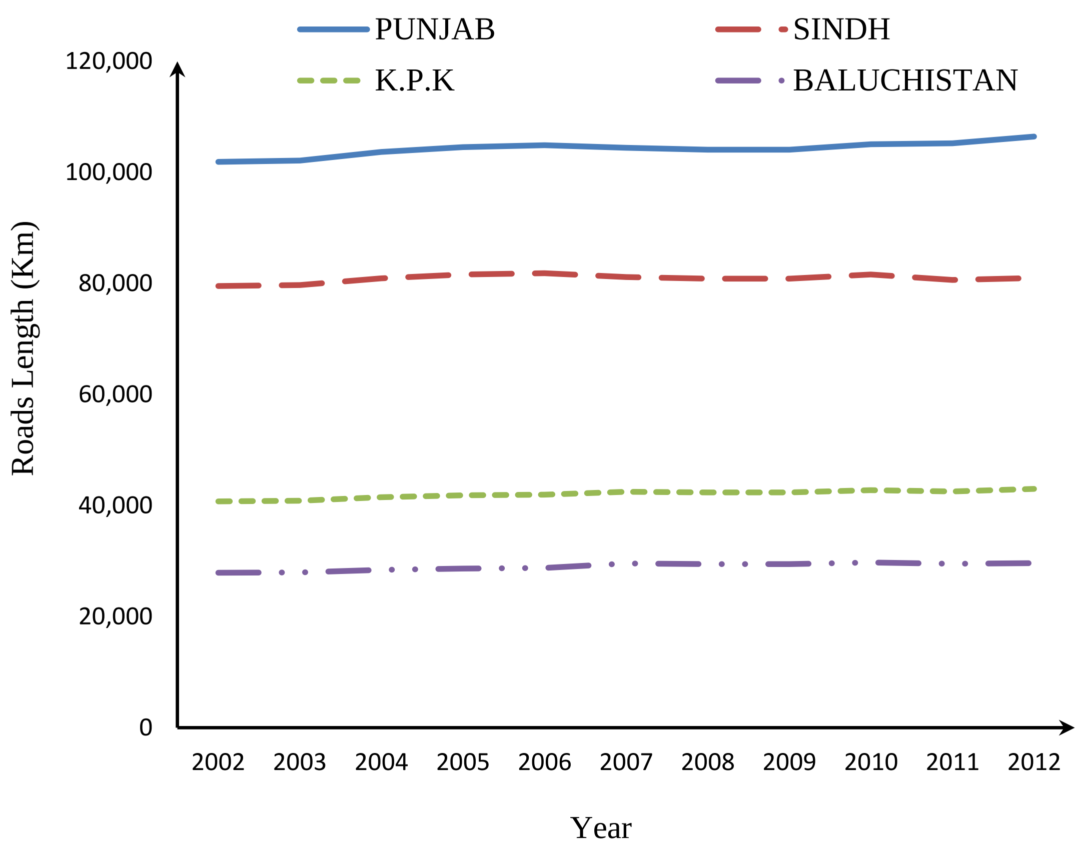

Figure 3.2 Total Road Length by Province for Year - 2002 - 2012

The details of the road network as per jurisdiction/ administration responsibility is provided in Annexure – B. In year 2011, there were approximately 10.91 million registered vehicles in Pakistan (all types) [ESP, 2012]. The compound annual growth rate of passenger cars and motorcycles has been 9.5% and 7.5% respectively for the last ten years. While the overall growth rate of registered vehicles is 7.5% for the last decade. The recent rapid growth in number of registered vehicles (especially cars and motorcycles) may be attributed to attractive car leasing schemes initiatives, and raised income per capita for some segment of the society. Although usage of motor vehicles has tremendously increased, but still Pakistan has low auto ownership (8 cars/ 1000 population) [Ahmed, A., 2007]. Figure 3.3 shows the motorization growth trends of Pakistan for year 1981 to 2011. In 1981, there were 755,698 registered vehicles in Pakistan that have increased to 10,910,400 by year 2011 [NTRC, 2011].

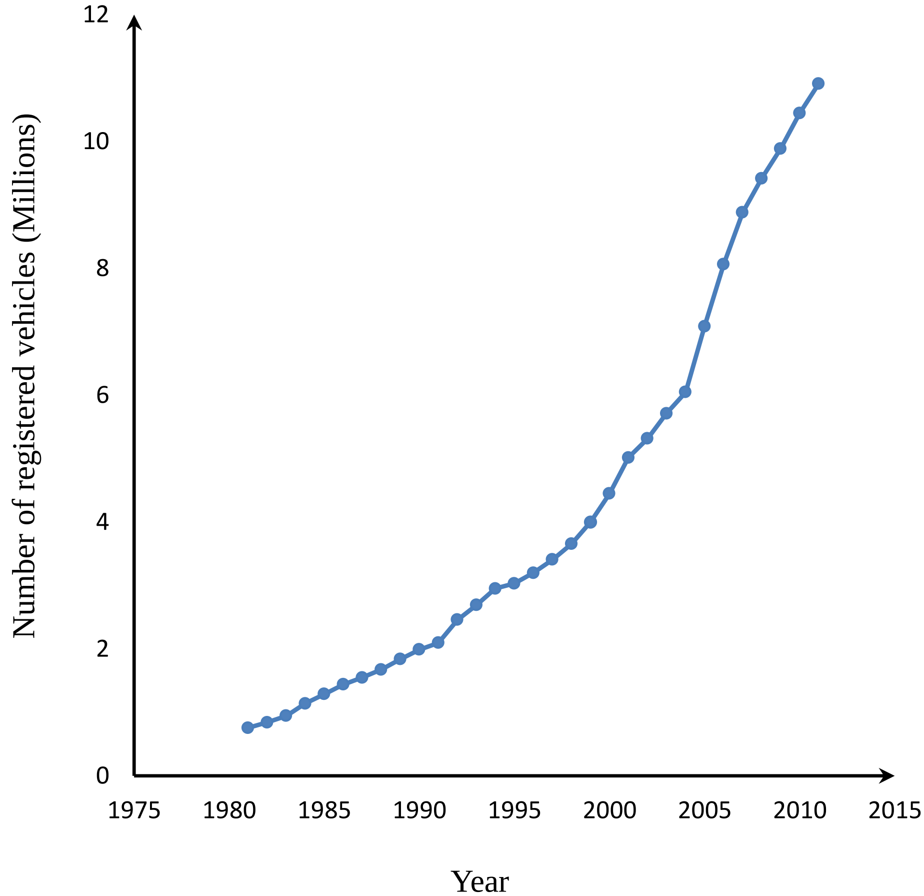

Figure 3.3 Trends in Registered Vehicle Growth in Pakistan

Proportions of different types of vehicles registered in Pakistan for travelling purpose are summarized in Annexure - C. A tremendous growth in the automobile sector occurred over the last thirty two years and road users are heterogeneous in nature as in other developing countries. The passenger cars (motor cars, jeeps, station wagons, taxis, delivery van, pickups and ambulances), motorized two wheelers, bicycles, animal-driven carts, buses, wagons, rickshaws, trucks and tractors are commonly used vehicles in Pakistan for mobility purposes.

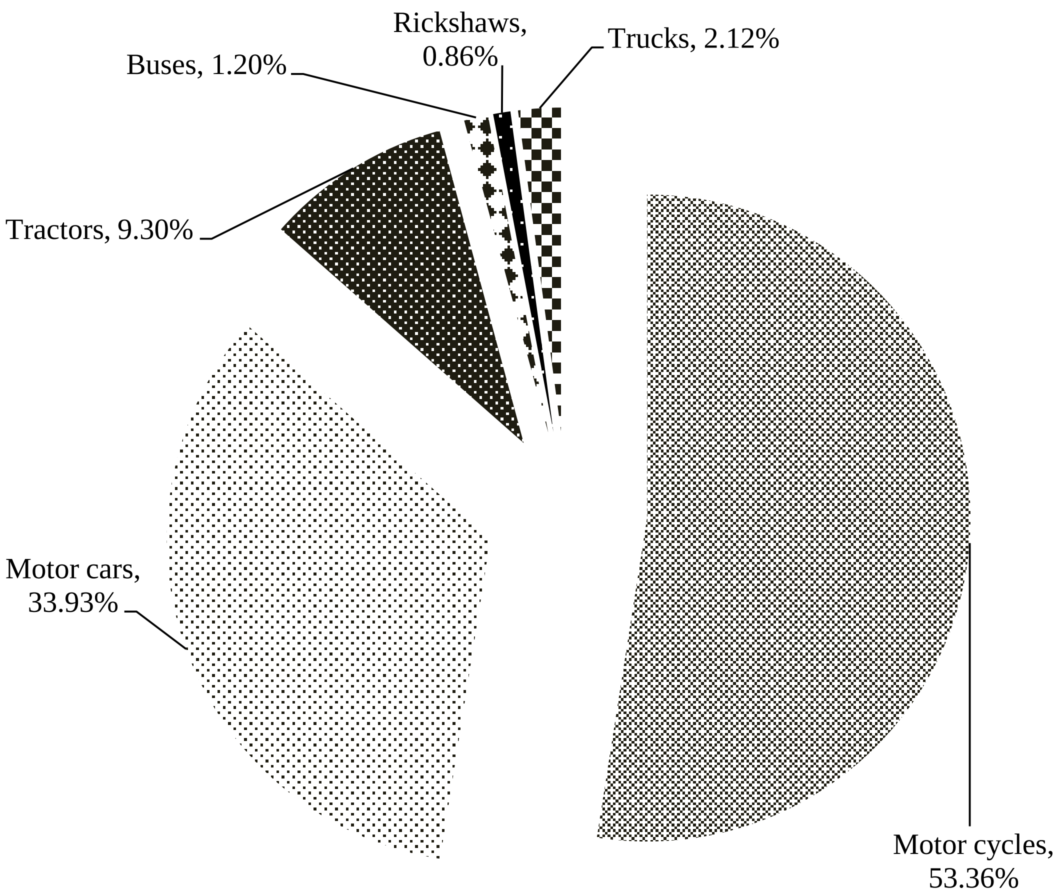

Figure 3.4 Vehicles Fleet Composition - Pakistan

The percentages of registered motor vehicles for the year 2002 - 2011 are given in Annexure - D. Figure 3.4 shows vehicle composition broadly classified into six different classes. The dominate vehicle groups are: motor cycles (53%), motor cars (34%), tractors (9%), buses (1%) and trucks (2%). Rickshaws an important component of both urban and rural traffic have approximately 1% share.

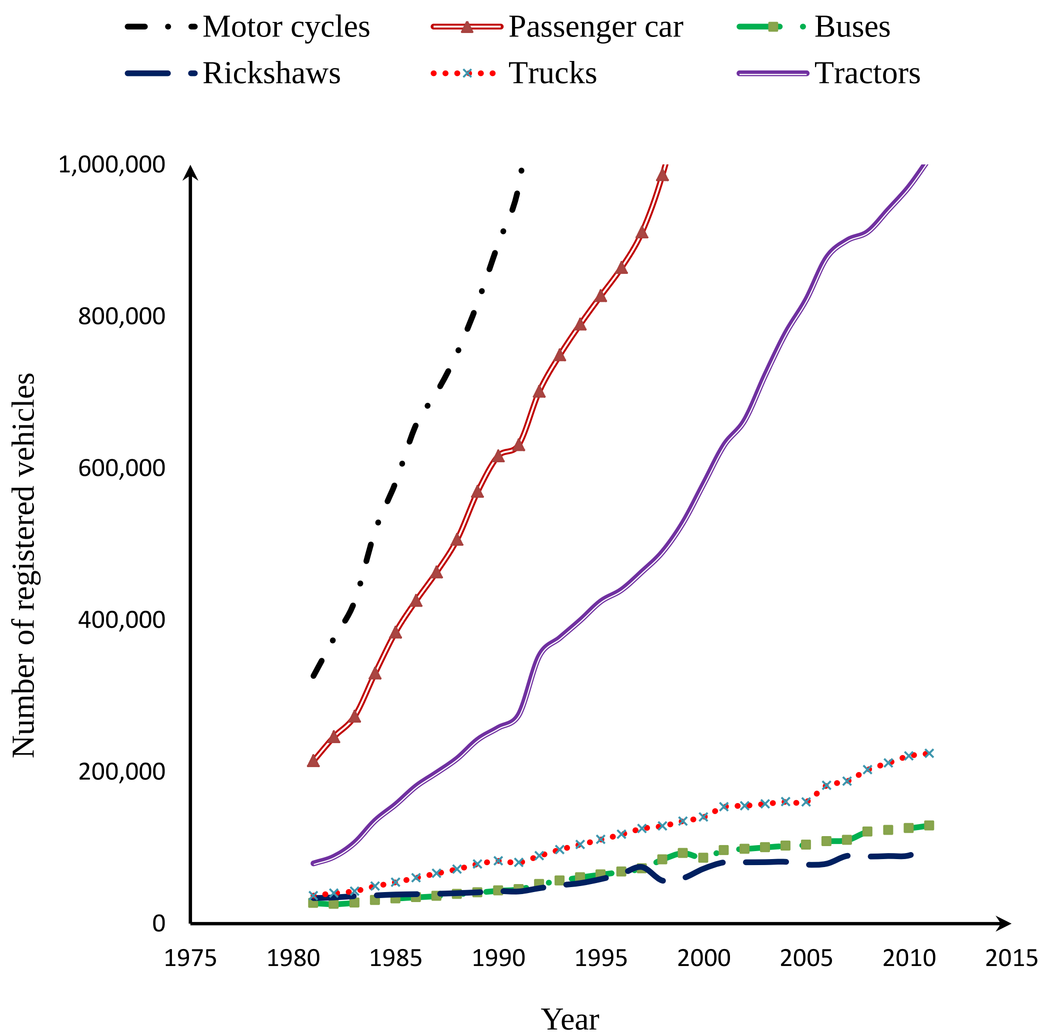

Figure 3.5 Growth Rates of Various Registered Vehicles for Year 1981- 2012

Figure 3.5 shows the growth rates of various vehicles over the year 1981- 2012. There has been a significant growth in motorcycles, as the number of motorcycles has increased from 0.32 million to 5.50 million (49.56% growth rate) in last thirty two years. However, during the same period the other vehicle groups have grown at a relatively slower pace as compared to motorcycles and cars [SPRSP, 2010]. In last ten years the situation has change at fast pace and overall 7.5% growth rate of vehicle fleet has been observed. Individual vehicle groups have increased at differ rates. The growth rate of motorcycles, cars, buses, rickshaws, trucks, tractors for last ten years is 7.5, 9.5, 2.7, 2.3, 3.7 and 4.3% respectively. A recent study [PTPS, 2006] predicts that in Pakistan cars, trucks and buses are expected to grow to 5.1, 1.49 and 0.66 million respectively by year 2030. Such an increase in vehicles is expected to result in higher numbers of road accidents in future.

3.3 Traffic Safety at National Level

In recent decades, rapid increase in motorization has improved the lives of many individuals and societies, but at same time the added benefits of enhanced motorization have led to a higher risk of RCF. RTC are among leading causes of injury and fatality worldwide [Soderlund and Zwi, 1995]. Rapid increase in RTC is a serious issue for low and middle income countries that results in loss of human life and severely hampers economy progress [Ahmed, A., 2007]. RCF remains a neglected problem in majority of the countries as only one third of the countries have the proper implementation of road safety laws. As a matter of fact RTC are not only predictable but also preventable through proper safety interventions [Ahmed, A., 2007].

Pakistan is facing a serious issue of RCF and RCI. Past studies provide estimates of RCF and RCI with wide variations. According to NTRC, in year 1999 approximately 1.4 million RTC occurred in Pakistan that resulted in 7,000 fatalities [NTRC, 1999]. Studies by Ghaffar et al., [2004] and Fatmi et al., [2007] found that approximately 1,500 individuals per 100, 000 population sustain injuries due to RTC in Pakistan annually. NRSS estimated that two million crashes occurred in the Pakistan in the year 2006 and 0.418 million were of serious nature [Ahmed, A., 2007]. However, recent data suggested that these figures could be four to ten times higher than those reported officially [WHO, 2009]. RCI are the second leading cause of disability, the fifth cause of overall healthy life-year losses and the eleventh cause of premature fatality in Pakistan [Hyder et al., 2006; Hyder and Morrow, 2000]. High numbers of road crashes not only cause pain and suffering to the bereaved families, but also a serious drain on the national economy [Kayani et al., 2011]. The estimated economic cost of traffic crashes (injuries and fatalities) is about Rs. one hundred billion per annum. Some studies estimate that RTC consumes approximately 1.5 – 3% of GDP [WHO, 2009; Baguley and Jacobs, 2000].

Studies have revealed that the main victims of RCF and RCI are men aged 15 - 45 years, who play an important part in the socio-economic growth of the country [Ghani et al., 2003; Ghaffar et al., 2004; WHO, 2004]. Also, poor’s are disproportionately affected by road crashes [Batool et al., 2012]. Pedestrians and motorcyclists accounted for the majority of RCF, with commercial vehicles being the most common striking vehicle even though they only represent 4% of the total vehicle fleet [Fatmi et al., 2007; WHO, 2004]. The RTC trends of Pakistan for the year 1981 – 2012 are given in Annexure - E. In 1981, the total number of RCF were 3,571, while in 2012 the number has grown to 4,348. Figure 3.6 presents the graphical illustration of growth trends of RTC in Pakistan for the year 1981 to 2012.

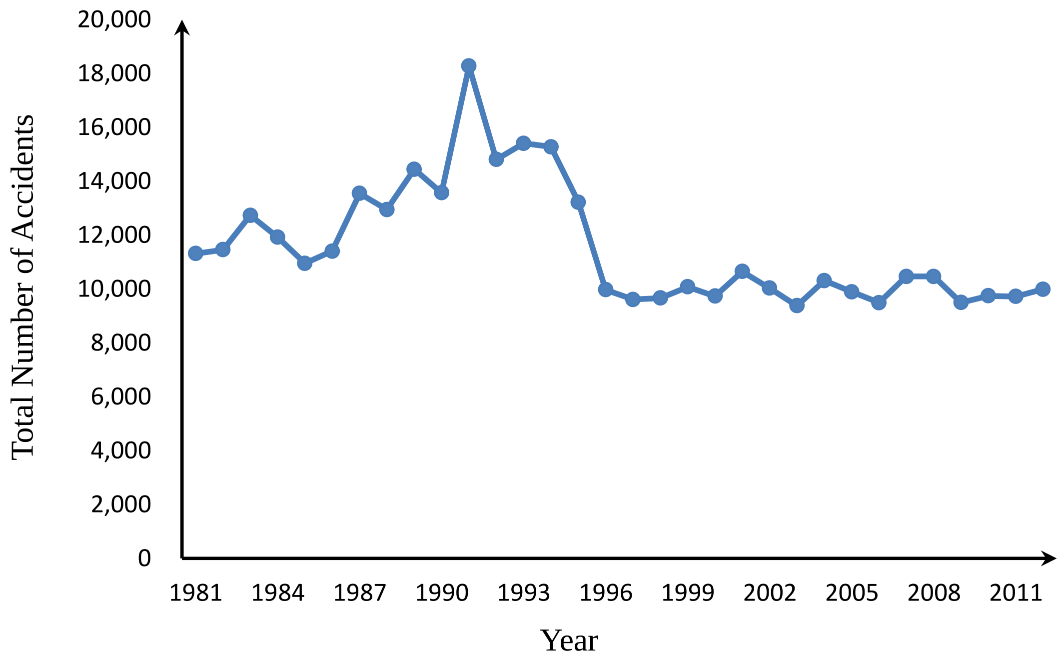

Figure 3.6 Road Traffic Crash Trends of Pakistan for Year 1981- 2012

Past research revealed that population and vehicle fleet are positively associated with RCF [Page, 2001]. During the last thirty two years, the “highest” numbers of accidents (18,275) have been recorded for the year 1991. The data recorded by Pakistan road safety agencies shows that the RCF in the country had a decreasing trend from 1995 to 2012. However, the number of registered vehicles and population increased during the same time period. This contradictory trend clearly depicts the lack of accurate and reliable road safety data in Pakistan. Furthermore, WHO (2013) estimates of the RCF (30,131 deaths) in Pakistan are also contradicting the Pakistan data collected by SIP

(2012) and NTRC (2011). Figure 3.7 shows the growth trend of RCF and RCI for Pakistan for the year 1981 to 2012. In 1981, the total number of RCF were 4,167 and increased to 5,323 in the year 2012, while the RCI increased from 10,310 to 11,475 during the last three decades. A gentle increase is noticed in RCF and RCI over the last three decades.

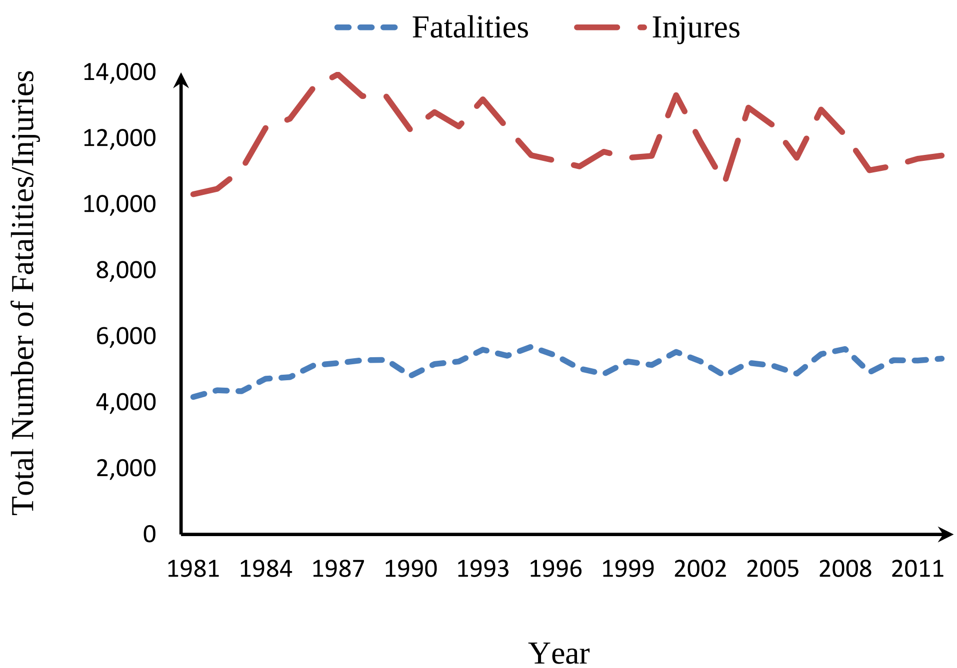

Figure 3.7 RCF and RCI Trends of Pakistan for Year 1981 - 2012

Figure 3.8 shows graphical representation of fatalities and injuries across all provinces of Pakistan. Minimal differences were observed between fatalities and injuries in Sindh and Balochistan. Punjab had the maximum number while Balochistan had least fatalities and injuries as compared to other provinces.

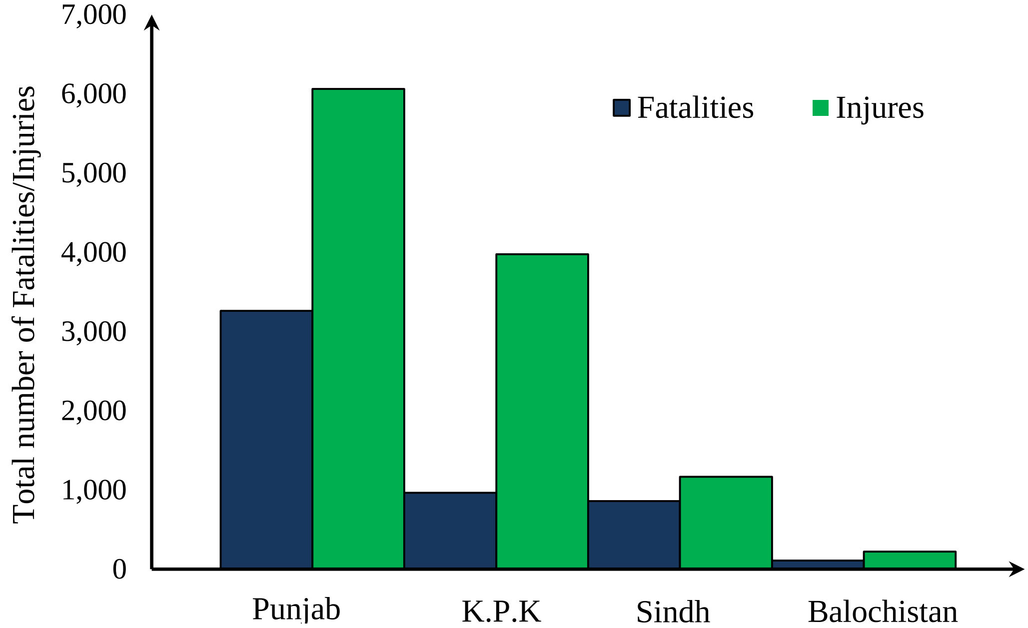

Figure 3.8 Fatalities and injuries across Provinces for the Year 2010

Provincial traffic crash statistics of the country for the year 2001 – 2010 are given in Annexure – F. Figure 3.9 shows temporal trends for RTC in different provinces of Pakistan from year 2001 to 2010. A total of 9,808 RTC occurred in the country in the year 2010, out of which 5,577 in Punjab, 2,732 in Khyber Pakhtunkhwa, 1,273 in Sindh and 226 in Baluchistan. On average 2510, 690, 825 and 72 fatal crashes occurred in Punjab, Khyber Pakhtunkhwa, Sindh and Baluchistan respectively. Figure 3.9 also shows a smooth temporal trend of RTC for all the four provinces. This shows that the recorded number of RTC remained same for the last decade; clearly indicating a weak road safety data reporting system.

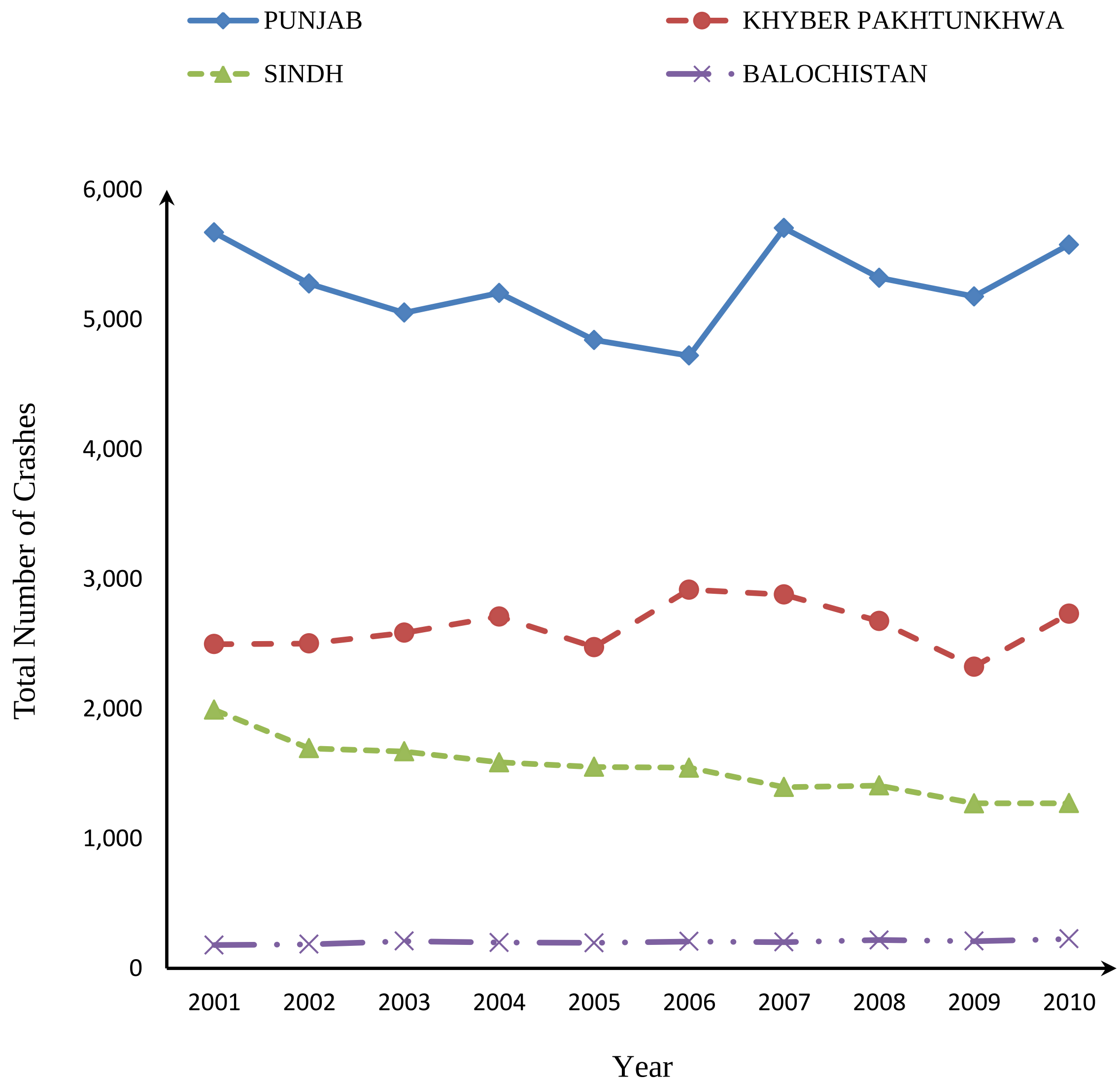

Figure 3.9 RTC Trends of Provinces for Year 2001- 2010

RCF per 100,000 populations for the year 2001 – 2010 are provided in Table 3.4. On average 3.15 RCF per 100,000 populations occurred in the last one decade. The Table 3.4 shows that the RCF per 100,000 populations have decreasing trend for year 2001 – 2010, while population of Pakistan had increasing trend during the same time span (Table 3.1). Research has shown that RCF are positively associated with population. The population and RCF trends for Pakistan contradict, thus indicating a serious issue of accident data recording system.

Table 3.4 RCF per 100,000 population for Pakistan for Year 2001 - 2010

Year	Fatalities	Population (Million)	Fatalities/100,000 Population
2001	5,104	142.86	3.57
2002	4,913	146.75	3.35
2003	4,681	149.65	3.13
2004	4,981	152.53	3.27
2005	4,616	153.96	3.00
2006	4,578	156.77	2.92
2007	5,147	162.91	3.16
2008	5,059	166.41	3.04
2009	4,528	169.94	2.66
2010	5,192	173.51	2.99

(NTRC, 2011)

3.4 Chapter Summary and Conclusion

In this chapter the current state of road safety in Pakistan has been reviewed. Population growth trends, road network, vehicle fleet and RCF over the last three decades were discussed. Pakistan is the sixth most populous country in the world. A significant increase in number of registered vehicles has been observed in last few decades. Vehicle fleet has increased from about 0.75 million in year 1981 to 11 million vehicles of all type in year 2012 (8.6% growth rate). Furthermore, the road users are heterogeneous in nature and motorcycles have been found to dominate the traffic stream (53% share in vehicle fleet). Pakistan has experienced a slow economic growth in recent past but still the road network system has improved at a reasonable pace. Length of paved road increased from 52,839 (Km) in 1981 to approximately 180,000 Km in 2012.

The rapid motorization, population increase and expansion of road network have led to a higher risk of RTC, because of increased exposure and higher interaction among vehicles. Pakistan is facing a serious issue of RCF and RCI. The estimated economic cost of RTCs in Pakistan is approximately Rs. 100 billion per annum. Past studies provide estimates of RCF and RCI with wide variations. According to NTRC, in year 1999 approximately 1.4 million RTC occurred in Pakistan while according to SIP, approximately 10,080 RTC occurred in the same year. This chapter also summarizes the temporal trends for RTC in different provinces of Pakistan from year 2001 to 2010. In 1981, the total number of RCF reported were 4,167 whereas in 2012 the number has grown to 5,323. Population and vehicle fleet of Pakistan have increasing trend over the past three decades (1981–2012), while police reported RTC data show a decreasing trend for the same time period.

CHAPTER 4. INTERNATIONAL COMPARISON

4.1 Introduction

In this chapter, comparative analysis of RCF in Pakistan with South East Asian countries, Asian Countries, Middle income countries and overall average RCF of all the countries of the World is carried out. The aim of this statistical comparison is to further explore the state of road traffic safety in Pakistan. For this purpose the data were obtained from the “WHO Global Status Report on Road Safety (2013)”. In this research study, the RCF rates are compared on the basis of “exposure”. The normalized measures of the relative road safety across the world are fatalities per hundred thousand population (FPHTP), fatalities per thousand registered vehicles (FPTRV) and fatalities per vehicle-miles travelled [Mcshane et al., 2004]. These measures have been found to be good surrogates to individual’s exposure to potential risk of crash. FPHTP and FPTRV are used in present study for the comparative analysis. These are defined as following:

$$FPHTP = \left(\frac{F}{P}\right) * 100{,}000 \tag{4.1}$$

$$FPTRV = \left(\frac{F}{RV}\right) * 1000 \tag{4.2}$$

Where, *FPHTP* is the number of fatalities per hundred thousand population; *P* is total population of a country; *F* is total number of fatalities in a country; *FPTRV* is the number of fatalities per thousand registered vehicles; *RV* is total number of registered vehicles in a country.

4.2 Comparison of RCF in Pakistan with Asian Countries

Asia is the most populous and world's largest continent. Majority of RCF occur in developing countries, whereas approximately half of those occur in Asia [Global

Burden of Disease, 2000; Jacobs and Thomas, 2002]. FPTRV and FPHTP for forty Asian countries are given in Table 4.1.

Table 4.1 RCF Rates of Asian countries - 2010

Country	FPTRV	FPHTP	Country	FPTRV	FPHTP
Afghanistan	2.05	19.8	Morocco	1.35	18.0
Bahrain	0.16	10.5	Myanmar	1.06	15.0
Bangladesh	1.77	11.6	Nepal	1.43	16.0
Bhutan	1.37	13.2	Oman	1.02	30.4
Brunei	0.13	6.8	**Pakistan**	**1.35**	**17.4**
Cambodia	1.10	17.2	Philippines	1.02	9.1
China	0.34	20.5	Qatar	0.30	14.0
Egypt	1.64	13.2	South Korea	0.28	14.1
India	1.13	18.9	Saudi Arabia	1.00	24.8
Indonesia	0.43	17.7	Singapore	0.20	5.1
Iran	1.13	34.1	Sri Lanka	0.63	13.7
Iraq	1.68	31.5	Sudan	30.69	25.1
Japan	0.06	5.2	Syria	1.02	22.9
Jordan	0.62	22.9	Thailand	0.47	38.1
Kuwait	0.24	16.5	Timor-Leste	10.25	19.5
Lao	0.76	20.4	Tunisia	0.81	18.8
Lebanon	0.35	22.3	UAE	0.37	12.7
Malaysia	0.34	25.0	Viet Nam	0.36	24.7
Maldives	0.12	1.9	Gaza Stripi	0.67	3.2
Mongolia	1.30	17.8	Yemen	3.96	23.7

(WHO, 2013)

Average number of FPHTP for Asia is 17.83. Based on FPHTP, Thailand is leading the Asian countries with highest RCF rate of 38.1, whereas Maldives has the lowest RCF rate of 1.9. Pakistan lies in the middle of the continent with 17.4 FPHTP (represented by the red dot in Figure 4.1). Pakistan's RCF rate in terms of population is quite high. There are eighteen countries that have population based traffic accident fatality rates lower than Pakistan, indicating better highway safety performance compared to Pakistan. Past research shows that the population is positively associated with the RCF [Page, 2001; Noland et al., 2003]. Population growth results in raised travel demand, consequently increasing the risk of RCF. The better road safety performance of some

Asian countries compared to Pakistan may be attributed to higher income or other highway safety related interventions.

The average number of FPTRV for the Asia is 1.87. On the basis of FPTRV the RCF rate is highest for Sudan (30.69) and least for Japan (0.06). Pakistan has the eleventh highest FPTRV (1.35) among Asian countries as shown in Figure 4.2 (represented by the red dot). It is observed that generally countries with high income level such as Philippines, Qatar, Singapore, Kuwait, Bahrain, China, Saudi Arab, Tunisia, Indonesia, UAE, Malaysia, Vietnam and Brunei having lower RCF in terms of registered vehicles compared to Pakistan.

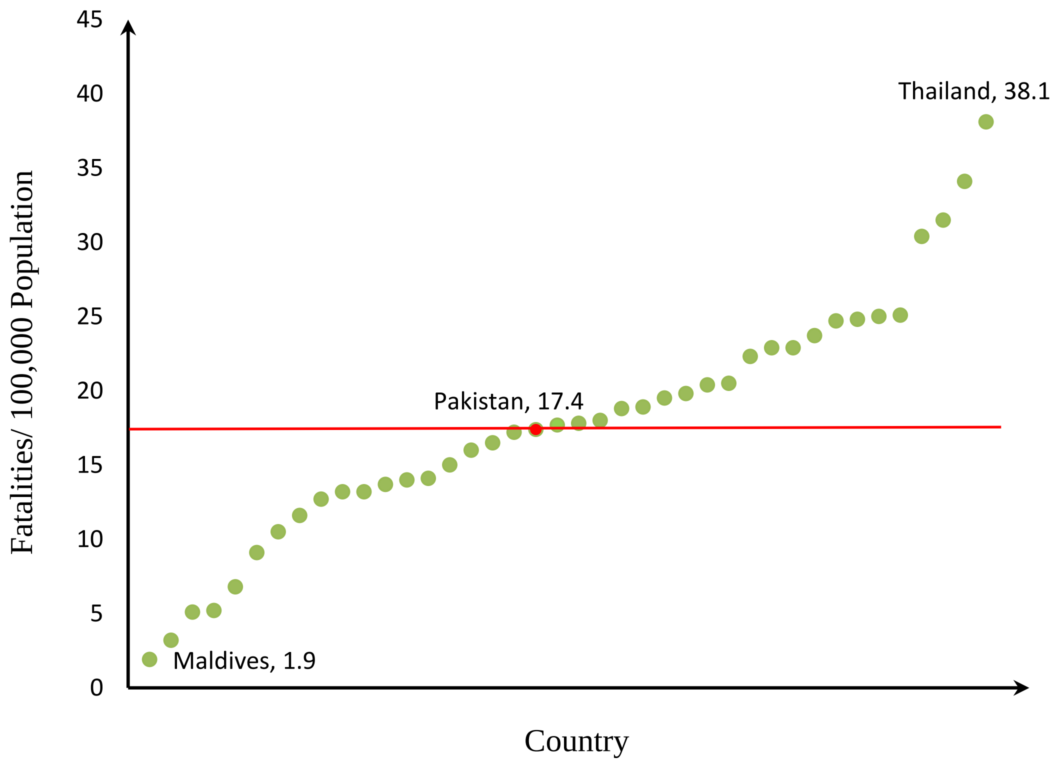

Figure 4.1 Comparison of RCF for Asian Countries Based on FPHTP

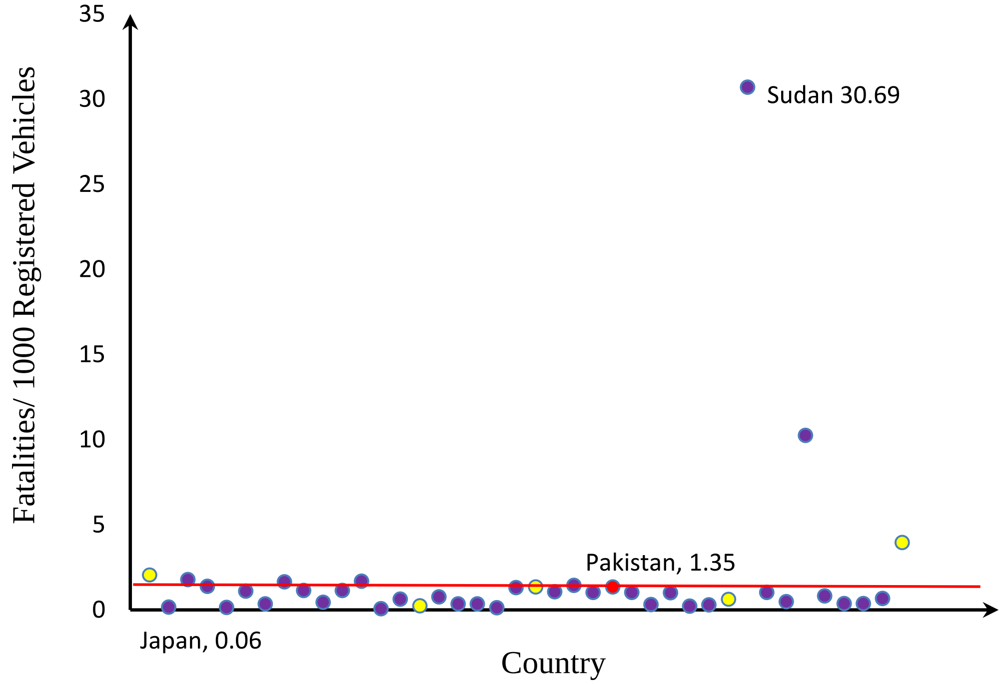

Figure 4.2 Comparison of RCF of Asian Countries Based on FPTRV

4.3 Comparison of RCF Rates of SAARC Countries

One of the fastest growing epidemics in the SAARC countries is RTC as approximately 40 people die in every hour due to collisions [WHO, 2009]. Approximately 2,65,000 people die every year in RTC in SAARC countries, which account for a third of all global RTC [WHO, 2009]. If appropriate road safety interventions are not taken, it is estimated that there would be approximately 144% increase in RCF for SAARC countries by the year 2020 [Murray and Lopez, 1996; WB, 2004].

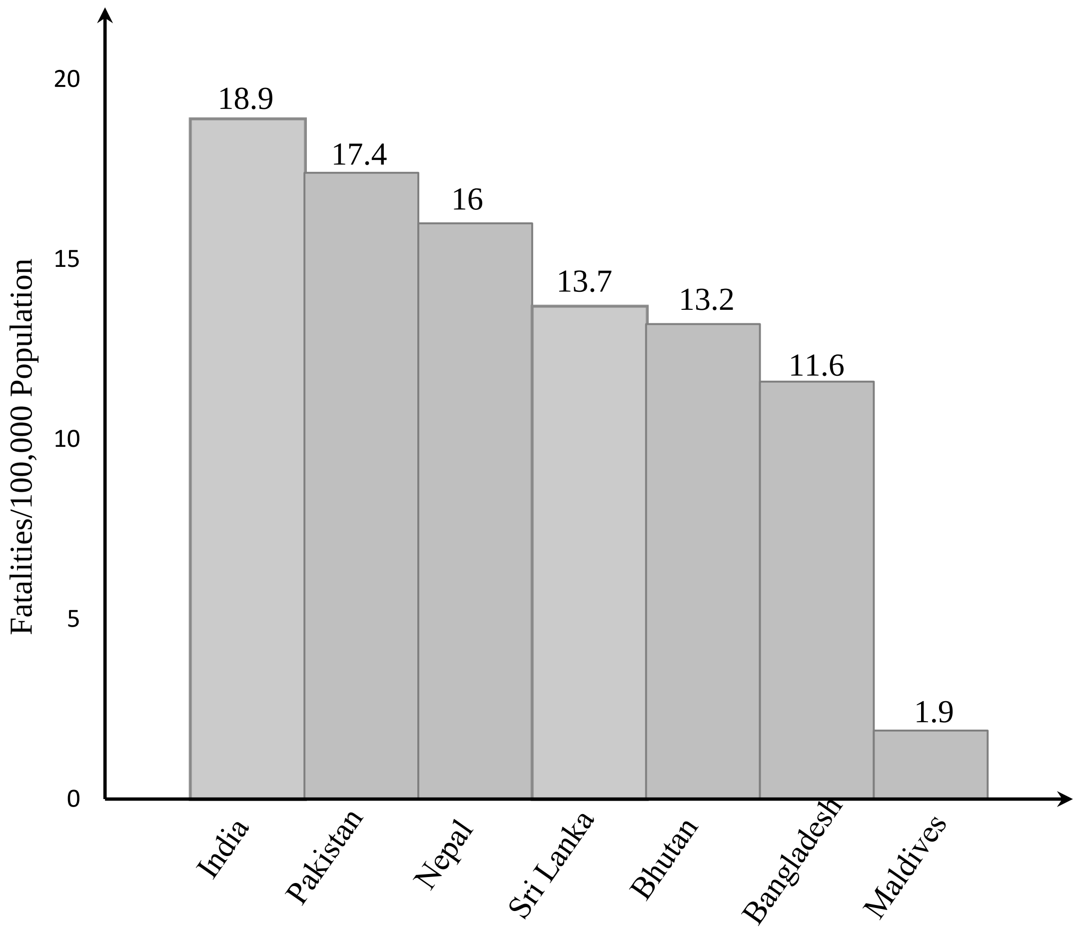

Figure 4.3 RCF in Pakistan Compared to SAARC Countries Based on FPHTP

Pakistan similar to other countries is confronting with the ever worsening situation of road safety. Pakistan has the second highest (17.4 FPHTP), road accident fatality rate based on FPHTP among the seven SAARC countries as shown in Figure 4.3. Pakistan's crash fatality rate in terms of population is quite high. India is leading the SAARC region with crash fatality rate of 18.9, whereas Maldives has the lowest crash fatality rate of 1.9 based on population. The RCF rate of Pakistan is low as compared to India but it is higher as compared to Bangladesh, indicating that still lot of improvement in road safety is needed.

In addition to FPHTP, road safety situation in SAARC countries is also compared on the basis of FPTRV. The average FPTRV in SARRC is 1.11. Among

SAARC countries Bangladesh has the highest (1.77) and Maldives has the lowest (0.12) FPTRV. Pakistan falls in the middle of the seven countries (Figure 4.4) with 1.35 FPTRV. On the basis of FPTRV the road safety situation, is better in India, Sri Lanka and Maldives compared to Pakistan. Since FPTRV is a better surrogate for exposure based crash fatality rate compared to FPHTP, therefore Pakistan should take lead from other SAARC countries (India, Sri Lanka and Maldives) and implement road safety interventions that have proved effective in those countries.

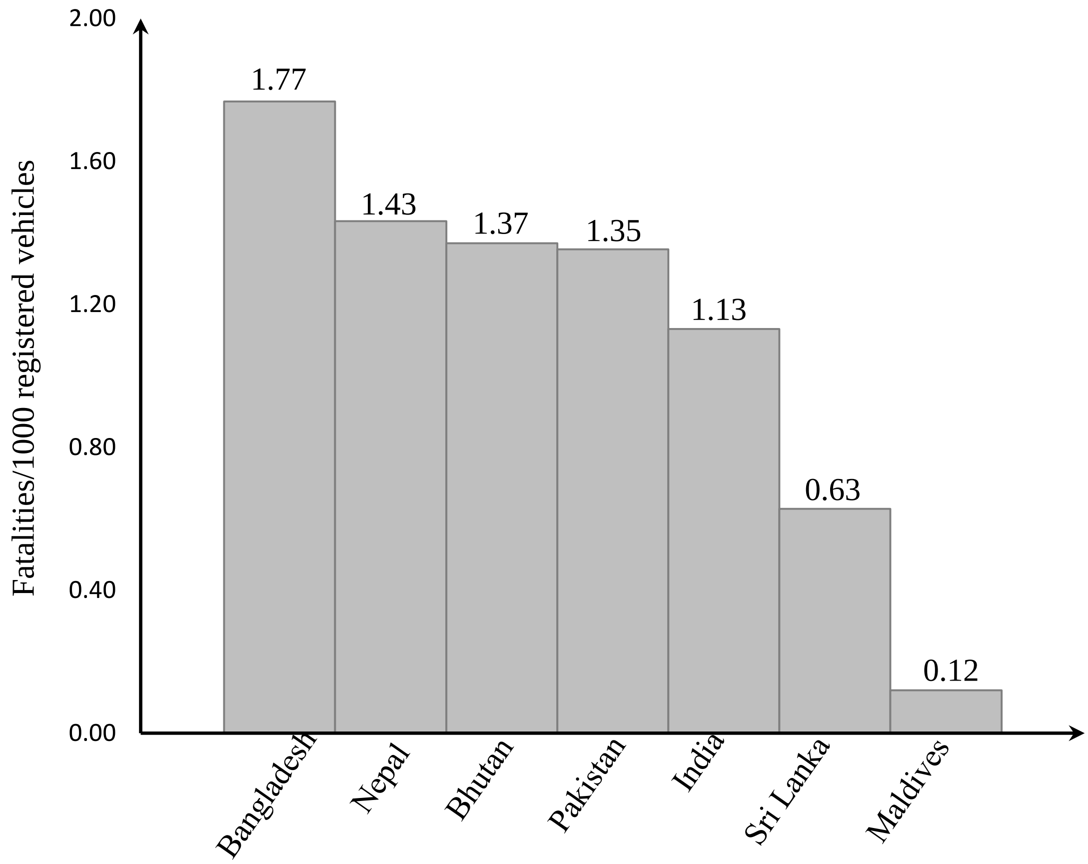

Figure 4.4 RCF in Pakistan Compared to SAARC Countries Based on FPTRV

4.4 Comparison of RCF Rates of Middle Income Countries

Past research has shown that in middle income countries the pedestrians and motorcyclists are a high risk group in terms of RCF, these group's accounts for 90% of fatalities due to RTC [Nantulya and Muli-Musiime, 2001]. Unfortunately, the use of seatbelts and helmets is still not mandatory in many middle income countries due to poor road safety policies [WHO, 2009]. Another major causes for the high proportion of the RCF in middle income countries is the, inadequacy of the public health infrastructure that can provide timely and adequate treatment to victims of RTC [Elechi and Etawo, 1990; Trunkey, 1990]. There are serious policy gaps and encumbers in execution of effective strategies in middle income countries due to lack of RTI data [Waters et al., 2004]. In order to further explore the RCF pattern for Pakistan, a comparative analysis with similar income group countries of the world is carried out. According to WHO (WHO, 2013) Pakistan fall in the middle income group countries having per capita income of 1,050 US dollars. There are total of ninety four countries in this group. Average number of FPHTP for middle income countries is 17.5 and for Pakistan it is 17.4 (Figure 4.5). There are forty eight countries that have population based crash fatality rates lower than Pakistan and forty five countries have higher crash as compared to Pakistan, thus indicating that even in same income group, Pakistan's performance is average.

Dominican Republic is leading the middle income countries with fatality rate of 41.7 based on FPHTP, whereas Micronesia has the lowest fatality rate of 1.8 based on population. In middle income countries Pakistan has forty sixth crash fatality rate of 17.4 based on FPHTP (Figure 4.5).

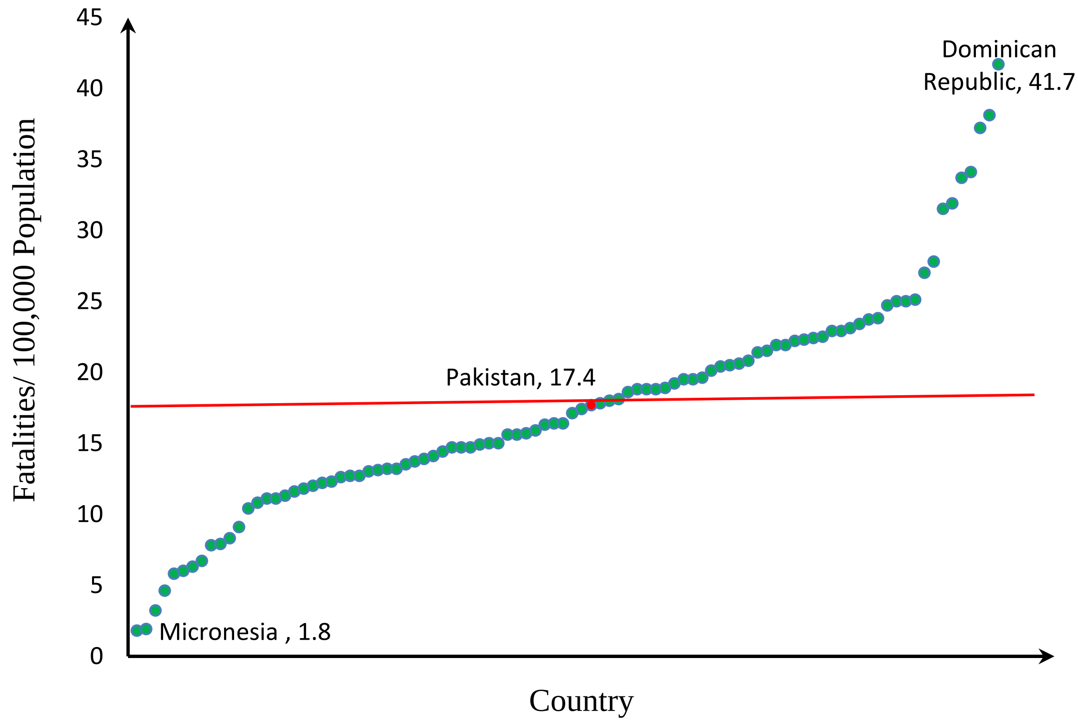

Figure 4.5 Comparison of Crash Fatality Rate of Middle Income Countries Based on FPHTP - 2010

Similarly, on the basis of FPTRV the crash fatality rate is highest for Sudan (30.69) and least for Maldives (0.12). The average crash fatality rate for middle income countries is 2.41. Seventy middle income countries have lower crash fatality rate based on registered vehicles compared to Pakistan. It shows that Pakistan is facing a serious road safety issues as compared to other MIC (Figure 4.6).

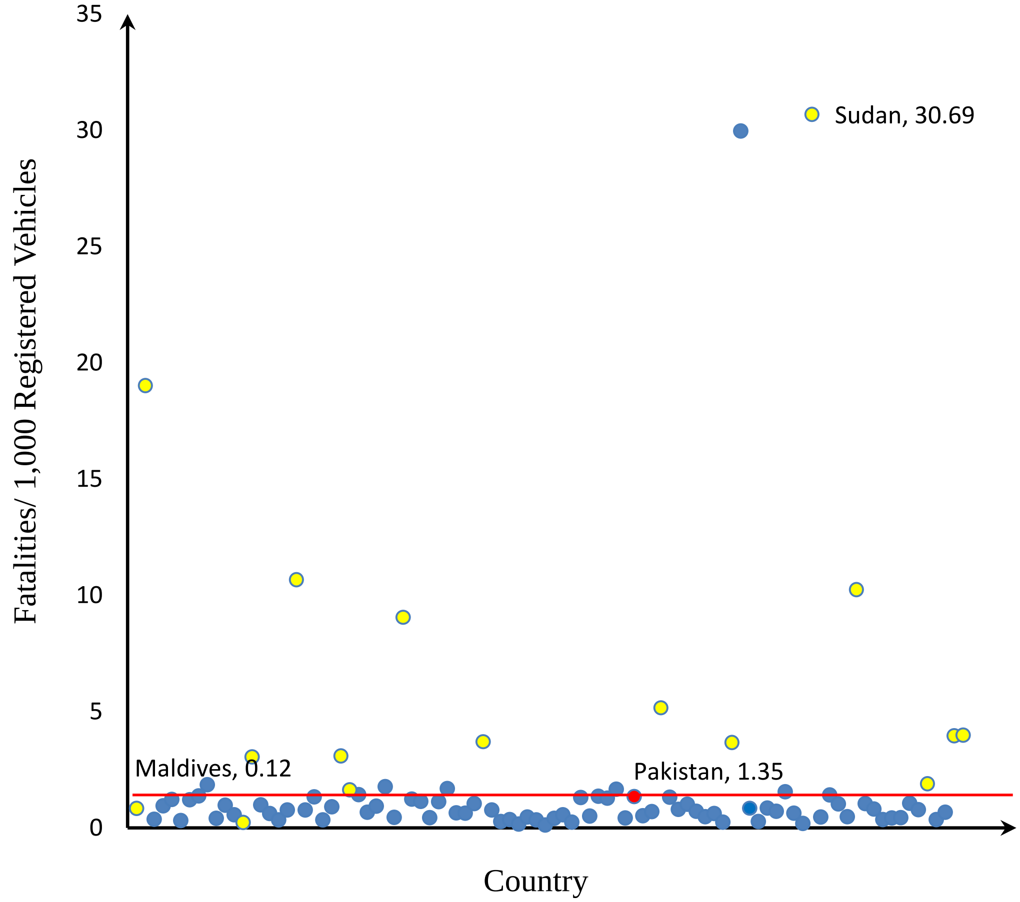

Figure 4.6 Comparison of Crash Fatality Rate of Middle Income Countries Based on FPTRV - 2010

4.5 Global Comparison of Crash Fatality Rates

The average number of FPHTP around the globe is 15.8. Based on FPHTP, Dominican Republic is leading all other countries with highest crash fatality rate of 41.7, whereas Micronesia has the lowest crash fatality rate of 1.8. Pakistan's road crash fatality rate in terms of population is 17.4 (i.e. quite high). There are ninety eight countries having less FPHTP rates compared to Pakistan (Figure 4.7).

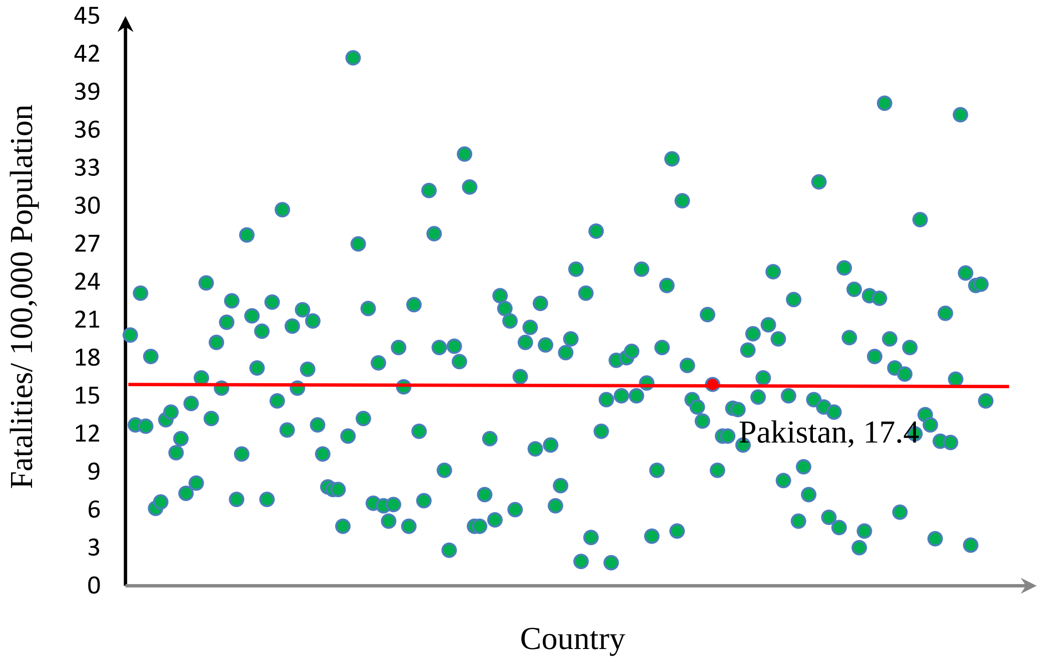

Figure 4.7 Global Comparison of Crash Fatality Rates Based on FPHTP, 2010

In addition to FPHTP, road safety situation among different countries of the world is also compared on the basis of FPTRV. The average global FPTRV is 2.28. Benin has the highest (31.86) and Iceland has the lowest (0.03) FPTRV. There are one hundred and twenty two countries having lower FPTRV rates than Pakistan (Figure 4.8). This shows that Pakistan is facing a serious road safety issues.

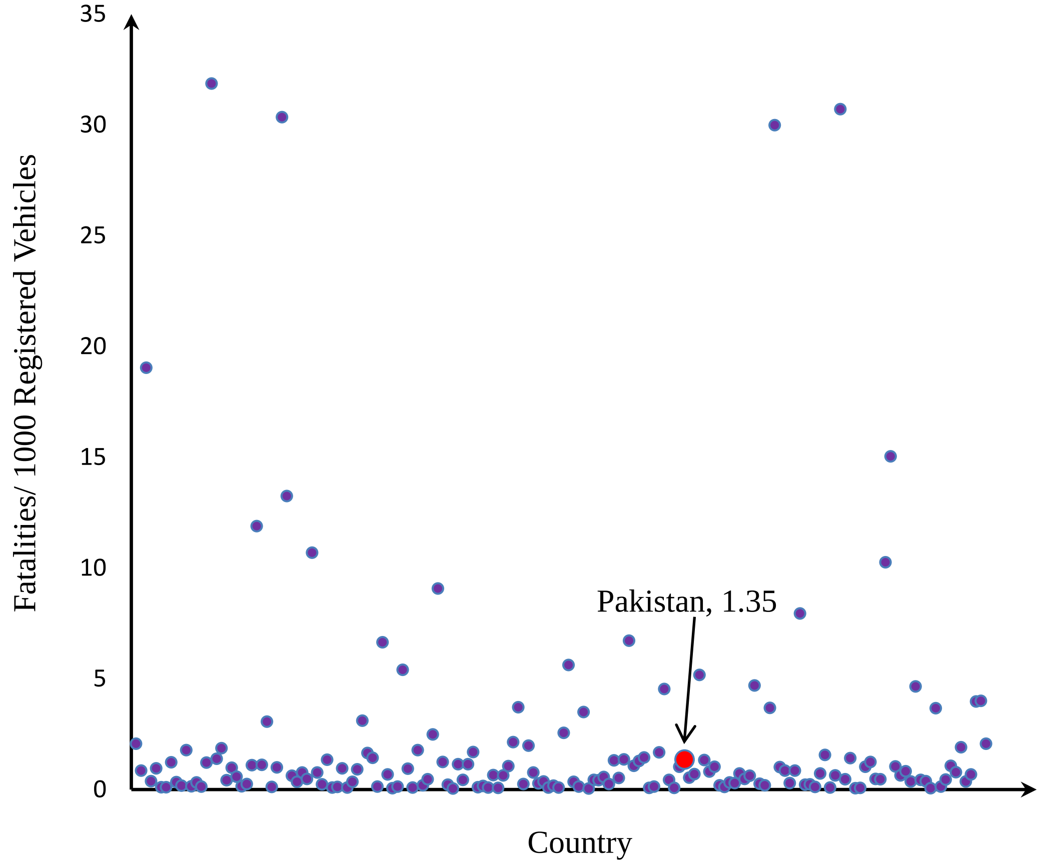

Figure 4.8 Global Comparison of Crash Fatality Rates Based on FPTRV - 2010

4.6 Comparison of Global Annual Crash Fatalities

In this section, comparison for different countries groups based on average total fatalities is carried out. The lowest crash fatality rate is observed in high income countries (2,091) that may be attributed to their enhanced infrastructure, high GDP and adoption of safety interventions. Low, middle income and Asian countries have high crash fatality rate as shown in Figure 4.9. In addition, there are two contradicting estimates of crash fatality rate in case of Pakistan; 5,108 annual fatalities have been reported by police for Pakistan, while WHO estimate show that 30,131 annual fatalities occur in Pakistan. There is a major difference between WHO estimates and police reported data for RCF in Pakistan. This might be attributed to weak reporting system in Pakistan.

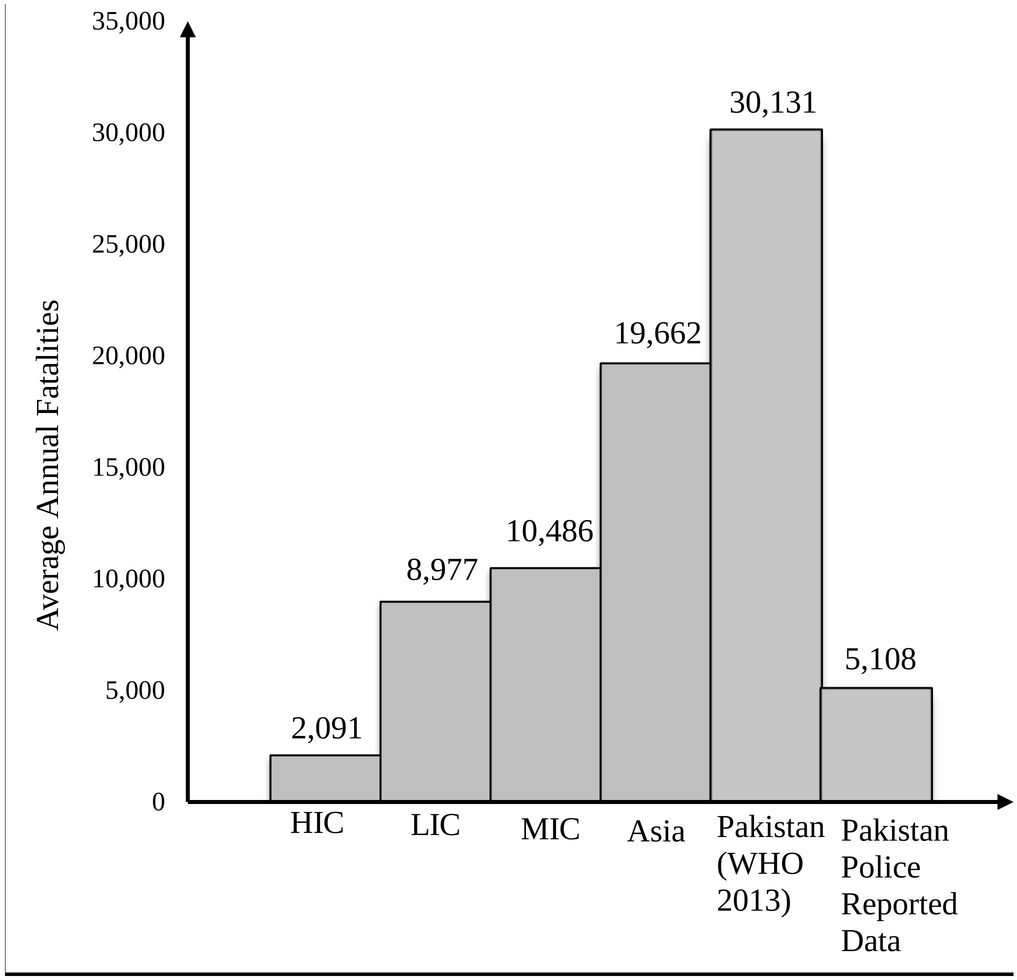

Figure 4.9 Comparison of Global Annual Crash Fatalities

4.7 Chapter Summary and Conclusion

In this chapter an international statistical comparison of RCF of Pakistan with Asian countries, SAARC countries, Middle income countries and all the countries of the world has been carried out. The purpose of this statistical comparison was to explore the road safety situation in Pakistan with respect to other countries. To achieve this objective, the data were obtained from WHO (2013). The crash fatality rates were compared on the basis of two normalized measures; FPHTP and FPTRV. Different comparisons showed that Pakistan has higher crash fatality rates, which clearly indicated the critical road safety situation in Pakistan. Comparison of different countries groups on the basis of average annual fatalities were also presented in the last section of the chapter. The low crash fatality rates were observed for high income countries (2,091), while high crash fatality rates were noticed for low, middle income and Asian countries. The most serious road safety problems exist in SAARC countries with an average fatality rate of 40,884. In addition, there are two contradicting estimates of crash fatality rate in case of Pakistan; 5,108 annual fatalities have been reported by police, while WHO estimate show that 30,131 annual fatalities occur in Pakistan.

CHAPTER 5. ACCIDENT PREDICTION MODELS

5.1 Introduction

In this chapter, accident prediction models are estimated and model results are discussed. RCF were predicted using two different data sets and, results were compared. One set of models used police reported RCF data for Pakistan. Using ordinary least squares (OLS) regression techniques, RCF have been predicted for Pakistan from year 2014-2040. Similarly using data from WHO Global Status Report on Road Safety, OLS regression models have been estimated. For prediction of RCF on basis of international data, separate models have been developed for Asia and World. Also, this chapter provides a comparison of RCF estimated using different modelling techniques/data sources.

5.2 Data Collection

5.2.1 Data Collection for Pakistan

For estimation of RCF the data for present study were collected from number of sources and a comprehensive database was prepared. Different old reports and published data sources of NTRC, SIP and ESP were explored to gather data on total population, total number of registered vehicles, total road lengths, paved road length, GDP, number of cars, vehicle kilometre travelled, vehicle classes, RTC, RCF and RCI for year 1981 to 2012 (thirty two years time period). Table 5.1 presents the descriptive statistics of data used for model estimation.

Table 5.1 Summary Statistics of Selected Variables – Pakistan Data

Descriptive Statistics	Mean	Std Dev.	Min	Max
Paved Road Length	1,19,339	44,478	52,839	1,81,940
Total Road Length	2,02,173	59,436	95,815	2,61,821
Population (Millions)	12.9	28.9	84.2	178.9
Number of fatalities/ 1,000,000 VKMT	0.17	0.12	0.04	0.46
GDP per capita (US $)	568	203	377	1,182
Number of fatalities/ 100,000 registered vehicles	2	1.46	0.48	5
Number of fatalities/ 100,000 population	4	0.79	2	5
Registered Vehicles	4,472,899	32,98,928	75,5698	10,961,000

5.2.2 Data Collection from WHO Global Status Report on Road Safety - 2013

Since in case of Pakistan, it is expected that there is serious underreporting, therefore another data set was obtained from "WHO Global Status Report on Road Safety – 2013" to estimate a model that can be used to predict crash fatalities for Pakistan. WHO gathered data on road safety through a standardized survey conducted in 182 countries across the globe in 2010. The WHO data were collected through the assistance of number of different sectors and stakeholders in each country, coordinated by a "National Data Coordinator". The WHO gathered country-level data on road safety for different categories that are; (1) road traffic deaths and proportion of deaths by road user, (2) post-crash response, (3) speed laws and enforcement, (4) drink-driving laws and enforcement, (5) helmet laws and enforcement and wearing rates, (6) seatbelt and child restraint laws and enforcement, (7) cell phone laws, (8) road safety management, strategies, targets and safer mobility.

A numbers of data elements were used in present study from WHO data sets for model estimation and are given as following:

(1) Population
(2) Number of registered vehicles
(3) Road density (km/km^2)
(4) Number of hospital beds per thousand population
(5) Continent
(6) Information on vital registration system
(7) National policy for promoting walking and cycling (1-Yes, 0-No)
(8) Effectiveness of overall enforcement level of speed limits (scale 0-10)
(9) Effectiveness of overall enforcement level of drink driving law (scale 0-10)
(10) Effectiveness of overall enforcement level of motorbike helmet law (scale 0-10)
(11) Effectiveness of overall enforcement level of seatbelt law (scale 0-10)
(12) Effectiveness of overall enforcement level of vehicle child restraint law (scale 0-10)
(13) Public access to pre-hospital care system (1-Yes, 0-No)
(14) Gross national income per capita (US $)
(15) Maximum speed on rural roads (km/hr)
(16) Maximum speed on urban roads (km/hr)
(17) Emergency room based injury surveillance system
(18) Legislation on cell phone use while driving
(19) Level of investment in public transportation
(20) Audits of existing/new roads
(21) Presence of lead road safety agency or not
(22) National road safety strategy
(23) Level of training in emergency medicine for doctors
(24) Availability of training in emergency medicine for nurses
(25) Speed limits are modifiable/setting at local or national level
(26) National drink driving law
(27) National helmet standards/law
(28) National seatbelt law and application (seat belt law applies to front and rear occupants, mandatory installation of seat belt in newly manufactured vehicles)
(29) Funding of lead road safety agency

(30) National child restraint law.

WHO data has some limitations and major one is the different definitions adopted by the agencies across different countries. The parameters with such definition issues are pre-hospital care system, vehicle and road standards and institutional policies because expert's opinion methodology has been used in gathering such information. Moreover, in developing countries the data gathering process might be inconsistent due to incomplete vital registration records. Similarly, total number of registered vehicles data, actual number of vehicle miles travelled, miles travelled by vehicle type, actual seatbelt usage rates and drivers age/gender also have limitations.

5.3 Crash Fatality Rate Models Based on Historical Data of Pakistan

5.3.1 Model Functional Form

It may be recalled that the main objective of this chapter is to estimate model for predicting road crash fatalities for Pakistan using historical (police reported road crash fatalities) and international data (WHO, 2013). With that objective in mind, OLS regression models that used the number of fatalities per hundred thousand population (FPHTP), the number of fatalities per hundred thousand registered vehicles (FPHTRV) and the number of fatalities per million vehicle kilometre travelled (FPMVKM) as dependent variable, were estimated. The models were estimated using LIMDEP (statistical software package) [Greene, 2007]. A number of functional forms were investigated and the best estimated model is presented and discussed in the ensuing paragraphs. The general functional form of the OLS model is as follows:

$$y_{(i)} = \beta_o + \sum_{i=1}^{j} (\beta_i x_i) + \varepsilon_i \qquad 5.1$$

Where, y (i) = fatality rate, β's are model coefficients; x_i is the set of independent variables representing factors affecting RCF; and ε's are the error terms. The fatality rate is a non-negative continuous variable therefore OLS regression analysis was selected for the development of traffic fatalities models in this research study. RCF models can be used to estimate the probable number of fatalities in the future. If the actual number of fatalities is less than the predicted number, it would be an indicator of the successful implementation of road safety improvement measures. The predictive capabilities of all the developed fatalities models were tested by calculating the Mean Absolute Percent Error (MAPE). It measures the relative error and expressed as a percentage.

5.3.2 Selection of Explanatory Variables (X)

There are numerous factors that cause road traffic accidents and fatalities. The most influential and important independent variables used in this research study are population, number of registered vehicles, road lengths, high type roads, GDP, vehicle kilometre travelled (millions) and vehicle classes. These are the common variable for which data is usually collected by highway agencies; therefore use of these variables makes models workable (fatalities can be predicted).

5.3.3 Selection of Response Variables (Y)

Exposure based response variables such as fatalities per vehicle kilometre are the most appropriate to use in prediction models. However other response variables that can act as suitable surrogates for exposure to RTC such as the number of fatalities per hundred thousand population (FPHTP) and FPHTRV (the number of fatalities per hundred thousand registered vehicles) are commonly used by researchers. In present study, the number of fatalities per hundred thousand population, the number of fatalities per hundred thousand registered vehicles and the number of fatalities per million vehicle kilometre travelled are used as response variables for the models estimation. The natural logarithm transformation of the response is used to ensure that the model outputs are positive. A number of models using different explanatory variables have been estimated that are discussed in ensuing paragraphs.

5.3.4 Model Estimation Results and Discussion using Pakistan Data

5.3.4.1 Model - 1: Dependent Variable - Log Fatalities/ 100,000 Population

The detailed model results are shown in Table 5.2. The estimated model is as follows:

$$Y = 1.83 - 6.54E\text{-}06 * (PRL) + 1.71E\text{-}06 * (TRL) \qquad (1)$$

Table 5.2 Model Results - Log Fatalities/ 100,000 Population as Dependent Variable

Variable	Coefficient	t-stat
Constant	1.83	48.31
PRL (Paved Road Length)	-6.54E-06	-8.26
TRL (Total Road Length)	1.71E-06	2.89
R^2	0.94	
Adjusted R^2	0.93	
Number of observations	32	
MAPE	0.0007	

The model results indicate that the significant variables are paved road length and total road length. The model has a very good fit for the rather highly-varied data that were collected over several years (1981- 2012). The R^2 value of 0.94 indicates that an approximately 94% variance in data is explained at a 95% level of confidence.

Paved road length is found to be significantly negatively associated with the total numbers of RCF. This finding is intuitive. A paved (high) type road indicates better road as compared to unpaved (low type) with suitable road safety interventions. Increase in length of high quality roads will provide a better driving environment to road user's thus reducing fatalities. In case of Pakistan 70 % are paved roads and 30 % are unpaved roads. By increasing the paved road length it is possible to reduce the number of fatalities. Total road length is the second significant variable in the model that is positively associated with total number of RCF. This finding is also intuitive and consistent with past studies [Kumara and Chin, 2004] as increase in total road length will results in higher mobility and exposure, thus resulting in higher number of RCF. Figure 5.1 presents the actual and predicted values of the Fatalities/ 100,000 Population. To evaluate the accuracy of the models the MAPE is estimated as follows:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}|PE_i| \qquad 5.2$$

Where, $PE_i = (A_i - P_i) / A_i$ is the percentage error for observation i of the actual and predicted rate. The MAPE result for the above discussed model is 0.0007. MAPE values closer to zero signify higher prediction accuracy of the model.

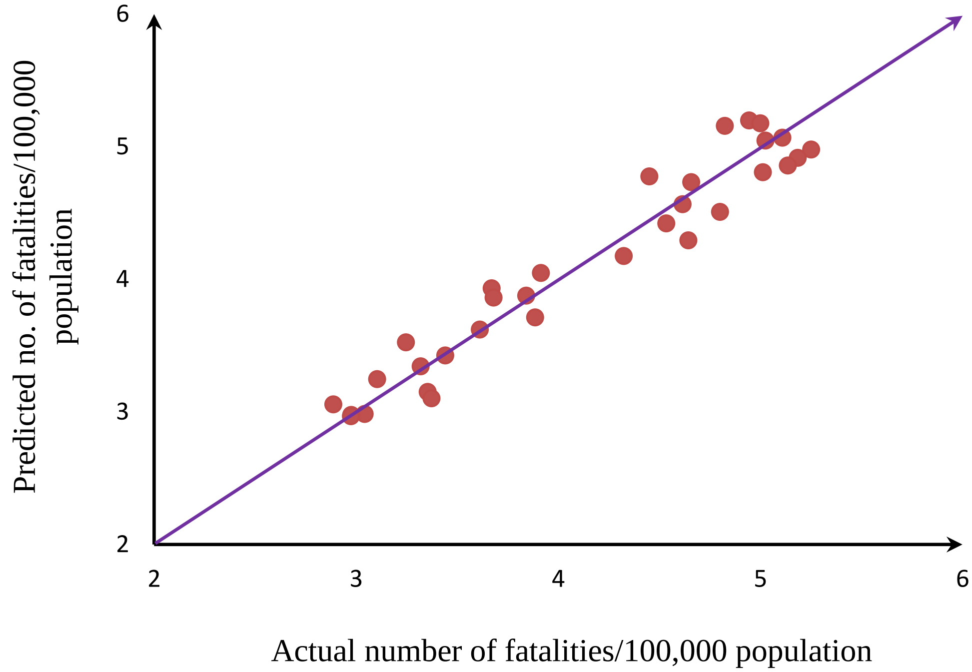

Figure 5.1 Comparison of Actual vs. Predicted Values (Model - 1)

5.3.4.2 Model - 2: Dependent Variable - Log Fatalities / 100,000 Registered Vehicles

The detailed model results are presented in Table 5.3. The estimated model is as follows:

$$Y = 7.12 - 1.6E\text{-}05 * (PRL) - 0.00029 * (GDP) \qquad (2)$$

Table 5.3 Model Results Using Log Fatalities/ 100,000 Registered Vehicles

Variable	Coefficient	t-stat
Constant	7.12	163.31
PRL (Paved Road Length)	-1.6E-05	-28.50
GDP (Gross Domestic Product)	-0.00029	-2.35
R^2	0.98	
Adjusted R^2	0.98	
Number of observations	32	
MAPE	0.002	

Two variables, paved road length and GDP, are found to be significant. The R^2 value of 0.98 shows that 98% variance in data is explained at 95% level of confidence. Paved road length is significantly inversely related with the RCF because more high quality roads will provide an enhanced driving environment to the road user's hence reducing fatalities. GDP is the second significant variable that is negatively related with total number of RCF. The results are quite intuitive and consistent with past studies. Kopits and Cropper [2005] observed that economic growth has a non-linear relationship with RCF. Rapid increase in RCF was observed in low income countries at the start of economic development, but as soon as income level reached certain income threshold the traffic fatality rates become constant resulting in less number of RAF. This trend is quite common in developed countries where economic development (increase in GDP) results in overall improved highway systems thus resulting in fewer fatalities per hundred thousand registered vehicles. Also, increase in GDP is a surrogate for superior health care services, strict enforcement of traffic safety laws and policies, safety audits, better vehicle maintenance and roads design [Noland et al., 2003]. The actual and predicted values of the FPTRV are shown in Figure 5.2. The MAPE value for the model is 0.002.

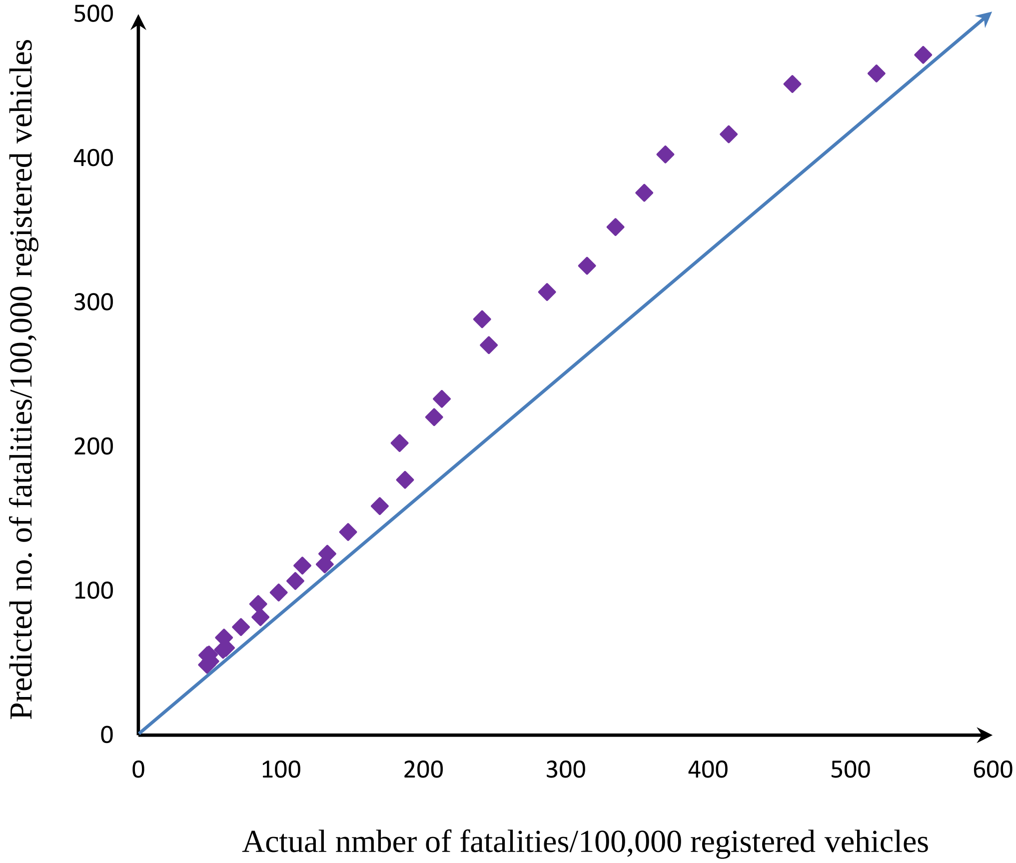

Figure 5.2 Comparison of Actual vs. Predicted Values (Model – 2)

5.3.4.3 Model - 3: Dependent Variable - Log Fatalities/ 100,000 VKM Travelled

The detailed model findings are given in Table 5.4. The estimated model is as follows:

$$Y = - 0.14 + 2.47E\text{-}06 * (TRL) - 1.96E\text{-}05 * (PRL) \qquad (3)$$

Two variables are found to be significant; total road length and paved road length. The estimated model has an R^2 value of 0.98. The model has a very good fit for the rather highly-varied data as approximately 98% variance in data is explained at a 95% level of confidence. The total road length is directly associated with RCF. Kumara and Chin [2004] observed that increase in total road length results in higher mobility and exposure, consequently causing more RCF. The second variable, paved road length is negatively related with the total number of RCF. This finding is intuitive as well. Paved roads provide overall better driving environment to different road users as a result the RCF are expected to decreased. Figure 5.3 represents the actual and predicted values of the fatalities, indicating that model has reasonable fit and good prediction ability.

Table 5.4 Model Results - Log Fatalities/ 100,000 VKM Travelled as Response Variable

Variable	Coefficient	t-stat
Constant	-0.14	-2.04
TRL (Total Road Length)	2.47E-06	2.21
PRL (Paved Road Length)	-1.96E-05	-13.21
R^2	0.98	
Adjusted R^2	0.98	
Number of observations	32	
MAPE	0.003	

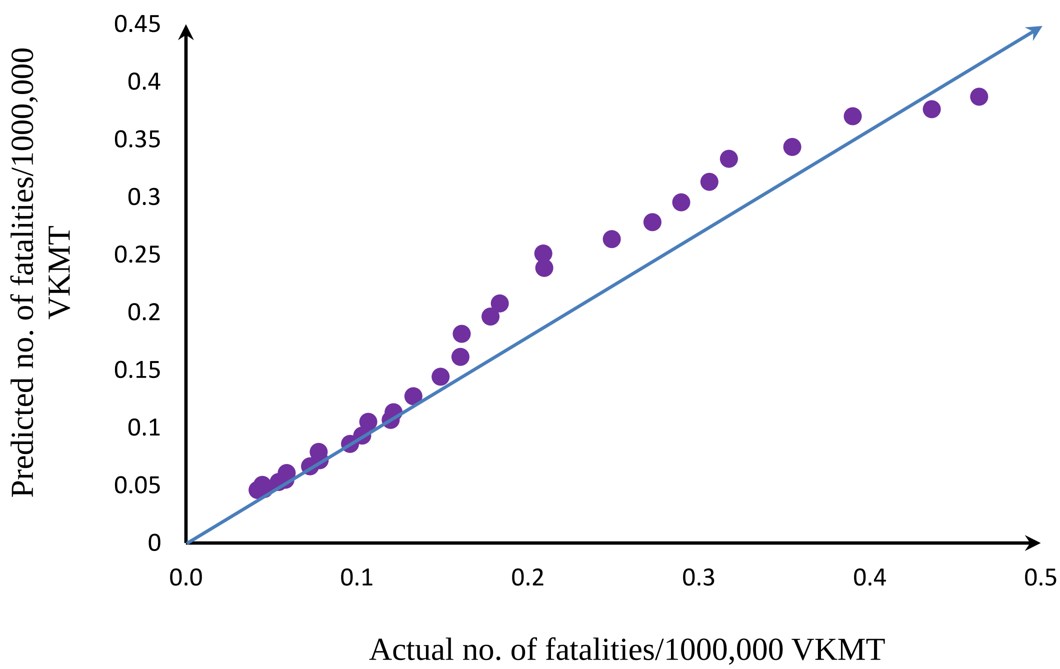

Figure 5.3 Comparison of Actual vs. Predicted Values (Model - 3)

5.4 Predicting Road Accident Fatalities using Pakistan Data

Three RCF prediction models are estimated using different explanatory variables. Using the estimated models RCF are predicted for Pakistan from 2014 – 2040. Road accidents data being the most important component of all road safety efforts that can help highway in improving road safety. Reliable estimates of RCF can help to monitor road safety efforts; identify possible causes and understand the extent of problem. Using each of the estimated models (section 5.3.4.1) the RCF are predicted. In order to predict the RCF for year 2014 - 2040 growth rates of 0.9, 1.01 and 1.50 for paved road length, total road length and population respectively were used. Growth rate were estimated using the trends observed over last decade. The predicted fatalities range from 5,382 to 6,135 annually. This indicates that there is a gentle increase in the RCF in Pakistan over the next twenty-six years; however studies indicate that the RCF are rapidly increasing in low and middle income countries due to rapid motorization [Jacobs and Cuttings, 1986; WHO, 2009]. Also, growth of registered vehicle is taking place at a rapid pace, as cars have almost doubled in last decade thus indicating that exposure to traffic crashes has increased at a very fast pace, but data set gathered by different road safety agencies of Pakistan contradicts the reality showing significant limitations of data collection efforts. Table 5.5 and Figure 5.4 present the predicted fatalities based on FPHTP. Similarly predicted RCF for year 2014 - 2040 using other two models (section 5.3.4.2 and section 5.3.4.3) were obtained (Table 5.5, Figure 5.5 and Figure 5.6). For prediction of fatalities a growth rate of 1.03, 1.07 and 1.07 for GDP, registered vehicle and VKM travelled have been used based on recent past trends. Again the predicted fatalities show a gentle increasing trend, thus contradicting the ground reality of enhanced accident exposure due to rapid motorization.

Table 5.5 Predicted Fatalities for Pakistan Using Police Reported Data - (2014 – 2040)

	Predicted Fatalities		
Year	FPHTP	FPHTRV	FPMVKMT
2014	5,382	6,368	6,336
2015	5,419	6,516	6,532
2016	5,455	6,663	6,731
2017	5,491	6,809	6,934
2018	5,526	6,954	7,139
2019	5,561	7,096	7,348
2020	5,596	7,237	7,560
2021	5,629	7,377	7,774
2022	5,662	7,514	7,992
2023	5,695	7,649	8,212
2024	5,727	7,782	8,434
2025	5,758	7,912	8,659
2026	5,789	8,040	8,886
2027	5,819	8,166	9,115
2028	5,848	8,288	9,345
2029	5,876	8,408	9,577
2030	5,904	8,524	9,810
2031	5,931	8,637	10,045
2032	5,957	8,747	10,280
2033	5,982	8,854	10,516
2034	6,007	8,956	10,752
2035	6,030	9,056	10,988
2036	6,053	9,151	11,224
2037	6,075	9,242	11,459
2038	6,096	9,329	11,693
2039	6,116	9,412	11,926
2040	6,135	9,491	12,158

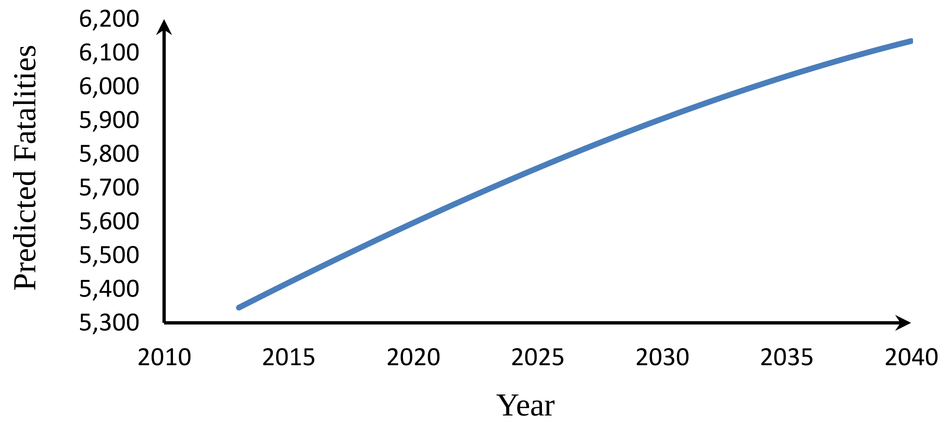

Figure 5.4 Total Annual Road Crash Fatalities Using Police Data – (FPHTP)

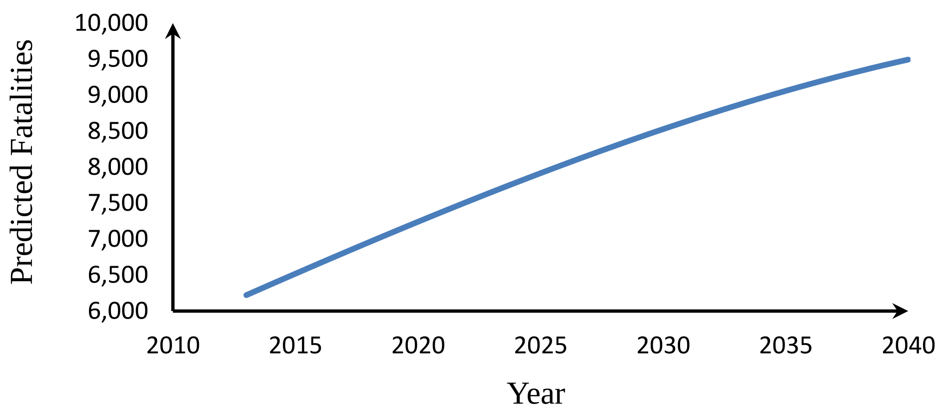

Figure 5.5 Total Annual Road Crash Fatalities Using Police Data – (FPHTRV)

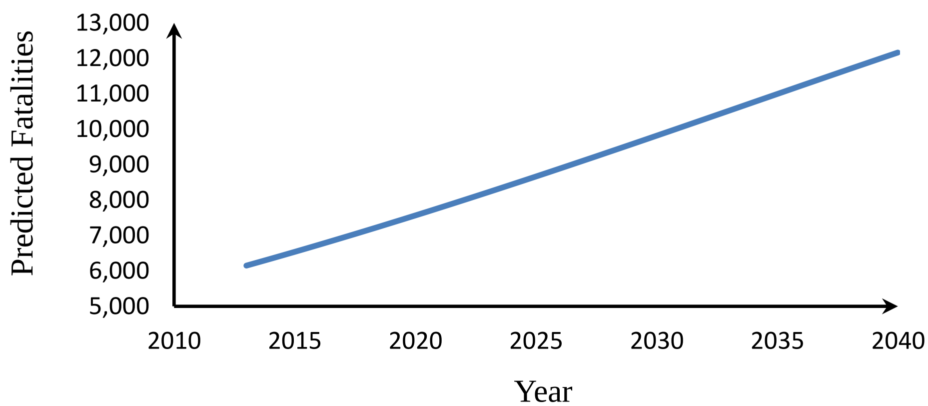

Figure 5.6 Total Annual Road Crash Fatalities Using Police Data – (FPMVKMT)

5.5 RCF Prediction Models using Data from International Sources

In this section models were estimated for predicting annual RCF for Pakistan using data from WHO (WHO, 2013) and IRF (IRF, 2009) data bases. Separate models were developed for Asian countries and overall world. Data for forty Asian countries and one hundred and seventy countries of the world were used to estimate the models. Different countries have been categories into three broad groups by WHO data collection team based on their gross national income (GNI) that are: (l) low income countries (GNI less than and equal to 1,005 US dollars) (2) middle income countries (GNI of a country is in between 1,006 – 12,276 US dollars) and (3) high income countries (if the GNI of a country is greater than 12,276 US dollars).

Numbers of explanatory variables were tried for model estimation (section 5.2.2). The significant independent variables are: number of registered vehicles, road density (km/km^2), vital registration system, effectiveness of overall enforcement level of speed limits on a scale of 0-10, effectiveness of overall enforcement level of vehicle child restraint law on a scale of 0-10, GNI per capita (US $), maximum speed on urban roads (km/hr), national road safety strategy, national drink driving law, national helmet law and seat belt law. Table 5.6 represents the descriptive statistics of all significant variables. The number of FPHTP and FPHTRV were used as response variables for the fatality rate models that have been used by several past studies [Soderlund and Zwi, 1995; Bester, 2001; Paulozzi et al., 2007; Bishai et al., 2006]. The natural logarithm transformation of the response and explanatory (GNI and registered vehicles) variables are used to ensure that the model outputs are positive.

Table 5.6 Summary Statistics of Selected Variables - WHO Data

Variable	Mean	Std.Dev.	Minimum	Maximum
Vital Registration System (VRS)	0.88	0.32	0	1
Effectiveness of Speed Limit law (ESLL) on a 0-10 scale	5.12	2.20	0	10
Effectiveness of Vehicle Child Restraint Law (EVCRL) on a 0-10 scale	2.51	3.14	0	10
National Road Safety Strategy (NRSS)	0.80	0.39	0	1
National Drink Driving Law (NDDL)	1.00	0.21	0	2
National Motorbike Helmet law (NMBHL)	0.98	0.26	0	2
Seatbelt Law Installation and Applies to Front and Rear Occupants (SBLAFRO)	0.64	0.48	0	1
Max Speed on Urban Roads (MSUR)	53.66	13.32	25	100
Fatalities/ 100,000 Thousand Population (FPHTP)	15.76	7.98	1.80	41.70
Fatalities/ 100,000 Registered Vehicles (FPHTRV)	2.28	5.22	0.3E-01	31.86
Road Density (RDEN)	0.65	0.99	0.1E-01	7.04
Gross National Income (GNI)	11,976	17,205	180	86,390
Registered Vehicles (RV)	9,153,395	29,205,840	1,101	2,58,957,503

5.5.1 Model Estimation Results and Discussion - Asia Model

The detailed model results are shown in Table 5.7. The estimated model using data from forty Asian countries is given as follows:

$$LogFPHTP = 1.185 + (0.008 * MSUR) + (1.242 * NDDL) - (0.202 * EVCRL) + (0.08 * LogRV) - (0.51 * VRS) - (0.78 * NMBHL) \qquad (4)$$

Table 5.7 Model Results – Asia Model

Variable	Coefficient	t-stat
Constant	1.185	2.28
Maximum Speed on Urban Roads (MSUR)	0.008	2.09
National Drink Driving Law (NDDL)	1.242	3.43
Effectiveness of Vehicle Child Restraint Law (EVCRL)	-0.202	-5.22
Natural Log of Registered Vehicles (LogRV)	0.081	2.51
Vital Registration System (VRS)	-0.514	-2.15
National Motorbike Helmet Law (NMBHL)	-0.788	-2.29
R^2	0.63	
Adjusted R^2	0.56	
Number of observations	40	
Durbin -Watson statistics	2.13	

The model results indicated that the significant variables are maximum speed on urban roads, national drink-driving law, effectiveness of overall enforcement level of child restraint law on a scale 0-10, total number of registered vehicles, vital registration system existences and national helmet law. This model has a reasonable fit (R^2 value of 0.63) for a highly varied data.

The RCF are found to be positively associated with maximum speed on urban roads. The finding is quite intuitive and consistent with past studies [Scuffham, 2003] as increase in maximum allowed speed on urban roads will results in speedy driving and increased risk to pedestrians and cyclists, thus resulting in higher number of RCF.

National drink-driving law is another significant variable in the model that is positively associated with total number of RCF. This finding is counter intuitive as proper legislation for risk factors (drink-driving) should minimize the crash probability and fatalities. The model finding gives a new direction for investigation of impact of actual implementation/ enforcement level of drink-driving laws on RCF. Since many Asian countries might have drink-driving laws but at the same time a lower level of enforcement thus resulting into higher number of RCF.

Effectiveness of overall enforcement level of vehicle child restraint law is negatively associated with the RCF. This finding is intuitive as well. High enforcement level of vehicle child restraint law results in lesser RCF as child restraint systems protect infants and young children from injury and fatality during accident. Over the past decade, vehicle safety technology has made a significant contribution in improving accurate installation of child restraints. However, in Pakistan the effectiveness of overall enforcement level of vehicle child restraint law is rated as zero on scale of 0 – 10 as per WHO data set.

The total numbers of RCF are directly related with total number of registered vehicles. The finding is consistent with past studies [Page, 2001] as increase in vehicle fleet will result into higher accident exposure and greater interaction among vehicles consequently resulting in higher RCF.

Presence of vital registration system in a country is negatively associated with RCF. This finding is also intuitive. Better and improved recording system results in reduction in total number of fatalities and crashes. An effective vital registration system helps in reducing the RCF, as it provides accurate fact and figures of a country condition and progress in a particular area so that the concerned government agency can take timely decisions and actions. In Pakistan the vital registration system exists, but improvements are required to make it work efficiently and effectively.

National motorbike helmet law is significantly negatively correlated with the RCF. This finding is quite intuitive. Wearing helmets reduces the fatality rate largely as head and neck injuries are the main cause of fatality among motorcycle users. Wearing a good, standard quality motorcycle helmet can reduce the fatality risk by 40% and the risk of serious injury by over 70% [WHO, 2013]. High income countries have comprehensive helmet laws than middle and low income countries. In the South East Asia motorcyclists comprise a third of all RCF. In Asia the comprehensive helmet law exists. Pakistan also practices the helmet law but improvements are required to enforce it effectively.

The predictive capabilities of the Asia model were test by calculating MAPE. Figure 5.7 shows the predicted and actual values of the fatalities.

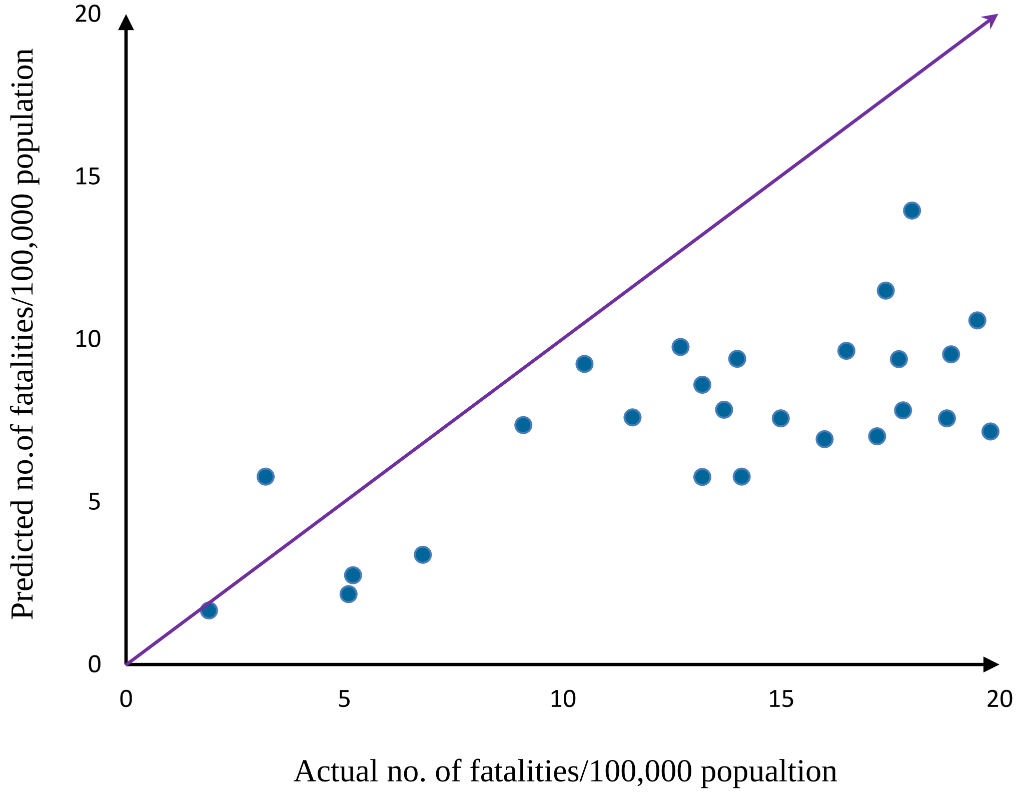

Figure 5.7 Comparison of Actual vs. Predicted Values (Asia Model)

5.5.2 Prediction of RCF for Pakistan based on Asia model

Using estimated model for Asian countries RCF have been predicted. To predict the RCF compounded annual growth rate (CAGR), computed using past trends were used. For predicting RCF using Asia models CAGR of 1.07 and 1.02 were used for registered vehicle and population respectively. The response variable used in Asia model is LnFPHTP. Table 5.8 and Figure 5.8 represents the RCF predicted for Pakistan for the year 2014 to 2040.

Table 5.8 Prediction RCF Based on FPHTP (2014 – 2040) - Asia Data

Year	Predicted Fatalities	Year	Predicted Fatalities
2014	21,095	2028	28,766
2015	21,568	2029	29,410
2016	22,051	2030	30,069
2017	22,545	2031	30,743
2018	23,050	2032	31,431
2019	23,566	2033	32,135
2020	24,094	2034	32,855
2021	24,634	2035	33,591
2022	25,185	2036	34,344
2023	25,750	2037	35,113
2024	26,326	2038	35,899
2025	26,916	2039	36,704
2026	27,519	2040	37,526
2027	28,136		

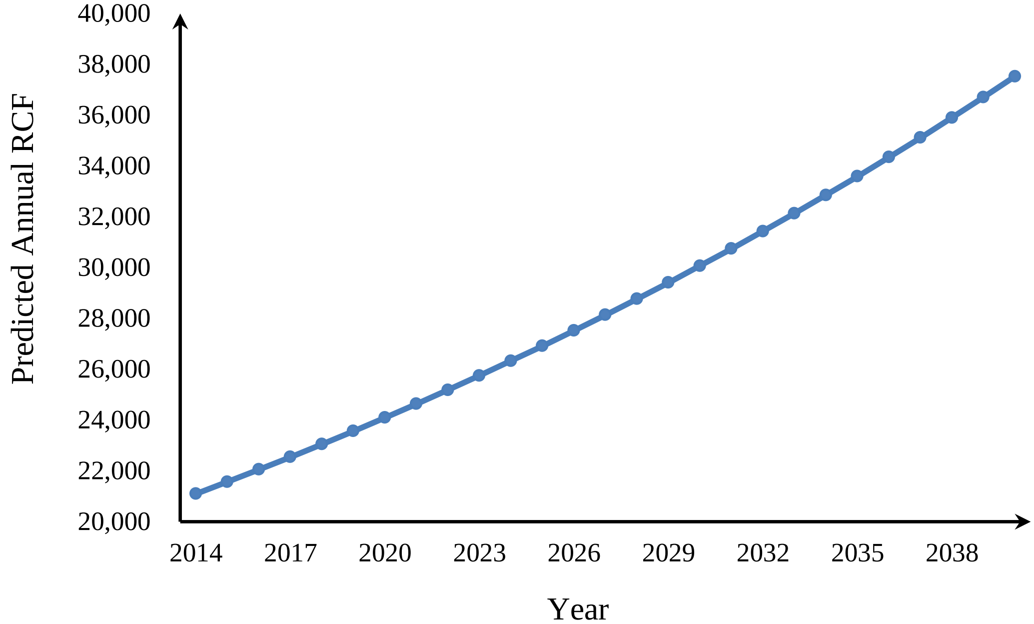

Figure 5.8 Predicted RCF Using Asia Data

5.5.3 Model Estimation Results and Discussion - World Model

The model results are given in Table 5.9 and the model equation is as follow:

$$\text{LogFPHTP} = 3.348 + (0.105 * \text{LogRV}) - (0.181 * \text{LogGNI}) - (0.147 * \text{RDEN}) - (0.25 * \text{NRSS}) - (0.21 * \text{SBLAFRO}) - (0.438 * \text{EOSL}) \quad (5)$$

The model data were collected for several countries (i.e. one hundred and seventy) for the year 2010. The significant variables in this model are total registered vehicles, gross national income, road density, maximum speed on urban roads, national road safety strategy, seatbelt installation is mandatory and law applies to front and rear occupants and effectiveness of overall enforcement level of speed limits law on a scale 0-10. Each significant variable is discussed in detail as follows.

The total number of registered vehicles is positively associated with the RCF. This finding is quite intuitive. Page [2001] observed that the increase in registered vehicles results in higher exposure and interaction with other vehicles therefore really into poor road safety conditions.

Table 5.9 Model Results - World Data

Variable	Coefficient	t-stat
Constant	3.348	14.13
Natural Log of Registered Vehicles (LogRV)	0.105	7.34
Natural Log of Gross National Income (LogGNI)	-0.181	-6.13
Road Density (RDEN)	-0.147	-3.77
National Road Safety Strategy (NRSS)	-0.25	-3.13
Seatbelt Mandatory Installation and Application to Front and Rear Occupants (SBLAFRO)	-0.21	-3.17
Speed Limits Law Enforcement Level (EOSL)	-0.438	-2.77
R^2	0.45	
Adjusted R^2	0.43	
Number of observations	170	
Durbin-Watson statistics	2.11	

The second significant variable is gross national income. GNI has statistically significant negative association with total number of RCF. The finding is quite intuitive and consistent with past studies [Van Beek et al., 2000], as GDP has a non-linear relationship with RCF. Increase in gross national income is a surrogate for superior health care services, strict enforcement of traffic safety laws and policies, better vehicle maintenance standard and improved roads design [Noland et al., 2003]. This trend is quite common in developed countries where economic progress has results in improved quality of life thus resulting in fewer RCF.

Road density is defined as the number of roadway kilometers per square kilometer. That is found to be significantly associated with the RCF. Jacobs and Cuttings [1986] observed that the higher road density indicates slower vehicles speeds and congestion therefore the risk of RTC is comparatively reduced. Countries with high road density and has enhanced accessibility and connectivity have better road safety condition.

RCF are found to be significantly negatively associated with national road safety strategy of country. The finding is intuitive as well. National road safety strategy provides polices regarding every major aspect of road safety (for example improved post-crash emergency services, investment in public transport, promote walking and cycling, road audits, improved vehicle design, better enforcement of speed law, drink driving law, helmet law and seatbelt law). Most of the developed countries have comprehensive national road safety strategy that has played role in improving road safety condition. We have not practiced this in our society.

The next significant variable in the model is the national seatbelt law and its application to front and rear occupants of the vehicle. It is found to be negatively associated with the total numbers of RCF. This finding is quite intuitive. No seatbelt use can cause drivers or passengers to be completely ejected from the vehicle, therefore greatly increasing the risk of serious injury and fatality. Research shows that the seatbelt use reduces the risk of a fatality by 50% for front seat occupants and up to 75% for rear seat occupants [WHO, 2013].

Effectiveness of overall enforcement level of speed limits law is found to be significantly associated with the RCF. This finding is intuitive as well. Lassarre et al., [2001] observed that the high speed enforcement reduces over speeding. In urban regions that have high concentrations of pedestrians and cyclists, measures to reduce speed are critical for the safety of road users. Speed reduction interventions can lead to substantial reductions in RCF. High income countries have stricter enforcement of speed limits law than middle and low income countries. That might be the one of the reason that these countries have low RCF.

To evaluate the accuracy of the estimated model, MAPE was estimated. Figure 5.9 shows the actual and predicted values of the FPHTP.

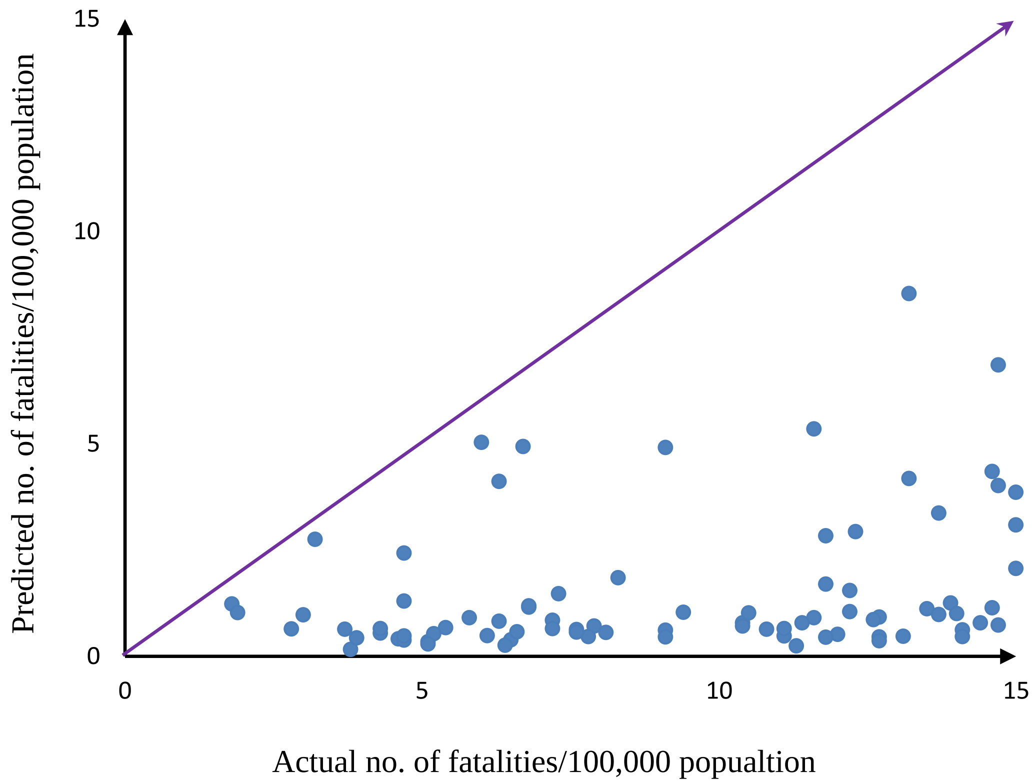

Figure 5.9 Comparison of Actual vs. Predicted Values (World Model)

5.5.4 Prediction of Annual RCF for Pakistan Using World Model

In this section, the RCF are predicted for Pakistan on basis of world model. Growth rates of 1.07, 1.03, 1.01 and 1.02 were used for registered vehicle, gross national income, road density and population respectively. The predicted fatalities are shown in Table 5.10 that are 19,222 and 32,319 for year 2014 to 2040 respectively. The response variable used for the world model is LnFPHTP. WHO estimate approximately 30,000 annual RCF for Pakistan for year 2013. However model predicted fatalities are approximately 19,222. Thus WHO study over predicts RCF for Pakistan.

Table 5.10 Annual RCF Predicted for Pakistan Using World Model

Year	Predicted Fatalities	Year	Predicted Fatalities
2014	19,222	2028	25,440
2015	19,611	2029	25,953
2016	20,008	2030	26,477
2017	20,413	2031	27,011
2018	20,826	2032	27,555
2019	21,248	2033	28,111
2020	21,678	2034	28,677
2021	22,116	2035	29,255
2022	22,563	2036	29,844
2023	23,019	2037	30,445
2024	23,485	2038	31,057
2025	23,959	2039	31,682
2026	24,443	2040	32,319
2027	24,937		

5.6 Comparison of RCF Estimated From Different Data Sources/ Modeling Techniques

In this section, the comparison of RCF prediction for Pakistan using different models and data set is carried out (Table 5.11, Figure 5.10). Lowest estimates are obtained where police reported data for Pakistan is used. Predicted RCF obtained using Asia model and world model are quite similar. However the estimated RCF for Pakistan obtained from WHO-2009 and WHO-2013 are quite high.

Table 5.11 Comparison of RCF Predicted for Pakistan Using Different Data Set

Various Models	Predicted RCF
Pakistan Model – Estimated using data from National sources	6,368
Asia Model – Estimated using data from International sources	21,095
World Model – Estimated using data from International sources	19,222
WHO, 2013	30,130
WHO, 2009	52,537

The main reason for under prediction of RCF for Pakistan using police reported data is underreporting. Unless and until the accurate data are available, it is not possible to obtain reliable estimates of RCF for Pakistan. Razzak et al., [1998] also noted that shortcomings in police reported data continue to make it difficult to determine the scale of the problem. Similarly two other studies also revealed that the number of fatalities and injuries are often under-reported in low-middle income countries like Pakistan [Razzak and Laflamme, 2005; WHO, 2004]. Incorrect functional form of the model used by WHO, might be the major reason for overestimation of RCF. In addition the lack of transparency (detailed calculation not shown) makes the WHO estimated questionable.

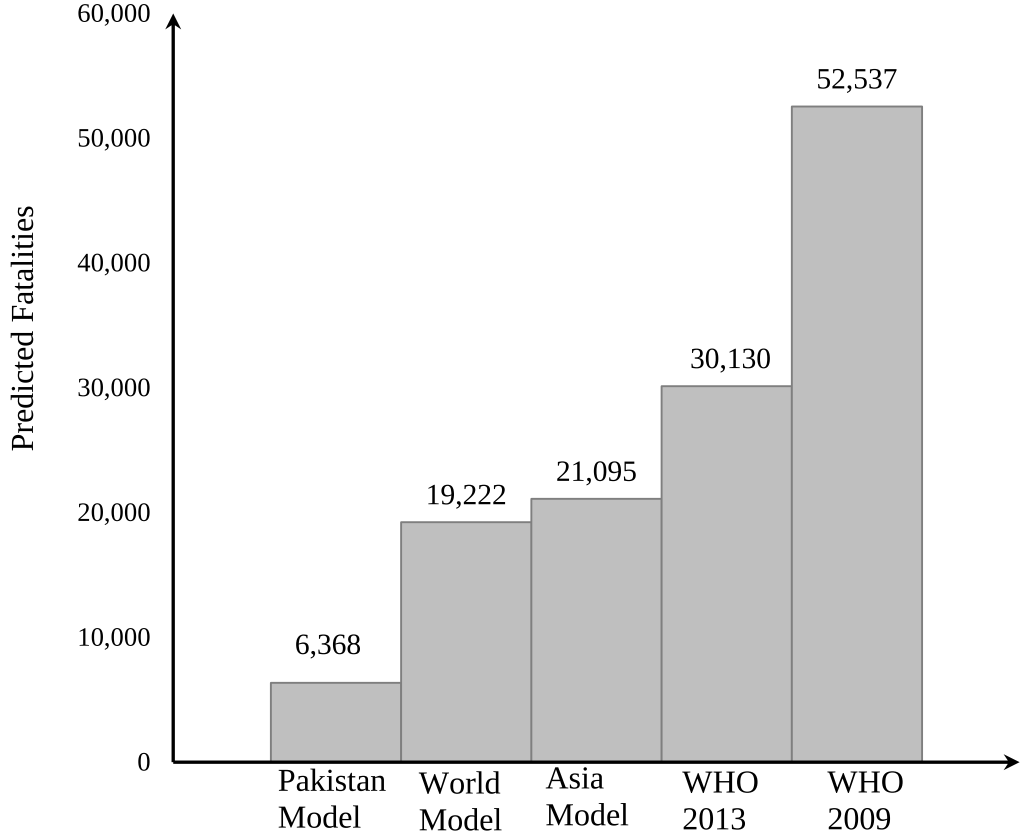

Figure 5.10 Comparisons between Predicted RCF for Pakistan

5.7 Chapter Summary and Conclusion

In this chapter, the accident prediction models were estimated and model results were discussed. The purpose of developing models using national data were; to demonstrate that with the availability of reliable data, estimates for annual RCF can be obtained. Secondly, the quality of data seriously affects the estimated RCF.

RCF were predicted using two different data sets: Pakistan data (reported by police) and international data (i.e. WHO global status report on road safety – 2013 and IRF 2009 data base). Pakistan data sources were explored to gather data on population, registered vehicles, total road lengths, paved road lengths, vehicle KM travelled, GDP, traffic stream composition, RCF, RCI and RTC for the past three decades (1981 to 2012). OLS regression techniques and statistical software LIMDEP was used for model estimation. The predictive capabilities of developed model were tested by calculating MAPE. Using each of the estimated models, the RCF are predicted based on Pakistan data.

The RCF prediction models have been also estimated using international data; two separate models were developed for Asian and world. The significant independent variables were: registered vehicles, road density, vital registration system, effectiveness of overall enforcement level of speed limits on a scale of 0-10, effectiveness of overall enforcement level of vehicle child restraint law on a scale of 0-10, GNI per capita (US $), maximum speed on urban roads (km/hr), national road safety strategy, national drink driving law, national helmet law and seat belt law. The FPHTP and FPHTRV were used as response variables for the fatality rate models.

Also, this chapter provides a comparison of RCF estimates obtain using different data sources. Overall, 21,095 road crash fatalities were predicted for year 2014, compared to approximately 30,000 annual fatalities predicted by WHO (2013) and 5,323 (2012) reported by police. Analysis of the results indicated that use of police reported data for models estimation and fatality prediction results into under prediction, while methodology adopted by World Health Organization over predicts the annual road crash fatalities for Pakistan.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Synopsis of the Research

This research study, addressed the vital issue of road crashes fatality estimation in Pakistan. The study began with an extensive review of literature, both at international and national level on road crash fatality estimation. Review of the international studies helped to identify the major factors associated with road crash fatalities and different approaches adopted in different countries for predicting road crash fatalities. The detailed literature review also helped to identify the gaps in existing practice and data availability issues. Similarly the review of past national studies helped to identify the research focus areas and limitations of adopted methodology. Before the estimation of crash fatality prediction models, a comprehensive review of existing state of road safety in Pakistan was carried out. Growth trends of population, road network, vehicle fleet and road crash fatalities during last three decades were thoroughly investigated. The impact of rapid motorization, population expansion and infrastructure growth on probability of occurrence of road crash fatalities was discussed. Similarly motorization level, population increase and expansion of road network were compared and discussed at provincial level. The vehicle fleet composition and its impact on increased risk of accidents was discussed in detail. The trends in total police reported road crash fatalities for last three decades were investigated and discussed, both at national and provincial levels.

Also, this study carried out a detailed comparison of road crash fatalities in Pakistan with Asian countries, SAARC countries, Middle income countries and overall with world average, using different measures of exposures to risk of accidents, and data from number of international sources. Finally, present research estimated crash fatality prediction models for Pakistan. Road crash fatalities were predicted using two different data sets and, results were compared. One set of model used police reported annual number of road crash fatalities for Pakistan while the second used data obtained from international organization like World Health Organization (WHO) and International Road

Federation (IRF). Road crash fatalities for Pakistan were predicted from year 2014 to 2040 and results were compared with national and international estimates.

6.2 Research Findings

A thorough review of the past studies focused on road crash fatality estimation revealed that the major factors that are found to be associated road crash fatalities are: road density, number of registered vehicles, population density, GDP, human development index, level of healthcare services, vehicle kilometres driven, the governmental laws and policies and their enforcement level. Literature review confirmed that there has been lack of serious research efforts to estimate the road crash fatalities for Pakistan and most of the past national studies, either using data for individual cities or certain highways investigated the factors associated with road crashes using descriptive statistics. Detailed study of the current state of road safety in Pakistan and related factors revealed that country has experienced a rapid motorization in last few decades; however country’s population, road infrastructure and GDP have increased at a moderate rate, while reported numbers of road crash fatalities have remained constant. Past research has shown that with increase in exposure level, the probability of occurrence of road crash fatality increases, while in Pakistan where vehicle fleet has doubled in last one decade, the police reported number of crash fatalities remained constant (5, 248 and 5, 323 fatalities in year 2002 and 2012 respectively) that clearly shows serious road crash fatality data recording lapses. Also, a high proportion of vulnerable road users (53% motorcycles) further add to increased exposure level.

Comparison of road crash fatalities of Pakistan with other countries revealed that Pakistan has very high road crash fatality rates compared to other countries. Pakistan’s road safety performance is comparable to other south East Asian countries, as average annual road crash fatalities are similar to other neighboring countries. Pakistan has the eleventh highest road crash fatality rate among forty Asian countries, twenty-fifth highest RCF rate among ninety-four middle income countries. Overall on global level there are one hundred and twenty two countries having lower road crash fatality rate compared to Pakistan. High crash fatality rate for sixth most populous country indicates serious road safety issues that need immediate remedial measures and policy interventions.

As part of this study OLS regression models were developed using police reported annual number of road crash fatalities for Pakistan and comprehensive data obtained from different international organization like WHO and IRF. Models results revealed that road crash fatalities are significantly associated with total number of registered vehicles, gross national income, road density, maximum speed on urban roads, national road safety strategy, mandatory law for seatbelt installation and its application to front and rear occupants, and effectiveness of overall enforcement level of speed limits law. It was observed that the increase in registered vehicles results in higher road crash fatalities while, higher road density and gross national income results into lower number of fatalities. It was also observed that national road safety polices and their enforcement level can significantly assist in improving the road safety condition in country. Overall, 21,095 road crash fatalities were predicted for year 2014, compared to approximately 30,000 annual fatalities predicted by WHO (2013) and 5,323 (2012) reported by police. Analysis of the results indicated that use of police reported data for models estimation and fatality prediction results into under prediction, while methodology adopted by World Health Organization over predicts the annual road crash fatalities for Pakistan.

6.3 Recommendations and Direction for Future Research

Accurate and comprehensive information on road crashes is essential for identification of risk factors responsible for road crash fatalities and selection of appropriate remedial measures for reducing the road fatality toll that is rapidly growing in Pakistan. A comprehensive accident reporting and data storage system is recommended for Pakistan. Furthermore, Pakistan need a university based research center where latest methodologies are adopted to conduct road safety research through international collaboration and counter measures are developed that can help in reducing the road crash fatalities in Pakistan. Also, future research efforts should explore the specific geometric and traffic characteristics that are associated with road crash fatalities.

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APPENDIX

Appendix A. Estimated Length of Roads by Provinces (Km)

Year	Category	PUNJAB	SINDH	K.P.K	BALUCHISTAN	GB & AJK	TOTAL
2002	Total	1,01,923	79,525	40,769	27,934	1,510	2,51,661
	Low Type	41,627	32,480	16,651	11,409	617	1,02,784
	High Type	60,296	47,045	24,118	16,525	893	1,48,877
2003	Total	1,02,128	79,685	40,851	27,991	1,513	2,52,168
	Low Type	40,072	31,266	16,029	10,983	593	98,943
	High Type	62,056	48,419	24,822	17,008	920	1,53,225
2004	Total	1,03,708	80,918	41,483	28,424	1,537	2,56,070
	Low Type	39,498	30,819	15,799	10,826	585	97,527
	High Type	64,210	50,099	25,684	17,598	952	1,58,543
2005	Total	1,04,577	81,596	41,831	28,661	1,549	2,58,214
	Low Type	38,626	30,138	15,451	10,586	572	9,5373
	High Type	65,951	51,458	26,380	18,075	977	16,2841
2006	Total	1,04,904	81,851	41,961	28,751	1,554	2,59,021
	Low Type	37,054	28,911	14,822	10,155	549	91,491
	High Type	67,850	52,940	27,139	18,596	1,005	1,67,530
2007	Total	1,04,456	81,129	42,509	29,548	1,547	2,59,189
	Low Type	34,807	27,034	14,165	9,846	510	8,6362
	High Type	69,649	54,095	28,344	19,702	1,037	1,72,827
2008	Total	1,04,115	80,863	42,369	29,451	1,552	2,58,350
	Low Type	33,864	26,301	13,781	9,579	505	84,030
	High Type	70,251	54,562	28,588	19,872	1,047	1,74,320
2009	Total	1,04,114	80,863	42,369	29,452	1,552	2,58,350
	Low Type	32949	25,591	13,409	9,321	491	81,761
	High Type	71,165	55,272	28,960	20,131	1,061	1,76,589
2010	Total	1,05,085	81,618	42,765	29,727	1,565	2,60,760
	Low Type	32,179	24,993	13,095	9,103	480	79,850
	High Type	72,906	56,625	29,670	20,624	1,085	1,80,910
2011	Total	1,05,253	80,625	42,550	29,500	1,535	2,59,463
	Low Type	32,147	24,000	13,000	9,000	450	78,597
	High Type	73,106	56,625	29,550	20,500	1,085	1,80,866
2012	Total	1,06,455	80,960	42,975	29,625	1,580	2,61,595
	Low Type	32,590	24,335	13,140	9,125	465	79,655
	High Type	73,865	56,625	29,835	20,500	1,115	1,81,940

(NTRC, 2011)

Appendix B. Administrative Classification of Roads

Classification	Administration	Length (Km)	Function
National Highways And Motorways Strategic Road	National Highway Authority (NHA), Ministry of Communication	9,000	Representing the main transport corridors & providing inter-provincial linkages & connections to the neighbouring countries
Provincial Roads	Communication & Works Department (C&WD),Works and Services Department (WSD) &Frontier Highway Authority (FHA)	101,000	Providing access to the economic & population centres in the four provinces
District Roads	District government	94,000	Providing access to villages & remote areas
Municipal & Cantonment roads	Municipal government & army	54,000	Providing access to villages & remote areas

(PTPS, 2006)

Appendix C. Estimated Registered Motor Vehicles (1981 to 2012) in Pakistan

Years	Type of vehicles							
	Motor cycles	Passenger car	Buses	Rickshaws	Trucks	Tractors	Others	Total
1981	3,26,420	2,14,436	26,881	33,707	36,842	79,407	38,005	7,55,698
1982	3,76,071	2,46,172	25,620	34,551	40,058	88,199	32,133	8,42,804
1983	4,24,215	2,72,984	27,361	36,228	42,761	1,06,479	33,874	9,43,902
1984	5,17,448	3,29,924	30,955	37,211	49,165	1,35,712	37,791	1,138,206
1985	5,81,255	3,84,101	32,947	38,384	54,428	1,57,043	40,537	1,288,034
1986	6,57,569	4,25,746	34,637	38,818	60,354	1,81,102	43,023	1,440,815
1987	7,00,004	4,63,391	36,117	39,366	66,120	1,98,891	44,974	1,548,315
1988	7,51,970	5,06,423	38,641	40,206	71,660	2,17,646	48,096	1,673,802
1989	8,18,398	5,69,344	40,814	41,282	78,413	2,42,493	49,836	1,839,504
1990	8,96,179	6,16,292	43,275	42,832	82,678	2,58,169	51,516	1,989,391
1991	9,71,800	6,31,100	45,000	42,400	80,400	2,75,300	49,500	2,095,500
1992	1,165,500	7,01,500	51,700	46,700	89,200	3,53000	52,700	2,460,300
1993	1,287,300	7,49,300	56,400	50,500	97,400	3,76,600	73,600	2,691,100
1994	1,482,000	7,90,000	60,900	53,400	1,04,200	3,99,800	60,700	2,951,000
1995	1,481,900	8,27,400	64,500	58,700	1,10,700	4,24,800	63,700	3,031,700
1996	1,576,000	8,64,300	68,200	65,600	1,17,500	4,39800	66,500	3,197,900
1997	1,691,400	9,11,100	72,500	74,600	1,25,200	4,63,600	69,700	3,408,100
1998	1,833,700	9,86,700	84,400	56,700	1,28,500	4,89,800	74,700	3,654,500
1999	2,010,000	1,095,200	92,800	59,900	1,35,100	5,28,400	78,800	4,000,200
2000	2,218,900	1,262,400	86,600	72,400	1,40,300	5,79,400	89,000	4,449,000
2001	2,481,083	1,501,510	96,638	80,804	1,53,764	6,30,572	71,494	5,015,865
2002	2,656,258	1,589,686	98,326	80,879	1,55,266	6,63,204	71,425	5,315,044
2003	2,882,493	1,696,127	1,00,404	81,029	1,57,763	7,22,721	71,355	5,711,892
2004	3,064,994	1,791,458	1,02,405	81,466	1,60,438	7,78,086	69,412	6,048,259
2005	3,791,153	2,069,111	1,03,559	77,769	1,60,413	8,22,304	60,211	7,084,520
2006	4,463,846	2,313,934	1,08,373	78,992	1,82,125	8,77,800	38,545	8,063,615
2007	5,037,013	2,513,368	1,09,881	89,348	1,87,592	9,00,521	40,739	8,878,462
2008	5,355,864	2,702,698	1,21,058	88,404	2,02,719	9,11,688	31,315	9,413,746
2009	5,412,050	3,087,794	1,23,300	89,105	2,11,600	9,40,810	21,765	9,886,424
2010	5,468,825	3,543,813	1,25,584	89,812	2,20,872	9,70,862	24,005	10,443,773
2011	5,503,500	3,942,400	1,29,200	1,02,400	2,24,200	1,008,700	50,400	10,910,400
2012	5,504,000	3,943,000	1,29,000	1,02,000	2,24,000	1,009,000	50,000	10,961,000

(NTRC, 2003; NTRC, 2011)

Appendix D. Percentage of Different Registered Motor Vehicles Classes of Pakistan

(2002 to 2011)

Vehicle Type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Motor cycles	49.46%	49.98%	50.46%	50.68%	53.51%	55.36%	56.73%	56.89%	54.74%	52.36%
Motor cars	20.73%	20.88%	20.89%	20.91%	21.16%	20.86%	20.88%	21.45%	24.15%	27.02%
Jeeps	0.86%	0.84%	0.84%	0.86%	0.93%	1.06%	0.93%	0.84%	0.79%	0.75%
Station Wagons	2.45%	2.38%	2.32%	2.32%	1.99%	2.10%	1.84%	1.78%	1.73%	1.68%
Tractors	12.57%	12.48%	12.65%	12.86%	11.61%	10.89%	10.14%	9.68%	9.52%	9.30%
Buses	1.93%	1.85%	1.76%	1.69%	1.46%	1.34%	1.24%	1.29%	1.25%	1.20%
Taxis	1.92%	1.96%	1.97%	1.99%	1.72%	1.48%	1.46%	1.47%	1.48%	1.48%
Rickshaws	1.61%	1.52%	1.42%	1.35%	1.10%	0.98%	1.01%	0.94%	0.90%	0.86%
Delivery Vans	2.33%	2.26%	2.12%	2.02%	2.02%	1.85%	1.84%	1.78%	1.72%	1.66%
Trucks	2.90%	2.76%	2.61%	2.51%	2.14%	2.15%	2.00%	2.04%	2.03%	2.01%
Pickups	1.56%	1.52%	1.48%	1.45%	1.32%	1.30%	1.30%	1.33%	1.32%	1.30%
Ambulances	0.08%	0.08%	0.08%	0.08%	0.06%	0.06%	0.06%	0.06%	0.04%	0.04%
Oil Tankers	0.15%	0.14%	0.13%	0.13%	0.11%	0.10%	0.10%	0.10%	0.10%	0.10%
Water Tankers	0.02%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Others	1.43%	1.34%	1.25%	1.15%	0.85%	0.48%	0.46%	0.33%	0.22%	0.23%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

(NTRC, 2011)

Appendix E. Traffic Crashes Record, 1981- 2012

Year	Total number of accidents	Accidents		Persons		Vehicle Km travelled (Million)
		Fatal	Non-fatal	Killed	Injured	
1981	11,317	3,571	7,746	4,167	10,310	8,979
1982	11,454	3,646	7,808	4,371	10,469	10,019
1983	12,735	3,745	8,990	4,337	11,049	11,118
1984	11,923	4,070	7,853	4,721	12,307	13,310
1985	10,953	4,017	6,936	4,769	12,591	15,016
1986	11,404	4,302	7,102	5,121	13,553	16,725
1987	13,550	4,468	9,082	5,191	13,936	17,916
1988	12,950	4,493	8,457	5,276	13,283	19,333
1989	14,445	4,373	10,072	5,284	13,274	21,204
1990	13,571	4,066	9,505	4,807	12,258	22,985
1991	18,275	6,591	11,684	5,162	12,795	24,622
1992	14,804	5,841	8,963	5,244	12,360	28,564
1993	15,405	6,550	8,855	5,594	13,183	31,394
1994	15,274	6,188	9,086	5,416	12,307	33,541
1995	13,222	5,556	7,666	5,684	11,491	35,374
1996	9,974	4,347	5,627	5,424	11,319	35,374
1997	9,610	4,191	5,419	5,027	11,149	37,781
1998	9,663	4,041	5,622	4,858	11,597	39,965
1999	10,080	4,340	5,740	5,240	11,413	43,726
2000	9,735	4,193	5,542	5,130	11,469	48,023
2001	10,651	4,491	6,160	5,532	13,307	53,605
2002	10,033	4,379	5,654	5,248	11,922	54,674
2003	9,377	4,045	5,332	4,813	10,643	61,872
2004	10,308	4,184	6,124	5,199	12,927	66,491
2005	9,896	4,250	5,646	5,112	12,401	70,407
2006	9,492	4,115	5,377	4,868	11,415	82,470
2007	10,466	4,535	5,931	5,465	12,875	93,867
2008	10,466	4,610	5,856	5,615	12,096	103,353
2009	9,496	4,145	5,351	4,907	11,037	109,584
2010	9,747	4,378	5,369	5,280	11,173	115,087
2011	9,723	4,280	5,443	5,271	11,383	121,575
2012	9,987	4,348	5,639	5,323	11,475	127,007

(SIP, 2012 Page 100; NTRC, 2003 Page 12-13)

Appendix F. Crash Statistics by Province, 2001- 2010

Province	Year	No. of Accidents				No. of Causalities (persons)		
		Fatal	Non-fatal	Others	Total	Killed	Injured	Total
PUNJAB	2001	2,629	3,042	0	5,671	3,272	7,214	10,486
	2002	2,565	2,712	0	5,277	3,124	6,387	9,511
	2003	2,344	2,709	0	5,053	2,806	6,300	9,106
	2004	2,460	2,745	0	5,205	3,088	6,629	9,717
	2005	2,275	2,567	0	4,842	2,732	5,758	8,490
	2006	2,170	2,552	0	4,722	2,669	5,825	8,494
	2007	2,909	2,796	0	5,705	3,315	6,508	9,823
	2008	2,609	2,713	0	5,322	3,141	5,688	8,829
	2009	2,445	2,733	0	5,178	2,866	5,820	8,686
	2010	2,691	2,886	0	5,577	3,260	6,061	9,321
Average Crashes		2,510	2,746	0	5,255	3,027	6,219	6,246
KHYBER PAKHTUNKHWA	2001	659	1,839	0	2,498	709	3,006	3,715
	2002	649	1,854	0	2,503	746	2,795	3,541
	2003	613	1,973	0	2,586	832	3,235	4,067
	2004	706	2,005	0	2,711	891	4,012	4,903
	2005	476	1,999	0	2,475	867	4,063	4,930
	2006	818	2,100	0	2,918	898	4,261	5,159
	2007	775	2,106	0	2,881	917	4,079	4,996
	2008	733	1,943	0	2,676	913	3,396	4,309
	2009	658	1,667	0	2,325	786	3,287	4,073
	2010	817	1,915	0	2,732	966	3,976	4,942
Average Crashes		690	1,940	0	2,631	853	3,611	4,464
SINDH	2001	984	894	115	1,993	1,079	1,640	2,719
	2002	904	693	99	1,696	976	1,236	2,212
	2003	885	673	113	1,671	976	1,310	2,286
	2004	861	618	109	1,588	943	1,334	2,277
	2005	835	611	106	1,552	920	1,217	2,137
	2006	835	631	80	1,546	943	1,312	2,255
	2007	783	507	107	1,397	872	1,159	2,031
	2008	787	549	74	1,409	900	1,240	2,140
	2009	736	436	99	1,271	832	1,093	1,925
	2010	738	466	68	1,273	858	1,168	2,026
Average Crashes		825	608	97	1,540	930	1,271	2,201
BALOCHISTAN	2001	43	134	2	179	44	214	258
	2002	55	129	1	185	67	240	307
	2003	64	145	1	210	67	216	283
	2004	56	142	0	198	59	247	306
	2005	88	108	0	196	97	179	276
	2006	64	143	0	207	68	229	297
	2007	79	123	0	202	43	269	312
	2008	87	131	1	218	105	216	321
	2009	90	120	0	210	44	278	322
	2010	98	128	1	226	108	223	331
Average Crashes		72	130	1	203	70	231	301

(NTRC, 2011)