ROAD SAFETY MANAGEMENT IN QATAR FROM FRAGMENTED TO INTEGRATED AND THE ROLE OF THE NATIONAL ROAD SAFETY STRATEGY

by

MOHD ABDULLA M AL-MALKI, BSc, MSc

A thesis submitted in partial fulfilment of the requirements

of Edinburgh Napier University, for the award of

Doctor of Philosophy

TRANSPORT RESEARCH INSTITUTE

School of Engineering and the Built Environment

Jun 2023

Declaration

I hereby declare that the work presented in this thesis has not been submitted for any other degree or professional qualification and that it is the result of my own independent work.

[redacted]

Mohd Abdulla M Al-Malki (Candidate)

Abstract

The World Health Organization (WHO) reports that Road Traffic Crashes (RTCs) caused 1.35 million deaths and 50 million injuries globally in 2016, with RTCs being the primary cause of disabilities and a leading cause of death among those aged 5-29. In Qatar, RTCs accounted for 10-14% of all deaths and nearly 51% of injury admissions to the Hamad Trauma Centre before 2011. In response, the UN General Assembly launched the Decade of Action for Road Safety 2011-2020, prompting Qatar to establish the National Traffic Safety Committee (NTSC) to oversee road safety strategies. The Committee, as the lead agency for Road Safety Management, launched a ten-year Action Plan to minimise the occurrence of road traffic crashes and the severity of any road crashes. In addition, the National Traffic Safety Office (NTSO) was also established in 2015 to promote Qatar as a world leader in Road Safety, assist in the promotion of the National Strategy and implementation of the associated Action Plan and undertake monitoring and evaluation of the implemented plans.

This research evaluates the impact of Qatar's National Traffic Safety Strategy (NTSS) on road safety management using five case studies. The five case studies were to evaluate the impacts, or potential impacts, of various traffic safety strategies implemented in the country. The first case study analysed the effects of the NTSS on RTCs and associated injuries and fatalities. Trends indicated a reduction in fatalities and severe injuries since the implementation of the NTSS from 2013 to 2020, although severe injuries showed a rising trend between 2010 and 2016. Using a public survey, the second case study investigates the effects of public transport (PT) infrastructure and services on road safety in Qatar. Results show that a remarkable 96.5% of participants expressed a willingness to use PT for daily trips. A total of 88.9% of those who actively use Qatar's public transportation services have expressed satisfaction with the quality of the Qatar Metro. This high level of satisfaction suggests the potential for reducing car travel, resulting in lower accident rates and fatalities. Moreover, the increased ridership on Qatar Metro and Karwa Bus could also contribute significantly to the reduction of car ownership and use in the country.

The third case study investigates the effectiveness of CCTV/speed cameras in Qatar to reduce road traffic crashes, fatalities, and injuries. The findings show an increase in the issued traffic tickets with the increase in the installed cameras. Additionally, there's a negative correlation between violations and recorded crashes/fatalities, indicating a potential impact on road safety.

Case Study 4 analyses pedestrian signals' impact on traffic safety in Qatar. Using Analysis of variance, the results reveal that increased motor vehicles contribute to rising crash casualties, which emphasises the need for suitable safety measures. The descriptive analysis shows that minor injuries fluctuated more than fatal crashes over the past seven years, possibly due to better injury notification and/or the rapid population growth that is leading to an increase in traffic density. The final case study (Case Study 5) examines how the NRTC manages road safety during pandemics, notably COVID-19. Despite a 55.2% population increase and a 123% rise in registered vehicles from 2010 to 2020, there's been a significant reduction (39.5%) in road traffic fatalities and injuries recorded between 2013 and 2020. RTC fatalities declined from 12.28 in 2010 to 4.79 per 100,000 population in 2020.

This research contributes to the road safety literature by examining Qatar's efforts to reduce RTCs, providing insights for researchers, policymakers, and stakeholders. It emphasises the importance of national-level strategies and policies in improving road safety and providing lessons for other countries facing similar challenges. Documentation of the NTSC's establishment and impact highlights its integration of various road safety efforts. By assessing the effectiveness of NTSS interventions through case studies, this research offers directions for further investigations and policymaking aimed at reducing RTCs. Furthermore, it addresses drivers' perceptions and behaviours during the pandemic; this is a topic that was not previously explored in Qatar. Overall, this research underscores the significance of the NTSS in improving road safety, reducing RTCs and fatalities, and raising awareness of its role in the ongoing efforts in Qatar and beyond.

Acknowledgments

The journey to completing my PhD has been possible because of several people's continuous support and guidance. First and foremost, I would like to express my sincere gratitude to Professor Wafaa Saleh, my supervisor, for her invaluable advice, encouragement, and mentorship throughout the PhD. I wish to thank my Doctoral Committee members, Prof. Pat Langdon, Prof. John McDougall, and Miss Amy Young, for their constant critiques and support of this research work. My sincere gratitude goes to my fellow research colleagues and all the administrative personnel at Edinburgh Napier University.

I want to thank the senior management of the Government of Qatar for supporting my research work towards improving Road Safety. A few people deserve recognition for their unwavering support, including Prof. Kim Jraiw, the National Traffic Safety Committee, and State of Qatar colleagues who have consistently encouraged me and contributed a significant amount of technical input to the completion of my thesis.

My family has always been a source of strength for me. My sincerest appreciation goes to my wife Ayda, my two sons Abdullah and Sultan and my daughter Sara for always believing in me. I would like to thank Edinburgh Napier University for allowing me to carry out my doctoral program. I am grateful for the support from the Transport Research Institute.

Table of Contents

Page No.

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

Road Traffic Crashes (RTC) were the 8th leading cause of death globally and the leading cause of death of children and young adults in 2016, according to the World Health Organization 2018. In the same year, 1.35 million deaths and about 50 million injuries and disabilities globally were attributed to road traffic crashes, and this represents an increase of 8% from the 2013 reported fatalities globally of 1.25 million (World Health Organization, 2015a, 2018). WHO, 2009, estimates that the annual global costs due to road traffic injuries are $518 billion, more than the total amount of international development assistance. The cost of road traffic crashes (RTC) is estimated to be between one and three percent of individual countries' Gross National Product (GNP).

Qatar recorded a high number of road traffic accidents before 2011 (Bener et al., 2010; National Traffic Safety Committee, 2013; Radwan and Hammuda, 2015). Road traffic crashes (RTC) have been a leading cause of death in Qatar (Consunji et al., 2018). Road traffic injuries are a major cause of death in Qatar; they are the second highest in the world. Road traffic injuries account for between 10-14% of all deaths in Qatar and nearly 51% of all injury admissions to the Hamad Trauma Centre (Consunji, 2019; Consunji et al., 2018). The World Health Organization (WHO) estimates that by 2030, if nothing is done, road traffic deaths will rise from eighth to fifth among the leading causes of death. Road safety management is emphasised in the Decade of Action, and Global Plan (United Nations, 2011) and the Global Status Report on Road Safety 2015 (WHO, 2015), which emphasise that improving road safety performance requires a systematic and planned approach.

Sequel to the publication of the UN General Assembly’s resolution 64/2551 on Global Plan for the Decade of Action for Road Safety 2011-2020 and the subsequent publication of the Decade of Action for Road Safety 2011-2020 guideline by the United Nations (United Nations, 2011), the National Traffic Safety Committee (NTSC) was established to provide clear leadership for road safety in the State of Qatar and oversee the implementation of the National Traffic Safety Strategy (NTSS) through the Road Safety Action Plans. It is believed that an effective road safety management system can only be achieved through the coordination of existing strategic plans and institutions, including land use Planning, Sustainable and Active Transportation and Travel Demand Management (NTSC, 2012). The NTSC, 2012, emphasised the importance of political will and governmental leadership. The government adopted an evidence-based approach to road safety, demonstrating its commitment to achieving favourable road safety outcomes, and ensured the establishment of key organizational arrangements for effective road safety management systems. The Gulf nation has been recording a decreasing trend of RTCs fatalities since 2010 (Consunji et al., 2018; Timmermans et al., 2019) and performing averagely better compared to the road fatality rate of its low, middle, and high-income neighbours as well as the global average (World Health Organization, 2018). Despite the observed decrease in fatal crashes, the number of RTCs resulting in severe injuries and property damage has increased over the same period (Timmermans et al., 2019). Consequently, opinions are divided on whether to credit the observed downward trend to the work of the Qatar National Traffic Safety Committee (NTSC).

The Qatari Public Roads Administration has established a comprehensive strategy for road safety management based on national objectives. An extensive set of objectives related to the integration of road safety, vehicle safety, user behaviour, standards, and regulations have been considered in the national strategy. The main national aim of reducing traffic accidents and improving road safety in Qatar has led to the development of the strategy and its objectives. One major component of the strategy is to integrate Qatar's efforts, policies, and directions for road safety under the National Traffic Safety Strategy (NTSS). After the responsibilities were divided among many organizations, including the public work authority, the Qatari police, the national road safety committee, the Ministry of Interior, and more, the title of the thesis is “Road Safety Management in Qatar from Fragmented to Integrated and the Role of the National Road Safety Strategy". This research delineates various facets of the system and offers a critical evaluation of various implemented sub-strategies, encapsulated within five case studies.

An extensive review of the existing works on road safety management in Qatar suggests that little is known about the actual impact of the National Traffic Safety Strategy (NTSS) as well as the various road safety management interventions implemented to improve road safety in Qatar (Consunji, 2019; Consunji et al., 2018, 2020). Therefore, the aforementioned uncertainties motivate this doctoral research, which aims to investigate the road safety management systems in Qatar, the role and impact of the National Traffic Safety Strategy (NTSS), and the road safety schemes and policies implemented since the National Traffic

Safety Strategy's establishment. The overall aim of this study is to contribute to the existing knowledge on road safety management systems using the road safety management systems in Qatar as a case study, as well as the impact of the National Traffic Safety Committee (NTSC) on road traffic management in Qatar.

This chapter, arranged as follows, offers a more comprehensive introduction to the research: Section 1.1 presents the background. Section 1.2 presents the research study's justification. Section 1.3 covers a general review of road safety management in Qatar. Section 1.4 outlines the research objectives and explains the research gaps. Section 1.5 presents the outline of the thesis and a summary of the research contributions.

1.2 Justification of the Research

In response to Qatar's growing concerns about road traffic crashes, fatalities, and injuries, the country greatly benefited from increased political support for road safety initiatives. This culminated in the development of the Road Safety Strategy Plan for Qatar in 2007 (Urban Planning and Development Authority, 2007), the recent formation of the National Traffic Safety Committee (NTSC) and the development of the National Road Safety Strategy (NRSS), the inclusion of road safety targets in the Qatar National Development Strategy, 2011-2016, (National Traffic Safety Committee, 2012). Aggressive road safety management policy, governmental intervention, and the consolidation and coordination of all relevant stakeholders have reported a decrease in road traffic crashes, fatalities, and injuries since their peak in 2006 (Consunji et al., 2020; Urban Planning & Development Authority, 2007). In spite of the reported reduction in the rate of road traffic crashes, there are concerns about the rate of RTCs resulting in injuries and property damage for some high-risk groups (such as young drivers, workers, and pedestrians) (Timmermans et al., 2019). According to reports, road traffic injuries rank among the top causes of death in Qatar (Consunji et al., 2020).

The National Traffic Safety Strategy (NTSS) in Qatar contains a discussion on the actual impact of various road safety management interventions in reducing TRCs and injuries, but the results are inconclusive (Consunji, 2019; Consunji et al., 2018, 2020). Empirical evidence regarding the impact of specific interventions to improve road traffic safety is nonexistent. There hasn't been an objective evaluation of road safety interventions like installing CCTV and speed cameras, or improving public transport infrastructure and service provision.

1.3 Road Safety Management in Qatar

The discovery of commercial quantities of crude oil in Qatar led to a rapid expansion of its economy, which consequently increased net immigration, population, and rapid urbanisation (Rasoul, 2010; Radwan and Hammuda, 2015). The rapid GDP growth, in conjunction with population growth and urbanisation, resulted in an increase in the number of vehicles, significantly straining the road transportation system (Planning and Statistics Authority, 2020). The resultant motorization outpaced the orderly development of traffic safety policies, which led to a consistent increase in the annual number of road traffic crashes between 2000 and 2006 with their resultant fatalities and injuries (Bener *et al.*, 2010; National Traffic Safety Committee, 2013; Radwan and Hammuda, 2015; National Traffic Safety Committee, 2012). In response to the worsening trend of TRCs, fatalities, and injuries, Qatar developed a road safety strategy to address the increasing numbers of fatalities and injuries arising from traffic crashes and to lower the crash and casualty rate in Qatar (Urban Planning & Development Authority, 2007). In consultation with all relevant stakeholders, they consequently produced a "Road Safety Plan" that outlined key priority areas and strategies. In 2010, Qatar identified road traffic injuries (RTIs) as the leading preventable death cause, disproportionately affecting young males. Qatar decided to take part in the Decade of Action for Road Safety after recognizing traffic safety as a public health concern.

Consequently, Qatar included road safety targets in its National Development Strategy, 2011-2016. Furthermore, it established the National Traffic Safety Committee (NTSC) as the lead agency to provide leadership for road safety in the State of Qatar. Through the Road Safety Action Plans, the NTSC oversees the implementation of the road traffic strategy. This new initiative builds on the 2007 Road Safety Strategy Plan for Qatar to promote road safety (National Traffic Safety Committee, 2012, 2018; Salt & Higham, 2013; Urban Planning & Development Authority, 2007).

Integrating all data, experiences, policies, and information related to road safety in Qatar across various organizations and public authorities, such as the public work authority, the Qatari police, the national road safety committee, and the Ministry of the Interior, proved to be the most challenging task. This process has also been the most difficult because different organizations collected and archived the same data in completely different formats, setups, and arrangements. This made it extremely difficult in some cases to combine or compare different data sets. The National Road Safety Committee's major task has been to integrate data, policies, and problems related to road traffic and road accidents. This is to gain a broader understanding of and be able to provide advice for appropriate road safety policies.

Notwithstanding the population growth and high vehicle ownership rates between 2010 and 2016, the official reported accident statistics indicated a reduction in road traffic crashes (RTCs) and their resultant fatalities and injuries. Reports indicate a 28% reduction in road traffic crash fatalities from 228 in 2010 to 178 in 2016, as compared to the 2010 data. The fatality rate per 100,000 population also decreased from 12.28 in 2010 to 6.93 in 2016. These data were below the projected targets of 213 for 2016 (National Traffic Safety Committee, 2018). These data seem to represent a substantial improvement from the 2006 reported rate of 26 fatalities per 100,000 people. Figure 1.1 below shows the road traffic fatalities per 100,000 people between 2010 and 2016. From 2011 to 2016, despite a 40% increase in Qatar's total population, the country recorded a 13% reduction in road deaths and a 43% decrease in the road death rate per 100,000 population. However, injuries resulting from RTCs increased over the period (Consunji et al., 2018). Following the success of the first action plan between 2013 and 2017, the NTSC launched the second 5-year National Road Safety Action Plan in January 2018. This second action plan is to elevate Qatar’s road safety performance to a world-leading standard and reflect Qatar's unique characteristics, including rapid population growth, infrastructure growth, and high vehicle ownership levels (National Traffic Safety Committee, 2018).

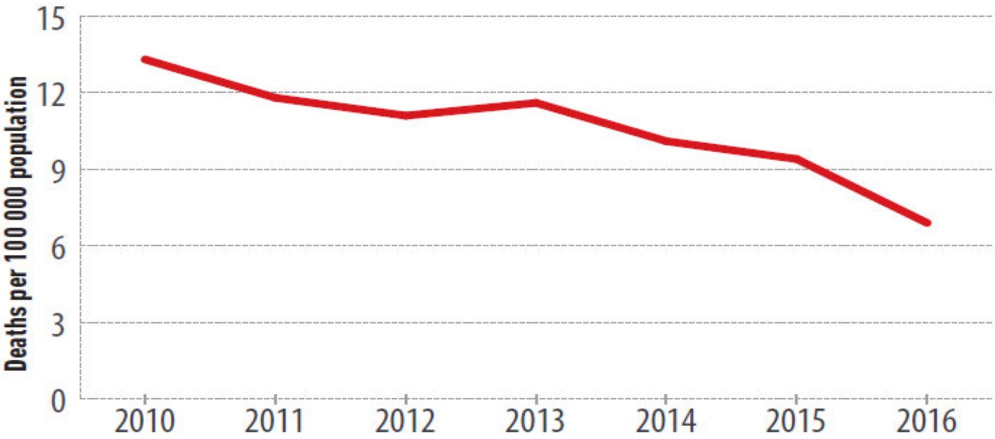


Figure 1.1 Road Traffic Casualties in Qatar 2010-2016 (source: WHO)

The safe system method used in the first five years of National Road Safety 2013–2017 has been modified to reflect Qatar's national needs. The amendments to the second 5-year National Road Safety Action Plan 2018-2022 include adding 25 sector agencies and stakeholders, an upgrade from the first 5-year plan's 6-sector system (National Traffic Safety Committee, 2018).

Qatar's bespoke safe system is also based on the principle of anticipating and accommodating humans, as well as accounting for the vulnerability of the human body. The challenge under the Safe System is to manage the interaction between road users, vehicles, traffic speeds, and roads to reduce crashes as well as to ensure that collisions do not result in deaths or serious injuries (National Traffic Safety Committee, 2018).

According to official government accident data, Qatar continues to see improvements in the number of recorded road traffic crashes between 2016 and 2020. The National Road Safety Committee (NTSC) has made great strides in reducing the toll from road traffic crashes in Qatar, which suggests the effectiveness of the traffic strategy's implemented interventions. It also observed a stabilization in the number of fatalities between 2016 and 2020. However, the number of severe injuries decreased from 2016 to 2018, and increased between 2018 and 2020. Despite the significant progress in reducing the occurrence of RTCs and RTCs leading to fatalities, Figure 1.2 underscores the importance of focusing on the occurrence of severe and minor injury RTCs and their causes. Empirical evidence regarding the impact of specific interventions to improve road traffic safety is limited. There hasn't been an objective evaluation of road safety interventions like speed enforcement through the installation of speed cameras and radars, or the provision of convenient and comfortable public transport services.

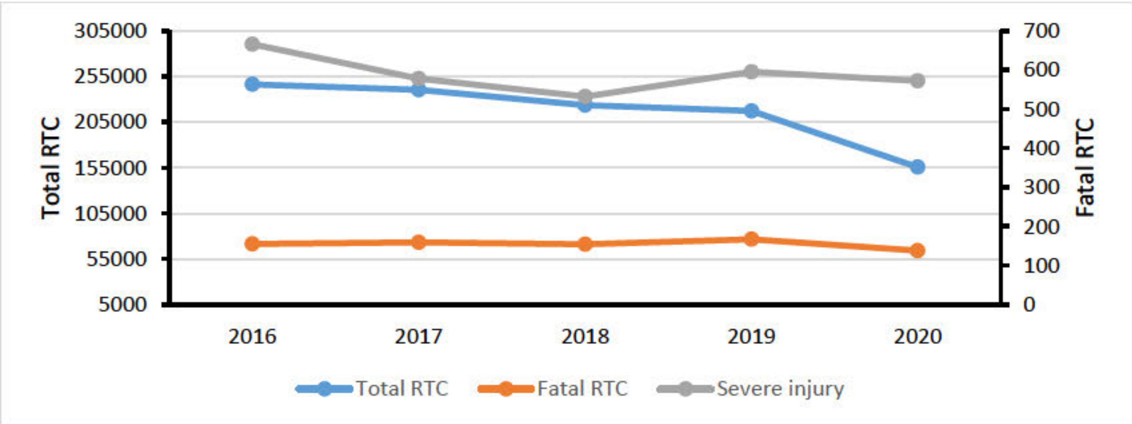


Figure 1.2 RTCs and Fatalities Between 2016 and 2020

From the discussions above, this study seeks to investigate and provide practical evidence regarding the impact of the NTSS and road safety interventions, such as installing speed cameras and radars and providing public transport services, on road safety in Qatar.

1.4 Research Aims and Objectives

The overall aim of the thesis is to use the knowledge and experiences gained at the national road safety management in Qatar to demonstrate and establish evidence of what the road safety management systems in Qatar have achieved, using five case studies. Then, for each research objective, a defined case study is selected to demonstrate the approach followed in managing the gap and achieving the defined objective.

For example, research gap 1 is defined as the limited empirical evidence on the impact of NTSS on road safety management in Qatar. The first objective was designed to "assess the impact of the National Traffic Safety Strategy (NTSS) on road safety management in Qatar." A related case study has been designed to illustrate the gaps, the opportunities, and the methodology that was followed to assess the research objective. The first case study has been designed to investigate the "impact of road safety management systems on road safety, road traffic crashes, fatalities, and injuries in Qatar. Research gap 2 was defined as the limited empirical evidence on the impact of Public Transport (PT) infrastructure and services on road safety in Qatar. The second objective was then defined as to assess the effectiveness of PT infrastructure and services on road safety in Qatar, and the second case study was designed to investigate the effects of Public Transport infrastructure and services on road safety in Qatar. Research gap 3 was designed to address the limited empirical evidence on the impact of CCTV and speed cameras on road traffic safety in Qatar. We then set the third objective and case study to investigate and assess the effectiveness of these devices on road traffic violations in Qatar. Similarly, the fourth case study was developed to assess Qatar's Pedestrian signal setting and impacts on road safety, while the fifth case study was designed to assess the road safety system in Qatar and the impact of (the COVID-19) pandemic on accident rates and trends. In total, there are five research gaps; five research questions, objectives, and case studies have been identified, as presented in Figures 1-3 below.

The following objectives and sub-objectives are developed to achieve the overall aim:

1. Assess the impact of the National Traffic Safety Strategy (NTSS) on road safety management in Qatar.
    1.1 Select five case studies to represent some examples of the impacts of the national road safety strategy on the Qatar road safety performance.

1.2 Assess the effectiveness of the road safety management interventions implemented in reducing road traffic crashes, fatalities, and injuries in Qatar in each of the selected case studies.

1.3 Propose measures to improve the road safety management systems in Qatar according to the above investigation.

2. Assess the effectiveness of Public Transport infrastructure and services on road safety in Qatar.
3. Assess the effectiveness of CCTV/ speed cameras on road traffic violations in Qatar.
4. Assess Qatar's Pedestrian signal setting and impacts on road safety.
5. Demonstrate the ability of road safety system to cope with a pandemic (COVID).

1.5 Thesis Structure and Research Contribution

The thesis aims to showcase knowledge and experiences in Qatar's national road safety management through five case studies. This section provides an outline of the thesis. The thesis consists of nine (9) chapters. Chapter 1 provides an introduction to the thesis. Chapter 2 presents the literature review, and chapter 3 presents the general research approach and the methodology of the study. Chapters 4, 5, 6, 7, and 8 present the five case studies. The final chapter (Chapter 9) provides a general discussion of the findings from the thesis, including the analysis of the five case studies, conclusions, contribution of the research work, limitations, and recommendations for future work. Figure 1.3 summarizes the relationship between the research gaps, the overall research aim (thesis level), specific research objectives (case study level), case studies, and research methods.

Chapter 2 presents the literature review. The literature on the relevant topics for the study was reviewed summarised and reported. In addition, the gaps that were identified during the literature review stage were presented.

Chapter 3 presents the research methodology. In order to achieve the set objectives, investigate gaps, and address research goals, this chapter details the adopted research methodology. Case studies assess the impact of road safety management interventions under Qatar's National Traffic Safety Strategy on road safety.

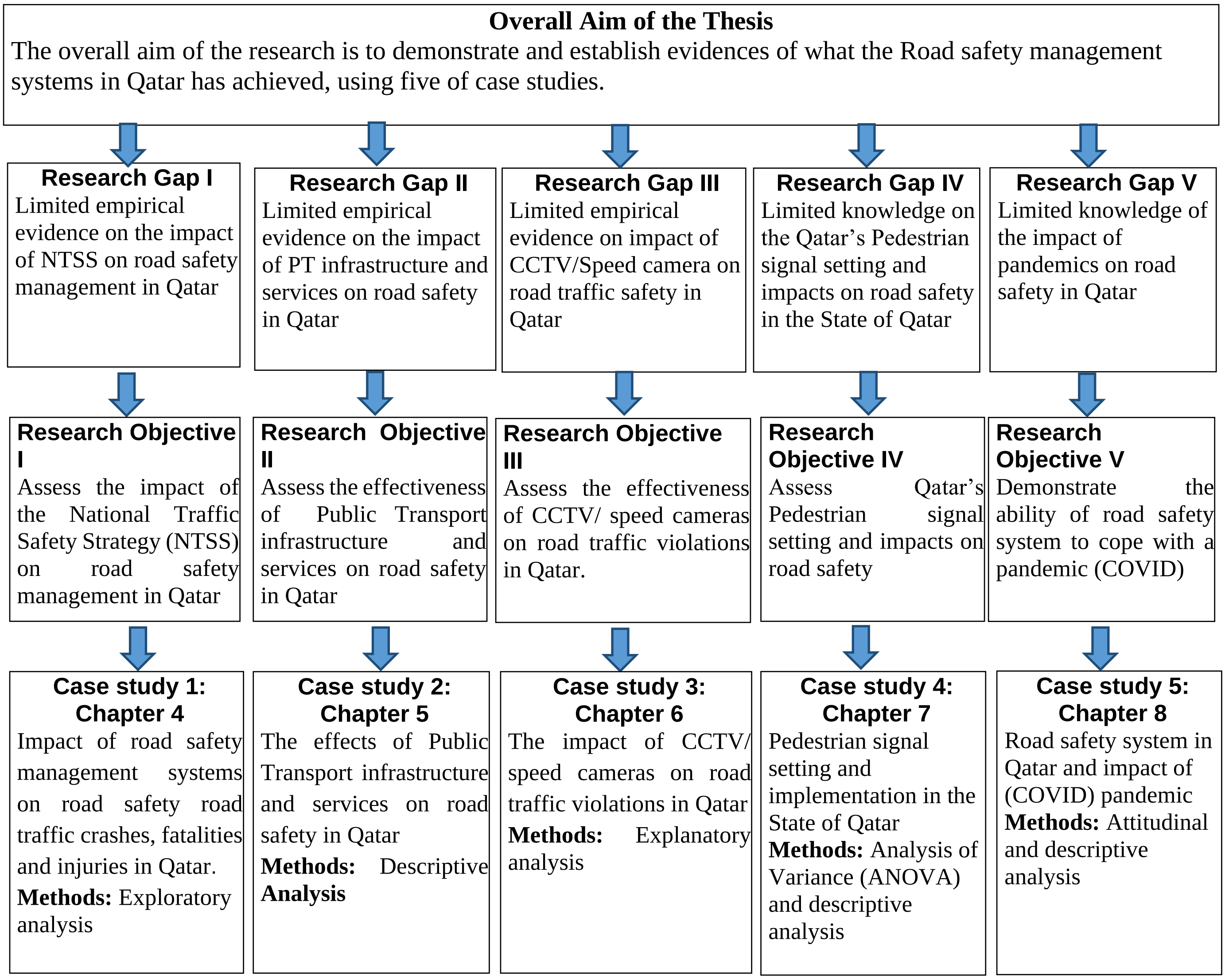


Figure 1.3 Relationship between the Research Gaps, Research Objectives, Case Studies and the Overall Research Aim

Chapter 4 presents the first case study, entitled "Impact of road safety management systems on road safety and road traffic crashes, fatalities, and injuries in Qatar." Given the need for knowledge concerning road safety management systems and road safety in Qatar (i.e., Research Gap 1), this case study aimed to investigate the occurrence of RTCs and RTCs resulting in fatalities and severe and minor injuries to assess the impact of the Qatar National Traffic Safety Strategy in reducing the frequency of RTCs in Qatar. The findings indicate that the number of RTCs resulting in fatalities and severe injuries has decreased from 2013 to 2020. This period corresponds to the time the NTSS has been in operation. The results also revealed a rising trend in severe injury RTC from 2010 to 2016, followed by a downward trend from 2016 to 2020.

The NTSS and the measures implemented do not appear to have a positive impact on reducing the occurrence of RTCs leading to minor injuries. The results of the descriptive analysis of RTC victims showed age, gender, and road user type variation in RTCs fatality and injury severity. Young people between 21 and 30 years old were more likely to die from RTCs than other age groups (0–10, 11–20, 31–40, and above 40). Both RTC fatalities and severe injuries disproportionally represented males as victims. It was also observed that between 2016 and 2020, drivers followed by pedestrians, were more likely to be casualties of RTCs, while drivers followed by passengers were more likely to be victims of severe injury RTCs between 2010 and 2020. The NTSS, despite its positive impact on reducing RTCs and their associated fatalities and severe injuries, should prioritize addressing the observed variations in age, gender, and road user type, as well as the increasing trend of minor injury RTCs.

Chapter 5 introduces the second case study, titled "The Effects of Public Transport (PT) Infrastructure and Services on Road Safety in Qatar." Examining the limited empirical evidence, this case study investigates the impact of Public Transport (PT) infrastructure on road traffic crashes, fatalities, and injuries. The findings reveal significant improvements in Qatar's PT infrastructure over the past two decades, with 88.9% of respondents using PT and 96.5% willing to do so daily. High user satisfaction suggests a potential for reducing car travel and RTCs. Increased Qatar Metro and Karwa Bus ridership could substantially cut car trips and accident exposure levels, potentially reducing accident rates and fatalities.

Chapter 6 presents the third case study, entitled “The Impact of CCTV and Speed Cameras on Road Traffic Violations in Qatar." This case study addressed research gap three and provided empirical evidence on the impact of CCTV and speed cameras on road traffic safety in Qatar (Consunji et al., 2018). This case study aimed to investigate the effectiveness of specific Road Safety Management interventions (the installation of CCTC and speed cameras) in reducing road traffic crashes, fatalities, and injuries in Qatar. The results indicate that the number of issued tickets increases with the number of installed cameras. Furthermore, the number of violations or tickets negatively correlates with the number of recorded crashes and fatalities.

Chapter 7 presents the fourth case study. " Pedestrian Signal Setting and Implementation in the State of Qatar" is the title of this case study. In signal design, pedestrian clearance time is a key design parameter for ensuring safe pedestrian crossing at signalized crosswalks. The performance of pedestrian signal control and its impact on pedestrian behaviour in Gulf

Cooperation Council (GCC) countries is rarely addressed in the literature. The characteristics of the population, cultural diversity, and extremely hot weather conditions, may lead to significantly different pedestrian behaviour in terms of crossing maneuvers (path and speed), compliance with signal control, and interaction with vehicular traffic. Using empirical observations, this case study examines pedestrian signal design practices in Qatar. The empirical analysis showed that the 85th percentile crossing times were longer than the provided Pedestrian Flashing Green (PFG) intervals at the observed crosswalks. Additionally, the speed analysis indicated that the observed 15th percentile speed was 1.22 m/s, which is similar to the assumed design speed by the Qatar Traffic Control Manual QTCM, 2015. Furthermore, the analysis revealed that pedestrian crossing speeds during PFG or BI were significantly higher than those during PG.

Chapter 8 presents the fifth case study, which is entitled "How the NRTC manages road safety during the pandemic. In this case, the Impacts of COVID-19 have been investigated. The five case studies have been designed to illustrate five application areas where the NTSC has successfully reduced road traffic casualties and enhanced road safety in Qatar.

Chapter 9 presents the overall conclusion of the thesis, its contribution, limitations, and suggestions for further research. The following section, Chapter 2, presents the literature review of the thesis.

Chapter 2: Literature Review

2.1 Introduction

This chapter conducted a meticulous literature review to explore various facets of road traffic safety in Qatar. The existing literature was examined to assess the prevailing road safety problems, identify the primary causes and contributing factors of traffic accidents, and examine the influence of road cross-sectional elements on accident occurrence. By synthesizing scientific literature, the study aimed to provide a comprehensive understanding of the road safety landscape in Qatar, laying the groundwork for effective intervention strategies. In terms of traffic regulations and enforcement, it is vital to consider the stringent traffic regulations and effective enforcement that are essential for reducing accidents. In addition, speed limits, seat belt laws, and DUI (Driving Under the Influence) regulations have shown significance and relevance in influencing road safety.

The impact of infrastructure on road safety has been highlighted in numerous studies that emphasise the importance of well-designed roads with proper signage, lighting, and road markings in reducing accidents. Researchers have extensively investigated automated enforcement methods and advanced technologies like speed cameras and red-light cameras, demonstrating their effectiveness in reducing violations. Human behaviour has been assessed and investigated using a variety of tools, including road safety audits and other assessment methods that have been identified as very important to help identify and address potential hazards in the road network. Through this meticulous literature revision, the researchers sought to inform their recommendations for appropriate interventions to mitigate road traffic accidents and enhance safety on Qatari roads. By analyzing previous research findings, the study sought to identify evidence-based interventions tailored to the specific challenges faced in Qatar's road safety landscape. Ultimately, the synthesis of scientific literature served as a crucial foundation for the formulation of recommendations and interventions aimed at enhancing road safety and reducing accident rates in Qatar. As part of Qatar’s Policy context, the Qatar National Development Strategy 2011-2022 promotes the Safe System approach to road safety and provides casualty reduction targets. These targets will be achieved through an ambitious program of activities and relevant projects to be implemented in line with Qatar Vision 2030.

The structure of the literature review is presented as follows; Statistics of Road Safety in Qatar (Section 2.2), Road Safety and Traffic Management in Developed and Developing Countries (Section 2.3), Human Factors in Road Safey (Section 2.4), Emergency Response and Medical Care Factors (Section 2.5), Road Safety Auditing (Section 2.6), Road Safety Management in Qatar (Section 2.7), Road Safety and Surveillance Cameras (Section 2.8), Qatar's Safe System Approach (Section 2.9), Ten Years National Road Safety Action Plans (Section 2.10), Qatar's Road Safety Management Process (Section 2.11), Road Safety and Public Transportation (Section 2.12) and Summary (Section 2.13).

2.2 Statistics of Road Safety in Qatar

The discovery of oil in commercial quantities in Qatar led to a rapid expansion of the Gulf State's economy, resulting in an increase in immigration, population, and rapid urbanisation (Rasoul, 2010; Radwan and Hammuda, 2015). Rapid GDP growth, in conjunction with population growth and urbanisation, resulted in an increase in vehicle numbers, thereby placing significant strain on the road transportation system (Planning and Statistics Authority, 2020). Consequently, the number of registered vehicles in Qatar increased from 124,998 in 1985 to 1,701,346 in December 2020. This represents an increase from the previous 1,629,467 vehicles for December 2019. Motorization has enhanced the lives of many individuals and societies, but the benefits come at a high cost. Road Traffic Crashes (RTCs) are one of the most common causes of death and injuries globally. In 2016, RTCs accounted for nearly 1.35 million deaths and about 50 million injuries and disabilities worldwide. A high percentage of these reported fatalities are recorded in low- and middle-income countries (World Health Organization, 2015a, 2018). The resultant effect of the rapid human and vehicular population has been an increase in the number of road traffic accidents with consequential fatalities and injuries, which raised severe public health concerns in Qatar (Bener et al., 2010; National Traffic Safety Committee, 2013; Radwan and Hammuda, 2015; Al-Thani et al., 2019).

Road traffic crashes were a major cause of death (about 10-14%) of all deaths in Qatar, the second-highest rate in the world. The main risk factors for these major crashes and injuries include a diverse, young, and highly mobile population, unrestrained passengers, and distracted driving. Children between 0 and 19 years old are most vulnerable, with 86% of their road traffic deaths occurring in the pre-hospital setting (HMC & QSA, 2010-2011).

Driver or human error is the most frequently reported contributing factor for road traffic incidents in the most documented cases of road traffic accidents. Human factors such as careless driving, tailgating, and excessive speed significantly contributed to Qatar's most recorded RTA cases (Bener, 2005; National Traffic Safety Committee, 2013; Austroads, 2013; Royal Society for the Prevention of Accidents, 2017). A motorized society will inevitably experience a certain minimum number of crashes and casualties, but we can minimise their frequency. Therefore, the foundation of road safety lies in the development and application of safety standards for roads, vehicles, and road users, with the aim of preventing road traffic crashes or reducing their negative effects on human health. Therefore, it is critical that all stakeholders involved in the planning, design, construction, and maintenance of roads and roadsides collaborate to minimise the risk of injury to all road users (National Traffic Safety Committee, 2012). From 2000 to 2006, the annual number of road crash fatalities increased steadily from 14 deaths per 100,000 people to 26 deaths per 100,000 people, until a sharp decrease in 2007 (16 deaths per 100,000 people).

The number of fatalities has decreased significantly since 2006. However, RTCs are still responsible for a significant proportion of deaths in the population of Qatar, from ages 1 to 45 (Mamtani et al., 2012; Consunji et al., 2022). RTCs have been a significant public health problem, threatening the quality of life of Qatar's population. Data available indicate that between 2000 and 2006, the annual death per 100,000 population resulting from RTCs in Qatar was much higher than the global annual average death per 100,000 population (see Figure 2.1) (World Health Organization, 2021).

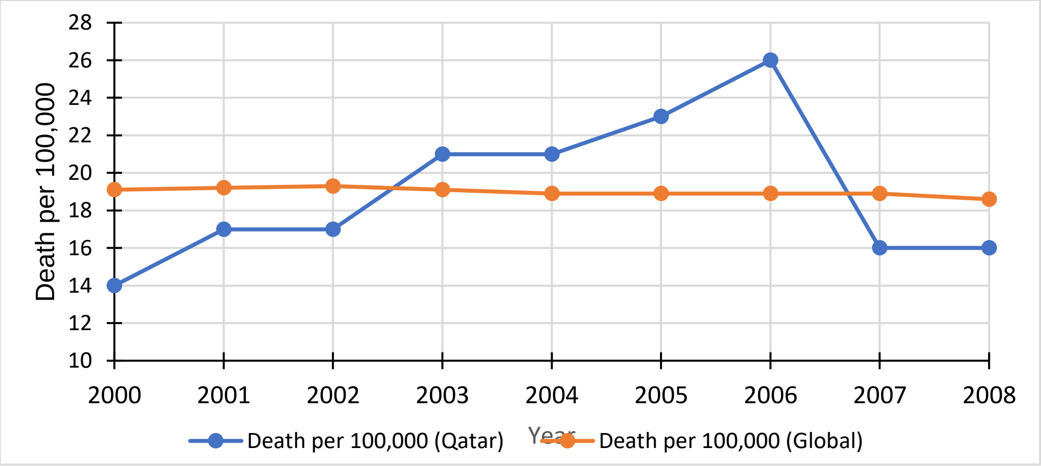


Figure 2.1 Qatar Road Traffic Deaths per 100,000

In 2006, Qatar recorded over 270 fatalities and over 1,000 serious injuries. Following the rising trend of fatalities between 2000 and 2006, as shown in Figure 2.2, the number of fatalities was projected to reach 820 deaths by 2016 if stringent measures were not put in place to arrest the situation (Urban Planning & Development Authority, 2007). The rapid increase in the number of road traffic accidents with their resultant fatalities and injuries raised public health concerns in Qatar (Bener et al., 2010; National Traffic Safety Committee, 2013; Radwan and Hammuda, 2015; Al-Thani et al., 2019). The recorded road traffic fatalities were about five times the number recorded in many developed nations (Jamieson, 2008).

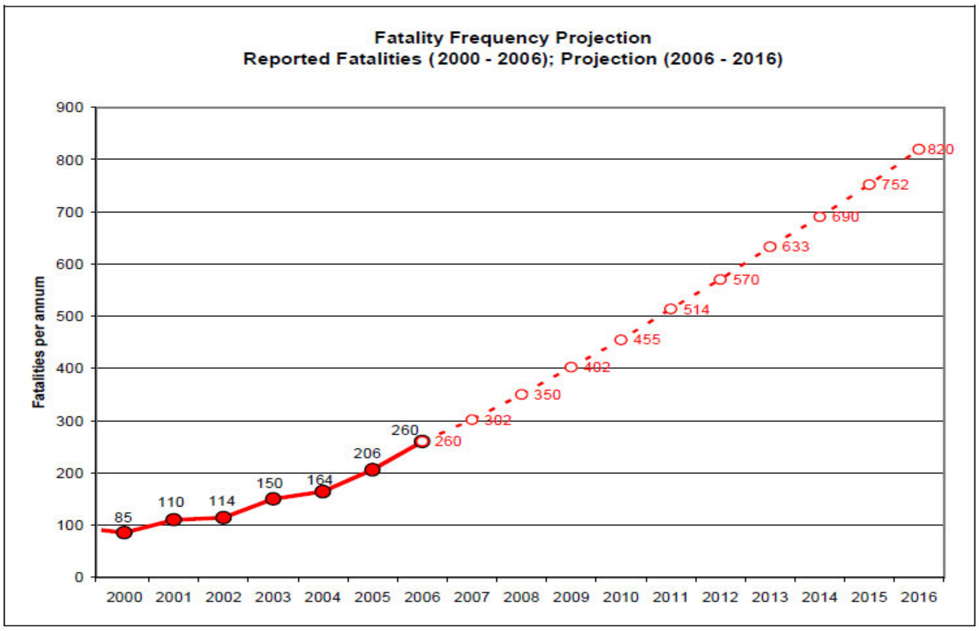


Figure 2.2 Projected Road Traffic Fatalities (UPDA, 2007)

Sequel to the occurrence discussed above and the fact that the RTC casualty rate was in the region of 30 deaths per 100,000 population, in 2006, the Qatari Government commissioned a consortium of international consultants to develop a road safety strategy for the Gulf state to reduce RTC fatalities to numbers comparable with levels in developed countries (Jamieson, 2007, 2008). The consultant's main task was to develop safety-related policies that would improve road traffic safety in Qatar. The major Road Safety issues of the Qatar transportation system were found to include (Jamieson, 2007):

- Insurance issues
- Enforcement
- Vehicle licensing and registration

- Laws and regulations
- Education and behavioural

Contrary to the World Health Organization/World Bank's recommendation to institutionalize traffic safety, Qatar still lacked an institutional structure focusing on traffic safety. Consequently, the World Health Organization/World Bank suggested developing policies concerning:

- Seatbelt usage;
- Mobile phone usage;
- Vehicle import controls; and
- Deregistering of aging vehicles

Early in 2007, Qatar implemented more stringent traffic control measures, installed numerous speed control cameras to discourage speeding on roads, instituted more punitive fines for traffic violations, and prioritized seat belt use. In 2007, the initial installation of 14 cameras led to an increase to 84 in the same year. According to reports, the number of tickets issued increased dramatically in the same year, resulting in a reduction in motor vehicle injury death rates. The recorded number of fatalities seems to suggest a positive impact of the cameras on road safety in Qatar in the same year (see Figure 2.3). A similar analysis conducted by Mamtani et al., 2012, found a reduction in the mean (SD) RTI death rate per 100,000 from 19.9±4.1 for the period 2000 to 2006 to 14.7±1.5 from 2007 to 2010 (Mamtani et al., 2012).

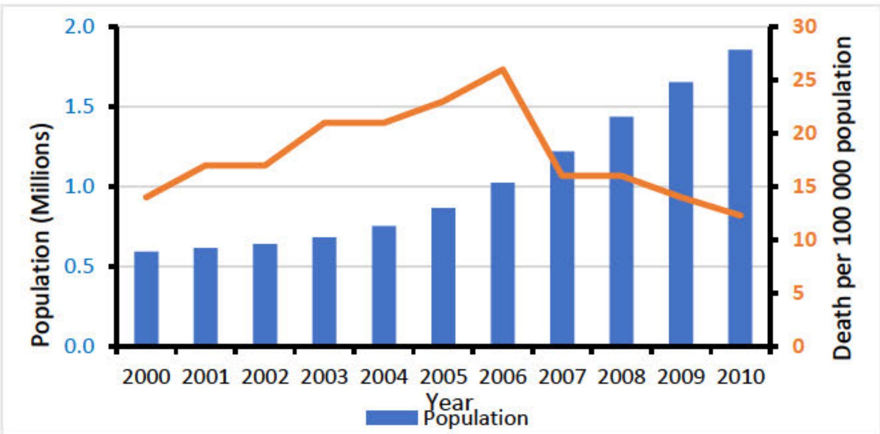


Figure 2.3 Road Traffic Deaths from 2000 to 2010

2.3 Road Safety and Traffic Management in Developed and Developing Countries.

Road safety and traffic management are critical global concerns, affecting millions of people's safety and well-being. While developing and developed countries share common road safety challenges, they also face unique issues due to differing levels of infrastructure, resources, and regulatory frameworks. In developing countries, they often grapple with inadequate road infrastructure, poorly maintained roads, and a lack of proper signage and lighting (J. Zijun Du et al., 2023). Enforcement of traffic laws can be weak due to limited resources, corruption, and a lack of trained personnel. This can lead to widespread violations and unsafe practices (Peden et al., 2004). Pedestrians often face significant risks due to a lack of designated pedestrian infrastructure and road-sharing practices (WHO, 2018). Developed countries boast well-maintained road networks with proper signage, lighting, and road markings, reducing the risk of accidents (Hauer, 1997). Developed countries have stringent vehicle safety standards, including mandatory safety features such as airbags, anti-lock brakes, and electronic stability control (NHTSA, 2018). The use of mobile phones while driving is a common issue worldwide, leading to accidents in both developing and developed countries (Caird et al., 2014). Excessive speeding is a significant contributor to accidents in both developing and developed countries (WHO, 2018). Road safety and traffic management are multifaceted challenges that require tailored approaches in both developing and developed countries. While infrastructure and enforcement differ between these contexts, common issues like distracted driving and speeding demand global attention and innovative solutions.

Road safety and traffic management are critical concerns in both developing and developed countries, but they manifest in different ways due to varying levels of infrastructure, resources, and regulatory frameworks. In developed countries, several issues always prevail as relevant, including:

1. Infrastructure: Developed countries typically have well-maintained road networks with proper signage, lighting, and road markings. They often invest in advanced technologies like intelligent traffic management systems and smart intersections.

2. Traffic Regulations: Developed countries have robust traffic laws and regulations, strict enforcement, and advanced systems for traffic monitoring, such as speed cameras and automated ticketing systems.

3. Safety Education: There is a strong focus on road safety education in schools and communities. Public awareness campaigns and educational programs are common.

4. Vehicle Safety Standards: Developed countries have stringent vehicle safety standards, including mandatory safety features such as airbags, anti-lock brakes, and electronic stability control.

5. Emergency Response: The emergency services are well-equipped and respond quickly to accidents. Hospitals are often nearby, ensuring prompt medical attention.

6. Traffic Management: Developed countries invest in advanced traffic management systems, including synchronized traffic lights, real-time traffic data analysis, and public transportation systems that reduce the reliance on private vehicles.

7. Pedestrian and Cyclist Safety: There are dedicated lanes and infrastructure for pedestrians and cyclists, reducing the risk of accidents involving vulnerable road users.

8. Public Transport: The public transportation networks are well-developed and provide viable alternatives to driving, reducing congestion and pollution.

In developing countries, on the other hand, the main relevant issues to road safety and traffic management include:

1. Infrastructure Challenges: Developing countries may have inadequate road infrastructure, poorly maintained roads, and a lack of proper signage and lighting. Rural areas often have limited access to roads.

2. Enforcement Challenges: Enforcement of traffic laws can be weak due to limited resources, corruption, and lack of trained personnel. This can lead to widespread violations.

3. Limited Safety Education: Due to resource constraints, road safety education is often limited, and public awareness campaigns may not be as effective.

4. Vehicle Standards: Older and less safe vehicles may be prevalent due to affordability issues. Vehicle safety standards may be less stringent.

5. Emergency Response: Response times to accidents may be longer, and medical facilities may be less accessible in remote areas.

6. Traffic Congestion: Developing countries often face severe traffic congestion due to rapid urbanisation and a lack of public transportation options.

7. Pedestrian and Cyclist Safety: Pedestrians and cyclists may face greater risks due to inadequate infrastructure and road-sharing practices.

8. Public Transport Challenges: Public transportation systems may be underdeveloped or unreliable, leading to a heavy reliance on private vehicles.

In both developed and developing countries, there are a number of common challenges, including:

1. Distracted Driving: The use of mobile phones while driving is a common issue worldwide, leading to accidents.

2. Drunk Driving: Driving under the influence of alcohol or drugs is a significant cause of accidents in both types of countries.

3. Speeding: Excessive speeding contributes to accidents everywhere, and enforcement remains a challenge.

4. Vulnerable Road Users: Protecting pedestrians, cyclists, and motorcyclists is a concern in both types of countries.

5. Road Maintenance: Adequate maintenance of existing road infrastructure is vital to road safety in both developing and developed countries.

6. Data Collection: Improved data collection and analysis are essential for evidence-based road safety strategies in all countries.

Therefore, efforts to improve road safety and traffic management should be context-specific, taking into account the unique challenges and resources available in each country. International organizations often provide support and best practices to help countries enhance road safety and reduce traffic accidents. For example, Jamee and Evdorides., 2023, reviewed the most commonly used indicators as the operational performance of road safety systems, which are developed based on the fundamentals of the 'safe system' vision. They identified a number of criteria for their selection process including comprehensiveness, measurability, and independence.

This literature review provides an overview of key issues and references for further exploration. It emphasises the importance of sharing best practices and fostering international collaboration to improve road safety and traffic management around the world.

2.4 Human Factors in Road Safey

Human Factors in Road Safety including distracted driving, impaired driving, and aggressive driving, remain a significant contributor to road accidents (J Zijun Du et al., 2023). Many researchers investigated human factors including education and awareness campaigns that can play a crucial role in changing behaviour and promoting safer driving habits. The other set of factors that affect road safety includes Vehicle Safety Standards. This category of research included investigations on vehicle safety features, such as airbags, anti-lock brakes, and electronic stability control, which have improved road safety. The possible measures that can be developed to deal with safety issues that belong to the human factors category include the development and implementation of safety standards for vehicles which are essential to reducing the severity of accidents.

2.5 Emergency Response and Medical Care Factors

The literature has also investigated emergency response and medical care factors as effective measures to deal with accidents and their severity. Quick response times from emergency services and access to medical facilities significantly impact the outcomes of road accidents. In addition, advances in telemedicine and communication technology can enhance emergency response. Human factors in road safety, including distracted driving, impaired driving, and aggressive driving, remain a significant contributor to road accidents (J Zijun Du et al., 2023). Many researchers investigated human factors, including education and awareness campaigns, that can play a crucial role in changing behaviour and promoting safer driving habits. The other set of factors that affect road safety includes vehicle Safety Standards.

This category of research included investigations on vehicle safety features, such as airbags, anti-lock brakes, and electronic stability control, which have improved road safety. The possible measures that can be developed to deal with safety issues that belong to the human factors category include the development and implementation of safety standards for vehicles, which are essential to reducing the severity of accidents. There has been prior research on the effects of emergency medical service (EMT) response times on patient outcomes. Quick response times from emergency services and access to medical facilities significantly impact the outcomes of road accidents.

According to Pons PT, et al., 2005, and Russell_Gryphon et al., 2013, based on thorough analyses of medical records, most trauma-related deaths happen in the first one to two hours following the event. This information has given rise to the idea of the "golden hour," which states that a patient's chances of recovery are higher the sooner they start receiving medical care (from an EMT or in a hospital) following trauma. Reduced emergency medical service response times appear to benefit trauma patients the most because they allow emergency medical care to begin sooner. In Portland, Oregon, Feero et al., 1995, examined the results of severe trauma accidents and discovered that survivors' overall reaction times from notice to hospital transportation were, on average, 10 minutes faster than those of patients who did not survive. According to the same study, survivors saw noticeably faster average response times from emergency personnel than non-survivors. In addition, advances in telemedicine and communication technology can enhance emergency response. Technology and Traffic Management measures and policies have also shown that intelligent Transportation Systems (ITS) and smart traffic management systems improve traffic flow and reduce congestion, as reported by Sun, R., 2017, Similarly, real-time traffic data analysis, adaptive traffic signals, and GPS-based navigation systems help optimise traffic management. Special attention is needed to protect pedestrians, cyclists, and motorcyclists who are at higher risk of accidents. Infrastructure improvements, such as dedicated lanes and crosswalks, are essential for their safety. The collection and analysis of traffic data are fundamental for understanding accident patterns and developing evidence-based road safety strategies. Predictive analysis has increasingly relied on big data analytics and machine learning techniques in recent times. In addition, educational programs targeting both drivers and pedestrians can lead to safer road behaviours. Public awareness campaigns can equally be effective in promoting seat belt use, reducing drunk driving, and discouraging distracted driving (Jagnoor J. et al., 2020).

Many countries benefit from international collaboration and knowledge sharing to adopt best practices in road safety and traffic management. Organizations such as the World Health Organization (WHO) provide guidelines and resources for road safety improvement. Governments play a crucial role in enacting and enforcing road safety policies and regulations. Strong political will and adequate funding are vital for implementing effective road safety measures. Emerging technologies such as autonomous vehicles and vehicle-to-infrastructure communication hold the potential to revolutionize road safety and traffic management. Sustainable transportation options and urban planning that prioritizes non-motorized modes of transport are gaining importance. Overall, the literature underscores the multidimensional nature of road safety and traffic management, emphasizing the need for comprehensive approaches that encompass infrastructure development, regulation, education, technology, and behaviour change to reduce road accidents and save lives. Additionally, the ongoing evolution of technology and transportation systems is expected to continue influencing road safety practices in the future.

2.6 Road Safety Auditing

A road safety audit (RSA) is an important formal examination of an existing, ongoing, or future road traffic project, or any project involving road users' interaction. These are critical components of transportation planning and engineering to assess and improve road safety for all users, including pedestrians, cyclists, and motorists. The audits involve the systematic evaluation of road infrastructure to identify potential safety hazards and recommend improvements. Independent and qualified examiners evaluate and report on the crash potential and safety performance of the project (Austroads, 2013; Wilson, 2000). Road safety audits primarily aim to pinpoint potential safety issues for all road users impacted by a project, implement appropriate solutions to enhance road safety, and guarantee a high standard of safety for all users. RSA is a proactive approach to preventing or reducing the impact and severity of future accidents. It also reduces the need for corrective interventions after the project is implemented and could reduce the project's total cost (Al-Adhoobi et al., 2018; Rahoof et al., 2017). This is achieved by promoting the removal of safety hazards in the cross-sectional layouts of roads and integrating appropriate accident reduction measures such as guard rails, traffic control devices, and road surface markings.

The American Association, 2018, and Federal Highway Administration (FHWA), 2004, publications provide comprehensive guidance on conducting road safety audits in the United States, and they serve as a valuable resource for transportation professionals. The guidelines, published by FHWA, provide detailed information on the process and methodologies of road safety audits. A study by B.P. Hughes et al., 2015, offers a review of the effectiveness of road safety audits, providing valuable insights into their impact on road safety. Another study by Baklanova K. et al., 2021, discussed the development of a tool to review road safety audits, which can be useful for quality control and evaluation. Jones, et al., 2013, provide case studies that illustrate some applications of road safety audits in real-world scenarios, offering practical insights into their implementation. These references and citations cover a range of topics related to road safety audits, including guidelines, effectiveness, case studies, and tools for conducting and reviewing audits.

2.7 Road Safety Management in Qatar

In this study, we investigate the road safety audit process in the state of Qatar to determine its impact on road traffic crashes (RTCs), road traffic injuries (RTIs) and accident severity or casualties. The discovery of oil in commercial quantities in Qatar led to a rapid expansion of its economy, increasing immigration, population, and urbanisation (Rasoul, 2010; Radwan and Hammuda, 2015). The rapid GDP growth, in conjunction with population growth and urbanisation, resulted in an increase in vehicle numbers, significantly straining the road transportation system (Planning and Statistics Authority, 2020). The resultant effect was a rapid increase in the number of road traffic accidents, whose consequential fatalities and injuries raised severe public health concerns in Qatar (Bener *et al.*, 2010; National Traffic Safety Committee, 2013; Radwan and Hammuda, 2015).

[redacted]

Figure 2.4 Road Traffic Casualties in Qatar 2000-2010 (Source: NTSS, 2012)

In response to rising road safety concerns in Qatar, the Cabinet, through resolution No. 33/2010, approved the establishment of the NRSC as a commitment to improving Qatar's road safety situation to internationally acceptable standards (Ramesh, 2013). Consequently, Qatar embarked on comprehensive safety and awareness campaigns and more aggressive law enforcement to minimise the occurrence of road traffic crashes, fatalities, and the severity of injuries (National Traffic Safety Committee, 2013).

In January 2013, the National Traffic Safety Committee, the lead agency for Road Safety Management and chaired by the Prime Minister, launched a ten-year Action Plan under the title National Road Safety Strategy 2013–2022. The National Traffic Safety Committee (National Traffic Safety Committee, 2018) developed the NRSS to reduce the frequency of road traffic crashes and prevent fatalities or severe injuries. Subsequently, the National Traffic Safety Office (NTSO) was also established in 2015 to promote Qatar as a world leader in Road Safety, assist in the promotion of the National Strategy and implementation of the associated action plan, and undertake monitoring and evaluation of the implemented plans.

[redacted]

Figure 2.5 Road Traffic Casualties in Qatar 2010-2016 (Source: WHO, 2018)

Road Safety Audit Guidelines and Procedures was prepared as one of the strategies to deliver road safety in Qatar by providing clear and coherent guidelines to facilitate the consistent implementation of Road Safety Audits of all road infrastructural works affecting the road user in Qatar. The objective of the guidelines is to encourage stakeholders involved in the planning, design, and construction of road projects across Qatar to undertake Road Safety Audits in all their processes (Ashgal, 2013). Notwithstanding the rapid population growth, massive infrastructure development, and high vehicle ownership rates between 2013 and 2017, Qatar recorded a reduction in road traffic crashes (RTCs) and their resultant fatalities and injuries. Reports indicate a decline in road traffic crash fatalities from 235 in 2013 to 177 in 2017, and a corresponding decrease in the fatality rate per 100,000 population from 14 in 2013 to 6.93 in 2016. These figures were below the estimated targets of 213 and 199 for 2013 and 2017, respectively (National Traffic Safety Committee, 2018). These figures seem to represent a substantial improvement from the 2006 reported rate of 26 fatalities per 100,000 population, as shown in Figures 2.4 and 2.5. Following the success of the first action plan between 2013 and 2017, the NTSC launched the second 5-year National Road Safety Action Plan in January 2018. This second action plan is to elevate Qatar's Road Safety performance to a world-leading standard and reflect the unique characteristics of Qatar, which include rapid population and infrastructure growth and high vehicle ownership levels (National Traffic Safety Committee, 2018).

Therefore, it is significant to create understanding by investigating the impact of the mitigation measures introduced by the NTSS to minimise the occurrence of road traffic crashes, fatalities, and the severity of injuries, as well as the frequency, nature, and severity of the road traffic crashes and offences recorded over the period.

2.8 Road Safety and Surveillance Cameras

Speeding increases the risk of crashes, as well as the severity of those that do occur. Vehicle speed capabilities far exceed posted limitations, necessitating the enforcement of speed limits designed to govern top speed. By defining a maximum speed limit and minimising vehicle speed variance, road speed limits regulate traffic speed and thereby enhance road safety. Typically, they classify them based on the category, kind, and design of the road (Chin, 1999). The primary goal of speed limits is to regulate vehicle speeds in order to strike a good balance between travel time and risk (Al-Adhoobi et al., 2017). Many countries have laws in place to ensure that drivers adhere to specified speed limits. The traditional methods of speed enforcement have significant drawbacks. They consume a lot of resources, are inconsistent in their applications, and don't do much to slow down drivers. It may also be tough to keep track of speeds in the most inconvenient locations and times. There may be no safe spot to pull over speeding automobiles in congested regions.

According to statistics from the Australian Transport Safety Bureau, 562 of the 1715 fatal crashes in Australia in 2002 involved excessive speed (Ayiei et al., 2020). Pilkington, 2002, projected that reducing the number of fast drivers would decrease both the likelihood and severity of a crash. Strict enforcement of speed limits is necessary to convey to drivers that exceeding them will result in consequences. Generally, fixed speed limit enforcement cameras are a popular intervention and a better option to urge drivers to adhere to the legal maximum speed limit. Strategically placed along designated routes, the cameras identify speed limit infractions, leading to monetary penalties, points on a driver's license, or criminal charges. Since their introduction, the impact of speed cameras on road traffic collisions has been the subject of extensive discussion. According to Graham et al., 2019, there have been claims that speed cameras either reduce road traffic collisions, have no effect, or even increase them by encouraging more erratic driving behaviour.

Automatic speed enforcement has the potential to be a significant source of net revenue. This may harden public perceptions of whether governments deploy the technology for security or fiscal reasons. Some have viewed the introduction of speed cameras as a violation of their civil liberties. There are other legal problems to consider, such as whether the speeding infraction is the fault of the vehicle's owner or the driver. In British Columbia, Canada, experts have discussed the benefits and drawbacks of speed cameras. According to the study by Chen et al., 2000, the introduction of cameras reduced speeding, which resulted in fewer crashes, injuries, and fatalities. Despite this, the incoming administration scrapped the speed camera program in June 2001. On the other hand, most countries that have used speed cameras tend to extend their use over time. Particularly, the United Kingdom and Australia have demonstrated this trend.

Many parts of the world have implemented automated speed detection systems, leading to fewer violations and RTIs. (Jeong-Gyu, 2002). According to prior research on speed detection cameras, the average reduction in RTIs after their adoption was between 20 and 25% (Savolainen & Ghosh, 2008). Road traffic collisions are a leading cause of mortality and disability in the United States. A vehicle's speed significantly influences injury; a faster vehicle imparts more energy to its occupants during a crash, leading to more injuries. Excessive speed can cause a significant number of collisions. Reducing the number of fast drivers is likely to decrease both the likelihood and severity of a crash. As a result, actions targeted at slowing down traffic are seen as critical to preventing road injuries and deaths. One such measure is the use of speed cameras and other automated systems to enforce safe speeds.

The majority of those killed in traffic accidents are normally between 21 and 30 years of age (very active labour force). Simultaneously, men account for a disproportionate number of RTC fatalities and severe injuries compared to women. This is due to the fact that the majority of men in this age group drive more frequently and recklessly (Enu, 2014; Hesse & Ofosu, 2014). Most countries in the region have a high rate of road traffic injuries among vulnerable road users, such as pedestrians, children, bicycle/motorcycle and public transportation riders. Pedestrians account for over half of all road traffic fatalities in the region (Khorasani-Zavareh et al., 2009).

In Saudi Arabia, RTIs are the leading cause of premature deaths (Years of Potential Life Lost (YPLL)) (Murray et al., 2013). Every minute, a traffic accident happens, and the annual death toll has surpassed 9000, averaging more than 25 deaths each day. Furthermore, projections indicate that RTIs incapacitate 79,000 people, with 80% of them experiencing lifelong disabilities. Around the world, Peden et al., 2004, have undertaken a variety of preventative methods to reduce the burden of RTIs. Speeding, not wearing a seat belt, and driving while talking on a cell phone are three prevalent and modifiable risky behaviours associated with a high prevalence of RTCs and RTI severity (Jafarpour & Rahimi-Movaghar, 2014). As a result, traffic enforcement agencies and prevention programs have focused their efforts on reducing these risks. Enacting policies such as mandating the use of seatbelts and improving vehicle safety (Bendak, 2005) has demonstrated this. Saudi traffic police have been attempting to introduce methods to limit the incidence and magnitude of RTIs, following the lead of developed countries. Even though written traffic laws and penalties have existed since the beginning of motor vehicle use, compliance rates are sadly relatively low (Bendak, 2007). El Bcheraoui et al., 2015, estimate that only 5% of front-seat passengers in Saudi Arabia use seatbelts. Germany's traffic death rate and severity decreased by 69% and 50%, respectively, following the establishment of preventative initiatives (Ernstberger et al., 2015). Similarly, the United States (US) has reported fewer fatalities as a result of lower speed limits, improved driving conditions, and increased traffic enforcement (Raj Ponnaluri & Fred Heery SR, 2016).

The increase in motor vehicles in Qatar has led to issues for pedestrians and bicycles, particularly when they lack proper planning. According to Bíl et al., 2016, motor vehicle collisions have been found to account for the majority of fatal bike collisions. A vehicle's speed significantly influences injury; as it moves faster, it imparts more energy to the occupants during a crash, leading to more injuries. Driving faster than the posted speed limit or too fast for the conditions has been linked to a significant percentage of collisions. Reducing the number of speeding drivers is likely to decrease both the likelihood and severity of a crash. As a result, actions targeted at slowing down traffic are critical to preventing road injuries and deaths. One such measure is to use speed cameras and other automated systems to enforce safe speeds.

Seat belt violations and mobile phone use while driving are common traffic violations in Qatar. As a result, the Traffic Department at Qatar's Ministry of Interior has installed surveillance cameras on major roads in Qatar, learning from the successes of countries in the Gulf region and worldwide. The cameras are to monitor and enforce street security by compelling drivers to observe the land's driving laws, protect people's lives, and ensure the safety and security of all road users. In addition, the surveillance cameras and radars also monitor safety belt violations, mobile phone violations, speeding, and overtaking from the wrong side while driving. This is to ensure people fasten their seat belts when in a vehicle and curb mobile phone usage while driving (Sidi, 2021).

Speed cameras utilize a low-powered Doppler radar speed sensor that triggers the camera to capture vehicles travelling faster than a pre-set speed when they pass a pre-determined spot. The cameras capture the date, time, vehicle speed, and license plate number, and they only activate when a vehicle surpasses the posted speed limit. The owner of the car receives a subsequent notification of the violation. After registering and validating a violation, the violator receives a text message with the violation's date, time, and type. Major intersections saw the installation of the first cameras in 2007. Qatar's Ministry of Interior deployed about 80 cameras at key intersections in Doha (ITS International, 2012). Qatar's number of surveillance cameras has been growing every year since the first deployment in 2007 after a policy decision to convert the key roundabouts into signalized intersections. (Shaaban, 2018)

Speed radars and surveillance cameras with the capacity to capture over-speeding as well as safety belt violations, mobile phone violations, and overtaking others on the right lane were installed every two to four kilometres on major roads with speed limits ranging from 80 km/h to 120 km/h, and major intersections in Qatar. Despite the widespread implementation of cameras in Qatar and their perceived success among motorists, there is a lack of empirical evidence regarding their effectiveness. Researchers have conducted few studies to explore their effectiveness in reducing RTCs and RTIs in Qatar (Shaaban, 2017, 2018).

2.9 Qatar's Safe System Approach

Notwithstanding the gains in road traffic safety after the installation of the cameras in Qatar, the greatest impact appears to be on fatal injuries rather than on severe or mild injuries. Younger people, who disproportionately represented RTI casualties in Qatar, showed more noticeable decreases in RTI deaths. To further sustain the gains, the Qatari government provided a significant amount of political support to road safety initiatives in the Gulf State. This culminated in the formation of the National Traffic Safety Committee (NTSC) in 2010 and the inclusion of road safety targets in the Qatar National Development Strategy, 2011-

2016. The Road Safety Action Plan provides the link between the Road Safety Strategy and vision and targets. It was aimed, among others, to raise road safety performance in Qatar through an ambitious program of 200 activities and projects to be implemented by government and quasi-government agencies over five years, 2011 - 2016.

In response to UN General Assembly resolution 64/255, "The Global Plan for the Decade of Action for Road Safety 2011-2020" (United Nations, 2011b), and the high numbers of road traffic fatalities and injuries in Qatar, the Cabinet, through resolution No. 33/2010, authorised the establishment of the Qatar National Traffic Safety Committee (NTSC) to improve the road safety situation in Qatar to internationally acceptable standards (Salt & Higham, 2013). The result was the development of a ten-year National Road Safety Strategy (NRSS) aimed at raising road safety awareness, preventing road fatalities and severe injuries from occurring on the road network, and halting or reversing the predicted increase in road traffic fatalities in Qatar

[redacted]

Figure 2.6 Safe System Approach

. The main goal of the NRSS was to significantly reduce road deaths by 2022 by ensuring safer roads, safer vehicles, safer road users, and safe vehicle speeds on the roads (National Traffic Safety Committee, 2018). Consequently, Qatar embarked on comprehensive safety and awareness campaigns and more aggressive law enforcement to minimise the occurrence of road traffic crashes, fatalities, and the severity of injuries (National Traffic Safety Committee, 2013). The Safe System principle, a holistic and comprehensive strategy that anticipates and accommodates human error, guided the development of the resulting strategy. The Safe System approach acknowledges that human error is inevitable and focuses on creating a forgiving road environment that takes into account human vulnerabilities. The structure also emphasises the creation of safe roads and infrastructure, safe speeds, safe vehicles, safe users, and the enhancement of post-crash care.

Figure 2.6 shows a brief description of the key elements of Qatar's Safe System approach. Safe roads and Infrastructure: Qatar places a strong emphasis on designing and maintaining safe road infrastructure. This includes ensuring clear road markings, proper signage, adequate lighting, and well-maintained roads. The aim is to create forgiving roads that minimise the risk of crashes and mitigate the severity of injuries in case an accident does occur.

Safe Speeds: Speed management is a crucial component of the Safe System approach. Qatar sets appropriate speed limits based on road characteristics, traffic patterns, and the presence of vulnerable road users. The goal is to ensure that speeds are conducive to the road environment and minimise the potential for severe accidents. Speed cameras and other enforcement measures are employed to enforce speed limits effectively.

Safe Vehicles: Qatar promotes the use of safe vehicles by implementing vehicle safety standards and encouraging the adoption of advanced safety technologies. This includes mandatory seatbelt usage, encouraging the use of child restraints, and raising awareness about the importance of vehicle maintenance. The goal is to improve vehicle crashworthiness and reduce the likelihood of severe injuries in an accident.

Safe Users: The Safe System approach recognizes the importance of promoting responsible behaviour among road users. Qatar emphasises road safety education and awareness campaigns targeted at drivers, pedestrians, cyclists, and other vulnerable road users. The aim is to foster a culture of responsible and safe road use, encouraging individuals to make informed decisions and follow traffic rules.

Post-Crash Care: Qatar prioritizes post-crash care to minimise the severity of injuries and provide timely and effective medical treatment to those involved in road accidents. This includes having a well-developed emergency response system, equipped with ambulances, trained personnel, and efficient communication networks. Prompt and appropriate medical care can significantly improve outcomes and reduce the long-term impacts of road accidents.

The Safe System approach in Qatar emphasises a multidisciplinary and collaborative approach, involving various stakeholders such as government agencies, law enforcement, transportation authorities, health care systems, and the public. Continuous monitoring, evaluation, and data analysis are essential parts of the system for identifying road safety issues, implementing targeted interventions, and measuring the effectiveness of road safety measures. By adopting the Safe System approach, Qatar created a road transport system that is forgiving of human error, prioritizes safety, and minimises the impact of accidents. This comprehensive approach aligns with international best practices and emphasises the shared responsibility of all stakeholders in ensuring road safety for everyone.

The progress includes initiatives like updating the Qatar Traffic Law, introducing a penalty points system, installing red-light and speed cameras, developing Road Safety Audit guidelines, and developing world-class emergency medical services (Jadaan & Almatawah, 2016b). However, the safe system implemented was fraught with lots of setbacks, the system was fragmented, and the coordination of the activities of all stakeholders was lacking, hence not yielding the desired results. Recognizing the need for improvement, the Qatari government made significant efforts to enhance road safety through the implementation of various initiatives and strategies, such as the National Road Safety Strategy. The government aimed to address the identified challenges and create a safer road environment for all road users in the country. Road safety in Qatar has since undergone a significant transformation from a fragmented system to an integrated one, with the implementation of the National Road Safety Strategy playing a crucial role. Before implementing the National Road Safety Strategy in Qatar, the road safety situation faced various challenges and had room for improvement. Qatar experienced a high number of road accidents, injuries, and fatalities, with factors such as speeding, lack of adherence to traffic rules, inadequate infrastructure, and limited awareness contributing to the problem. The Qatari government recognized the need for a comprehensive and coordinated effort to address the challenges associated with road safety, and thus developed a strategic plan to enhance safety on the country's roads. Qatar therefore transitioned from a fragmented approach to an integrated one in road safety, with the National Road Safety Strategy serving as a guiding framework. By addressing infrastructure, education, enforcement, and emergency response, the strategy aims to create a safer road environment and reduce road accidents. The collaborative efforts of various stakeholders are essential to implementing the strategy effectively and achieving the desired road safety outcomes.

The National Road Safety Strategy in Qatar serves as a roadmap to guide all relevant stakeholders, including government agencies, law enforcement, transportation authorities, and the public, towards a common goal of reducing road accidents and improving safety outcomes. The strategy aims to integrate various elements of road safety, including infrastructure, education, enforcement, and emergency response, into a cohesive framework. Sequel to the adoption of the safe system concept by the National Road Safety Strategy, the National Traffic Safety Office (NTSO) was formed in 2015 to promote Qatar as a world leader in Road Safety, assist in the promotion of the National Strategy and the implementation of the associated Action Plans and monitor and evaluate the implemented Action Plans. The Qatar Road Safety website (Qatar Transportation and Traffic Safety Centre, QTTSC) is one of the outcomes of Qatar’s National Road Safety Strategy 2013-2022 (National Traffic Safety Committee, 2018).

One of the strategies to deliver road safety in Qatar is the preparation of Road Safety Audit Guidelines and Procedures. The guidelines' goal is to encourage stakeholders involved in the planning, design, and construction of road projects in Qatar to conduct road safety audits in all of their processes (Ashghal, 2013).

2.10 Ten Years National Road Safety Action Plans (2013-2022)

The "Public Works Authority" actively participated in the development of the National Road Safety Strategy (Ashghal, 2013), which aimed to guide concerted efforts to improve road safety in the Gulf State over a 10-year period and lay the foundations for a safe road transport system that will benefit future generations by reducing death and serious injury inflicted by road traffic crashes (National Traffic Safety Committee, 2012).

Two 5-year Action Plans (the first and second 5-year National Road Safety Action Plans) were developed for the ten-year national National Road Safety Strategy. The NTSC launched the first 5-year National Road Safety Action Plan from 2013 to 2017, marking a significant step towards achieving Qatar's long-term vision for a safe road transport system that will benefit future generations. The NTSC provided leadership and supervised the implementation of Qatar’s road traffic strategy through the Road Safety Action Plan 2013-2017.

The Road Safety Action Plan links the Road Safety Strategy, vision, and targets and translates these into a series of key road safety deliverables (National Traffic Safety Committee, 2012). As a step towards realizing Qatar's long-term vision for road safety, this first 5-year National Road Safety Action Plan was launched from 2013 to 2017 to, among others, reduce the annual number of fatalities to 199 at the end of 2017.

Despite the rapid population and vehicular growth between 2013 and 2017, Qatar recorded a reduction in road traffic crashes (RTCs) and their resultant fatalities and injuries. Reports indicate a decline in road traffic crash fatalities from 235 in 2013 to 177 in 2017, and a corresponding decrease in the fatality rate per 100,000 population from 14 in 2013 to 6.93 in 2016. These figures were below the fatality target of 199 in 2017 (National Traffic Safety Committee, 2018). These figures seem to represent a substantial improvement from the 2006 reported rate of 26 fatalities per 100,000 people. Despite the success of the first 5-year plan, it only achieved 62% of its targets during the period. The National Traffic Safety Committee, 2018 noted several implementation limitations and transferred 38% of non-achieved targets to the second 5-year plan 2018-2022 for redress.

After the successful implementation of the first action plan between 2013 and 2017, the NTSC launched the second 5-year National Road Safety Action Plan in January 2018. This second action plan was designed to uplift Qatar's Road Safety performance to a world-leading standard that reflects the unique characteristics of Qatar, such as rapid population and infrastructure growth and high vehicle ownership levels (National Traffic Safety Committee, 2018). To address the limitations of the safe system noted during the implementation of the first phase, the safe system in Qatar was modified to account for Qatar's development needs (Qatar's Vision 2030). The amendments led to the addition of 25 sectors to the original six sectors and took into consideration all areas related to road safety, sustainability, congestion, security, and the need for economic growth within the Gulf State (National Traffic Safety Committee, 2018).

The NTSC developed Bespoke Road Safety System, as shown in Figure 2.7, recognizes the fact that the occurrence of a certain minimum number of crashes and casualties is an inevitable part of a motorized society; however, the rate at which these events occur can be minimised.

Figure 2.7 Qatar Bespoke Safe System

Qatar's bespoke safe system Therefore, road safety relies on the creation and application of safety standards for roads, vehicles, and road users to prevent road traffic crashes or lessen their effects on human health. Thus, under the leadership of the Chairman of the National Road Safety Committee (NTSC), who also serves as the Minister of State for Interior Affairs, all stakeholders (see Table 2.1) involved in the planning, design, construction, and maintenance of transport facilities and road safety-related services have an obligation to collaborate in order to reduce the risk of injury to all road users (National Traffic Safety Committee, 2012, 2018). The objective of this study is to investigate the impact of the Qatar Bespoke Safe System, the National Road Safety Action Plan, 2013-2022, and the implemented strategies on the occurrence and severity of road traffic crashes in Qatar between 2013 and 2020.

Table 2.1 Stakeholder for the Qatar Safe System

Name of the Stakeholder	Officer In-charge
Ministry of the Interior (MoI)	Executive, Traffic Department, Accident Investigations and Operations, Media and Traffic Awareness, Planning, Strategic and Security Studies.
National Traffic Safety Committee & Office (NTSO)	Secretary General & Director.
Ashghal (Public Works Authority)	Chief Executive, road safety professional officers, data analysts.
Ministry of Transport (MoT)	Chief Executive, professional officers
Ministry of Public Health (MoPH)	Chief Executive, professional officers
Ministry of Municipalities and Environment (MoME)	Senior Manager
Ministry of Education (MoE)	Senior Manager
Insurance industry	Company managers
Qatar Media Corporation	Senior manager
Qatar Petroleum	Senior safety manager
Qatar National Research Foundation	Senior manager
Qatar Traffic & Transportation Centre, Qatar University	Strategy Coordinator
Planning & Statistics Authority	Strategy Coordinator

2.11 Qatar’s Road Safety Management Process

A comprehensive program of consultation with key stakeholders was conducted to benefit from their knowledge and insights about all aspects of road safety in Qatar. Consultation took place with the following agencies: According to available data, the implementation of the National Road Safety Strategy has resulted in a significant improvement in Qatar's road safety situation. The National Road Safety Strategy has played a vital role in reducing the number of road accidents in Qatar. The strategy's focus on enhancing infrastructure, promoting responsible behaviour, and enforcing traffic rules has led to a decrease in the occurrence of accidents. Improved road design, such as better signage and road markings, has helped minimise confusion and enhance driver awareness, resulting in a safer road environment.

Additionally, the implementation of the National Road Safety Strategy has contributed to a significant reduction in both fatalities and injuries on Qatar's roads. Through stricter enforcement of speed limits, increased awareness campaigns, and improvements in emergency response systems, the strategy has effectively minimised the severity of accidents and improved post-crash care, leading to a decline in the loss of lives and the number of serious injuries. The sections below present and discuss data showing Qatar's road safety situation since 1983. Finally, human error is cited as one of the main contributing factors to road traffic crashes. Driver or human error is the most frequently reported reason for road traffic incidents in the most documented cases of road traffic accidents (National Traffic Safety Committee, 2013; Austroads, 2013; Royal Society for the Prevention of Accidents, 2017). As long as humanity continues to play a role in the road transportation system, human error will remain an unavoidable part. However, it can be minimised. The human body can only withstand a limited level of force in these crashes. To prevent road fatalities and severe injuries from occurring on the road network, it is prudent that planners and design engineers ensure that no road user is subject to forces in a collision that can result in severe injuries or death. The foundation of road safety lies in the development and application of safety standards for roads, vehicles, and road users, with the aim of preventing road traffic crashes and reducing their negative effects on human health. As a result, it is critical that all stakeholders involved in the planning, design, construction, and maintenance of roads and roadsides work together to minimise the risk of injury to all road users (National Traffic Safety Committee, 2012).

Speeding increases the risk of crashes, as well as the severity of those that do occur. Vehicle speed capabilities far exceed posted limitations, necessitating the enforcement of speed limits designed to govern top speed. By defining a maximum speed limit and minimising vehicle speed variance, road speed limits regulate traffic speed and thereby enhance road safety. Typically, they classify them based on the category, kind, and design of the road (Chin, 1999). The primary goal of speed limits is to regulate vehicle speeds in order to strike a good balance between travel time and risk (Al-Adhoobi et al., 2017). Many countries have laws in place to ensure that drivers adhere to specified speed limits. The traditional methods of speed enforcement have significant drawbacks. They consume a lot of resources, are inconsistent in their applications, and don't do much to slow down drivers. It may also be tough to keep track of speeds in the most inconvenient locations and times. There may be no safe spot to pull over speeding automobiles in congested regions. According to statistics from the Australian Transport Safety Bureau, 562 fatal crashes in 2002 in Australia involved excessive speed

(Ayiei et al., 2020). Pilkington, 2002, projected that reducing the number of fast drivers would decrease both the likelihood and severity of a crash. Strict enforcement of speed limits is necessary to convey to drivers that exceeding them will result in consequences. Generally, fixed speed limit enforcement cameras are a popular intervention and a better option to urge drivers to adhere to the legal maximum speed limit. Strategically placed along designated routes, the cameras identify speed limit infractions, leading to monetary penalties, points on a driver's license, or criminal charges. Since their introduction, the impact of speed cameras on road traffic collisions has been a subject of extensive discussion. According to Graham et al., 2019, there have been claims that speed cameras either reduce road traffic collisions, have no effect, or even increase them by encouraging more erratic driving behaviour.

Automatic speed enforcement has the potential to be a significant source of net revenue. This may harden public perceptions of whether governments deploy the technology for security or fiscal reasons. Some have viewed the introduction of speed cameras as a violation of their civil liberties. There are other legal problems to consider, such as whether the speeding infraction is the fault of the vehicle's owner or the driver. In British Columbia, Canada, experts have discussed the benefits and drawbacks of speed cameras. According to the study by Chen et al., 2000, the introduction of cameras reduced speeding, which resulted in fewer crashes, injuries, and fatalities. Despite this, the incoming administration scrapped the speed camera program in June 2001. On the other hand, most countries that have used speed cameras tend to extend their use over time. Particularly, the United Kingdom and Australia have demonstrated this trend.

Many parts of the world have implemented automated speed detection systems, leading to fewer violations and RTIs. (Jeong-Gyu, 2002). According to prior research on speed detection cameras, the average reduction in RTIs after their adoption was between 20 and 25% (Savolainen & Ghosh, 2008). Road traffic collisions are a leading cause of mortality and disability in the United States. A vehicle's speed significantly influences injury; a faster vehicle imparts more energy to its occupants during a crash, leading to more injuries. Excessive speed can cause a significant number of collisions. We expect both the likelihood and severity of a crash to decrease if we reduce the number of fast drivers. Therefore, we view actions aimed at slowing down traffic as crucial in preventing road injuries and deaths. One such measure is the use of speed cameras and other automated systems to enforce safe speeds.

The majority of those killed in traffic accidents are normally between 21 and 30 years of age (very active labour force). Simultaneously, men account for a disproportionate number of RTC fatalities and severe injuries compared to women. This is due to the fact that the majority of men in this age group drive more frequently and recklessly (Enu, 2014; Hesse & Ofosu, 2014). Most countries in the region have a high rate of road traffic injuries among vulnerable road users, such as pedestrians, children, bicycle/motorcycle and public transportation riders. Pedestrians account for over half of all road traffic fatalities in the region (Khorasani-Zavareh et al., 2009). In Saudi Arabia, RTIs are the leading cause of premature deaths (Years of Potential Life Lost (YPLL)) (Murray et al., 2013). Every minute, a traffic accident happens, and the annual death toll has surpassed 9000, averaging more than 25 deaths each day. Furthermore, Alghnam et al., 2018, project that RTIs incapacitate 79,000 people, with 80% of them suffering lifelong disabilities.

Peden et al., 2004, have undertaken a variety of preventative methods around the world to reduce the burden of RTIs. Speeding, not wearing a seat belt, and driving while talking on a cell phone are three prevalent and modifiable risky behaviours associated with a high prevalence of RTCs and RTI severity (Jafarpour & Rahimi-Movaghar, 2014). As a result, traffic enforcement agencies and prevention programs have focused their efforts on reducing these risks. Enacting policies such as mandating the use of seatbelts and improving vehicle safety (Bendak, 2005) has demonstrated this. Saudi traffic police have been attempting to introduce methods to limit the incidence and magnitude of RTIs, following the lead of developed countries. Even though written traffic laws and penalties have existed since the beginning of motor vehicle use, compliance rates are sadly relatively low (Bendak, 2007). El Bcheraoui et al., 2015 estimated that the use of seatbelts for front-seat passengers in Saudi Arabia is as low as 5%. Germany reduced its traffic death rate and severity by 69% and 50%, respectively, following the establishment of preventative initiatives (Ernstberger et al., 2015). Similarly, the United States (US) has reported fewer fatalities as a result of lower speed limits, improved driving conditions, and increased traffic enforcement (Raj Ponnaluri & Fred Heery SR, 2016).

The increase in motor vehicles in Qatar has led to issues for pedestrians and bicycles, particularly when they lack proper planning. According to Bíl et al., 2016, motor vehicle collisions have been found to account for the majority of fatal bike collisions. A vehicle's speed significantly influences injury; as it moves faster, it imparts more energy to the occupants during a crash, leading to more injuries. Driving faster than the posted speed limit or too fast for the conditions has been linked to a significant percentage of collisions. Reducing the number of speeding drivers is likely to decrease both the likelihood and severity of a crash. As a result, actions targeted at slowing down traffic are critical to preventing road injuries and deaths. One such measure is to use speed cameras and other automated systems to enforce safe speeds.

Speed cameras with a low-powered Doppler radar speed sensor that triggers the camera to capture vehicles travelling faster than a pre-set speed when they pass a pre-determined spot were used. The cameras capture the date, time, vehicle speed, and license plate number, and they only activate when a vehicle surpasses the posted speed limit. The owner of the car receives a subsequent notification of the violation. After registering and validating a violation, the violator receives a text message with the violation's date, time, and type. Major intersections saw the installation of the first cameras in 2007. Qatar's Ministry of Interior deployed about 80 cameras at key intersections in Doha (ITS International, 2012). Qatar's number of surveillance cameras has been growing every year since the first deployment in 2007 after a policy decision to convert the key roundabouts into signalised intersections. (Shaaban, 2018)

Speed radars and surveillance cameras with the capacity to capture over-speeding as well as safety belt violations, mobile phone violations, and overtaking others on the right lane were installed every two to four kilometres on major roads with speed limits ranging from 80 km/h to 120 km/h, and major intersections in Qatar. Despite the widespread implementation of cameras in Qatar and their perceived success among motorists, there is a lack of empirical evidence regarding their effectiveness. Researchers have conducted few studies to explore their effectiveness in reducing RTCs and RTIs in Qatar (Shaaban, 2017, 2018).

Figure 2.8 shows the percentage reduction in traffic fatalities in April 2020 compared with the average fatalities in April for the previous 3 years, 2017-201, for different countries. The figure is based on a report from the European Transport Safety Council (ETSC, 2020), which reported a reduction in traffic fatalities in several European countries. The figure reveals a reduction in traffic fatalities in most countries, with Italy, Belgium, and Spain exhibiting the highest reductions of 84%, 68%, and 63%, respectively. However, some countries, such as the Netherlands and Slovakia experienced an increase in traffic fatalities. While comparing Qatar with these countries, we found a similar trend to most EU countries, where the number of fatalities in Qatar resulting from RTCs decreased by 51%.

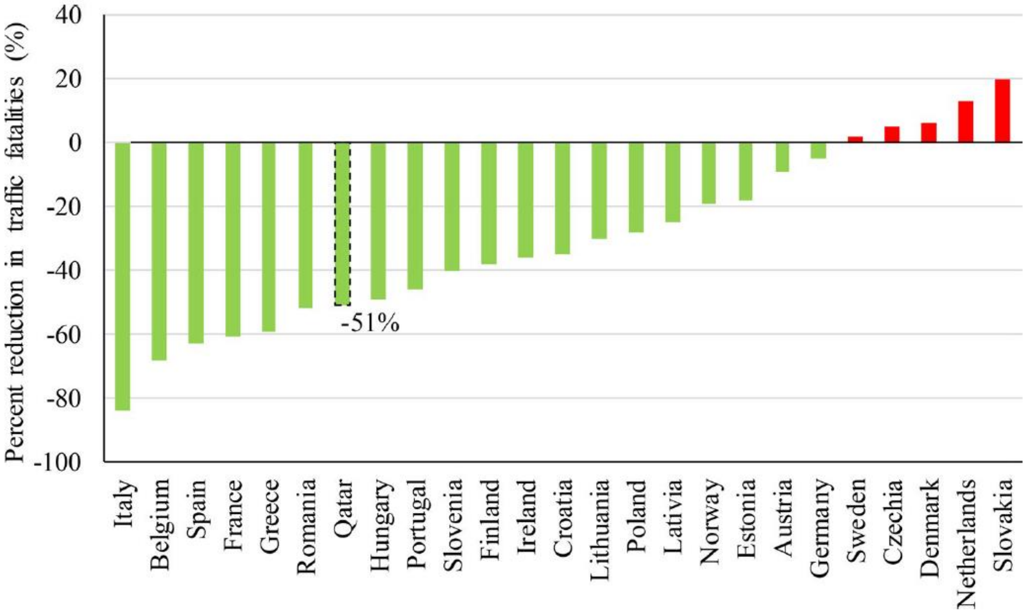


Figure 2.8 The Reduction in Traffic Fatalities in Qatar and 20 European Countries in April 2020 Compared to April 2017–2019 Average (ET SC, 2020).

Generally, the COVID-19 pandemic around the world saw a reduction in both average daily traffic and the number of RTCs, which is reasonable and expected. Saladie et al., 2020 investigated the impact of the COVID-19 lockdown on RTCs and mobility trends in Tarragona province, Spain. The study's results showed a 74.3% reduction in RTCs between the 6 weeks before and after the lockdown on March 16, 2020. In addition, compared with the same period of lockdown in 2018–2019, RTCs decreased by 76%. A 62.9% reduction in mobility trends occurred between the pre- and post-lockdown periods, 62.9% of mobility trends decreased. Santander City, Spain experienced similar trends, with a 67% reduction in RTCs and a 76% reduction in private vehicle mobility following the government's lockdown (Aloi et al., 2020). Another study from Turkey revealed that the government's strict measures in April 2020 reduced RTCs by 60% and reduced deaths and injuries by 72% and 19%, respectively, compared to April 2019 (Oguzoglu, 2020).

In the United States, Qureshi et al., 2020, performed an in-depth analysis to study the impact of the mandated lockdown on RTCs using data from the Missouri State Highway Patrol from January 1, 2020, to May 15, 2020. The study found that there was a significant reduction in RTCs resulting in no or minor injuries, but not RTCs resulting in serious or fatal injuries. Moreover, after the expiry of the mandated lockdown orders, a significant increase in RTCs resulting in no or minor injuries was observed. Similar results were reported in another study showing that overall RTCs were reduced by 20% because of the safer-at home orders, however, severe RTCs increased by 18% (Brodeur et al., 2021). The authors attribute the rise in severe RTCs to the adoption of speeding behaviour by some drivers. Doucette et al., 2021, conducted a time series.

The analysis revealed a significant 2.29-fold increase in the single-vehicle crash rate on a mileage-driven basis following the imposition of the lockdown in Connecticut. In addition, the authors reported a significant increase of 4.10 times in the rate of single-vehicle fatal crashes. The authors argued that the reduced traffic volumes during COVID-19 would increase the likelihood of some risky driving behaviours such as speeding. The annual spotlight report from the Governors Highway Safety Association, 2020, presented a comprehensive analysis of the state and national trends in pedestrian deaths for January–June 2020. Despite the significant reduction in traffic flow, the report revealed that 2957 pedestrians lost their lives in the first half of 2020, nearly matching the number of pedestrian fatalities in the same period in 2019. Interestingly, the report estimated a 20% increase in the pedestrian fatality rate per one billion vehicle miles traveled for the first six months of 2020 compared to the first six months of 2019. The report suggests that a similar pedestrian fatality rate to the first half of 2019 would have resulted in approximately 600 fewer pedestrian deaths in the first half of 2020.

Inada et al., 2021, forecasted the number of fatal RTCs from 10 years of data (i.e., January 2010 to February 2020) in Japan caused by speeding during the lockdown, which started in March 2020. Based on the results, during the second month of the lockdown (April 2020), there was a significant increase in the observed ratio of speed-related fatal RTCs to that of non-speed-related fatal RTCs compared with the forecasted ratio. The results indicated that drivers who continued driving during the lockdown were more likely to drive at higher speeds, which resulted in fatal RTCs. Several other studies also revealed similar trends in speeding behaviour and speeding-related RTCs during the lockdown period (Kaji et al., 2020; Lockwood et al., 2020; Paparella, 2020; Shilling & Waetjen, 2020). Katrakazas et al., 2020, studied the effect of the COVID-19 lockdown on driving behaviour with the help of a smartphone application in two different countries, i.e., Greece and Saudi Arabia. The results revealed that, compared with the normal situation before the COVID-19 pandemic, the trips were shortened, however, driving speed increased by 6%–11% with harsh accelerations and decelerations. Furthermore, during the two months of lockdown, mobile phone use while driving increased by 42%.

2.12 Road Safety and Public Transportation

According to numerous studies, a sustainable city cannot exist without a sustainable transportation infrastructure (Givoni & Rietveld, 2014). Such studies emphasise the importance of transportation in any city because it specifies the means of moving people and goods from one region to another. The enormous demand for urban transportation services illustrates how unsustainable transportation services contribute to environmental degradation by polluting the air, water, and soil. However, certain cities in the world have developed sustainable transport programs that are focused on increasing sustainability standards within the transport industry. Despite being one of the world's smallest countries, Qatar is considered a rising regional force in the Arabian Peninsula. Motor vehicles are the main mode of mobility in Qatar. In 2015, the population of Qatar was 2.3 million people, with almost 1.4 million automobiles (Furlan, 2019). Private cars dominate the travel habits of residents in affluent cities like Qatar, which boasts one of the highest per capita automobile ownership rates in the Middle East area (Al Mamun et al., 2021). Most people rely on private cars, and the number of private cars is rapidly expanding as the population grows. The population explosion comes with externalities like traffic congestion, air pollution, and road traffic crashes (RTC).

Further to this, one of the goals of Qatar's 2030 vision is to enhance Qatar’s road transport systems by providing a safer and more sustainable transportation system with efficient and seamless travel to reduce RTCs and their related fatalities and injuries. Qatar's road safety strategy, which runs from 2013 to 2022, has been so far successful in lowering the number of fatal crashes in the five years, 2013-2017, (Al Mamun et al., 2021). Despite a decrease in the number of fatal incidents over the last five years, the number of personal injuries and property damage caused by road crashes involving at least one car is still high in Qatar (Abou-Amouna et al., 2014). As a result, it is critical to have a better knowledge of the nature and characteristics of RTCs, recognizing several important elements influence the number of RTCs. Road conditions, traffic density, vehicle conditions, and human factors such as driver irresponsibility, aggressive driving, violation of traffic restrictions, and speeding are generally cited as leading causes of RTCs in the Gulf area (Ali et al., 1998). Because Qatar is a car-dependent nation, it is currently dealing with a rapidly expanding economy, activities, and population, which has led to an increase in demand for transportation.

This demand requires safe mobility, business accessibility, and minimal negative effects of transportation on the built, natural, and social environment. (Shaaban & Khalil, 2013). The Qatar National Traffic Safety Committee (NTSC) has proposed several transportation interventions, policies, schemes, and campaigns to promote road safety in Qatar since its formation in 2013.

The efficiency of any transportation system depends on the quality and condition of the infrastructure (Wang et al., 2020). In Doha, Qatar, public transportation emerged in 2004, when the business Mowasalat provided the first phases of a national bus system for public use (Shaaban and Khalil, 2013). Initially limited in scope, the system has gradually expanded to reduce the number of vehicles travelling through Doha (Qatar, 2000). The 2006 Asian Games preparations significantly improved the bus system. The official mode of transportation for the major event was the public bus system. According to Shaaban and Khalil, 2013, low-income users make up the majority of those who use the bus service. This scenario marred the service's reputation in the community and discouraged other demographic groups from using it. As a result, there is a low level of bus acceptance in Qatar. In 2004, Qatar established the KARWA bus and taxi service to suit the country's ongoing demand (Al Mamun et al., 2021). Al Mamun et al., 2021, assert that time reliability, safety, comfort, and privacy, rather than frequency, influence the decision to use the bus service. Al Mamun et al., 2021, link this to a variety of factors, such as insufficient supply to demand, unappealing stoppages, time reliability, longer wait times, convenience, privacy, and safety. Another issue in this area is people's aversion to public transportation due to their conservative religious beliefs. Accepting a new mode of transportation, particularly public transportation in this region, is fraught with uncertainty. To increase ridership and appeal to commuters, the public transport operator (Mowasalat (Karwa)) has been working to improve its services by replacing the fleet with modern buses equipped with current technology and upgrading their stops and stations.

In Qatar, the ex-pat community and Qatari natives often regard taxis as public transportation due to the low ridership of bus services and the dominance of private cars. Taxis dominate as the major mode of shared transport, and buses offer limited services (Belwal, 2017). The government of Qatar owns and operates the main taxi service (Karwa taxis), a metered taxi service in Doha. The taxi service officially began in 2004, with a fleet of 250 taxis, which increased to 1250 in 2011 (Shaaban & Kim, 2016a). Due to the rapid urbanisation and population growth in the past two decades, the Gulf State decided to diversify its transportation systems to sustainably accommodate the rising population and established Qatar Rail in 2011 (Eiraibe et al., 2016). Additionally, the NTSC formed to address the growing concerns about road traffic safety, and subsequently developed the Qatar National Traffic Safety Strategy (NTSS) to outline action plans to address the situation (National Traffic Safety Committee, 2012).

As part of plans to improve transportation, Qatar developed the Doha Metro system to meet transportation demand and enhance Qatar's readiness for the FIFA 2022 World Cup (Naser et al., 2020). The development of mass transit is part of the Qatar National Vision 2030 (QNV-2030) adopted by the government (Tan et al., 2014) and has been in operation since 2019 (AlKhereibi et al., 2021). The metro system in Doha connects the Doha Port, Hamad International Airport, the city's central business district, and all major stadia. The metro services currently run on three lines: the Red, Green, and Gold lines, but when completed, the metro system will consist of four lines: the Red, Green, Gold, and Blue lines, which span 300 km, serve 100 stations, and operate underground, ground-level, and above-ground rails as shown in Figure 2.9 (Nafi et al., 2021).

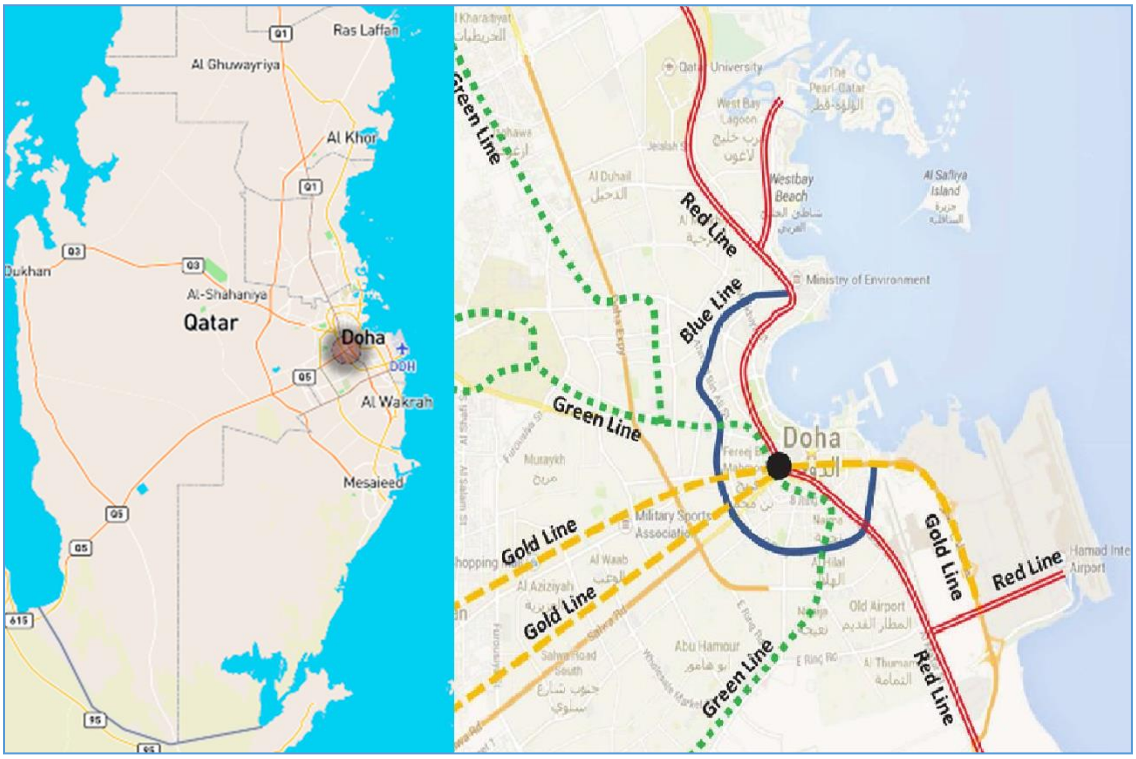


Figure 2.9 Qatar Metro Network

From Al Wakra in the south to Lusail in the north, the Red Line, also known as the Coast Line, extends for 40 km. This railway connects Hamad International Airport and the city centre. It covers 18 active stations, with Qatar University, Katara, and West Bay being the most notable. On this line, the Lusail QNB and Legtaifiya stations have tram and metro interchange stations (Al-Janahi et al., 2020), as well as stations connecting to the Green Line. From Al Riffa to Al Mansoura, the Green Line, commonly known as the Education Line, stretches 22 km east to west. Msheireb, Hamad Hospital, Qatar National Library, and Education City are among the 11 stations along the line (Fort et al., 2017). The Historic Line, also known as the Gold Line, stretches 14 km from Al Aziziya to Ras Bu Aboud, stopping at 11 stations, including Souq Waqif, Qatar National Museum, Sport City, and Al Aziziya. Finally, the Blue Line ("City Line") connects the West Bay and Airport City North regions along the main C-Ring Road in a 7.5-kilometre semi-circular route (Al-Thawadi et al., 2021b). Table 2.2 summarizes the important characteristics of the metro stations as of 2020. Regarding lines, it is worth saying that whereas only 1 line in West Bay served 1610 thousand users in 2020, the three lines in Msheireb served up to 3228 thousand users, and the two lines in Al Bidda served up to 2663 thousand users.

Table 2.2 Characteristics of the Train Station and Performance (Source: Qatar Rail)

Station 2020	Lines	Number of Lines	Users per Month in 2020 (Thousand)
Msheireb	Red, gold, green	3	3228
Souq. Waqif	Gold	1	908
Lusail	Red	1	361
Hamad Intl. Airport	Red	1	1744
West Bay	Red	1	1610
Corniche	Red	1	729
Hamad Hospital	Green	1	256
Al Bidda	Red, green	2	2663

Following the significant investments by the government of Qatar to upgrade the Gulf state's transportation infrastructure and services to modern standards, it is important to consider the influence of the upgraded transport systems, including the newly constructed Doha Metro, on road user satisfaction, perception of safety, and road safety in Qatar. As a result, this study aims to investigate whether the investment translates into users' safety and satisfaction, as well as a reduction in RTC fatalities and injuries.

2.13 Summary

According to the literature, most of the above-mentioned studies have focused on the impact of imposed restrictions on RTCs in specific cities and locations. A few have also investigated the severity of the RTCs. Additionally, most studies compared the RTCs during COVID-19 with a previous year, excluding data from other prior years. Even though the restrictions significantly reduced traffic volume, many drivers continued to use the less congested roads. This could potentially explain why various studies have observed instances of speeding and aggressive driving behaviour on the roads. The current research investigates the role of the National Road Safety Strategy in Qatar, which was not addressed previously. This area of investigation represents a gap in the literature not only in Qatar, but also in many other similar countries in the region. This research aims to increase awareness of its role and provide evidence of strategies designed to improve road safety, thereby reducing road traffic crashes and fatalities. This study goes one step ahead by investigating not only real-world road safety situations, but also the public and experts' perceptions about traffic safety and driving behaviour during the pandemic. To the best of our knowledge, we have not investigated drivers' perceptions and perspectives about road safety and driving behaviour during COVID-19 (i.e., reduced traffic volume). In addition, unlike many other countries, Qatar did not have a complete lockdown, allowing different activities to continue with limitations and restrictions. In accordance, Du et al., 2021, stated that the state of Qatar experienced a reduction in traffic demand ranging from 5% to more than 50% on May 24, 2020. Seat belt violations and mobile phone use while driving are common traffic violations in Qatar. Therefore, learning from the successes of countries in the Gulf region and worldwide, the Traffic Department at Qatar's Ministry of Interior has installed surveillance cameras on major roads in Qatar. The cameras are to monitor and enforce street security by compelling drivers to observe the land's driving laws, protect people's lives, and ensure the safety and security of all road users. In addition, the surveillance cameras and radars also monitor safety belt violations, mobile phone violations, speeding, and overtaking from the wrong side while driving. This is to ensure people fasten their seat belts when in a vehicle and curb mobile phone usage while driving (Sidi, 2021).

Therefore, investigating the actual traffic safety situation with drivers' perceptions would allow us to fill this research gap. Studying this particular case for Qatar would be interesting because of its diverse driving population and aggressive driving behaviour (Alhajyaseen et al., 2020; Almallah et al., 2020; Hussain et al., 2019, 2020; Soliman et al., 2018; Timmermans et al., 2019a, 2020). In summary, we believe that the findings of this case study can be helpful for relevant authorities to enhance COVID-19 and traffic-related policies (Section 8.2).

Chapter 3: Research Methodology

3.1 Introduction

In order to achieve the overall research objectives and address the research gaps discussed in previous chapters, this chapter discusses the research methodology (see Figure 1.3). This study presents five case studies aimed at assessing the impact of road safety management (RSM) interventions implemented through Qatar's National Traffic Safety Strategy (NTSS) on Qatar's road safety. In addition, this chapter serves to elucidate the strategies and techniques employed to collect and analyse data, ensuring rigour and reliability in the study's findings.

In Qatar, a developed nation with abundant resources, there is a need to incorporate multiple crucial stages to determine and create an adequate approach for evaluating traffic safety management. To guarantee accurate and thorough coverage, this is being done. This thesis presents a strategy that consists of the following:

1. Identify the Key Stakeholders: Identifying the key stakeholders (see Table 2.1) involved in traffic safety management is the first step in the methodology. In this research, the main stakeholders include government agencies, law enforcement, transportation departments, traffic engineers, road safety advocates, and community representatives. It is important to assess and integrate data from all stakeholders for the research to be realistic and representative of the case study.

2. Review Existing Data and Research: More than 200 research and scientific publications have been reviewed, and a thorough review of existing data, research studies, and reports related to traffic safety management in the country and beyond has been conducted. This includes examining crash statistics, traffic fatalities and injuries, road infrastructure assessments, enforcement efforts, and relevant policies and regulations. The data relevant to all factors were discussed in all case studies (Sections 4.2.2, 5.2.1, 6.3.1, 7.5, and 8.4.3).

3. Define research gaps, pinpoint research questions, establish objectives, and choose case studies that effectively address these gaps and objectives (see Figure 1.3). Determine the analysis and pinpoint the indicators for use in the analysis. The objectives and indicators include assessing the reduction in traffic fatalities, improving public transportation, enhancing enforcement measures, assessing pedestrian safety, increasing public awareness, and assessing

the transport system's performance under contagions and pandemics. Determine specific indicators, such as the following, to track progress towards these objectives.

- ❖ Number of traffic accidents, fatalities, and injuries
- ❖ Public awareness and acceptability of public transportation options
- ❖ Enforcement effectiveness (e.g., the traffic speed cameras, their effectiveness)
- ❖ Pedestrian safety and infrastructures
- ❖ Performance of the transport system under contagions and pandemics

4. Develop data collection and analysis methods: Determine the data collection and data analysis methods needed to gather and analyse the information on the identified indicators. This research includes surveys and interviews with stakeholders (see Appendix 1), crash reports and police records analysis (Section 4.2.3), surveys of the impacts of speed cameras (Section 6.3.2), pedestrian surveys, and accident statistics (Section 7.1).

5. Identify several specific case studies to represent some gap areas, set objectives, identify data collection, etc. In this research, we have identified five case studies (see Figure 1.3) that showcase the efforts Qatar has made to improve and enhance traffic safety management, as detailed in Chapters 4-8.

Pilot Test of the Methodology: Before the full-scale implementation of the methodology in this research, a pilot test of the methodology in a representative sample of locations around Qatar University premises has been chosen for pedestrian bridges and the installation of speed cameras on the intersections. The survey design and data collection approaches (see Appendix 1) have been refined to reflect on any of the experiences and feedback that were obtained from stakeholders. Other parts of the country have implemented the successful pilot study to enhance road safety management during July 2022 (Pedestrian Bridge planned 37 and completed 23 as per Ashghal's internal progress report 2022).

Please keep in mind that this study builds on and targets real-world case studies that already exist in Qatar. Therefore, the study aims to implement and evaluate the technique across the country, collecting data and conducting evaluations according to the established methodology. Even when the current study is over, it will continue to assess how well the technique captures pertinent data and accomplishes the intended goals on a regular basis. It intends to regularly review and improve the methodology, based on ongoing evaluation and feedback under Section 3.4 of the research approach, to address new issues and enhance the precision and applicability of the assessment process. Indicators, data collection techniques, and assessment tools will also be adjusted as needed.

3.2 Scope of the Research

Assessing the impact of Road safety management (RSM) systems on reducing RTIs, RTC-related deaths, and property damage covers a potentially wide field of research. To make this research more focused and manageable, the study was scoped based on two main dimensions presented in this section: the geographic area and the focus of the study.

3.3 Site Description

The study area is the state of Qatar. Qatar is one of the seven Arab states bordering the Arabian Gulf. The state is on the eastern coast of the Arabian Peninsula and comprises a few islands. The state of Qatar has a total area of 11,521 km^2, with a population of about 2.69 million as of November 2021, of which 28% are female and 72% are male. The median age in Qatar is 32.3 years. Figure 3.1 (Ministry of Development Planning and Statistics [MDPS], 2021) indicates in red that less than 15% of the geographic area contains more than 80–90% of the population. The population density in Qatar is 248 per Km^2 (643 people per mile^2). According to the data, the Ministry of Interior (MOI) recorded 1,328,973 active driving licenses in 2021.

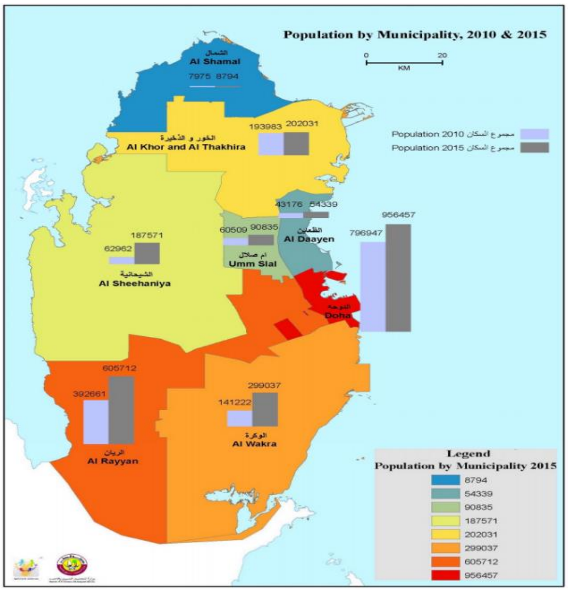


Figure 3.1 Map of the study area (Source: MDPS, Qatar)

Qatar has experienced very rapid development over the last few years, and it is now facing a major challenge due to the subsequent development of road traffic. It describes international public transport links that connect Qatar to Bahrain's neighbors via the proposed causeway, Saudi Arabia, and the U.A.E. Ideas for integrating the planned G.C.C. rail connection and the Maglev system between Qatar and Bahrain are being considered. A comprehensive set of corridors in the Greater Doha Area is selected to accommodate the future metropolitan public transport system. A Metro rail network of 166 km track length is the backbone of the metropolitan public transport system, providing infrastructure for six Metro lines with a total of 212 km route length. The system's primary goal is to link demand hubs within the Greater Doha Area.

The connective links serving the western and northern sub-centres of the Greater Doha Area will host bus rapid transit services. The system will gradually come to life as both Qatar and the Greater Doha Area develop, along with the resulting passenger volumes. These elements' design ensures maximum flexibility to accommodate various network concepts and adapt to future land use development. The whole system concept allows for gradual, phased implementation and minimises the number of different systems. A feeder network based on bus services, complemented by developer-run systems and water transport, is to provide area coverage for all zones with relevant metropolitan activity. A completely separate guideway at grade, elevated, or below-ground level without any interaction with private transport is essential for ensuring a high speed and reliable operation of the rail-based system. According to experiences around the world, such an independent rail-based system enjoys an important psychological advantage: a so-called ‘rail bonus’. Potential passengers have a greater inclination to use such a system, when in competition with a road-based public transport system. The transport model shows passenger volumes per link and direction between 50,000 and 170,000 passengers per day, i.e., the peak hour values range between 5,000 and 17,000 pphpd (passengers per hour in peak direction). Passenger volumes per route, direction, and link are expected to range from 30,000 to 90,000 per day. For the Ultimate Capacity scenario, there are passenger volumes modelled between 90,000 and 260,000 passengers per link and direction per day. The final part of this report includes a description of intermodal services like park & ride, drop-off, pick-up & ride, and bike & ride to explore ways to enhance the desired integration of private and public transport systems.

3.4 Theoretical Frameworks

Road traffic crashes (RTCs) are defined as a collision or crash involving one or more vehicles that take place on any public roads or when a moving vehicle on a roadway collides with another vehicle or object, usually resulting in slight injury, severe injury, fatality, and property damage (Harith et al., 2019). According to the World Health Organization (WHO), road traffic crashes are a major cause of death among all age groups and the leading cause of death for children and young persons aged 5–29 years. About 1.35 million people die from road traffic crashes, and about 20–50 million are injured annually (World Health Organization, 2018).

RTC was a leading cause of avoidable death in Qatar in 2010 (Consunji et al., 2018). Currently, Qatar has been performing averagely better compared to the road fatality rate of its low, middle, and high-income neighbors and the global average (World Health Organization, 2018). Available data suggest that Qatar continues to observe a decreasing trend of RTC fatalities since 2010 (Consunji et al., 2018; Timmermans et al., 2019). Analysts believe the road safety strategy 2013–2022 of Qatar's National Traffic Safety Committee (NTSC), which aims to prevent severe injuries or fatalities from RTCs, could explain this observation. Despite the decrease in fatal crashes in recent years, the frequency of property damage and injuries from RTCs is on the rise (National Traffic Safety Committee, 2012, 2018; Consunji et al., 2018). Literature suggests that RTCs involving young drivers between the ages of 17 and 25 are much higher than older drivers (Rowe et al., 2016). In Qatar, the majority of RTC victims are young individuals aged between 21 and 30. Simultaneously, we observed a disproportional representation of males in both RTC fatalities and severe injuries. As a result, it is important to understand the causes of the reduction in RTCs, as well as the nature and severity of the RTCs. This study seeks to achieve this by investigating the impact of some of the measures implemented to reduce the occurrence and mitigate the impact and severity of RTCs.

In general, it can be argued that traffic offences or violations such as failure to comply with traffic signs, speeding, illegal use of mobile phones while driving, tailgating, drunk driving, etc., are among the causes of RTCs in most countries around the globe, including Qatar. Therefore, measures implemented to deter the occurrence of such violations will have an impact on the number and nature of RTCs.

3.5 Research Approach

The research paradigm is scientific practice based on philosophies and assumptions about the world and the nature of knowledge" (Hussey and Hussey, 1997, p. 47). Thus, our belief system about how the real world operates closely aligns with a research paradigm. The researcher's chosen research paradigm, along with the availability of resources for the research work, primarily dictates the type of methodology for a study (Sam, 2011). Since this research aims to assess the effectiveness of road safety management (RSM) in Qatar and propose measures to improve the existing RSM systems, it proposes to examine the road safety strategies, action plans, and policies of the study area (Qatar). Road Safety Management (RSM) is significant in curbing road traffic offences and reducing the occurrence and severity of RTCS. In a more general term, governments and sector agencies develop RSM plans by developing strategic plans, and interventions and setting road safety targets to achieve road safety-specific goals. For example, to address the alarming health hazards of RTCs in Qatar, the government, through Resolution Number 33/2010, approved the establishment of the National Traffic Safety Committee (NTSC) as a commitment to improving the road safety situation in Qatar.

Consequently, Qatar embarked on comprehensive safety and awareness campaigns and more aggressive law enforcement to minimise the occurrence of road traffic crashes, fatalities, and the severity of injuries (National Traffic Safety Committee, 2013). These interventions were made up of both soft and hard RSM measures. The soft measures involved public awareness campaigns in print and electronic media through the implementation of road safety education programs as well as road safety training programs to educate the public to observe road safety rules and regulations. Similarly, the hard RSM measures included stricter and punitive interventions such as traffic tickets, fines, seat belt use laws, and surveillance cameras to ensure road discipline. It can discuss the Fear Appeal Theory: the Drive Model, and the Reinforcement Theory, which underpin the application of the soft and hard RSM strategies. When a person experiences fear, they tend to avoid the behaviour that triggers it. Thus, the right level of fear element is required when delivering a message in order to obtain the maximum deterrent in behaviour (Carey, McDermott, & Sarma, 2013; Shen & Dillard, 2014). Secondly, elements of reinforcement and punishment, akin to the carrots and sticks analogy, can influence individual behaviour. Negative reinforcement or sanctions are applied to increase the likelihood of an individual performing the desired/targeted behaviour. Applying these concepts to elucidate the suggested research framework, scrutinizing the actions taken by the NTSS to decrease car accidents, fatalities, and severe injuries, along with the categories of accidents and offences that transpired in that time frame, taking into account their frequency, severity, and regularity, it is significant to establish whether the implementation of specific soft and hard measures, such as installing CCTV and speed cameras and developing PT infrastructure and services, yielded the expected results according to the Fear Appeal Theory: the Drive Model, and the Reinforcement Theory.

This study, therefore, investigates the relationship between traffic violations and RTC occurrence and nature. Additionally, it examines the influence of road safety management interventions (such as the installation of CCTV and speed cameras and the development of modern PT infrastructure and services) on reducing RTC fatalities and injuries. Consequently, there is data on road traffic crashes (RTCs), road traffic injuries (RTIs) and deaths. It will also collect and analyse RTC data, opinions, and perceptions from transport system users. Therefore, a mixed-method approach involving both quantitative and qualitative methods was adopted for the study.

3.6 Research Framework

The research framework, Figure 3.2, outlines the structure of the research plan (Amiri, Akanbi and Fazeldehkordi, 2014; Mills, Gabrielle Durepos, 2010). Research begins with the identification of a problem or a phenomenon (Sahay, 2022; Garg, 2016). The phenomenon the study identified was the impact of the Qatar National Traffic Safety Strategy (NTSS) on road traffic crashes (RTCs). This has been based on two components; firstly, the literature review, which identified the main gaps and opportunities for road safety schemes that have been discussed in the literature. Secondly, it designed five case studies to evaluate the effects of various traffic management schemes on road safety in Qatar. The data has been collected to include:

1. To identify the local gaps and opportunities in road safety systems in Qatar, we conducted interviews with many stakeholders (see Appendix 1) who are involved in road safety and road safety analysis.
2. Data obtained from various sources that include the progression of accidents in the State of Qatar over the last two decades, as discussed in Section 2.2.

3. Design five case studies (see Figure 1.3) to assess the impacts of traffic management schemes that have been adopted in Qatar on road safety and accident progression in the State.
4. Analyse the data and discuss the results (Sections 4.3, 5.3, 6.4, 7.8 and 8.5)
5. Draw conclusions from the analysis (Sections 4.4, 5.4, 6.5, 7.9, and 8.7)

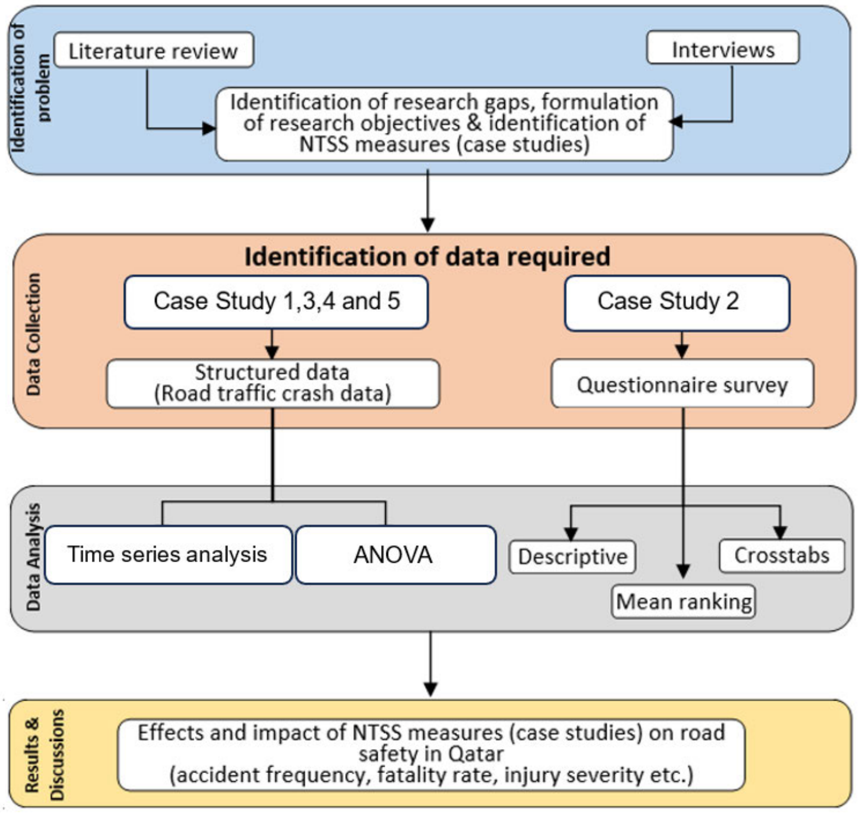


Figure 3.2 General Framework

After identifying the problem, literature related to the phenomenon (Marvasti, 2018; Garg, 2016) was utilized to identify research gaps or facts about the phenomenon that are yet to be explored (Anbazu, 2017). The research gaps were then developed into specific study objectives (Sahay, 2022; Garg, 2016). Then, the identification of the data required to achieve the specific research objectives followed. Afterwards, the data sources, collection, and processing approaches were identified. This led to data analysis and discussion before moving to conclusions and recommendations on the specific objectives. The five case studies (see Figure 1.3) that have been designed in this study are:

Case Study 1: Road Safety in Qatar (Chapter 4)

Exploratory analysis (Case Study 1) aims to investigate road traffic crashes (RTCs) in the state of Qatar between 2010 and 2020, taking into account the shortage of empirical evidence regarding the impact of improved transport infrastructure and services on road safety in Qatar. The investigation will focus on RTC occurrences, as well as RTCs that result in fatalities and severe and minor injuries, in order to evaluate the effectiveness of the NTSS's initiatives to reduce RTCs and the impact of the RTC strategy.

Case Study 2: The effects of Public Transport (PT) infrastructure and services on road safety in Qatar (Chapter 5)

In this chapter, the descriptive analysis aims to investigate the effectiveness of specific Road Safety Management interventions, in this case, the provision of public transport infrastructure and services, in reducing road traffic crashes, fatalities, and injuries in Qatar. This is investigated in terms of the perceived effects of Public Transport infrastructure and services on road safety in Qatar.

Case Study 3: The effectiveness of CCTV/speed cameras in Qatar (Chapter 6)

In this case study, the explanatory analysis aims to investigate the impact of the speed cameras installed on some major roads in Qatar on road traffic speed violations and the number of traffic crashes through a before and after comparison of crash frequencies and speed tickets or sanctions.

Case Study 4: Impacts of pedestrian signals on traffic safety in Qatar (Chapter 7)

This study employs Analysis of variance (ANOVA) and descriptive analysis that involve the assessment and the adequacy of pedestrian signal timings in the State of Qatar while focusing on clearance timing, for safe pedestrian crossings. The analysis in this case study is performed using empirical observations at several signalized intersections in Doha city.

Case Study 5: Road safety system in Qatar and impact of (COVID) pandemic (Chapter 8)

Using attitudinal and descriptive analysis, assess how the NRTC manages road safety during pandemics, notably COVID-19. This case study examines the impact of COVID-19 on road safety status and explores public and road safety experts' opinions of pedestrian signal settings and their implementation in traffic safety analysis in the State of Qatar.

3.7 Data Collection

The research used both primary and secondary data. The study primarily relied on secondary data on road traffic crashes from the Traffic Department in the Ministry of Interior (MOI), which covered the period between 2010 and 2020 (see Table 4.1) for three case studies (case study 1, case study 3, and case study 4) discussed in chapters 4, 6, and 7. The period was selected to reveal the trend of crashes over time and to account for changes in infrastructure level (Hadi et al., 1995). In Case Study 1, we decomposed the monthly and yearly frequency of road traffic violations and road traffic crashes into different categories, including slight injury, severe injury, fatality, and property damage (see Table 4.1). Aspects of the data also include the characteristics of the victims, such as driver, passenger, and pedestrian, as well as the demographics of the victims, such as age and gender. The time series data (Figures 4.2 and 4.3) of the total number of RTCS recorded monthly with the corresponding number of casualties and severely injured, respectively, The trend of population, vehicular population, and road traffic crashes between 1983 and 2020 (see Table 4.2) indicates that the number of injuries and fatalities per 100,000 of the population resulting from RTCs has been declining since 2000.

The data in case study 3 comprised exploratory descriptive statistics (see Table 6.2). The number of minor injuries showed more variation in seven years than the number of fatal crashes. Similarly, among the victim category, there is more variation in the number of passengers injured during the six years as compared to pedestrians and drivers.

The data in case study 4 comprised an analysis of variance (see Table 7.6) to understand whether there was a there was a significant difference in traffic violations for the three years, 2019-2021. A one-way ANOVA was performed. It compares which of the three years recorded significantly different numbers of violations.

Additionally, a questionnaire survey (see Appendix 1) of residents in Doha randomly recruited for this study revealed preference data from users of the transport system. The questionnaire was designed to collect participants' opinions regarding the level of transport infrastructure, public transport service quality, and the perceived level of safety of the public transport system. The intercept survey requires brevity due to the short contact time between data collectors and respondents. Relatively speaking, the survey instrument had fewer questions, which satisfied the requirement for brevity. Therefore, considering the research objective of case study two (the effects of Public Transport infrastructure and services on road safety in Qatar) and the fact that respondents were required to answer relatively few questions, the intercept questionnaire survey was considered most suitable for administering the survey instrument in the study.

For an effective and efficient intercept survey and reducing sampling biases, the recommendation of Richardson et al., 1995, for planning and conducting travel surveys was adopted in this study. The steps are as follows:

a. definition and clarification of the survey objectives
b. identification of the population and sample
c. identification of the appropriate survey methods
d. development of a survey plan
e. questionnaire design
f. recruitment and training of surveyors
g. conducting pre-test of questionnaires
h. conducting the survey
i. processing and analysing the data and
j. reporting the results

3.8 Sample Size Requirement

There are several methods for estimating the sample size requirements for a study. However, several researchers have proposed a simple rule of thumb for determining the minimum sample size for a survey (Arbuckle, 2017; Kline, 2011). These researchers proposed a threshold above 200 cases to account for model complexity (Kline, 2011). Therefore, they recommended using a minimum of 300 cases. Richardson et al., 1995, recommend 500 cases to improve the generalizability of the estimates, but we adopt a threshold of 300 cases for the questionnaire survey.

3.9 Data Analysis

Data analysis involves actions and methods performed on processed data that help describe facts, develop explanations, detect patterns and relationships (Karma, 1999), and interpret results (Marvasti, 2018). Since the data obtained from the Traffic Department were de-identified, ethics approval was not required (Thompson et al., 2013). To meet the study goals, the issues that were discussed above, and the fact that the research goals were based on facts, we used statistical analysis based on the analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) theoretical frameworks to plan the research, collect data, and analyse it. Below is a brief discussion about the statistical tests or analyses conducted on the sample data to achieve the specific research objectives.

3.9.1 The Analysis of Variance (ANOVA)

This study proposes an Analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) techniques as the two main statistical approaches to analyzing the data for this study (case study 4, sections 7.7.3, 7.7.5, 7.7.6, and 7.7.7). Ronald Fisher developed ANOVA, also known as the Fisher analysis of variance, in 1918 to expand the t and z tests (McHugh, 2011). use the one-way analysis of variance (see Tables 7.4, 7.5, and 7.6) to identify any statistically significant differences between the means of three or more independent (unrelated) groups. The rationale for using ANOVA and MANOVA stems from the fact that in this type of analysis, a variable's monthly or yearly frequency (i.e., traffic violations, RTCs, RTIs, fatalities, property damage, etc.) is measured to determine the effect of an RSM intervention. That was precisely the main aim of this study: to assess the effectiveness of road safety management (RSM) interventions in Qatar over some time. Therefore, repeated-measures ANOVA and MANOVA were considered the appropriate statistical methods for this study. In this current study, only ANOVA analysis has been performed.

3.9.2 Time Series Analysis

To identify patterns and trends and forecast future values, time series analysis involves examining data gathered over multiple time intervals. State-space models, transfer function-noise models, autoregressive integrated moving average models, and other statistical techniques for modelling and analyzing time-dependent data are included. Identification of basic trends and future value prediction are made possible by these methods, which take temporal relationships and fluctuations into consideration (Zeger, Irizarry, and Peng, 2006). A fundamental assumption in any time series analysis/modelling (Sections 4.2.3, 4.3.2, and 4.3.3) is that some aspects of the past pattern will continue to remain in the future (Ramasubramanian, 2014). Four types of time series components can be distinguished. They are horizontal, trending, cyclic, and seasonal (Ramasubramanian, 2014). When seasonal factors influence a time series and it recurs regularly, it is considered seasonal.

3.10 Summary

Research methodology refers to the procedures used to identify, select, process, and analyse information about a phenomenon or topic. This chapter discussed all the methods that were utilized to address or investigate the research objectives. Below is a list of highlights from this chapter.

a. A simple random sampling method was considered appropriate for the study after a careful review of the strengths and weaknesses of the most popular sampling techniques.
b. A sample size of 300 was found adequate and recommended for the questionnaire survey.
c. Intercept survey was deemed suitable for administering the questionnaire survey.
d. Computer-assisted survey method (using Google form on a tablet computer or iPad) is adopted for the study.
e. Statistical analysis methods are also presented and discussed in the chapter, including time series analysis, analysis of variance etc.

The next chapter presents one case study from the research.

Chapter 4: Cast Study 1: Impact of Road Safety Management Systems on Road Safety and Road Traffic Crashes, Fatalities and Injuries in Qatar

4.1 Introduction

Road traffic crashes (RTC) were the 8th primary cause of death globally and the leading cause of death of children and young adults in 2016, according to the (World Health Organization, 2018). In the same year, 1.35 million deaths and about 50 million injuries and disabilities globally were attributed to road traffic crashes, representing an increase of 8% from the 2013 reported fatalities globally of 1.25 million (World Health Organization, 2015a, 2018). In 2016, the Eastern Mediterranean Region recorded the third highest road traffic fatality rate in the world, 18.0 per 100,000 population, after the regions of Africa and South-East Asia. Figure 2.5 shows the improvement from 2013 and 2015 reported deaths per 100,000 populations of 21.3 and 19.9, respectively (World Health Organization, 2013, 2015b, 2018). Notwithstanding, contrary to the general observation of decreasing road fatalities with increasing wealth (Reich & Nantulya, 2002), the road traffic fatality rate of high-income countries in the region exceeds the rate of the regional average and more than doubles the global average for high-income countries (Organization, 2013; World Health Organization, 2015b). Similarly, RTC is a leading cause of avoidable death in Qatar (Consunji et al., 2018). Qatar has been performing averagely better compared to the road fatality rate of its low, middle, and high-income neighbours and the global average (World Health Organization, 2018). Qatar has observed a decreasing trend of RTC fatalities since 2010 (Consunji et al., 2018; Timmermans et al., 2019). Analysts credit the observed downward trend in the death rate to the work of the Qatar National Traffic Safety Committee (NTSC). However, despite a successful reduction in fatal crashes, the rate of RTCs resulting in severe injuries and property damage has increased over the same period (Timmermans et al., 2019). The National Traffic Safety Committee (NTSC) launched the National Traffic Safety Strategy (NTSS) in January 2013 as a commitment to reduce fatalities and injuries resulting from RTCs from 2013 to 2022. The state of Qatar is implementing various specified engineering measures and conducting awareness campaigns to reduce the frequency and severity of RTCs and their associated fatalities. According to the Qatar Action Plan 2018-2022, Road Safety Auditing (RSA) systems are one of the areas requiring more attention in addressing road safety in Qatar (National Traffic Safety Committee, 2018). There is limited scientific literature on the impact, if any, of the measures introduced by the NTSS on road safety in Qatar seven years after its establishment. As a result, it is critical to investigate the RSA procedures in Qatar and identify their impact on RTCs there.

This chapter presents Case Study 1 of the research study (see Figure 1.3). It is investigating the measures and policies introduced or implemented to improve Qatar's road safety situation. The main objective of this case study is to examine the impact of the RSA procedures and the Qatar National Traffic Safety Strategy in reducing the occurrence of RTCs, resulting in fatalities and severe and minor injuries (Section 4.3.2). In addition, this chapter includes data collection methods (Section 4.2.2) that encompass various sources, ensuring comprehensive coverage. Statistical analysis techniques (Section 4.2.3) are employed to discern patterns and correlations. Descriptive analysis (Section 4.3.1) provides a nuanced understanding of road traffic crash (RTC) occurrences. Furthermore, the study delves into the investigation of deaths within a 30-day period post-motor vehicle injury (Section 4.3.3), shedding light on critical aspects of road safety management.

4.2 Methodology

4.2.1 Study Area

Qatar is one of the seven Arab states bordering the Arabian Gulf. The state is located on the eastern coast of the Arabian Peninsula and comprises a few islands, as shown in Figure 4.1. The state of Qatar had a population of about 2.74 million as of August 2020 and covered an area of 11, 521 Km^2 (Planning and Statistics Authority, 2020). More than 50% of Qatar's population lives in Doha; the city is the state's administrative capital, commercial or financial hub, and educational and cultural hub. Qatar has a dry, subtropical desert climate with low annual rainfall and hot and humid summers. More than 80% of Qatar's population lives in the urban area, and about 15% of Qatar's geographic area (Timmermans et al., 2019).

4.2.2 Data

This study analyses twelve (12) years of data on recorded road traffic crashes, fatalities, and deaths spanning the period between 2008 and 2020. The study relied on the monthly recorded road traffic crashes and violation data from the Traffic Department in Qatar's MOI. This data comprised the frequency of RTCs with different levels of severity (slight injury, severe injury, and fatality), different victim types (driver, passenger, and pedestrian), and recorded RTC causes, as well as the number of tickets issued for traffic speed violations.

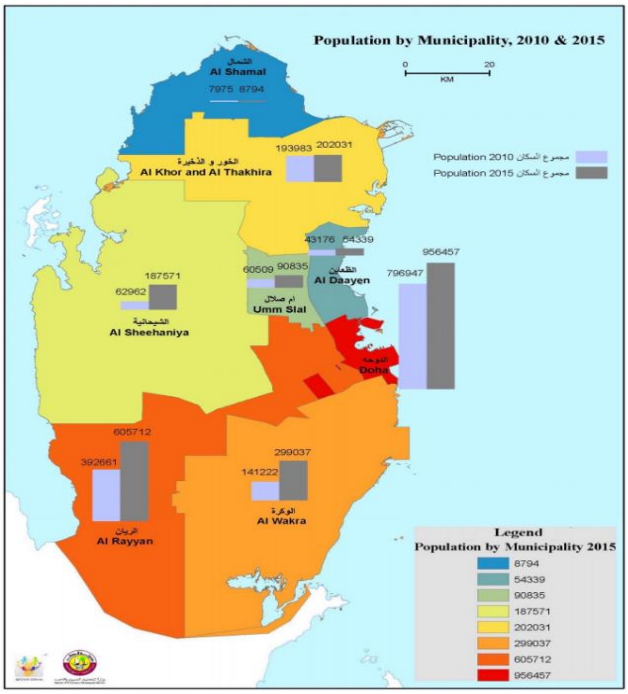


Figure 4.1 Map of Qatar (Source: Ministry of Development Planning)

4.2.3 Statistical Analysis

Statistical and descriptive data analysis is conducted on the time series data obtained from the MOI to investigate the relationship between the frequency, nature, and level of severity of the RTCs. For this analysis, the monthly RTC rates from 2008 to 2020 will be classified into fatalities, severe injuries, and minor injuries, as well as the nature of the RTC leading to minor/severe injury and fatality, and the different RTC causes will be evaluated using descriptive analysis. This study investigates the relationship between speed tickets issued for road traffic speed limit violations and the frequency of crashes, fatalities, and injury severity before and after the establishment of the NTSS in 2013. Using standard deviations and student t-tests, Additionally, the study applies chi-square tests to explore whether the measures implemented by the NTSS have had any positive impact on the frequency, nature, and level of severity of road traffic crashes between 2013 and 2020. Similarly, the study uses the student t-test to determine the significance of the differences between the pre-2013 and post-2013 accident data at a 95% confidence level.

4.3 Results and Discussions

4.3.1 Descriptive Analysis

Table 4.1 below presents the description of the victims of fatal and severe injury RTCs in Qatar between 2010 and 2020 with regard to the gender, road user type (i.e., driver, passenger, or pedestrian), and age of the RTC victim. Similar to the findings in Timmermans et al., 2019, the results show that, compared with females, males dominate both the fatal and severe injury RTCs over all the years. The higher number of male drivers and male foreign workers in Qatar explains the observation. According to Soliman et al., 2018, women are less likely to violate traffic rules and, consequently, are less likely to be involved in a crash.

Table 4.1 Descriptive Analysis of RTC Victims

			Year																					
			2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020	
RTC severity	**Victim description**		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Fatal RTC	Gender	Male	220	96.5	186	90.7	184	90.2	220	93.6	207	90.8	199	87.7	169	94.9	170	96	158	94	141	91.6	126	91.3
		Female	8	3.5	19	9.3	20	9.8	15	6.4	21	9.2	28	12.3	9	5.1	7	4	10	6	13	8.4	12	8.7
	Road user type	Driver	91	39.9	83	40.5	73	35.8	107	45.5	93	40.8	92	40.5	66	37.1	80	45.2	81	48.2	70	45.5	65	47.1
		Passenger	63	27.6	62	30.2	76	37.3	72	30.6	72	31.6	69	30.4	55	30.9	41	23.2	41	24.4	40	26	27	19.6
		Pedestrian	74	32.5	60	29.3	55	27.0	56	23.8	63	27.6	66	29.1	57	32.0	56	31.6	46	27.4	44	28.6	46	33.3
	Age	0-10	6	2.6	6	2.9	5	2.5	8	3.4	13	5.7	11	4.8	5	2.8	4	2.3	4	2.4	9	5.8	1	0.7
		11-20	31	13.6	30	14.6	38	18.6	60	25.5	35	15.4	39	17.2	20	11.2	29	16.4	31	18.5	22	14.3	16	11.6
		21-30	65	28.5	61	29.8	57	27.9	71	30.2	66	28.9	72	31.7	71	39.9	55	31.1	51	30.4	38	24.7	43	31.2
		31-40	54	23.7	50	24.4	52	25.5	53	22.6	51	22.4	35	15.4	48	27	49	27.7	39	23.2	36	23.4	41	29.7
		Above 41	72	31.6	58	28.3	52	25.5	43	18.3	63	27.6	70	30.8	34	19.1	40	22.6	43	25.6	49	31.8	37	26.8
Severe injury	Gender	Male	517	92.7	525	89.9	555	91.3	592	91.1	622	89.6	625	90.2	774	88.9	657	88.7	624	91.2	680	87.4	517	90.4
		Female	41	7.3	59	10.1	53	8.7	58	8.9	72	10.4	68	9.8	97	11.1	84	11.3	60	8.8	98	12.6	55	9.6
	Road user type	Driver	242	43.4	231	39.6	278	45.7	267	41.1	310	44.7	310	44.7	378	43.4	340	45.9	338	49.4	371	47.7	317	55.4
		Passenger	184	33.0	202	34.6	173	28.5	215	33.1	217	31.3	192	27.7	291	33.4	228	30.8	202	29.5	232	29.8	149	26
		Pedestrian	132	23.7	151	25.9	157	25.8	168	25.8	167	24.1	191	27.6	202	23.2	173	23.3	144	21.1	175	22.5	106	18.5

While the results show a general reduction in victim numbers for both severe injury and fatal RTCs, the results further indicate that the likelihood of drivers becoming victims is higher in both fatal and severe injury RTCs compared to other road users. The results also revealed that from 2011 to 2020 and from 2011 to 2015, there were more recorded cases of severe injuries and fatal RTCs involving passengers than pedestrians. However, between 2016 and 2020, there were more recorded pedestrian deaths than passenger deaths. The measures implemented by the Qatar National Traffic Safety Strategy (NTSS) appeared effective in reducing RTC-related fatalities and injury severity between 2010 and 2020. However, the increasing proportion of pedestrian fatalities resulting from RTCs between 2016 and 2020 suggests that protecting pedestrians is less effective. Hence, there is a need for further investigation and additional measures to ensure pedestrian safety. Additionally, it was found that by comparing the age profiles of victims of RTCs fatalities for 0–10 years, 11–20 years, 20–30 years, 31–40 years, and above 40 years, victims of RTCs fatalities are more likely to be young people between the ages of 20–30 years.

4.3.2 RTC Frequency and Level of Severity

This section assesses the trend and severity of RTCs between 2015 and 2020. Figures 4.2 and 4.3 present the time series data of the total number of RTCS recorded monthly with the corresponding number of casualties and severely injured, respectively. Both graphs display the monthly recorded RTC frequencies in blue, and the fatalities and severely injured in brown. The yellow line on both time series plots shows the calculated central moving average (CMA) for the RTC fatality and severe injury. Both figures observe a general reduction in the number of recorded RTCs over the period. The time series plot in Figure 4.2 for RTC resulting in fatalities shows a downward trend in the recorded RTC frequency after 2015, as evident from the linear trend line (dotted yellow line). The observed downward trend could be attributed to the measures implemented by the Qatar National Traffic Safety Strategy.

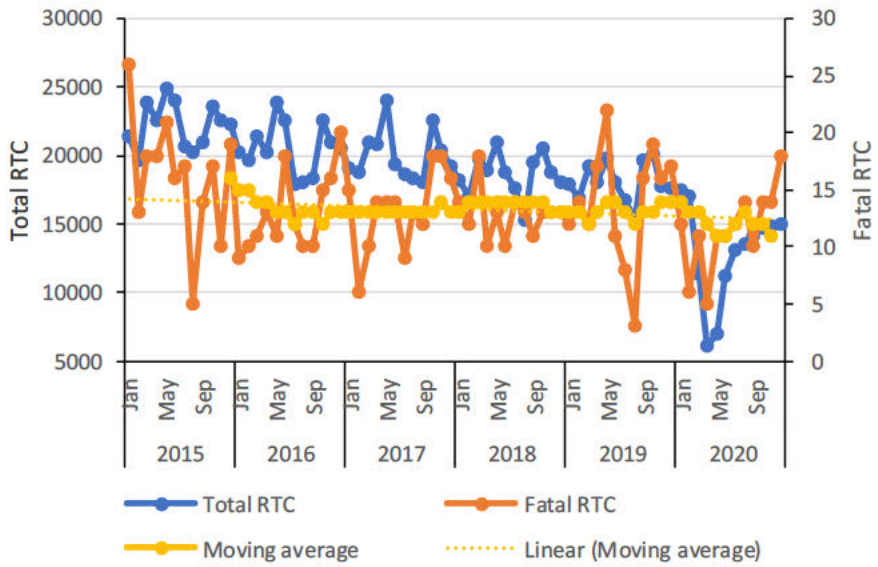


Figure 4.2 RTC frequency and fatality

Similarly, Figure 4.3 compares the total monthly recorded RTCs with the monthly recorded RTCs resulting in severe injuries. Similar to the observation in Figure 4.2 above, the plot indicates that the average number of severe injuries resulting from RTCs is decreasing. The aforementioned observation could potentially showcase the beneficial effects of the 2013 implementation of the Qatar National Traffic Safety Strategy, which effectively decreased the frequency of RTC fatalities and the severity of injuries. Additionally, Figure 4.4 provides an overview of the total yearly recorded RTC occurrence compared to RTCs resulting in deaths and severe injury. As presented above, results over the past 11 years show similar decreasing trends for RTC fatalities.

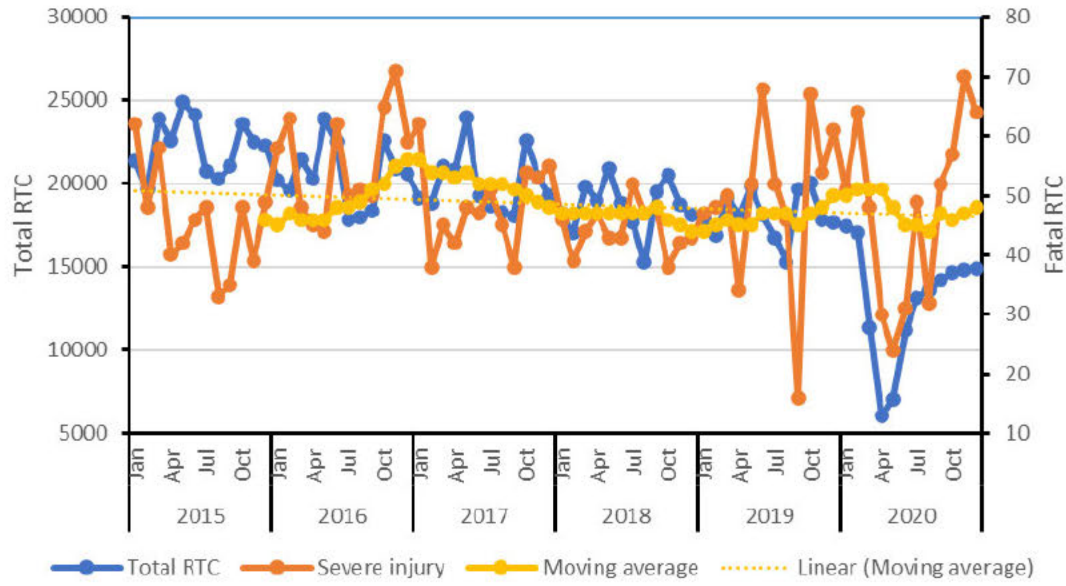


Figure 4.3 RTC frequency and severe injury

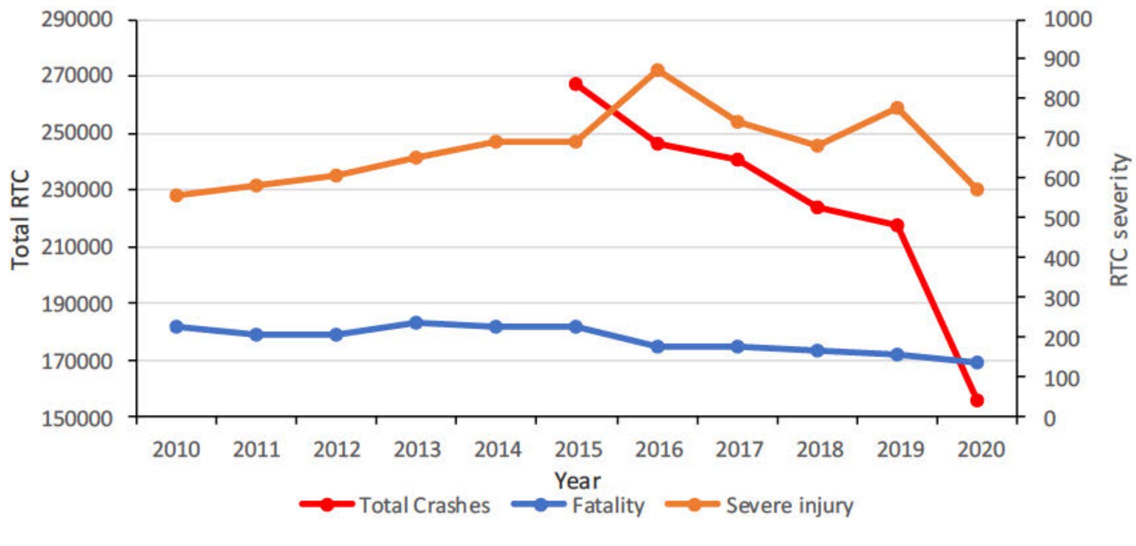


Figure 4.4 Yearly RTC severity

RTCs resulting in severe injuries, however, show a rising trend between 2010 and 2016 and a decreasing trend from 2016 to 2020. This is clear evidence of the Qatar NTSS's positive results. Figure 4.5 shows a rising trend for RTCs resulting in minor injuries, despite a reduction in

RTCs related to both fatalities and severe injuries in 2016. Although significant progress has been made in reducing the occurrence of RTCs and RTCs leading to fatalities and severe injuries, the observation in Figure 4.4 emphasises the need to focus particularly on the occurrence of minor injury RTCs and their causes.

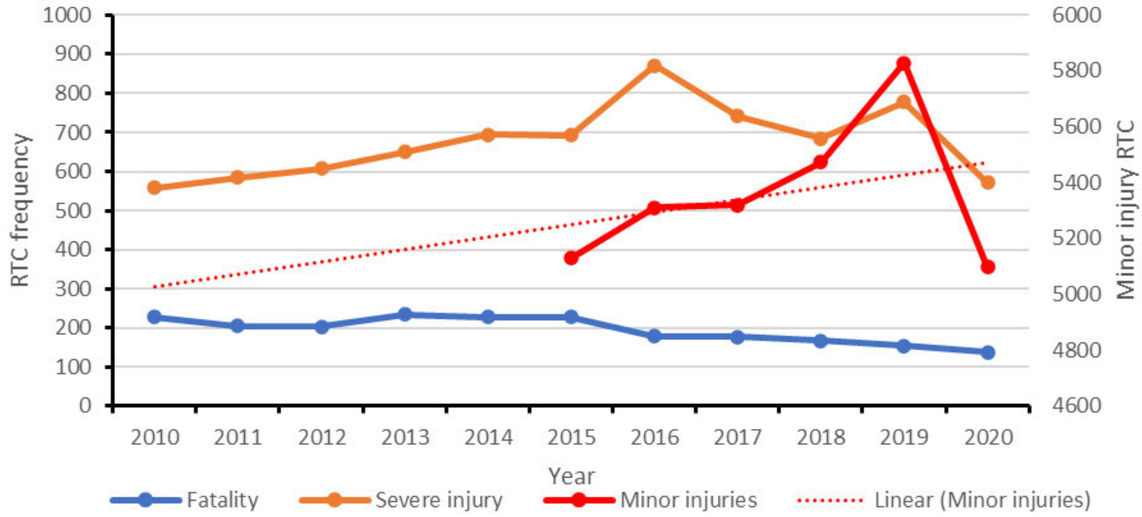


Figure 4.5 Yearly minor injury RTC

4.3.3 Investigation of the Deaths within a 30-day Period after a Motor Vehicle Injury

The state of Qatar has an area of 11,437 km^2, with a population of about 2.88 million as of December 2020, of which 14% are native Qataris and 86% are foreigners. Cities house more than 80–90% of the population. This case study also relied on yearly RTC data collected and stored by the Ministry of Interior's Traffic Department from 1983 to 2020. We considered any death that occurred within 30 days following a motor vehicle injury as the result of that injury. This category includes drivers, passengers, and occupants of trucks and buses, as well as pedestrians and bicyclists who have been injured by motor vehicles. In addition to motor-vehicle-associated deaths, we also recorded non-fatal injuries classified as severe (requiring hospitalization) or mild (not requiring hospitalization). The traffic department provided information on the number of traffic violations issued annually. We used means, standard deviations, and student t-tests to compare the frequency of RTCs before and after the National Traffic Safety Committee.

During the study period, the overall population of Qatar increased from 0.3 million in 1983 to 2.88 million in 2022. Similarly, the vehicular population increased from 0.12 million vehicles in 1983 to 1.7 million vehicles in 2020. The objective of this study is to assess the impact of the National Road Safety Action Plan, 2013-2022, and the Qatar Bespoke Safe System on RTI fatalities, and injury reduction. Table 4.2 shows the population, vehicular population, and road traffic crash trends from 1983 to 2020.

Table 4.2 Trend of Road Traffic Accidents, Fatalities and Injuries in Qatar, 1983-2020

Description	Year				
	1983	1993	2000	2010	2020
Population	300,279	464,009	578,470	1,856,329	2,881,060
Registered motor vehicles	119,144	205,852	303,245	761,049	1,701,346
Motorization level (vehicles/1000 population)	396.8	443.6	524.2	410.0	590.5
Accidents	32,382	41,615	52,160		155,630
Accidents over registered vehicles (%)	27.2	20.2	17.2	-	9.15
Injuries	1,560	1,472	1,130	483	595
Injuries per 100,000 population	519.5	317.2	195.3	26.02	20.65
Fatalities	115	84	85	228	138
Fatalities per 100,000 population	38.2	18.1	14.7	12.30	4.80

Table 4.2 shows the trend of RTAs, fatalities, and injuries from 1983 to 2020. In the last two decades, 2000 to 2020, the population of Qatar increased by 386%, and the number of registered vehicles in Qatar increased by 461% during the same period. The number of accidents per registered vehicle declined from 17% in 2000 to 9% in 2020. A similar decreasing trend is observed for injuries per 100,000 population between 2000 and 2020. RTC occurrence was observed to rise by 198% between 2000 and 2020 but declined by 61% between 2010 and 2020. Despite the 198% increase in RTCs between 2000 and 2020, the rate of road traffic fatalities and injuries per 100,000 population decreased by 67% and 89%, respectively. It is obvious from Table 4.2 that the number of injuries and fatalities per 100,000 of the population resulting from RTCs has been declining since 2000. Similarly, Figure 4.6 presents an overview of the frequencies of RTCs per year leading to severe injuries, fatalities and the number of deaths per 100,000 of the population in Qatar. The results show a decreasing trend in the occurrence of RTCs resulting in fatalities and the number of RTCs fatalities per 100,000 population from 2010 to 2020.

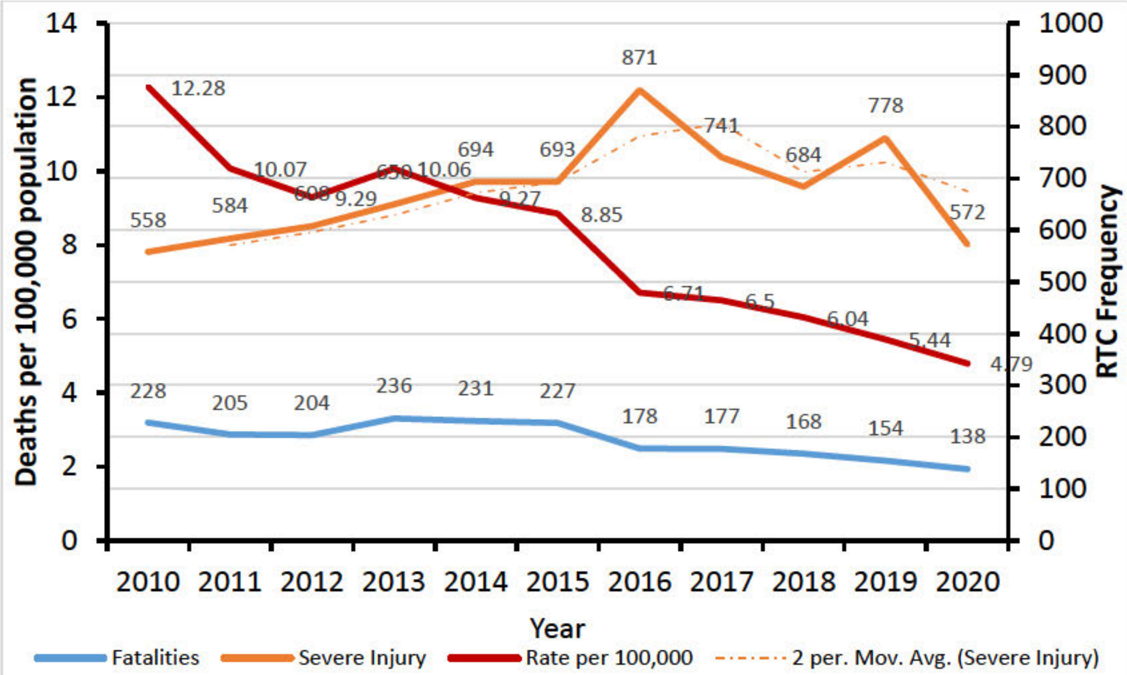


Figure 4.6 Total Number of Road Traffic Crashes from 2010 to 2020

It is clearly visible from the time series plot that a more noticeable decline was recorded after 2015 (blue and red trend lines) with a continuous reduction of RTC fatalities per 100,000. This suggests that the implementation of the Qatar National Traffic Safety Strategy in 2013 has been effective in reducing RTC fatalities, even with the increasing population and number of registered vehicles. However, the moving average trend (yellow lines) shows that RTCs resulting in severe injury have been increasing between 2010 and 2019, which is consistent with the findings of Timmermans et al., 2019. A 26.5% decrease was observed between 2019 and 2020, which is an indication of a positive impact of the second 5-year action plan, 2018-2022. In line with the above and Figure 4.6, Figure 4.7 presents an overview of the population of Qatar, the total number of RTC fatalities for every 100,000 people, using RTC data from the World Health Organization (WHO, 2021) and RTC data from the Qatar Traffic Department from 2000 to 2020. Although the WHO's annual number of fatalities per 100,000 people is higher than that of Qatar's Traffic Department, both records show a similar pattern of variation over time. The results over the 20 years confirm the trends discussed above; a decreasing trend for the number of RTC fatalities per 100,000 people despite the 386% increase in population and 461% growth in the number of registered vehicles over the period.

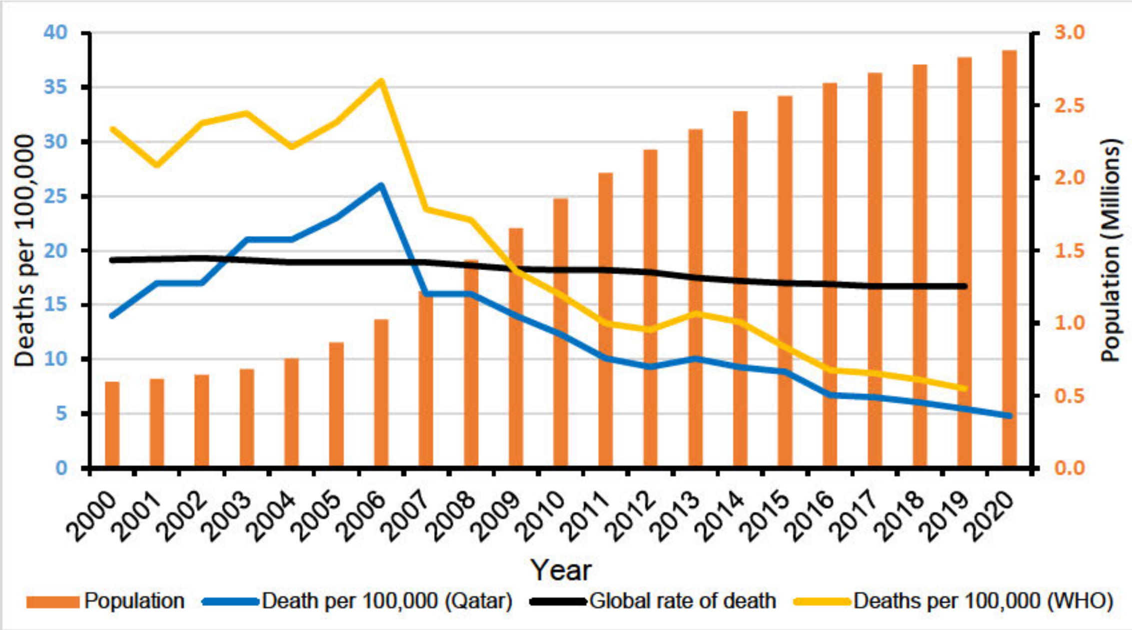


Figure 4.7 Road Traffic Fatalities in Qatar (Source: WHO, 2021 & Qatar)

Figure 4.8 provides a comparison of RTC fatalities per 100,000 population in Iceland, Sweden, the UK, Germany, the USA, the Netherlands, Qatar, the United Arab Emirates (UAE) and globally using the estimated data of WHO (World Health Organization (WHO), 2021b).

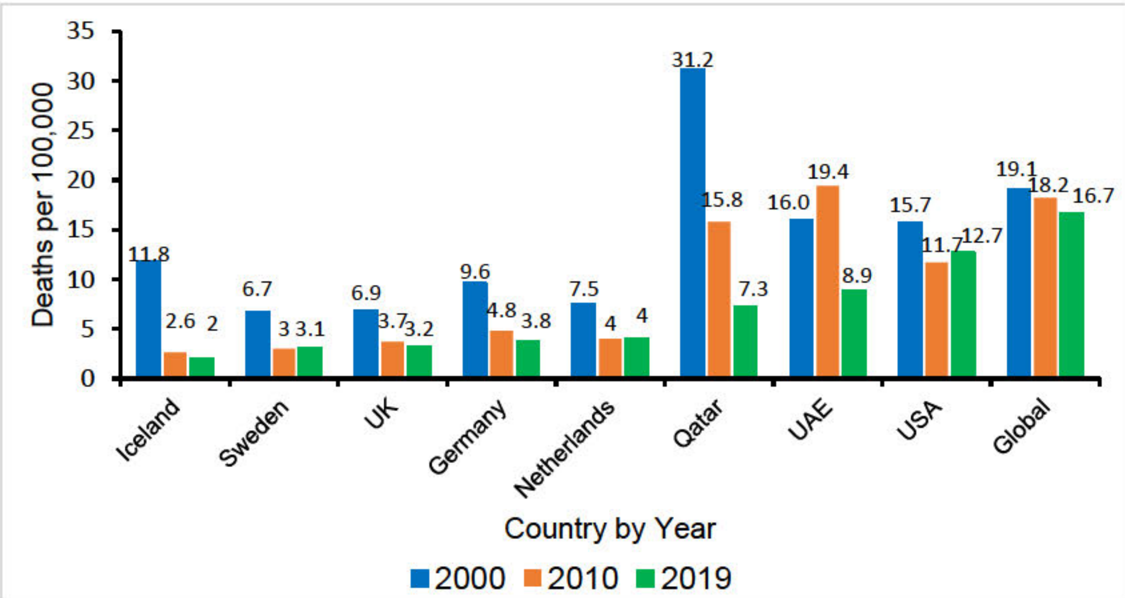


Figure 4.8 Road Traffic Fatality Comparison by Country (Source: (WHO, 2021)

The data from the WHO indicates that Qatar was the worst-performing country among the list of countries presented in 2000. Despite a nearly 50% reduction from the 2000 death rate, the 2010 rate outperformed both the global average and the UAE. In 2019, the fatality rate per 100,000 population in Qatar was 7.3, lower than the rates in the USA, UAE, and the global average, but higher than the rates of best-performing countries like Iceland, Sweden, the UK, Germany, and the Netherlands.

4.4 Conclusions and Recommendations

This study investigates RTCs in the state of Qatar between 2010 and 2020, aiming to investigate the occurrence of RTCs and RTCs resulting in fatalities and severe and minor injuries to assess the impact of the Qatar National Traffic Safety Strategy and the possible effectiveness of measures implemented by the NTSS to reduce the occurrence of RTCs.

The results of time series plots indicate that the occurrence of RTCs resulting in fatalities and severe injuries shows a decreasing trend from 2013 to 2020, corresponding to the period the NTSS has been in operation. Despite a rising trend in RTC injury severity between 2010 and 2016, a downward trend emerged from 2016 to 2020. However, the impact of the NTSS and the measures implemented have not been observed to have a positive impact in reducing the occurrence of RTCs leading to minor injuries. The results of the descriptive analysis of RTC victims indicate age, gender, and road user type variation in RTCs fatality and injury severity. Young people between the ages of 21 and 30 are more likely to die from RTCs compared to other age groups (0-10, 11–20, 31–40, and above 40). Both RTC fatalities and severe injuries disproportionally represent males as victims. It is also observed that between 2016 and 2020, drivers, followed by pedestrians, are more likely to be casualties of RTCs, while the trend among victims of severe injury RTCs has been drivers, followed by passengers, between 2010 and 2020. Despite the NTSS's positive impact in reducing RTCs and their associated fatalities and severe injuries, the NTSS should prioritize addressing the observed variations in age, gender, and road user types, as well as the increasing trend of minor injury RTCs.

In addition, the RTCs in the state of Qatar for a period of 20 consecutive years from 2000 to 2020 have been investigated. The aim was to explore the road safety situation in Qatar before and after the constitution of the Qatar National Traffic Safety Committee (NTSC), the development of the National Road Safety Strategy, and the implementation of the National Road Safety Action Plans. The time series analysis results revealed that the total number of RTCs leading to fatalities shows a visible decreasing trend from 2013 to 2020. This observation coincides with the NTSC's establishment and operational period, which may indicate the effectiveness of the National Road Safety Action Plans in halting or reversing the predicted increase in road traffic fatalities in Qatar. Although Qatar has seen a significant decrease in road traffic injuries and deaths over the past two decades, the progress from 2013 to 2020 has been awe-inspiring and a testament to the effectiveness of the Qatar Bespoke Safe System. Meanwhile, an increasing trend in the frequency of severe injury RTCs is observed from 2010 to 2019. However, the NTSC's implementation of the second 5-year action will require a concerted effort to sustain the 26.5% reduction between 2019 and 2020.

The study also analysed aggregated RTC frequency data based on several categories. The researcher could not procure disaggregated crash data for statistical analysis. However, the study does provide an exploration of RTCs in the State of Qatar. It thereby delivers information that can give direction and guidance in the implementation of the second 5-year action plan (Qatar bespoke safe system), particularly prioritizing measures in the action plan to reduce severe-injury RTCs sustainably. Moreover, it would be interesting for future research to provide insight into Qatar's Bespoke Safe System. Overall, Qatar's implementation of the National Road Safety Strategy has brought about substantial improvements in the road safety situation. The strategy's holistic approach, encompassing infrastructure improvements, enforcement measures, awareness campaigns, and collaborative efforts, has contributed to a significant reduction in road accidents, fatalities, and injuries. These positive changes reflect Qatar's commitment to ensuring a safer road environment for all residents and visitors.

Chapter 5: Case Study 2: The Effects of Public Transport Infrastructure and Services on Road Safety in Qatar

5.1 Introduction

Land-use planning and transportation incorporate urban growth plans to facilitate people's movement towards a mass transit system. To support long-term sustainable transportation use, urban planners must conduct a transportation demand analysis of a specific area, if feasible. When addressing sustainable land use planning, decongestion of the road network, and economic growth, urban planners must consider people's movement across metropolitan regions. Planners must also consider how to preserve the area's social and cultural fabric. Congestion is caused by rising vehicle ownership and the slow development of roadways and accompanying infrastructure (such as parking, side roads, and expressways). Congestion increases waiting times, pollution in the vicinity, unproductive fuel usage, and economic activity loss. Motorization is on the rise around the world, particularly in Asia and South America's big cities. Predictions made in 2004 (Sperling & Claussen, 2004) projected that the number of cars and motorised vehicles worldwide will double by 2020, reaching roughly 1.3 billion.

Automobiles, both private and public, can be beneficial because they provide access to activities, participation, goods, and services, as well as convenience and flexibility. Private vehicles, on the other hand, are responsible for negative effects on cities, such as traffic congestion, pollution, excessive energy use, physical and social fragmentation, and increased fossil fuel consumption. The recent urban expansion of Qatar's capital city, Doha, is a healthy sign of economic prosperity, but more people and activities entail higher transportation needs. The city also boasts the greatest per-capita CO_2 emissions in the world, at 44 metric tonnes per person, due to its high car usage (Song & Zhang, 2019). With Qatar's current population growth, the country is working to develop strategies that will help it transition from being known as the world's country with the highest carbon footprint to a country that promotes sustainable ideals (Al-Thawadi et al., 2021a). Qatar has recently benefited from greater official support for projects aimed at improving road safety. The National Traffic Safety Committee (NTSC) was established in 2010 as a result, and road safety goals were later included in the Qatar National Development Strategy, 2011- 2016, (Jadaan & Almatawah, 2016a).

According to the National Road Safety Strategy (NRSS), by 2016 and 2022, there should be 10 and 6 fatalities per 100,000 people, respectively, and there should be 15 instead of 33 seriously injured persons each year. Through an ambitious program of 200 actions and initiatives to be implemented by 13 government and semi-government bodies over five years, the Road Safety Action Plan seeks to improve road safety performance in Qatar. The NTSC introduced the NRSS in 2013, with the goal of enhancing road safety in Qatar over the next ten years. The Safe System principle, which anticipates and accommodates human error, guided the creation of the resulting plan. Among the advancements made are the development of top-notch emergency medical services, initiatives to update the Qatar Traffic Law and implement a penalty point system, speed and red-light cameras, and road safety audit criteria. Additionally, the State of Qatar's National Road Safety Strategy (NRSS) advocated expanded installation of state-of-the-art road safety barriers and the design of forgiving roads in order to reduce the number of major injuries and fatalities caused by traffic accidents (NRSS, 2013).

Additionally, NRSS called specific attention to the treatment of medians, unprotected roadside obstructions, accessibility and parking at crossings, and pedestrians exposed to fast traffic. As a result, the Public Works Authority (PWA), ASHGHAL, decided to put more sophisticated Vehicle Restraint Systems (VRSs) in place on newly constructed highways in the State of Qatar (Muley et al., 2020). The majority of the parts of the Qatari Road network currently have cutting-edge, cutting-edge VRS systems installed, significantly raising the bar for driving safety (Muley et al., 2020). Considering the limited empirical evidence on the impact of the improvement of transport infrastructure and services on road safety in Qatar, the aim of this case study was to investigate the effectiveness of specific Road Safety Management interventions (the provision of public transport infrastructure and services) in reducing road traffic crashes, fatalities, and injuries in Qatar.

Hence, this chapter (case study 2) was organized in such a way to attain structured methodology (Section 5.2), as the methodological components include questionnaire design and survey administration (Section 5.2.2), and sampling techniques (Section 5.2.3) to capture diverse perspectives. Descriptive analysis (Section 5.3.1) provides insights into the current state of road safety. Additionally, the study examines public perceptions of transport infrastructure (Section 5.3.2), enriching our understanding of its impact on road safety.

5.2 Methodology

5.2.1 Study Area

Qatar is an affluent emerging country in the Arabian Gulf. The state of Qatar had a population of about 2.74 million as of August 2020 and covered an area of 11,521 Km^2 (Planning and Statistics Authority, 2020). More than 50% of the population of Qatar lives in Doha; the city is the administrative capital and the commercial, financial, educational, and cultural hub of the state (Timmermans et al., 2019). Rising traffic demand, limited land, and inadequate infrastructure pose challenges for the country. Because of the country's high affluence, most individuals living and working in Doha, the capital, have become car dependent. Some people take cabs, while a small percentage of the population uses other public transit options (Shaaban & Kim, 2016b). Given Qatar's hot environment and the local preference for a leisurely drive, driving is often the most convenient and comfortable mode of transportation. Although road conditions are generally good, Qatar's high automobile ownership percentage means traffic congestion can clog entire neighborhoods.

5.2.2 Questionnaire Design and Survey Administration

A survey questionnaire was designed to measure the perception of transportation in Qatar and the level of satisfaction with the road transportation infrastructure and services. The data collection questionnaire consists of three main components: (1) Transport characteristics, (2) Users' perceptions of the quality of service, and (3) demographic information. Table 5.1 below displays the general layout of the questionnaire.

Table 5.1 Questionnaire Layout

<table>
<tr><th colspan="3">1: Transport</th><th colspan="3">2: User perception</th><th colspan="3">3: Socio-demographics</th></tr>
<tr><th colspan="2">Variables</th><th>Scale</th><th colspan="2">Variables</th><th>Scale</th><th></th><th>Variables</th><th>Scale</th></tr>
<tr><td>A.1</td><td>Car Ownership</td><td rowspan="8">Closed responses</td><td rowspan="8">B</td><td rowspan="3">User perceptions of Public Transportation</td><td rowspan="3">Likert Scale</td><td>C.1</td><td>Gender</td><td rowspan="8">Closed responses</td></tr>
<tr><td>A.2</td><td>Travel Card</td><td>C.2</td><td>Age</td></tr>
<tr><td>A.3</td><td>Travel Mode</td><td>C.3</td><td>Marital Status</td></tr>
<tr><td>A.4</td><td>Trip Purpose</td><td rowspan="3">Transport Challenges</td><td rowspan="5">Open responses</td><td>C.4</td><td>Educational</td></tr>
<tr><td>A.5</td><td>Travel Cost</td><td>C.5</td><td>Occupation</td></tr>
<tr><td>A.6</td><td>Travel Time</td><td>C.6</td><td>Income</td></tr>
<tr><td>A.7</td><td>Licence</td><td rowspan="2">Suggestions for</td><td>C.7</td><td>Household Size</td></tr>
<tr><td></td><td></td><td>C.8</td><td>Nationality</td></tr>
</table>

5.2.3 Participants and Sampling Techniques

Based on the recommendations of Kline, 2011, Mundfrom, Shaw, and Ke, 2005, Preacher and MacCallum, 2002, and Guest, Namey, and McKenna, 2017, we estimated a minimum sample size of 300 for this study. The study chose electronic data collection because of its quick turn-around time, reduction in data entry errors, environmental friendliness, and savings in data input and processing time. Participants for the survey were residents of Doha, at least 18 years old, and randomly selected through an intercept survey technique at bus stops, metro stations, supermarkets, and shopping malls in Doha using a simple random sampling technique. Mail-in questionnaires and phone interviews were not considered since it would be difficult to provide a representative sample of the population at large, resulting in many population segments not using the service. Therefore, it was decided to exclusively utilize internet-assisted questionnaires through Google Forms for this study. Four field data collectors were recruited and given electronic gadgets (iPads and tablet computers) loaded with a survey instrument (an online Google form) for the data collection. Using this approach, 316 online survey responses were received from randomly intercepted road users at various metro stations, bus stops, and supermarkets in Doha.

5.3 Results and Discussion

5.3.1 Descriptive Analysis

This study explored the perceptions of public transport users in Qatar through an online survey via Google Forms. A total of 316 valid responses were received and used in the analysis. Of the 316 participants, 167 males and 149 females took part in this study; 42 respondents were Qataris, and 274 were non-Qataris. Table 5.2 presents a summary of the descriptive statistics of the survey participants. A little over half of the participants (52.8%) were males, while about 47.2% were females. This percentage reflects a similar study (Shaaban & Hassan, 2014). On the occupational level, a little more than one-third of the participants (38.3%) were bachelor's degree graduates, while about 11% have primary, secondary, or no formal education. About 87% of the participants were non-Qatari, while the rest were Qataris.

Table 5.2 Characteristics of Respondents

Variables	Category	Frequency	%
Gender	Male	167	52.8
	Female	149	47.2
Age	<18 years	1	0.3
	18 to 24 years	76	24.1
	25 to 34 years	78	24.7
	35 to 44 years	84	26.6
	45 to 54 years	57	18.0
	55 to 60 years	18	5.7
	60 years or older	2	0.6
Household Size	1	105	33.2
	2	14	4.4
	3	64	20.3
	More than 3	133	42.1
Nationality	Qatari	42	13.3
	Non-Qatari	274	86.7
Occupation	No formal education	36	11.4
	Primary	36	11.4
	Secondary	35	11.1
	College	26	8.2
	Bachelor's degree	121	38.3
	Master's degree	46	14.6
	PhD	16	5.1
Marital Status	Married	228	72.2
	Unmarried/Single	88	27.8
Household Income	<10,000 Riyal	108	34.2
	10,000-15,000 Riyal	31	9.8
	15,000-20,000 Riyal	55	17.4
	20,000-25,000 Riyal	36	11.4
	25,000-30,000 Riyal	39	12.3
	30,000-40,000 Riyal	31	9.8
	40,000-50,000 Riyal	13	4.1
	Above 50,000 Riyal	3	0.9
Vehicle Ownership	None	111	35.1
	One	166	52.5

Variables	Category	Frequency	%
	Two	26	8.2
	Three and above	13	4.1
Drivers' License	Hold a valid Driving License in Qatar	191	60.4
	Temporary license for 3 months	2	0.6
	International driving license for 6 months	7	2.2
	Never held a Qatari driving license	114	36.1
	Other	2	0.6
Employment Status	Employed full-time	265	83.9
	Employed part-time	42	13.3
	Student	2	0.6
	Retired	3	0.9
	Unemployed	4	1.3

Figure 5.1 shows a breakdown of respondents by nationality. The majority (about 84%) of respondents have full-time employment. Almost two-thirds of the participants (65.1%) reported owning at least one car, 12.3% of respondents owned two or more cars, and 63.3% had a valid Qatari driver's license or international driver's license.

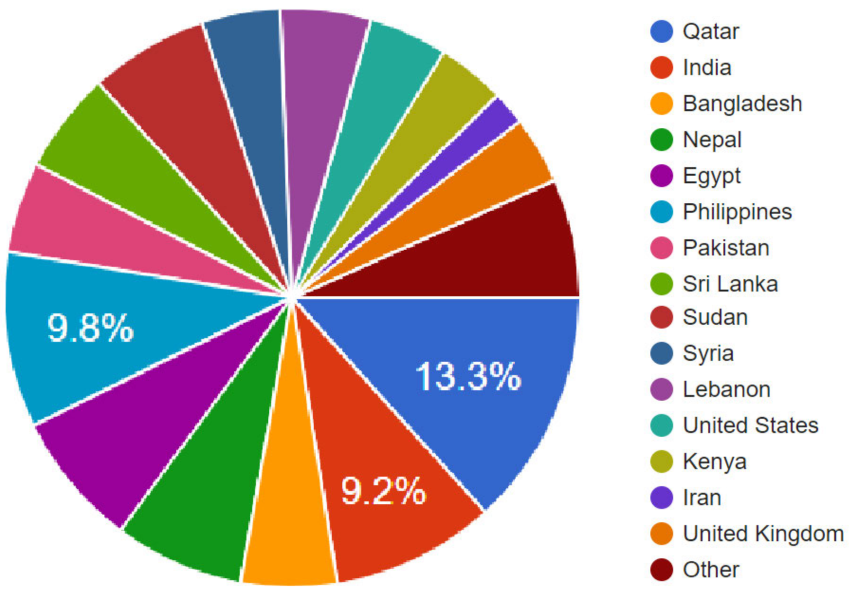


Figure 5.1 Nationality of Respondents

Women were found to significantly differ (p-value 0.007) from men in terms of car ownership, while 56% and 73% of women and men reported owning a car, respectively. On average, 60.4% of the foreign nationals in Qatar own at least one car, compared to 95.2% of Qataris. All nationals from Lebanon and Pakistan own at least one car. One respondent indicated that there are more cars in Doha than required and made the following recommendation:

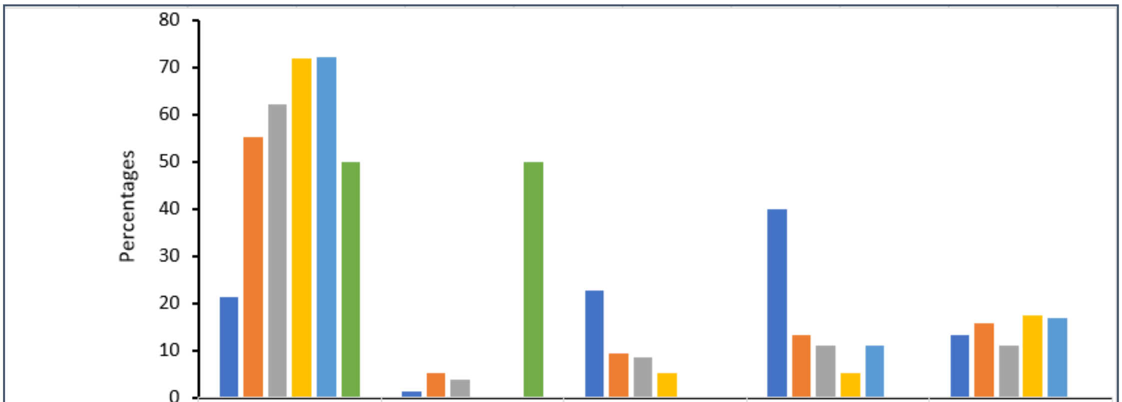
> "*Make PT services free. Could consider cess being levied from all people holding, say, more than two vehicles, which could fund free PT services.... It may also serve as a deterrence to hold more than two vehicles.... Sometimes, I feel there are more vehicles in Qatar than the people living in it.....*"

Income levels were also found to have a significant effect (p-value = 0.000) on car ownership. The percentage decreases with rising income, with 80.2% of respondents earning less than 10,000 riyals a month not owning a car. All respondents earning above 50,000 riyals own a vehicle. Notably, 86.7% of PT users are non-Qatari residents between 18 and 44 years old. This corroborates the findings of (Shaaban and Khalil, 2013). The public transportation system primarily, if not entirely, serves the expatriate community. For most of their trips, the nationals use special buses, which are institution-based and personal vehicles. Respondents were also asked to provide their preferred travel means for different trip purposes. The results showed that most respondents used the bus, metro, and tram for leisure and visiting trips. Most of the respondents (52.7%) drive for work, school, and shopping trips. This indicates that the people living and working in Qatar are car dependent. 87.5%, 81.2%, 76.9%, 75.6%, and 71.4% of respondents from Pakistan, Lebanon, the United States, Qatar, and India, in that order, reported driving to work. 25% of nationals from Bangladesh and Kenya, followed by Filipinos (22.6%), use a bus, metro, tram, or a combination for work trips. 50% of nationals from Bangladesh cycle or ride scooters to work, 39% of nationals from Nepal, the Philippines, and Sri Lanka, compared to 2.4% of Qataris.

Figure 5.2 presents statistics on respondents' mode of choice by age. The proportion of car drivers to work is found to vary with age, while only 21.3% of respondents aged 18–24 reported driving to work, and 72.2% of respondents between 55 and 60 years drive to work. Respondents over 60 either drive or receive transportation to work. Figure 5.2 reveals that in Qatar, the same age group (18 and 34 years) accounts for 72.7% of cyclists or scooter riders and 50% of motorbike riders, potentially increasing their exposure to RTC risk in the absence of appropriate safe and protective infrastructure. Meanwhile, the accident statistics in Qatar show a disproportional representation of this age group in road traffic crash (RTC) casualties. However, the same age group (18 and 34 years) accounts for 70.6% of all public transport riders in Qatar. The observations above provide the Qatar National Traffic Safety Committee

(NTSC) with an opportunity to develop policies, schemes, and campaigns to promote the public transport modes (bus, metro, and tram) among this age group, as well as the development of segregated bicycle infrastructure for the safety and protection of cyclists and scooter riders to reverse their high representation in Qatar's accident statistics.

Furthermore, a little over 60% of the participants claimed that they spent an average of 5 minutes or less from home to bus stations, and from bus stations to their final destination. This corroborates the findings of (Shaaban and Hassan 2014). The results show public transport stops are within 5 minutes of walking distance for about 60% of respondents.



	I drive a car/van	Passenger (someone drives me)	I get a Bus/ Metro/Tram	I ride a Bicycle/ scooter	I ride a motorbike
18 to 24 years	21.3	1.3	22.7	40	13.3
25 to 34 years	55.3	5.3	9.2	13.2	15.8
35 to 44 years	62.2	3.7	8.5	11	11
45 to 54 years	71.9	0	5.3	5.3	17.5
55 to 60 years	72.2	0	0	11.1	16.7
60 years or older	50	50	0	0	0

Figure 5.2 Mode Choice for Work Trip by Age

5.3.2 Perception of Public Transport in Qatar

Following the governmental support for projects aimed at improving road safety in Qatar, road safety goals have been included in the Qatar National Development Strategy, 2011- 2016, (Jadaan & Almatawah, 2016a). The Qatar National Road Safety Strategy (NRSS) proposes to reduce RTC fatalities per 100,000 people to six by 2022 and reduce the yearly number of seriously injured people from 33 to 15 per 100,000 people (National Traffic Safety Committee, 2012). An ambitious program involving 200 actions and initiatives is to be implemented by 13 government and semi-government bodies over a 10-year period to improve road safety performance in Qatar. Additionally, NRSS included actions to improve the road transport infrastructure and operations in Qatar. As a result, the Public Works Authority (PWA), ASHGHAL, developed ambitious plans to modernize Qatar's transport infrastructure with sophisticated Vehicle Restraint Systems (VRSs) on newly constructed highways and provide ultra-modern public transport systems and services in the State of Qatar (Muley et al., 2020). Currently, a significant proportion of the road network in Qatar has cutting-edge VRS systems installed to significantly raise the bar for driving safety. While some sections have mobile barriers built, others have a combination of steel and concrete barriers. Road users' perception of safety depends on the condition of the transport infrastructure and facilities (Wang et al., 2020). Given the significant investments in upgrading road transport infrastructure, public transport services, and pedestrian facilities in Qatar, it was crucial to evaluate the users' perceptions of these improvements in terms of their safety and comfort when using these facilities and services. The respondents were asked to indicate their level of agreement or disagreement with statements regarding the use of the transport systems in Qatar, in order to measure the participants' views and perceptions about the state and performance of the road infrastructure in terms of safety and security when making a trip (see Table 5.3).

Table 5.3 User Perception of PT Infrastructure

Variable	**Statement**	**Mean**	**Rank**
Safety	I feel safe using PT (Bus/Metro / Tram) services in Qatar	4.54	1
Comfort	I feel comfortable using PT (Bus/Metro / Tram) services in Qatar	4.53	2
Supports Walking	The transport infrastructure adequately supports walking in Qatar	4.28	3
Infrastructure	Pedestrian facilities (pedestrian lanes and crossings) in Qatar encourage walking and cycling	4.28	4
Confident Walking	I feel confident walking around in Doha	4.36	5
Safe Walking	I feel safe walking around in Doha	4.39	6

According to the analysis, both sexes did not differ in opinion, and all agreed with the statements, with mean scores ranging from 4.28 to 4.54. The results show that participants are generally satisfied with the current state of Qatar's road transport infrastructure and public transport services. Table 5.3 and Figure 5.3 present the ranking of the statements. Overall, at least 96% of the respondents showed satisfaction with public services in terms of safety and comfort while using PT services, and about 92% of respondents are satisfied with the level of safety provided by the pedestrian infrastructure in Doha and feel safe and confident walking. This finding is consistent with the findings of Shaaban et al., 2021.

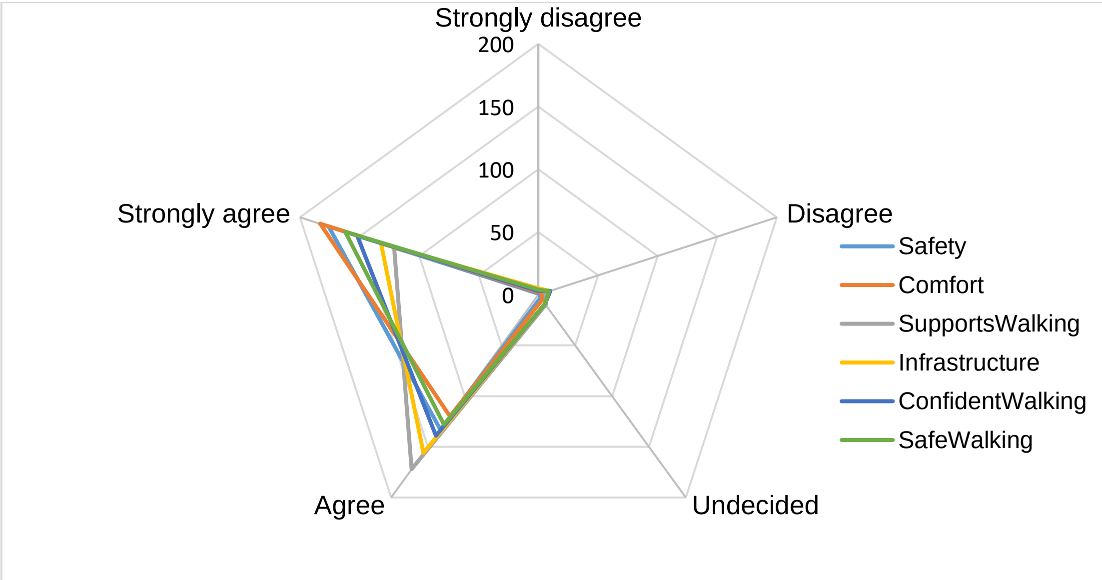


Figure 5.3 Users' Perception of Transport Infrastructure

Notwithstanding the high level of satisfaction and users' approval of the level of safety offered by the transport services and infrastructure, participants called for more attention to be paid to the management and use of the pedestrian sidewalks along the road corridors, particularly the indiscriminate parking of vehicles on the sidewalks. Most respondents were also concerned about drivers' non-compliance with the traffic rules and lack of respect for pedestrians and pedestrian facilities. Users mostly expressed the need for more recreational spaces along the public transport changeovers, assign lanes to buses, add more minibuses, and the introduction of female-only minibuses, improvements in linking bus, cycling, and walking lanes, very poor penetration, which makes it very inconvenient to use metro services if you aren't directly on the metro line. Inadequate parking facilities further discourage metro use, unpredictable journey time (waiting for pickup and trip to the drop-off point) on metro express, difficulty in accessing metro services during the summer (weather conditions), and issues of reliability of metro services (unannounced cancellation of trains). Others believe road construction has made it difficult and unsafe to walk on the roads, as well as the lack of dedicated footpaths to walk in most local or residential areas. For example, the concerns of the pedestrian can be summarized in the quotation below from some respondents:

> *"There are virtually no pavements to walk in Qatar. Vehicles are parked all over the area where pedestrians need to walk. This forces pedestrians onto the road with every possibility of getting knocked down by speeding traffic...."*
>
> *Male, 45-54 years*
>
> *"Walking or cycling lanes required in streets and frequent bus connectivity. At present, these lanes are available only adjacent to highways and main roads"*
>
> *Male, 35-44 years*

To improve the safety and level of satisfaction of road users, the following suggestions were made for the consideration of the sector agencies and the NTSC. Accident statistics indicate a disproportional representation of pedestrians and young people in RTC casualty numbers. Meanwhile, according to Figure 5.2, and Timmermans et al., 2019, pedestrians, cyclists, or scooter riders who use the sidewalks and pedestrian facilities are mostly younger people between the ages of 18 and 34 years. To ensure the safety of this part of the population, participants called for public awareness campaigns about respecting pedestrian and pedestrian facilities for pedestrian safety; the enforcement of road safety laws for cyclists and pedestrians; the provision of more and properly connected sidewalks, and giving pedestrians priority at unsignalized crossings.

The views and suggestions of respondents can be summed up by the quotes below from two respondents:

> *"Provide and properly connect sidewalks, further give pedestrians priority at un signalized crossings"*
>
> *Female, 45-54 years*
>
> *"Providing more facilities along corridors (sidewalks). Improving the operation of intersections to provide efficient service to pedestrians. Applying more speed calming measures and strengthening enforcement on vehicles for the pedestrian right of way"*
>
> *Male, 35-44 years*

Participants predominantly expressed their concerns about the discontinuous nature of pedestrian walkways and the introduction of pedestrian barriers at an unsafe road crossing. There are no sidewalks along some roads. There should be a complete walking network so that people can walk efficiently and comfortably from one origin to a destination. Another key concern for respondents is the provision of safe lanes for pedestrians is also another key concern of the respondents. The study also discussed the current state of the road infrastructure in Qatar by exploring the views and perceptions of road users. In responding to their satisfaction with the overall quality of public transport, almost 60% of the respondents showed satisfaction with bus safety, comfort, and safety whilst using foot mobile. In terms of non-motorized road users, about 40% expressed satisfaction with the availability of pedestrian walking facilities (Figure 5.3). According to Figure 5.4, approximately 70% of the respondents assigned a high level of importance to the consideration of travel time and cost when choosing a trip mode. Reliability, convenience, and comfort received nearly the same level of significance, while weather conditions received slightly more than 50%. Less than half of the respondents (about 45%) rated the environment, health, safety, and capacity to carry goods as significant factors to consider when making their modal choices.

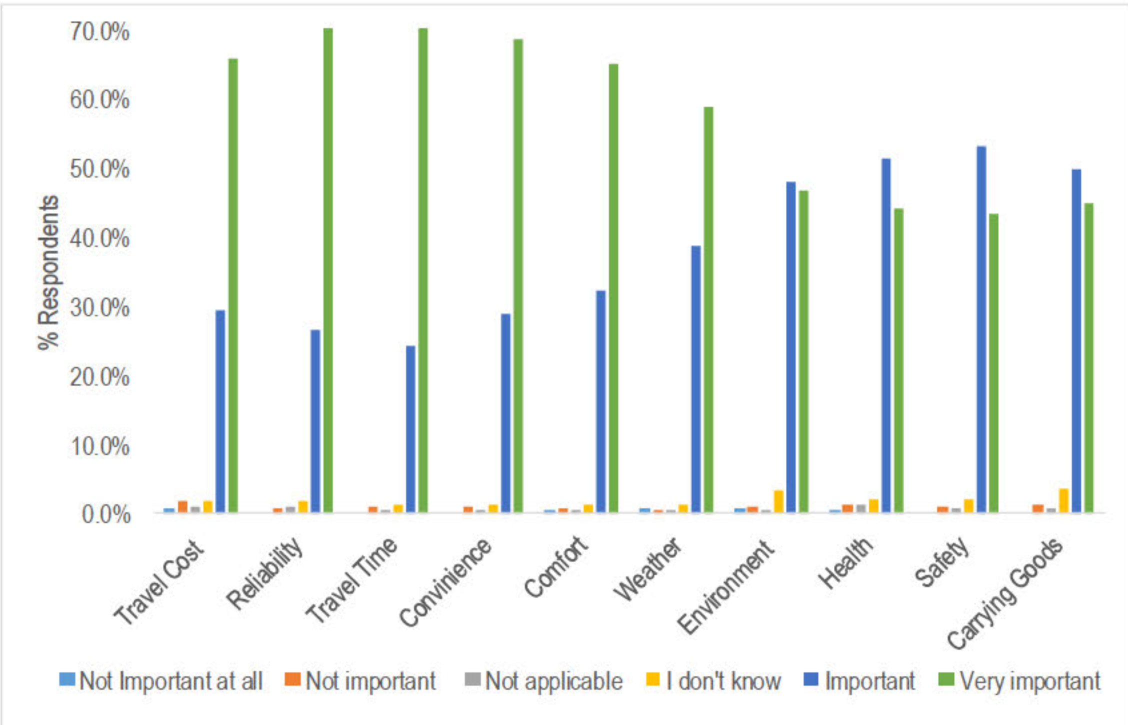


Figure 5.4 Users' Preference when Choosing Travel Mode.

Users were asked to indicate which of the transport attributes in Figure 5.4 influences their choice of transport mode. The attributes were ranked to understand which transport characteristics are prioritized mainly by public transportation users. Figure 5.5 presents a plot of the error bars of the mean rank and standard deviation values. The investigators almost equally ranked all attributes as important. However, users are more sensitive to travel time, with the highest mean rank (5.69), followed by the reliability of transport mode and associated service (5.66), and the level of convenience offered by public transport (5.64).

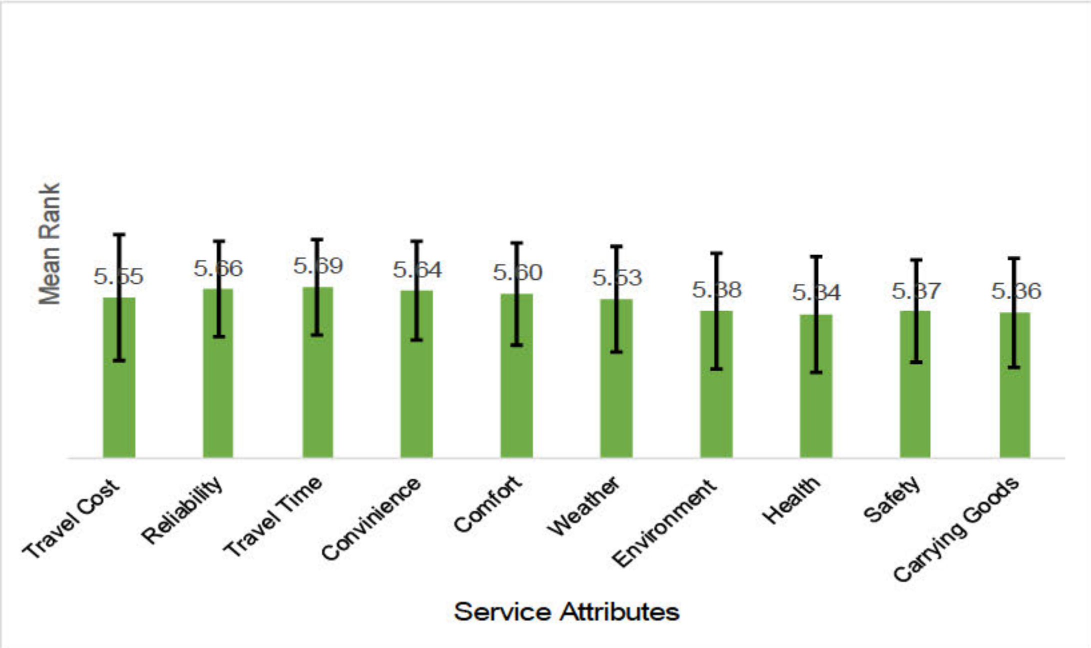


Figure 5.5 Mean Rank of Service Attributes

The findings indicate that travel time and service reliability are essential factors affecting the mode-choice decisions of public transport users in Qatar. Participants indicated that Metro Express travel time is unpredictable and were concerned about journey time (waiting time and in-vehicle travel time). The results further suggest that unpredictable PT travel conditions could encourage mode switching to private cars. In addition, the participants in this study were asked about their willingness or tendency to use public transport. Approximately 96.5% of the participants (both sexes) expressed their desire to use PT for their daily trips. Only about 3.5% declined to use the service. This percentage may have reflected those who expressed dissatisfaction with the nature of PT in Qatar. However, if the service quality improves, they will show interest in using it. Users also recommended increasing the number of buses on busy routes. Women make up 55.9% of participants who use public transport for work trips, 45.2% for shopping trips, 51.7% for leisure trips, and 55.4% for visits to family or friends. On average, more women than men travel on public transport for urban mobility. When asked about their usage, 281 of the respondents, representing 88.9% of participants, indicated they currently use the public transport services and have had a pleasant experience using them, and they stated they were willing to continue using them. In terms of household income, relatively low-income earners are currently accustomed to using public transport. This corroborates the findings of Shaaban and Khalil, 2013. Users at all income levels expressed a willingness to use public transport. However, the majority (33.5%) of them earn less than 10,000 riyals, followed by those with incomes between 15,000-20,000 riyals (17.1%).

5.4 Conclusions and Recommendations

The population of Qatar has almost quadrupled between 2000 and 2020. Similarly, the number of registered vehicles increased almost fivefold over the same period. This population explosion brought the nation's transport infrastructure under enormous stress, leading to high road traffic crash fatalities and injuries. To halt or reverse this externality of the road transportation system, the government of Qatar has made the development of mass transit a key part of the Qatar National Vision 2030 (QNV-2030) to enhance Qatar's road transportation systems by providing a safer and more sustainable transportation system with efficient and seamless travel to reduce RTCs and their related fatalities and injuries. Qatar has made substantial investments to upgrade the nation's transportation infrastructure and services to modern standards. Therefore, this study explores the public transportation systems to determine if the road transportation sector's investment contributes to user safety and satisfaction, while also reducing the frequency of road traffic accidents, fatalities, and injuries.

According to the results of a survey of 316 participants from Doha, 88.9% of the total respondents are active users of Doha's public transportation services and enjoy the travel experience, particularly with the Qatar Metro. 96.5% of the participants (both sexes) expressed their willingness to use PT for their daily trips. This observation has important implications for car travel and RTC reduction. It is expected that increasing the ridership of Qatar Metro and Karwa Bus would reduce the number of car trips made daily and annual vehicle kilometres travelled, reducing accident exposure levels and consequently a possible reduction in accidents rate and fatalities. The enhanced transport infrastructure and services could reduce road users' exposure to accident risk, leading to a decrease in RTC frequency and fatality rate.

Chapter 6: Case Study 3: The Effect of Surveillance Cameras on Traffic Violations and Crashes in Qatar

6.1 Introduction

This chapter reports and presents Case Study 3. This introduction sets the stage for understanding the impact of surveillance cameras on traffic violations and crashes in Qatar, a topic of significant interest in enhancing road safety measures. With the rapid development of transportation infrastructure in Qatar, concerns about road safety have become increasingly pertinent. Sidi M. 2021, contributes to enhanced road safety outcomes by reducing speeding-related crashes and collisions, thus mitigating the risk of accidents on roadways. The presence of surveillance cameras was linked to a significant reduction in speeding behaviours among motorists (Graham D. J et al., 2019), serving as a deterrent to speed limit violations. Surveillance cameras represent a proactive measure for monitoring traffic behaviour and enforcing regulations. Surveillance cameras are effective tools for promoting compliance with traffic regulations (Pilkington, P., & Kinra, S. 2005), fostering accountability and increasing adherence to laws. Surveillance cameras play a crucial role in comprehensive traffic management strategies (Alghnam S. et al., 2018), providing real-time data to identify high-risk areas and implement targeted interventions for improved road safety.

This study aims to investigate the extent to which these surveillance systems influence traffic violations (Section 6.4.2.2) and subsequent crash occurrences. By analysing the relationship between the presence of surveillance cameras and the frequency of traffic violations and crashes, valuable insights can be gleaned to inform future policies and interventions (Section 6.3.1). Understanding the effectiveness of surveillance cameras in mitigating road safety risks is crucial for policymakers and transportation authorities in Qatar. The findings of this study have the potential to contribute to the enhancement of road safety measures, thereby fostering safer road environments for all road users in Qatar. Through a systematic examination of available data and rigorous analysis (Section 6.3.2), this study endeavors to shed light on the nuanced dynamics between surveillance cameras, traffic violations, and road crashes. In summary, this study presents a comprehensive examination of the impact of surveillance cameras on traffic violations and crashes (Section 6.4.1) in Qatar. By integrating data collection (Section 6.3.1), statistical analysis (Section 6.3.2), and descriptive statistics (Section 6.4.2), it seeks to unravel the intricate relationship between surveillance systems and road safety outcomes. Through systematic inquiry and rigorous analysis, this research endeavors to inform evidence-based policy interventions aimed at enhancing road safety measures and fostering safer road environments for all road users in Qatar.

6.2 Background

Road traffic accidents are a hidden epidemic, particularly in developing countries. The high incidence of traffic accidents is one of the most serious health and social policy concerns in all countries around the world. According to Goniewicz et. al., 2012, every 50 seconds, a fatal road traffic accident happens, and every 2 seconds, a road traffic injury occurs. Every year, nearly 1.3 million people lose their lives on roads worldwide, whereas 20–50 million sustain severe trauma, most of them requiring long-term and costly treatment (Violence et al., 2009). Many developing countries' continued progress towards motorization is anticipated to increase the problem of road traffic accidents. According to Puvanachandra et al., 2012, road traffic incidents claimed the lives of 1.27 million individuals in 2004, which is very similar to the number of people who died from infectious diseases. According to (Krug EG, and Sharma GK. 2000), a host of factors were observed to cause road traffic crashes (RTCs); the speed of vehicles, impairment by alcohol, driver's fatigue or sleepiness, the use of hand-held mobile telephones, inadequate visibility, and road-related factors.

The total economic losses resulting from traffic collisions are unfathomable. Elvik, 2000 conducted a study that revealed road crash costs to be between 1% and 2% of the gross national product (GDP). Wijnen and Stipdonk, 2016, analysed the national cost of road crashes in ten high-income countries and seven low- and middle-income countries. The results indicate that the cost of RTC was about 2.7% of the Gross domestic product (GDP) on average in high-income countries and 2.2% of GDP in low- and middle-income countries. In 2010, the economic consequences of traffic accidents in the United States totaled $242 billion. This amount accounts for 1.6% of the $14.96 trillion of the US economy (Blincoe et al., 2015). Many studies have looked at the association between speeding and crash rates, as well as the relationship between speeding and injury rates (Al-Adhoobi et al., 2017; Graham et al., 2019). The need to address road accidents is a global concern and one of the challenges faced by transportation planners. Researchers (Alghnam et al., 2017; Graham et al., 2019) are increasingly using speed cameras to reduce traffic speeds and curb road traffic crashes and fatalities. Several countries, including Qatar, are expanding their usage of speed cameras (Pilkington & Kinra, 2005). Due to the absence of readily available evidence of speed camera efficiency, road safety and health professionals have found it challenging to engage in an informed debate about the effectiveness of speed cameras. An initial modest, non-systematic evaluation of six studies revealed that the implementation of speed cameras resulted in a 17 percent reduction in collisions (Elvik, 1997).

Qatar has seen a significant increase in road crashes due to traffic violations in recent years (Abdulbari Bener, 2012; Consunji et al., 2020; Mamtani et al., 2012). However, the quantification of these infractions, which have resulted in serious accidents in the country, receives less attention. In Qatar, there are few published scientific articles about the true burden of RTIs. Small-scale, city-based, or facility-based investigations are the only ones available. The lack of public awareness of the issue and a national focus on traffic safety policies have resulted in a lack of interest in the subject.

6.3 Description

In this case study, the study area is taken to represent the state of Qatar. Qatar is one of the seven Arab states bordering the Arabian Gulf. It is located on the eastern coast of the Arabian Peninsula and comprises a few islands. As of November 2021, the State of Qatar has a total area of 11,521 km2, with a population of approximately 2.69 million, of which 28% are female and 72% are male. The median age in Qatar is 32.3 years. Less than 15% of the geographic area contains more than 80–90% of the population (Ministry of Development Planning and Statistics [MDPS], 2021). The population density in Qatar is 248 per Km^2 (643 people per mi^2). Automobiles are the dominant mode of transportation in Qatar. The number of registered vehicles and motorcycles in 2019 was 1,655,700, and the number of active driving licenses in 2019 was more than 1.4 million, according to Qatar's Ministry of Interior (Ministry of Interior, 2019).

6.3.1 Data Collection

This case study exclusively examined the roads in Qatar that have surveillance cameras installed. This means that we exclusively analysed data from roads equipped with surveillance cameras. The traffic enforcement cameras collected a total of 5,655,835 records of traffic violations from January 1st, 2019 to January 1st, 2021. These cameras saved and recorded traffic violations on the selected roads in the form of screenshots and corresponding documents. The records included passing traffic signals, passing traffic signals and lanes, driving license violations, traffic movement violations, stand-and-wait rules & obligations violations, and others. The roads with different traffic characteristics, such as speed limit, traffic volume, peak hour volumes, and signal timing, were considered. The posted speed limits for the studied roads ranged from 80 to 120 km/h. Table 6.1 below provides details about the roads considered in this study.

Table 6.1 Roads with Surveillance Cameras

Item	Road	Speed limit (Km/h)
1	Air Force Street	100
2	Dukhan/Shahaniya	120
3	Shamal Highway	120
4	Salwa road	120
5	F Ring Road	100
6	Al Dafna	80
7	Al Waab	80
8	Orbital Highway	120
9	Al Refaa	100
10	The Pearl	80
11	Madinat Khalifa	80
12	Ain Khalid	80
13	Mesaeeid	120
14	Abu Hamor	100
15	Hamad Port	80
16	Al Mazrouaa	120

6.3.2 Statistical Analysis

The most commonly used study design to evaluate the effectiveness of a traffic safety measure on the number of crashes is a before- and after study (Elvik, 2002). This method compares the occurrence of crashes before the implementation of a measure with that after the implementation. In a before-and-after study, it is important to control for other variables that could have influenced the number of crashes across the study period.

Version 26 of the IBM Statistical Package for Social Sciences was used for all statistical analyses. The installation of speed cameras has prompted comparisons of whether there has been a statistically significant decrease in traffic accidents using the Chi-Square test of independence and Wilcoxon signed-ranked tests. Mortality (percentage of patients with death discharge status) and severity scores were compared before and after the measure was implemented using the chi-square test for categorical variables. A p-value of 0.05 was used to calculate the statistical significance. The main purpose of the Chi-squared test of independence was to show how much the crash rate before and after the intervention were related. This test has several advantages, including its robustness in terms of data distribution, ease of computation, detailed information that can be derived from the test, use in studies where parametric assumptions are not met, and flexibility in handling data from both two and multiple-group studies (Mchugh, 2013).

Additionally, according to Anaene Oyeka, and Ebuh, 2012, the Wilcoxon signed-rank test is a rank-based alternative to the parametric t-test that only requires the distribution of differences between pairs to be symmetric rather than normally distributed. It examines whether two or more sets of pairs are statistically significantly different from one another. The rank-sum test and the signed-rank test are two variations of this test that compare two paired groups. It assumes that the magnitudes and signs of differences between paired observations contain relevant information. Therefore, by studying the results of these tests, we can be confident about any significant improvement in the occurrence of road crashes after installing the cameras.

6.4 Results and Discussion

6.4.1 Results

This study investigates the impact of the installation of surveillance cameras on the frequency and nature of traffic violations and RTCs in Qatar. All sites were within 80 km/h, 100 km/h, and 120 km/h speed limit zones.

6.4.2 Descriptive Statistics

6.4.2.1 Accident Cases

Table 6.2 presents exploratory descriptive statistics of the dataset. The number of minor injuries showed more variation in seven years than the number of fatal crashes. Similarly, among the victim category, there is more variation in the number of passengers injured during the six years as compared to pedestrians and drivers.

Table 6.2 Descriptive Statistics of Accident Cases and Victims

Parameter	Mean	St. Dev	Minimum	Maximum	Sum
Minor Injuries	5403.7	802.7	4043	6722	37826
Serious Injuries	548.9	74.6	438	666	3842
Fatal Crashes	159.3	17.0	138	194	1115
Drivers	77.9	13.3	56	93	545
Passengers	43.1	15.3	21	69	302
Pedestrians	48.6	12.4	32	66	340

Figure 6.1 presents a comparative graphical display of all accident cases for the past 7 years. Although traffic deaths and serious injuries decreased with time, the number of minor injuries that did not require hospitalization climbed. Better notification of minor injuries or rapid population growth, leading to higher traffic density, could explain this. Another explanation is that speed cameras reduce speeds sufficiently to lower the death rate while having little effect on less serious injuries.

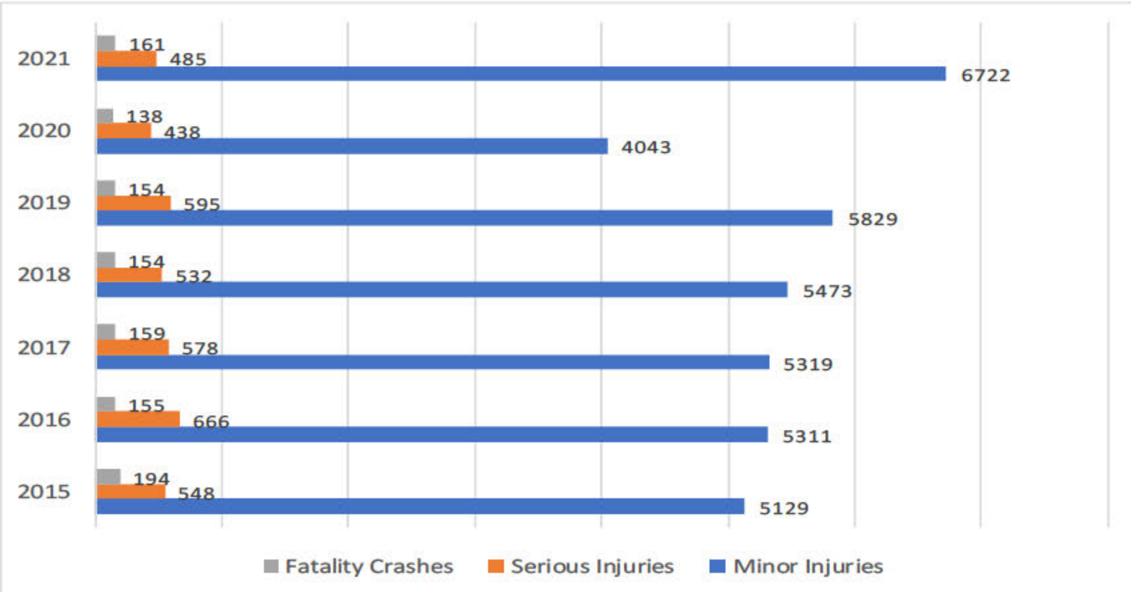


Figure 6.1 7–Year Accident Cases

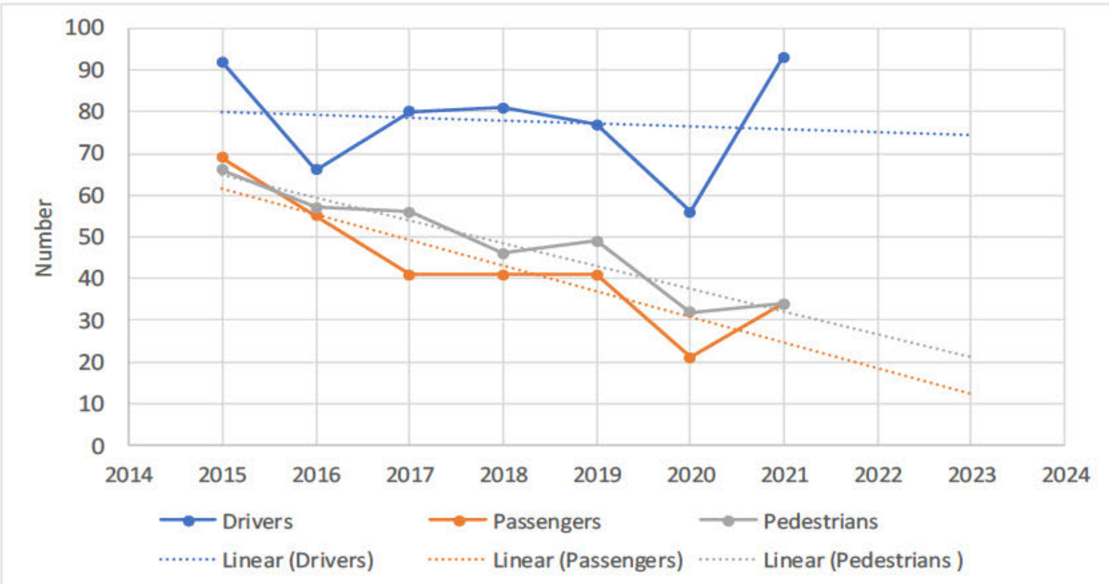


Figure 6.2 Accident Victims

Figure 6.2 shows that, compared to passengers, drivers suffered the most overall. The year 2021 recorded the highest number of affected drivers. However, it has experienced a sharp decline from 2015 to 2016 and 2019 to 2020. Pedestrians were the least affected casualties. From 2014 to 2017, there was a decline in this number, which remained constant for three consecutive years before declining to the lowest rate in 2020. The accident cases revealed a higher number of minor injuries and a lower number of fatalities. The lowest and highest minor accidents for the entire 7-year period were recorded in December 2021 (Figure 6.3).

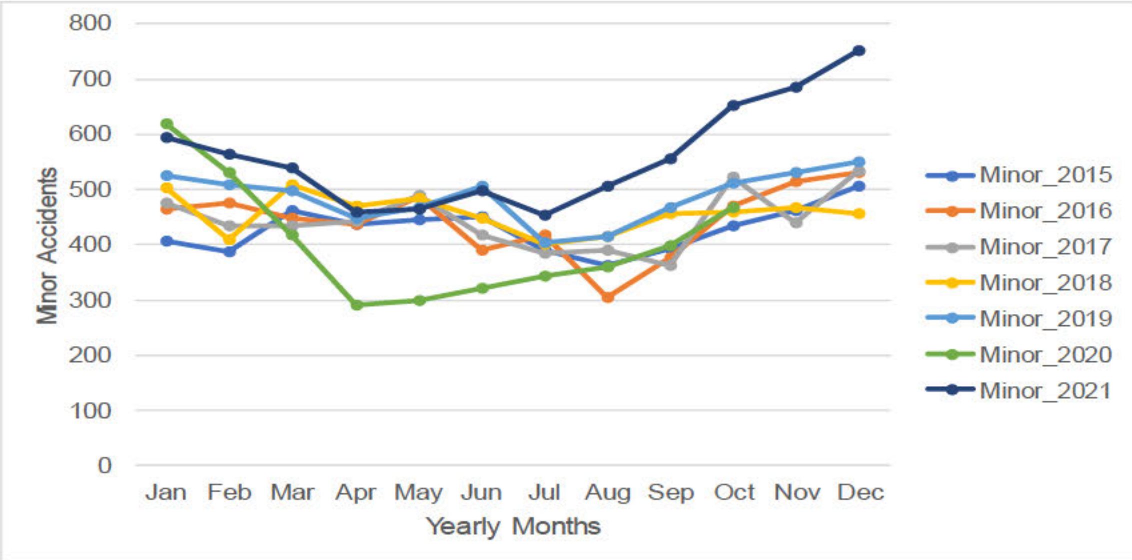


Figure 6.3 7-Year Minor Accident Cases

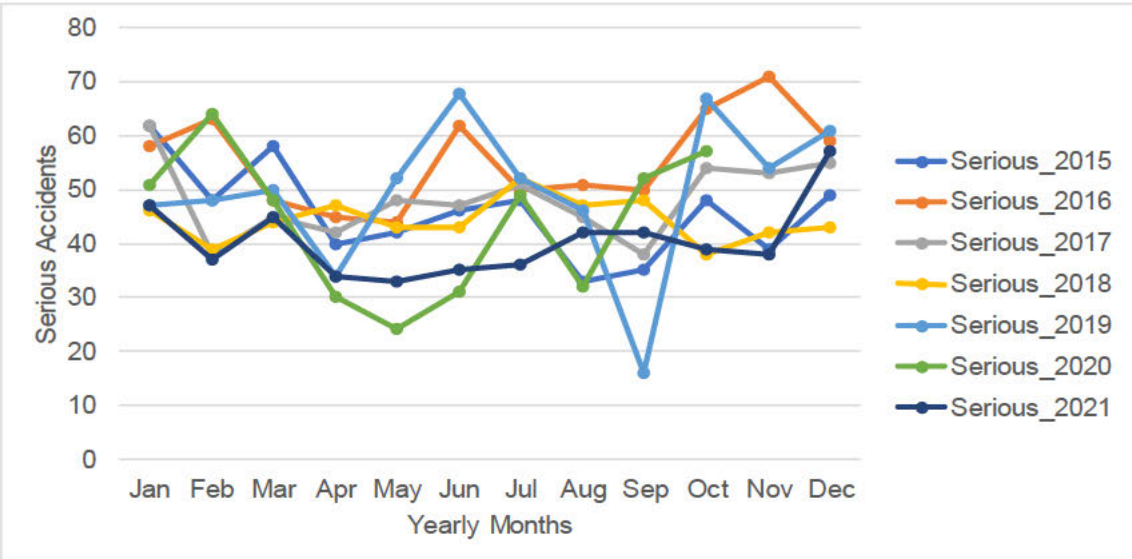


Figure 6.4 7-Year Serious Accident Cases

The first four months of 2020 saw a sharp decline in the number of minor accident cases, followed by a gradual rise in May. In 2018, reports of minor accidents remained relatively constant throughout the year. Across the 7 years, the most severe accidents occurred in November 2016, with September 2019 recording the lowest (Figure 6.4). However, an abrupt fluctuation in serious accident cases was observed in the year 2019, where correspondingly, the second most severe cases were recorded. January 2015 saw the most fatal accidents, while August 2019 reported the fewest (Figure 6.5). Over the course of six years, we observed a sharp decline in fatal cases between the first two months of each year, with the exception of 2016, when cases gradually increased.

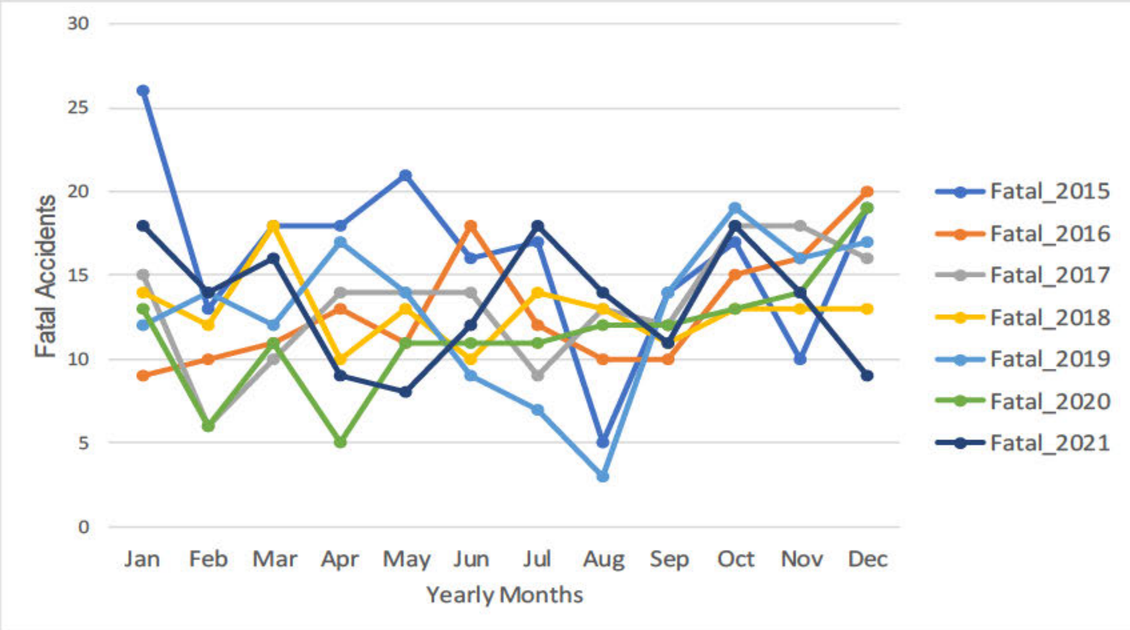


Figure 6.5 7-Year Fatality Cases

6.4.2.2 Road Traffic Violations

From January 1st, 2019 to January 1st, 2021, traffic enforcement cameras collected a total of 5,655,835 records of traffic violations. Figure 6.6 shows the variation of traffic violations by month across three years. From 2019 to 2020, there was a decrease in violations until June 2021, when there was an increase. The month of February recorded the least number of violations for 2019 and 2021. However, in 2020, May recorded the fewest violations, possibly because the COVID-19 lockdown reduced the number of vehicles on the road. The COVID-19 period witnessed a drastic decrease in the number of crashes recorded in Qatar compared to the previous 5 years (Alhajyaseen et al., 2022). In 2019 alone, there was a sharp decline in traffic violations from January to April, and it remained almost steady until May. Almost midway through the year, a spike was recorded.

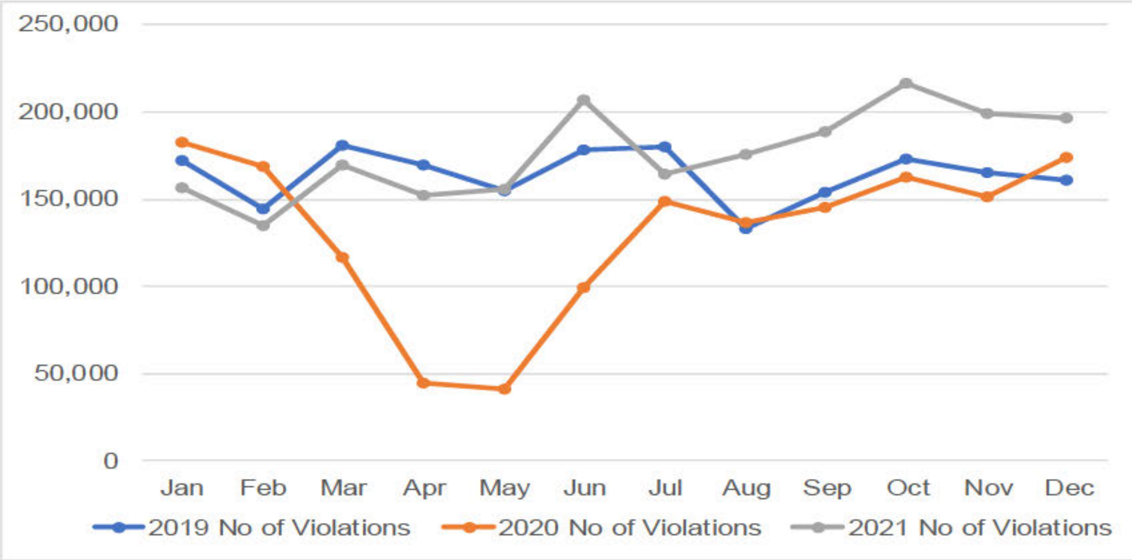


Figure 6.6 3-Year Variation in Traffic Offences

6.4.3 Discussion

This research was carried out during a period of fast population growth in Qatar, which increased the number of registered vehicles and led to a far bigger increase in the number of licensed drivers. This increased number of motor vehicles is one of the key reasons contributing to the rise in road crash casualties. The issue lies not only in the increase in numbers and risk exposure, but also in the implementation of appropriate road safety measures to accompany this growth. The automobile, along with the following increases in the number of automobiles and road infrastructure, has provided society with benefits, but it has also resulted in societal costs, of which road traffic injury is a key contributor. The increase in motor vehicles in Qatar has posed challenges for pedestrians and bicycles, particularly when improper planning has occurred. According to Bíl et al., 2016, motor vehicle collisions have been found to account for the majority of fatal bike collisions. However, among non-fatally injured cyclists, crashes with motor vehicles are not the most common type of collision. While crash analysis is the preferred approach to evaluating the camera's efficiency, this type of analysis is not possible in this study due to a lack of extensive crash data. Furthermore, no investigations into the rate of breaches were undertaken before the cameras were put in Qatar, making a before-and-after comparison impossible.

According to the descriptive analysis, over the past seven years, the number of minor injuries fluctuated more than the number of fatal crashes. Although traffic deaths and serious injuries decreased with time, the number of minor injuries that did not require hospitalization climbed. Better notification of minor injuries or rapid population growth, leading to higher traffic density, could be responsible for this. Another explanation is that those speed cameras reduced speeds sufficiently to lower the death rate, but had little effect on less serious injuries. Similarly, the number of passengers injured over the past six years is more varied than the number of pedestrians and drivers. In comparison to passengers, drivers were the most affected during the era. The year 2021 reported the highest number of affected drivers. It was also found that accident instances reported more minor injuries, while fatalities remained minimal. The 6-year period's lowest and highest minor accidents occurred in December 2021. The most serious accidents happened in November 2016, with the lowest number occurring in September 2019. From 2019 to 2020, there was a decline in traffic offences, with an increase not occurring until June 2021. In both 2019 and 2021, February saw the fewest violations. The number of cameras installed on the driver's regular routes could have a significant impact. The likelihood of receiving more tickets will almost certainly increase as the number of cameras on the road increases. This important aspect explains why people are prone to disobeying rules and exceeding speed limits. Even if they receive the same ticket as the coups in the same circumstances, people are not terrified of the camera. The increase in traffic offences from 2019 to 2021 demonstrates this.

It is also assessed for the variability in accidents between the three different accident cases using a one-way ANOVA. The results showed a significant difference in the mean score between fatal and minor accidents. Serious accident cases differed significantly from minor cases. A variety of factors may have contributed to this variation, resulting in varying victim severity among passengers, drivers, and pedestrians. However, we observed no significant differences between passenger and pedestrian victims. It was also observed that there was a significant variation in traffic offences between 2020 and 2021. However, there were no significant differences between 2019 and 2020, or between 2019 and 2021.

6.5 Conclusions and Recommendations

Speeding is the primary cause of an increase in the frequency of accidents worldwide. Many countries are attempting to strengthen their traffic systems in order to curb this behaviour among drivers. In order to reduce the number of speeding drivers, Qatari authorities have implemented a speed camera enforcement system on a few selected routes. For this study, we examined a sample size of various highways in Qatar to better understand the variances in road traffic accidents, the effects of speed camera enforcement on driver behaviour, and the major factors driving the rising number of speed penalties. The study's findings indicate that from

2015 to 2021, there were more reported minor accidents than severe and fatal ones. In addition, a considerable difference in traffic offences was noticed between 2020 and 2021. Traffic movement violations, stand-and-wait rules and obligations violations, passing traffic signals, the number of speed cameras installed on the driver's routine roads, the driver's age, ignorance of the seatbelt rule, and covering the car's plate to hide from the speed camera could all be contributing factors.

It is worth noting that the effectiveness of speed cameras (Section 6.3.1) in reducing traffic crashes and fatalities is influenced by various factors, including the placement of cameras, appropriate speed limits, and enforcement measures. Regular evaluation and adjustment of speed camera programs based on data analysis and feedback are crucial for optimizing their impact on road safety. Speed cameras have played a significant role in reducing traffic crashes and fatalities in Qatar. It is believed that the implementation of speed cameras has helped enforce speed limits, deter speeding behaviour, and improve road safety outcomes.

Additionally, speed cameras serve as a visual reminder for drivers to adhere to speed limits. Research has consistently shown that speed is a major contributing factor to road accidents and their severity. By enforcing speed limits through cameras, drivers are more likely to reduce their speed, leading to a decrease in the probability of crashes and the severity of injuries. Speed cameras also act as a deterrent for drivers who might otherwise exceed speed limits. The presence of cameras creates a perception that there is a higher risk of being caught and fined for speeding violations. This deterrence effect encourages drivers to comply with speed limits, resulting in safer driving behaviour and a decrease in the number of accidents.

Moreover, speed cameras contribute to raising awareness about the importance of adhering to speed limits and the risks associated with speeding. Publicizing the presence of speed cameras through signage and awareness campaigns helps reinforce the message of responsible driving and fosters a culture of road safety among road users. It is also believed that, over time, the consistent presence of speed cameras leads to a positive behaviour change among drivers. Speed cameras help create a societal norm for safer driving practices by encouraging compliance with speed limits. This behaviour modification contributes to a sustained reduction in speeding-related accidents and fatalities. Overall, speed cameras have had a positive impact on reducing traffic crashes and fatalities in Qatar. By enforcing speed limits, raising awareness, and promoting responsible driving behaviour, speed cameras contribute to creating a safer road environment and improving road safety outcomes for all road users.

However, there are several limitations to this study. First, researchers might benefit from a longer recording period to break down violation data by time of day and/or signal cycle. Furthermore, if the violation data and accident cases were also accessible before the installation of the cameras, a rigorous statistical before-and-after analysis (Section 6.3.2) might be undertaken utilizing quasi-experimental research.

Chapter 7: Case Study 4: Pedestrian Signal Setting and Implementation in the State of Qatar

7.1 Introduction

This chapter (case study 4) delves into "Pedestrian Signal Setting and Implementation in the State of Qatar," aiming to analyse and optimise pedestrian signal settings through a multifaceted approach. The effectiveness of optimised crosswalk signal timing in reducing pedestrian-vehicle conflicts and improving pedestrian safety in urban areas (Iryo-Asano M et al., 2014; Ma W et al., 2015). By analyzing pedestrian crossing behaviours and signal configurations, the research underscores the importance of tailored signal timing strategies for enhancing pedestrian safety outcomes (Bennett S et al., 2001; Alhajyaseen WKM, Iryo-Asano M, 2017). The findings reveal that optimised signal timing parameters contribute to reduced pedestrian-vehicle conflicts and enhanced pedestrian safety, emphasizing the importance of signal timing optimization in urban environments (Ivan JN et al., 2018). Methodology (Section 7.3) serves as the cornerstone of this study, guiding the systematic collection and analysis of data to inform evidence-based decision-making. To provide a comprehensive understanding, the study begins with an exploration of basic terminology and international best practices in pedestrian signal settings, drawing upon a rich tapestry of global experiences. Site descriptions offer valuable context, detailing the unique characteristics of pedestrian environments in Qatar. Data analysis forms a central component of this study, encompassing various dimensions such as an overview of pedestrian data (Section 7.7.1), analysis of start and complete crossing timings (Section 7.7.2), and assessment of crossing speeds (Peters D, et al., 2015). Furthermore, the study conducts a meticulous examination of pedestrian signal settings (Section 7.7.4), utilizing advanced statistical techniques such as analysis of variance (ANOVA) to discern patterns and variations (Section 7.7.5). Crucially, the present study extends its analysis beyond pedestrian behaviours to encompass road safety outcomes, including accident cases, victims, and traffic violations. By integrating these diverse elements, the study seeks to provide actionable insights into optimizing pedestrian signal settings to enhance safety and efficiency for pedestrians across Qatar. This study looks closely at methodology (Section 7.3), international best practices (Section 7.5), site-specific features (Section 7.6), and detailed data analysis (Section 7.7) in order to help people make decisions about urban planning and road safety management that are based on facts.

7.2 Background

Pedestrian signal control is a major influence on the level of service provided by crossing facilities as well as the safety performance when dealing with vehicles. In signal design, pedestrian clearance time is a key design parameter for ensuring safe pedestrian crossing at signalized crosswalks. The performance of pedestrian signal control and its impact on pedestrian behaviour in Gulf Cooperation Council (GCC) Countries is rarely addressed in the literature. The characteristics of the population, cultural diversity, and extremely hot weather conditions may lead to significantly different pedestrian behaviour in terms of crossing maneuvers (path and speed), compliance with signal control, and interaction with vehicular traffic. Using empirical observations, this study reviews pedestrian signal design practices in various countries and investigates the current signal settings and their adequacy in the State of Qatar. The empirical analysis showed that the 85th percentile crossing times were longer than the provided Pedestrian Flashing Green (PFG) intervals at the observed crosswalks. Study sites are characterized by unrealistically long Buffer Intervals (BIs) which, from one side, provide sufficient time for pedestrians who started crossing during PFG to complete the crossing. On the other hand, they encourage pedestrians to continue crossing after the PFG ends. Additionally, the speed analysis indicated that the observed 15th percentile speed was 1.22 m/s, which is similar to the assumed design speed by the Qatar Traffic Control Manual, (QTCM 2015). Furthermore, the analysis revealed that pedestrian crossing speeds during PFG or BI were significantly higher than those during PG.

The function of signalized crosswalks is to provide secure locations and time for pedestrians to perform safe crossing manoeuvres. In most countries, including the State of Qatar, pedestrian signals have three signal indications, green (PG), flashing green (PFG) and red (R). However, in some countries, like Germany and France, pedestrian signals have only two indications, green and red. In the US, pedestrian signals have three indications, green (or “WALK”), flashing red (or flashing “DONOT WALK”) and steady red (or “DONOT WALK”). To ensure pedestrian crossing safety, the provision of PG and PFG should be sufficient. In fact, in designing pedestrian signals, two parameters are essential; clearance time and red buffer interval (BI). Generally, the clearance time is defined as the time pedestrians, entering crosswalks at the end of the green indication, need to complete their crossing before the release of conflicting vehicular traffic movements. BI is the interval from the end of PFG to the onset of the green phase of the subsequent conflicting vehicle phase. Theoretically, PFG and BI should match the clearance time, and pedestrians can use the remaining time of the parallel vehicle phase as their green time. Providing short PFG and BI intervals that are not sufficient for pedestrians to clear the crosswalk will lead to pedestrians left on the crosswalk after the onset of successive vehicle phase 1. Long BI and/or PFG intervals will be paired with short PG intervals. This will impose longer delays on pedestrians because of the shorter crossing intervals, and as a result, it will push pedestrians to cross during the BI or red interval, increasing their risk of conflicts. Therefore, a clear and effective approach for setting pedestrian signal control parameters that can maximize pedestrian compliance and minimise conflicts with vehicles is still missing. As a result, we can easily find significantly different pedestrian signal settings (in terms of indication and timing) in various countries. An adaptive pedestrian crossing signal control was proposed by Xiao et al., 2013, which reduced the waiting time for pedestrians by capturing the number of pedestrians waiting at crosswalk. Using a simulation technique, Ma et al., 2015, developed criteria for selecting appropriate pedestrian phase patterns that take into account efficiency and safety for both walkers and vehicles.

A quadratic programming approach was used to optimise the signal timing for pedestrian and vehicle signals for one- or two-stage crosswalks. In an observational study, pedestrian compliance at concurrent and exclusive phasing was studied using data from 42 signalized intersections in Connecticut, United States. Pedestrian crossing behaviour and the impact of signal timing were addressed by several studies. Alhajyaseen WKM, 2015, investigated the influencing factors on pedestrian crossing speed, including signal timing, in Japan6. Iryo-Asano et al., 2014, extended the analysis to consider the impacts of crosswalk geometry on pedestrian crossing decisions and speed at signalized crosswalks. All these studies had a common conclusion that pedestrian maneuvers are widely varying and are significantly affected by control type (signal timing and indication), crosswalk geometry, the presence of conflicting vehicles, and others. Pedestrian signal indication and time setting can even cause behavioural changes while crossing. Depending on the available timing to complete crossing combined with other factors (such as crosswalk geometry and the presence of vehicles), pedestrians may suddenly accelerate or decelerate without paying attention to the surrounding conditions, which may increase safety risks. Studies that address pedestrian crossing behaviour and investigate the rationality of pedestrian signal setting in Gulf Cooperation Council Countries (GCC) are missing. Therefore, the objective of this chapter is to assess the adequacy of pedestrian signal timings in the State of Qatar while focusing on clearance timing, for safe pedestrian crossings. The analysis in this case study is performed using empirical observations at several signalized intersections in Doha city.

7.3 Methodology

Empirical observations were collected at four crosswalks from three different signalized intersections located near popular shopping centers in the State of Qatar. All these crosswalks are characterized by standard signal indications comprising PG, PFG, and R. Each study site was videotaped for 1.5 hours in order to collect signal information and pedestrian maneuvers. The video recording was conducted in December 2016, with a temperature range of 15°C to 21°C. The pedestrian movements during active pedestrian signal phases were observed. Only the pedestrians who waited for the pedestrian signal and crossed the crosswalk were considered in the observations. The pedestrians who jaywalked from irregular locations, away from the crosswalk, were not considered. It was observed that some pedestrians crossed during the red interval in two stages to prevent conflicts with vehicles, so they were excluded from the analysis. The crosswalk lengths and widths were measured in the field using a measuring wheel.

The videos included information on gender, start and end times, and corresponding signal indications for pedestrians. The corresponding vehicle signal setting was also noted. The age of the pedestrian was not noted because so few young people and the elderly were seen crossing. To make sure the clearance times and signal timing were adequate, the pedestrians' 85^{th} percentile crossing times were calculated and compared to a number of benchmarks. In order to ascertain design speed and look into the effects of location features such as crosswalk length, pedestrian speeds were analysed. IBM SPSS Statistics Version 23.0 was used for all statistical analyses.

7.4 Basic Terminology

This section defines the basic terminologies related to pedestrian signals used in this research. The Pedestrian Green (PG) Interval is the designated time for pedestrians to begin crossing. This time includes pedestrian start-up time and mainly depends on pedestrian demand (the number of pedestrians waiting to cross at the onset of the green signal). Pedestrian Flashing Green (PFG) interval: There are different definitions and settings for the PFG intervals1. In this study, we adopted the definition proposed by the Qatar Traffic Control Manual (QTCM) which is defined as the time required for the pedestrian who started crossing at the end of PG to complete the crossing safely. The time for PFG is also referred to as the clearance interval. This time is determined by dividing the length of the crosswalk by the crossing speed.

Pedestrians on the crosswalk must complete their crossing during this time, while those on the sidewalk should refrain from starting their crossing. Buffer Interval (BI): It is the time difference between the end of PFG and the onset of the green phase of the subsequent conflicting vehicle phase. BI is provided to ensure pedestrian safety, especially for those pedestrians who do not complete the crossing in the given PFG time. In some signal-setting practices, BI is used to compensate for short PFG intervals which is implemented to reduce the probability of pedestrians starting to cross during PFG. Indicating BI in red prevents pedestrians from initiating crossings. Red (R) interval: The remaining time in a cycle after assigning PG and PFG intervals is called the red interval and is indicated in red. In this period, similar to vehicles' red signal indication, pedestrians are not allowed to cross.

7.5 International Practices

This section provides a brief overview of the practices used to set pedestrian signal timings in various countries, such as Qatar, the USA, the UK, and France. In the State of Qatar, the QTCM specifies pedestrian signal timing provisions for standalone signals and intelligent pedestrian crossings. The pedestrian signal indication is provided in two parts; green time (PG) and clearance time (PFG). For standalone crossings, the PG typically ranges from 4 to 12 seconds. The PG is determined based on pedestrian flow, crossing distance, the availability of a small-sized median, and the presence of a higher proportion of elderly or disabled pedestrians. Crosswalk length and crossing speed determine the PFG, or clearance time. It ranges between 0 and 30 seconds. The crossing speed is assumed to be 1.2 m/s. However, it should be noted that most signalized intersections in Doha city are equipped with push buttons to activate the pedestrian signal. These push buttons do not alter the intersection phasing plan to give pedestrians the right of way. They only give the controller a sign to turn on the pedestrian green indicator when the relevant phase starts. In the US, the Traffic Signal Timing Manual (TSTM) recommends a walk duration (PG) of 7 seconds. However, it can vary between 4 and 15 seconds depending on the pedestrian volume, cycle length, and surrounding area. The walk time allows pedestrians to cross the central median to minimise their chances of stopping in the middle. The clearance time is provided based on the distance from the near side curb to the far side curb, which means crosswalk length. The Manual on Uniform Traffic Control Devices MUTCD recommends a speed of 1.22m/s or 1.07 m/s, or 0.9 m/s for the setting of PFG. Slower speeds are recommended where pedestrians with disabilities, the elderly, and children are frequently observed. Nevertheless, the manual indicates that recent studies recommend the use of 1.07 m/s.

Despite the recommendation to provide a green time of 10 seconds, the minimum green time in France is 6 seconds. The pedestrian flashing green is calculated by considering a maximum walking speed of 1m/s. Depending on the road width, the presence of disabled pedestrians, and the availability of a central refuge, the UK sets the green time between 4 and 9 seconds. A maximum PFG interval of 18s is recommended based on crosswalk length. An additional clearance time of one and two seconds is provided for crossings up to 10.5m in length and for crossings of more than 10.5m in length, respectively. Further, based on site conditions, generally for divided crossings, an additional PFG of 0 to 2 seconds is provided to indicate the end of PG and the onset of PFG. Table 7.1 provides a summary of practices in different countries. Additionally, Table 7.1 provides a detailed summary of pedestrian signal settings for France and UK. Most of the previous guidelines or manuals do not have a clear estimation methodology for BIs, which is dependent on the PFG interval setting.

Table 7.1 International Comparison for Pedestrian Signal Settings

Country	G (s)	FG (s)	BI (s)	Equation for PFG (s)
Qatar	4-12	0-30s	-	d(m)/1.2
US	4-15	-	Min 3	d(m)/0.9 or d(m)/1.07, 1.22
France	6-10	-	-	d(m)/1
UK	4-9	6-18	0-2	6+((d-6)/1.2)

Table 7.2 Study site characteristics

Site	Crosswalk Location (Approach)	Abbreviation	Center Island	L(m)	W(m)	C_L (s)	PG (s)	PFG (s)	BI (s)
City Center	South	CC	Yes	19.20	3.0	150	10	9	23-62
Lulu Hypermarket	East	LH	Yes	37.65	3.0	167	7	21	40
Sana Intersection	East	SI(EA)	No	24.50	3.0	140	8	12	27
	South	SI(SA)	No	20.30	3.0	140	8	12	29 or 31

Note: C_L is cycle length in seconds, L is crosswalk length, and W is crosswalk width

7.6 Site Description

In the State of Qatar, private vehicles are the main mode of travel. Due to the lack of efficient public transport, it only observes pedestrians on a limited scale, typically concentrating around commercial and recreational areas. However, it is expected to have a significant increase in pedestrian activities with the planned world-class metro system, which is expected to be partially operational by 2019. Therefore, three intersections located near major shopping centres and governmental offices in Doha were selected for the analysis. The intersection at City Center is situated between one of the biggest shopping malls and many government offices. Lulu Hypermarket is one of the most well-known shopping complexes for residents. The Sana Intersection is adjacent to a very popular shopping destination and surrounded by residents who have limited access to cars. Table 7.2 presents the geometric characteristics of the study sites along with their pedestrian signal settings. Figure 7.1 displays the signal phasing plans for the selected sites. The QTCM recommends providing a central refuge for pedestrians if the crossing length is more than 15 m. Nevertheless, two of the observed crosswalks do not have a central refuge. The Sydney Coordinated Adaptive Traffic System (SCATS) operates all three intersections, allocating signal timing based on real-time traffic demand. Note that the timings for pedestrian signal indications (PG and PFG) stay consistent throughout the day. The BI's length is the only change.

7.7 Data Analysis

7.7.1 Overview of Pedestrian Data

The total number of observed pedestrians is 133, as shown in Table 7.3. The proportion of female pedestrians was highest (about one-third) for CC and lowest (about 5.71%) for SI (SA). It can be attributed to the surrounding land use at the selected sites. The average crossing time was 14.44 seconds, 25 seconds, 17.21 seconds, and 14.05 seconds for CC, LH, SI (EA), and SI (SA), respectively.

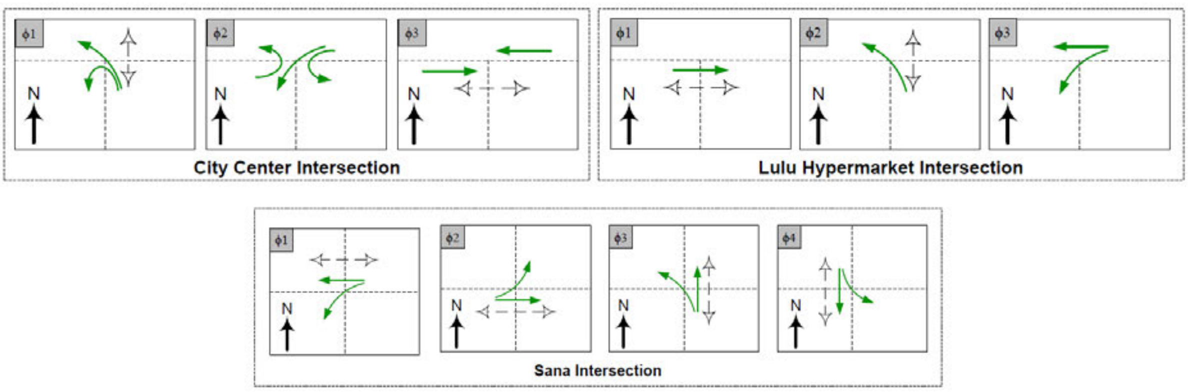


Figure 7.1 Phase Diagram for Selected Intersections

Table 7.3 Details of collected pedestrian data

Name	Abbreviation	N	% Male	% Female	C_t(s)	$C_{t85\%}$(s)	C_{tmax}(s)	V(m/s) (SD)	$V_{15\%}$(m/s)
City Center	CC	31	67.74	32.26	14.44	17.87	20.22	1.39(0.33)	1.07
Lulu Hypermarket	LH	34	76.47	23.53	25.00	29.14	33.08	1.56(0.34)	1.29
Sana Intersection	SI(EA)	33	87.88	12.12	17.21	20.01	21.14	1.47(0.30)	1.22
	SI(SA)	35	94.29	5.71	14.05	15.93	18.96	1.50(0.33)	1.27

Note: C_t(s) is average crossing time, $C_{t85\%}$(s) is 85th percentile crossing time, C_{tmax}(s) is maximum crossing time, V(m/s) is average crossing speed, SD is standard deviation of the speed, and $V_{15\%}$ is 15th percentile crossing speed.

7.7.2 Analysis of Start and Complete Crossing Timings

This section analyses the distribution of pedestrians' start and complete crossing times. Figure 7.2 represents the cumulative distribution of the times when pedestrians started and completed crossing. Only pedestrians waiting on the sidewalk at the onset of PG, as well as those who arrived during PG, PFG, and BI, were considered for the analysis. For the CC intersection, almost 70% of the pedestrians who started crossing in PG finished in PFG, and the remaining completed crossing in BI. At the LH intersection, 60% of the pedestrians who started crossing in PG completed crossing in PFG, and the remaining completed crossing in BI. For SI (EA), the proportion of pedestrians who completed crossing in BI was almost 60%, while for SI (SA), it was much smaller, about 20%. This indicates that even though the pedestrians started crossing in the PG interval, a significant proportion of them were not able to complete crossing within the provided clearance time. However, the provision of a large BI enabled most pedestrians who started crossing during PFG to complete their crossing before the onset of successive conflicting vehicle green phases. Simultaneously, due to the unreasonably long BI intervals, pedestrians continued to start crossing during BI, and it was observed (but not included in the analysis) that pedestrians who arrived after the end of BI did not wait and attempted to start crossing by looking for gaps between vehicles. The long cycle length and short PG intervals lead to long-expected waiting times (Table 7.2). It is interesting to observe that CC and SI (SA) crosswalks had a significant percentage of early crossing pedestrians before the start of PG. The shorter length and long waiting time (long cycle length) may account for this, suggesting that crosswalk length and expected waiting time can significantly influence a pedestrian's decision to cross.

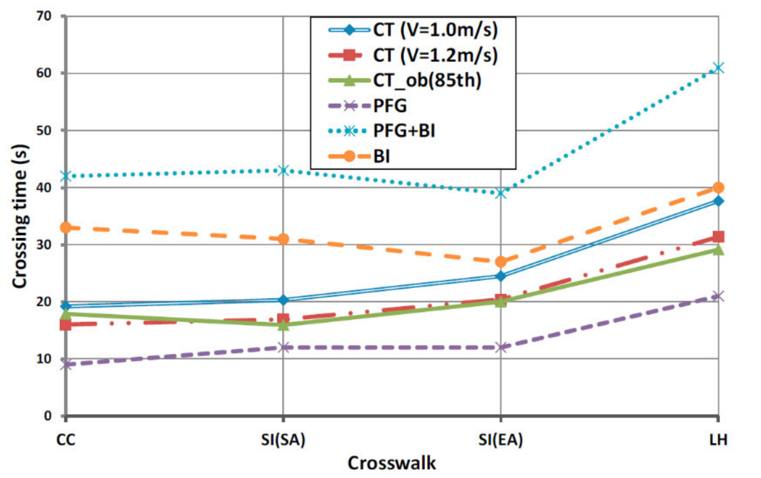


Figure 7.2 Pedestrian Clearance Time Comparison

7.7.3 Analysis of Crossing Speed

The crossing speeds of all observed pedestrians (N = 133) were analysed to determine the design speed. The distribution of observed travel speeds provided, 1.22 m/s as the 15th percentile speed. This speed aligns with the MUTCD's recommended speed for the clearance interval design. Alhajyaseen et al., 2010, reported a similar 15% speed between 1.0 and 1.25 m/s from observations at different sites in Japan. Furthermore, Bennett et al., 2001, observed a similar 15th percentile speed of 1.24 m/s at four crosswalks in Melbourne City. In general, this highlights the importance of setting signal control based on locally observed parameters. Analysis of variance (ANOVA) for the four sites indicated that the speeds at the four sites were significantly different ($\chi2 = 8.587$, $p = 0.035$). The post-hoc tests between the sites showed that the average pedestrian speed at LH was significantly higher than SI (EA) (K-S Z=1.525, p=0.019), SI(SA) (K-S Z=1.508, p=0.021), and CC (K-S Z=2.075, p=0.001). LH crosswalk is the longest at 37.65m. This indicates that long crosswalks have significantly higher crossing speeds, which is in accordance with the results from previous studies (6, 7). However, the post hoc test showed that the crossing speed at the other three sites was not statistically different.

The estimated pedestrian speeds during different signal indications were statistically compared, from a non-parametric ANOVA, it was found that the pedestrian speeds in different signal indications are significantly different ($\chi2$=16.103, p=0.001). The post-hoc test revealed that the speeds of pedestrians who started crossing during PG were significantly different from the speeds of pedestrians who started crossing in PFG (K-S Z=1.406, p=0.038), and BI (K-S Z=1.563, p=0.015). The average crossing speed during PFG and BI intervals was significantly higher (about 25%) than the average crossing speed during PG. This is in accordance with Alhajyaseen, 2014, and Peters et al., 2015, results from 6,15. Furthermore, the analysis showed that the average pedestrian speeds during PFG, BI, and R were not significantly different. The limited number of pedestrians observed at these intervals can explain this. Therefore, these results should be validated by collecting more data in the future.

7.7.4 Assessment of Pedestrian Signal Setting

It was found that the 85th percentile of pedestrian crossing times, compared them to the observed PFG and BI intervals, and guessed the standard clearance intervals based on speeds of 1.2 m/s and 1.0 m/s to see if the pedestrian signal timing was correct. As illustrated in Fig. 7.2, this study chooses the observed 85th percentile crossing time as the reference for the necessary clearance time setting. All sites are characterized by PFG intervals that are shorter than the required clearance times. However, the provided BIs compensated for that and even provided much longer clearance times than needed. For CC and SI (SA), the BIs were almost double the observed 85th percentile crossing times, while for SI (EA) and LH, the BIs were 30% higher. People perceived the long BI intervals as irrational, leading to an increase in crossings during the red period. They lead to longer red indication intervals, which, as a result, impose more delays on pedestrians. These unreasonable long BIs can be partially used to lengthen the PG interval, which provides more opportunity for pedestrians to cross.

This research investigates the status of pedestrian signal settings in the State of Qatar and the impacts of signal control on pedestrians' crossing behaviour. The review of various signal design standards in different countries indicated that there are significantly different practices without a common methodology for setting PFG and BI intervals (clearance time). For clearance time 9, QTCM recommends a speed of 1.2 m/s for the setting of clearance time 9. This speed is similar to the empirical observations in this study, which indicated that the 15th percentile speed was 1.22 m/s. Furthermore, this study demonstrates that crosswalk geometry and pedestrian signal setting have a significant impact on crossing speed. Long crosswalks have significantly higher crossing speeds compared to shorter ones. Furthermore, crossing speeds during PFG and BI were significantly higher than crossing speeds during PG. Although the current PFG intervals at observation sites are shorter than the needed clearance intervals, BI complements PFG to provide sufficient clearance intervals. Surveyed study sites had irrationally long BI intervals, which imposed longer delays on pedestrians since some of the time could be allocated as PG, providing more crossing opportunities for pedestrians.

The presented data sample in this study is limited. Therefore, a collection of large sample sizes from different locations with different geometric and control parameters is necessary to draw concrete conclusions. Furthermore, pedestrian countdown signals are implemented at several signalized intersections in the City of Doha. For that reason, the settings of these countdown signals and pedestrian behavioural characteristics (including compliance, speed, etc.) need to be studied to provide the safest crossing environment for pedestrians and to improve the level of service at pedestrian crossings.

7.7.5 Analysis of Variance for Accident Cases

The ANOVA test is one of the most applicable methods in transportation data analysis (Qu et al., 2014). It is used to assess if the mean of the accident cases significantly differs at the 0.05 level. A one-way ANOVA was initially conducted for accident cases with three levels; minor, serious, and fatal. It compares the variability in accidents between the three different accident cases. Table 7.4 presents the obtained results.

Table 7.4 Analysis of Variance for Accident Cases

			Test of Homogeneity of Variance		**ANOVA**	
Accident Cases	Mean	St Dev	Levene's Statistic	Sig	F	Sig
Minor	5403.7	802.7	4.973	0.019	275.729	0.000
Serious	548.9	74.6				
Fatal	159.3	17.0				

Group Differences				
Accident Cases	Mean Difference	Sig	95% CI (LL, UL)	
Serious-Minor	-4854.9	0.000	-5822.9	-3887.1
Fatal-Minor	-5244.4	0.000	-6213.0	-4275.8
Fatal-Serious	-389.6	0.000	-479.2	-299.9

The hypothesis tests if the severity of road accidents differs across different accident cases. The ANOVA results suggest that the severity of accidents differs significantly *(*$F_{2,18} = 275.729$*,* $P\ \ 0.05$*).* Since Levene's statistic is significant, the equal variance assumption was violated. To check for individual differences between the three accident cases, post-hoc comparisons were made using Dunnett's T3. The test indicated that the mean score for fatal accidents *(*$M = 159.3$*,* *SD = 17.0)* was significantly different from minor accidents *(M* = 5403.7, *SD* = 802.7*)*. Serious accident cases *(M* = 548.9, *SD* = 74.6*)* differed significantly from minor cases. The mean differences were significant at the 0.05 level.

7.7.6 Analysis of Variance for Accident Victims

A one-way ANOVA was also performed for accident victims at three levels: drivers, passengers, and pedestrians. The study compares the significant impact of a crash on each of the three groups. Table 7.5 presents the obtained results. The hypothesis examines whether the severity of road accidents varies among different accident victims. The ANOVA results suggest that accidents affect the three categories of victims significantly differently *(*$F_{2,18}$ *= 12.986, P 0.05)*. Since Levene's statistic is statistically insignificant, an equal variance was assumed. The Scheffe and Turkey HSD post-hoc comparisons are used to check for individual differences between the three victim categories. Both tests returned similar outcomes with the same level of conclusion. The results indicated that the mean score for passenger victims *(M = 43.1, SD = 15.3)* was significantly different from that for driver victims *(M = 77.9, SD = 13.3)*. Pedestrian victims *(M* = 48.6, *SD* = 12.4*)* differed significantly from driver victims. The mean differences were significant at the 0.05 level. However, there are no significant differences between passenger and pedestrian victims.

Table 7.5 Analysis of Variance for Accident Victims

			Test of Homogeneity of Variance		**ANOVA**	
Victim Cases	Mean	St Dev	Levene's Statistic	Sig	F	Sig
Driver	77.9	13.3	0.037	0.964	12.986	0.000
Passenger	43.1	15.3				
Pedestrian	48.6	12.4				

Group Differences				
Victim Cases	Mean	Sig	95% CI (LL, UL)	
Passenger-	-34.7	0.000	-53.4	-16.0
Pedestrian-	-29.3	0.002	-48.0	-10.6

7.7.7 Analysis of Variance for Traffic Violations

To understand whether there exists a significant difference in traffic violations for the three years, 2019-2021, a one-way ANOVA was performed. It compares which of the three years recorded significantly different numbers of violations. Table 7.6 presents the obtained results.

Table 7.6 Analysis of Variance for Traffic Offences

			Test of Homogeneity of Variance		ANOVA	
Year	Mean	St Dev	Levene's Statistic	Sig	F	Sig
2019	163881.	14848.	6.008	0.00	6.397	0.004
2020	131060.	47222.				
2021	176377.	25157.				
			Group Differences			
Year	Mean Difference		Sig	95% CI (LL, UL)		
2020-2021	-45317.5		0.027	-		-4588.9

Since Levene's statistic is significant, the equal variance assumption was violated. To check for individual differences between the three years, post-hoc comparisons were made using Dunnett's T3. The test indicated that the mean traffic violations for 2020 *(M* = 131060.2, *SD* =47222.2*)* were significantly different from those of 2021 *(M* = 176377.7, *SD* =25157.5*)*. The mean differences were significant at the 0.05 level. However, no significant differences were observed between 2019 and 2020 or between 2019 and 2021.

7.8 Results and Discussion

This research was carried out during a period of fast population growth in Qatar, which increased the number of registered vehicles and led to a far bigger increase in the number of licensed drivers. This increased number of motor vehicles is one of the key reasons contributing to the rise in road crash casualties. The issue lies not only in the increase in numbers and risk exposure, but also in the implementation of appropriate road safety measures to accompany this growth. The automobile, along with the following increases in the number of automobiles and road infrastructure, has provided society with benefits, but it has also resulted in societal costs, of which road traffic injury is a key contributor. The increase in motor vehicles in Qatar has posed challenges for pedestrians and bicycles, particularly when improper planning has occurred. According to Bíl et al., 2016, motor vehicle collisions have been found to account for the majority of fatal bike collisions. However, among non-fatally injured cyclists, crashes with motor vehicles are not the most common type of collision.

According to the descriptive analysis, over the past seven years, the number of minor injuries fluctuated more than the number of fatal crashes. Although traffic deaths and serious injuries decreased with time, the number of minor injuries that did not require hospitalization climbed. Better notification of minor injuries or rapid population growth, leading to higher traffic density, could be responsible for this. Another explanation is that those speed cameras reduced speeds sufficiently to lower the death rate while having little effect on less serious injuries. Similarly, there is more variance in the number of passengers injured over the past six years than there is in the number of pedestrians and drivers. In comparison to passengers, drivers were the most affected during the era. The year 2021 reported the highest number of affected drivers. It was also discovered that more minor injuries were reported in accident instances, and fatalities were kept to a minimum. The 6-year period's lowest and highest minor accidents occurred in December 2021. The most serious accidents happened in November 2016, with the lowest number occurring in September 2019. From 2019 to 2020, there was a decline in traffic offences, with an increase not occurring until June 2021. In both 2019 and 2021, February saw the fewest violations. The number of cameras installed on the driver's regular routes could have a significant impact. The likelihood of receiving more tickets will almost certainly increase as the number of cameras on the road increases. This important aspect explains why people are prone to disobeying rules and exceeding speed limits. Even if they receive the same ticket as the coups in the same circumstances, people are not terrified of the camera. This is exemplified by the increase in traffic offences from 2019 to 2021.

The variability in accidents between the three different accident cases was also assessed using a one-way ANOVA. The results showed a significant difference in the mean score between fatal and minor accidents. Serious accident cases differed significantly from minor cases. A variety of factors may have contributed to this variation, resulting in varying victim severity among passengers, drivers, and pedestrians. However, no significant differences were observed between passenger and pedestrian victims. The data also revealed a significant variation in traffic offences between 2020 and 2021. However, no significant differences were observed between 2019 and 2020, as well as between 2019 and 2021.

7.9 Conclusions and Recommendations

This chapter presents case study 4. The case study investigates the influence of the pedestrian signal setting (Section 7.7.4) and its implementation on traffic safety analysis in Qatar. The Analysis of Variance techniques (Section 7.7.5) have been used to assess the accident rates. Based on the descriptive analysis, the number of minor injuries fluctuated more than the number of fatal crashes over the past seven years. Although traffic deaths and serious injuries decreased with time, the number of minor injuries that did not require hospitalization climbed. This could demonstrate better monitoring of minor injuries, or rapid population growth, which led to higher traffic density. Similarly, there is more variance in the number of passengers injured over the past six years than there is in the number of pedestrians and drivers. Further studies should be carried out to assess the factors that affect each type of accident, each type of road, and also types of injuries separately, as well as carry out comparative analysis.

Chapter 8: Case Study 5: Road Safety Status during COVID-19 Pandemic: Exploring Public and Road Safety Expert's Opinions

8.1 Introduction

This chapter, Case Study 5, delves into COVID-19's effects on road safety and assesses public and expert opinions on pedestrian signal settings' impact on traffic safety in Qatar. Utilizing surveys from Qatar residents, international road safety experts, and crash data, the study analyses COVID-19's influence on traffic safety trends. Over the years, the transportation system has played a significant role in affecting the spread of contagious viruses (e.g., influenza A/H1N1, SARS, and Ebola) (Xu et al., 2019; Zhang et al., 2011). Zhao et al., 2018, suggest imposing travel restrictions at appropriate times to prevent a large-scale outbreak of any disease. Recently, the new contagious coronavirus, also known as COVID-19, was declared to be a global pandemic on March 11, 2020, by the World Health Organization (WHO) (World Health Organization, 2020). By the end of 2020, WHO reported more than 82 million confirmed cases of COVID-19, with more than 1.8 million confirmed deaths (World Health Organization, 2021a). Different countries imposed strict restrictions and policies to limit the spread of COVID-19, including lockdowns, limiting work, education, shopping, and/or physical activities, and prohibiting social gatherings. During COVID-19, traffic decreased significantly, prompting behaviour shifts among drivers. Enforcement faced challenges, emphasizing the need for innovative strategies (WHO, 2019). However, opportunities emerged, such as promoting active transportation and leveraging technology for safety enhancements. These findings highlight the dynamic interaction between changing traffic patterns, driver behaviour, and enforcement practices during the pandemic (Saladie, O et al., 2019; Aloi, A et al., 2020). Furthermore, many countries have restricted air travel by shutting down airports. Individuals significantly reduced their daily trips as a result, potentially affecting traffic situations and traffic safety (WHO, 2021a). Policymakers and researchers from different countries have shown a great interest in understanding the impacts of the COVID-19 pandemic on transport systems. Furthermore, the impacts of the adopted restrictions on the transport system, including traffic safety, are crucial for each country, as every country has its own unique set of preventive measures and circumstances.

The main goal of this chapter is to investigate the impacts of the COVID-19 pandemic on traffic safety in Qatar, as well as drivers' perceptions of traffic safety during the pandemic. The analysis is carried out using crash data, and questionnaire surveys that were collected from the general public in the state of Qatar and road safety experts from the international community. This will allow us to compare real-world traffic situations with individuals' perceptions of the improvement or deterioration of traffic safety during the pandemic. The organization of this chapter is as follows: The background of the studies related to COVID-19 impact is summarised in Section 8.2, and Section 8.3 summarizes the research questions that are related to the impacts of COVID-19 on traffic safety. Section 8.4 contains a description of the collected data and sample descriptions. Section 8.5 presents the overall findings of the impact that COVID-19 has had on traffic safety. Section 8.6 then discusses the main findings. The last section presents conclusions and policy-related recommendations.

8.2 Background

In this case study, a detailed analysis of the traffic safety status during the COVID-19 pandemic is conducted in the state of Qatar. This study looks at traffic safety from three perspectives, road crash records, the general population of drivers, and road safety expert opinions. The analysis is based on original surveys from Qatari residents, international road safety experts, and road crash data, which would identify and clarify the impacts of the COVID-19 pandemic on traffic safety.

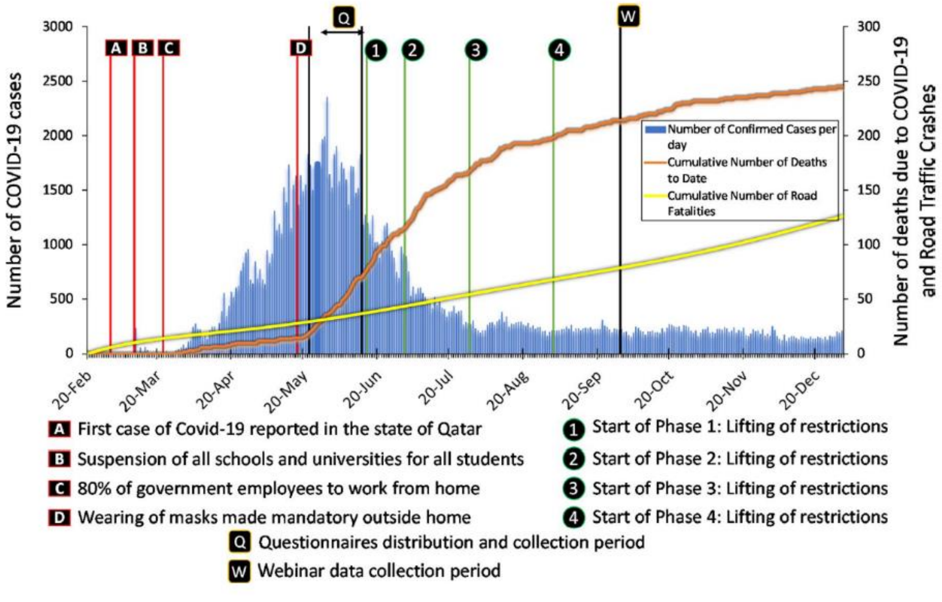


Figure 8.1 Daily New Positive Cases of COVID-19 and Cumulative Number of Deaths from COVID-19 and Crashes

Figure 8.1 shows the reported confirmed cases and the cumulative number of deaths due to COVID-19 in Qatar on a daily basis from February 20, 2020, until December 31, 2020 (JHU CSSE, 2021). In addition, the figure also exhibits the cumulative deaths due to Road Traffic Crashes (RTCs). COVID-19 reported 245 deaths by the end of 2020, while RTCs caused 126 deaths. Qatar reported the first positive case of COVID-19 on February 29, 2020. Soon after that, the cases increased, and the Qatari government imposed new regulations to counteract the spread of the virus in the country, such as the suspension of all schools and universities for all students on March 10 and work from home orders for 80% of government employees on March 22, 2020 (Government Communications Office, 2020a; Hukoomi Qatar e-Government, 2020).

However, a noticeable increase in confirmed cases began at the start of April 2020. Therefore, further restrictions were applied starting May 17, 2020, including the obligation to wear a face mask outside the home, allowing only two persons to sit in a vehicle with exceptions for families and taxis (i.e., a maximum of three persons), physical activities being allowed only near the place of residence, and mandated orders to install the mobile application ‘Ehteraz’ for location tracking, etc. (Gulf Times, 2020a, 2020b). The World Gulf, 2020 implemented fines of up to 200,000 QAR or up to 3 years of imprisonment in cases of violation to ensure adherence to the orders. As of December 31, 2020, more than 140 thousand confirmed cases of COVID-19 were reported in Qatar, of which 245 infected individuals lost their lives (World Health Organization, 2021b). In order to ease the restrictions, the government executed a four-phase plan (Government Communications Office, 2020b). Despite the gradual lifting of the restrictions, basic COVID-19 precaution measures remained mandatory at all times, such as wearing a face mask in public, using the 'Ehteraz' mobile application, and maintaining social distancing and thermal screening before entering indoor places. The first phase of lifting the restrictions started on June 15, 2020. During that phase, several restrictions were partially lifted, such as allowing an additional 20% of government employees to work in their workplace, reopening several public gardens in different areas, and reopening 30% of the shops inside malls. Phase 2 (1 July 2020) allowed restaurants to reopen, while Phase 3 (28 July 2020) increased the allowable percentage of employees in the workplace to 50% and 80%, respectively. In Phase 3, the Ministry of Public Health allowed Qatari residents from low-risk countries to enter the country. Eventually, on September 1, 2020 (phase 4), the Ministry of Public Health partially or fully lifted most restrictions, including the reopening of schools with a maximum attendance rate of 30% and the reopening of public transport with a maximum capacity of 50%.

The restrictions associated with the COVID-19 pandemic have not only reduced traffic volumes on the roads, but could also have altered driving behaviour. In this regard, Bavel et al., 2020, indicated that factors associated with psychological distress about the virus infections and the imposed governmental restrictions could also have strong impacts on individual driving behaviour. Around the world, the imposed restrictions have reduced traffic volume and congestion on the roads (Du et al., 2021; Google, 2021). However, as a negative consequence, this might have triggered certain drivers to engage in unsafe driving behaviours such as speeding, mobile phone usage, and stunt driving (Katrakazas et al., 2020; Vingilis et al., 2020). Therefore, despite global reports of fewer TRCs (Aloi et al., 2020; Brodeur et al., 2021; Oguzoglu, 2020; Qureshi et al., 2020; Saladie et al., 2020), the ratio of RTCs to the number of trips and/or the proportion of severe crashes may have increased during the COVID-19 pandemic. Consequently, researchers have shown a great interest in quantifying the changes in traffic safety during COVID-19. However, it is also crucial to understand the perceptions of individuals (the general public and road safety experts) about traffic safety and driving behaviour during the COVID-19 pandemic.

8.3 Research Questions in Relation to Case Study 5

As mentioned above, the main objective of this study is to analyse the impacts that COVID-19 has had on traffic safety in Qatar, including Qatar citizens' perceptions of road safety during the pandemic. This case study will address the following research questions.

- To what extent did COVID-19 affect the RTCs and severity of RTCs in the State of Qatar?
- During the pandemic, how did the general public and road safety experts perceive road safety status and driving behaviour?
- According to road safety experts, did the COVID-19 pandemic affect attention to road safety?

8.4. Methodology

8.4.1. Data Collection

This case study uses data from questionnaire surveys conducted among the general public in Qatar and experts during a webinar, as well as data from road crashes in the same state.

8.4.1.1. Questionnaire Development

The questionnaire's purpose was to capture public perceptions about road safety in Qatar. The questionnaire was designed for residents of Qatar who have a valid Qatari driving license. The questionnaire was composed of two different sections, as explained below:

- Section I – Socio-demographic characteristics: The aim of this section was to collect data about the socio-demographic characteristics of each respondent, such as age, gender, occupational status, educational level, ethnicity, family setup, etc.
- Section II – Perceptions about Road Safety and Other Contextual Factors: This section comprised questions related to individuals' perceptions about road safety, driving behaviour, and congestion status on the roads during the COVID-19 pandemic. The questionnaire also included other contextual factors like working from home, owning multiple vehicles, and household income, among others.

We prepared the questionnaire in both Arabic and English. To collect the data, a web-based survey tool named Qualtrics was used (Molnar, 2019). After obtaining ethical approval from Qatar University (QU-IRB), we distributed the questionnaire to the general public through social media platforms. The data was collected during the peak spread of COVID-19 in Qatar which was from May 22, 2020, until June 13, 2020. The questionnaire began with general information and required electronic consent from the respondents. In total, 505 respondents filled out the questionnaire. To obtain the final sample, 101 respondents were excluded because they either resided outside Qatar or lacked a valid Qatari driving license. Therefore, we ended up with a final sample of 404 that was considered for the analyses.

8.4.1.2. Webinar Questions Development

In an international webinar entitled 'Global trends on the status of traffic safety under the COVID-19 pandemic' conducted on September 29, 2020, and organized by the World Conference on Transport Research Society (WCTRS), International Road Federation (IRF), and National Traffic Safety Committee of the State of Qatar, the attendees were asked to answer three different questions along with the regular demographic questions. Individuals' perceptions of road safety and driving behaviour shaped two of the three questions. The third question asked whether the COVID-19 pandemic had a negative impact on road safety. Road safety experts from different international organizations, including WHO, the United Nations, the International Association of Traffic and Safety Sciences (IATSS), the World Bank Group (WBG), the Washington State Department of Transportation, and the Asian Development Bank, attended the webinar with the common aim of mitigating road traffic causalities and addressing the potential impacts of the current COVID-19 pandemic on road safety. In total, 153 respondents attended the webinar, of whom 30 did not answer at least one question. Thus, 123 respondents answered all the questions used in the analyses.

8.4.1.3 Road Crash Data

The crash data was provided by Qatar's National Traffic Safety Committee of the State of Qatar provided the crash data. The data summarizes the number of total crashes, serious injuries, and fatality crashes of drivers, passengers, and pedestrians from January 2015 to December 2020 for each month. Moreover, it is important to provide the aggregated values per month for several other parameters, such as the number of speeding tickets, traffic signal violations, and other violations in 2019 and 2020.

8.4.2 Sample Description

8.4.2.1 Sample Description of the Public Questionnaire

Table 8.1 presents the demographic characteristics of the collected sample (N = 404), as well as the population of Qatar (Planning and Statistics Authority, 2019a, 2019b, 2019c).

Table 8.1 Questionnaire Respondents Demographic Characteristics

Variable	Levels	Sample (%)	Population[a] (%)
Gender	Male	62.9	78.1
	Female	35.9	21.9
	Prefer not to say	1.2	
Age groups (years)	18 – 25	19.8	15.5
	26 – 35	25.0	40.8
	36 – 45	27.7	27.0
	46 – 55	20.3	11.5
	>55	7.2	5.2
Ethnicity	Qatari	14.4	9[b]
	Non-Qatari (Arab)	41.8	Other than Qatari: 91
	Asian (non-Arab)	20.3	
	European and Australian	13.1	
	American	6.7	
	African (non-Arab)	3.7	
Educational level	High school or lower	13.9	76[b]
	Bachelor or higher	86.1	24
Occupational status before COVID-19	Employed for wages	77.4	87.7[b]
	Self-employed	2.3	
	Unemployed	2.0	1.5[c]
	Students	17.4	5.1
	Housewife/househusband	0.9	5.6
Occupational status during COVID-19	No change after COVID-19	35.9	
	Working from home	46.0	
	Online Education	11.6	Not applicable
	Others	6.4	

[a]Demographic characteristics of the population in the state of Qatar (Planning and Statistics Authority, 2019a, 2019b, 2019c).
[b]As per the population aging 15 years and above.
[c]Includes disabled and retired population.

The sample consisted of 62.9% males and 35.9% females. While the rest (1.2%) of the sample did not disclose their gender. The respondents' ages varied between 18 and 67 (mean: 38 years, standard deviation (SD): 11.7 years), with more than 70% of the respondents being less than 46 years of age. Among the different nationalities, 14.4% of the respondents were Qatari, 41.8% were non-Qatari Arabs, 20.3% were Asian (non-Arab), 13.1% were European and Australian, 6.7% were American, and 3.7% were African (non-Arab). The pandemic has caused 46% and 66% of the sample's workers and students to shift to remote work and education, respectively. As per the comparison between the population data and sample data in Table 8.1, most of the demographic characteristics of the sample are at a high scale of representation of the population. However, the noted sample skewed towards higher education levels, specifically bachelor's or higher. The reason for this might be the difficulty in delivering the questionnaires to the population with low income or education as the surveys were distributed online.

8.4.2.2. Sample Description of the Webinar

The final sample of the webinar (N = 123) consisted of 69.9% males vs. 30.1% females. Regarding their residential status, 51.2% of the respondents were residing in Asia, 13% in Africa, 8.9% in America, and 26.8% were residing in Europe and Australia. At the time of the webinar, the respondents were residing in 41 different countries. It is worth mentioning that most of the respondents were affiliated with road safety-related international organizations or institutions.

8.4.3. Data Analysis

Two main areas of analysis were carried out: one used crash data to look at how the COVID-19 pandemic affected road traffic safety in the state of Qatar, and the other sought to understand how the general public and specialists perceived traffic safety during the pandemic. Three distinct data sets were examined in this regard. The National Traffic Safety Committee of the State of Qatar provided the crash data, which contained information on traffic infractions from the previous two years (2019 and 2020) as well as crash data spanning six years, 2015-2020. The relevant data was presented using line graphs in terms of the number of crashes and violations and the percentage of serious or fatal crashes in total crashes in order to examine the effects of the COVID-19 epidemic on crashes and violations. Z-tests were further carried out to determine whether the decline or rise in collisions or infractions was noteworthy. Researchers frequently use Z-tests to assess the statistical significance of reported changes in collision or injury rates (Chimba et al., 2010; Khattak et al., 2018; Williams et al., 1995). The p values were obtained using a two-tailed technique, and a p value of less than.05. was deemed significant.

As previously explained, two questionnaire surveys collected the data to understand individuals' perceptions of traffic safety during the pandemic. The main variables were in discrete ordinal form (1 = strongly disagree, 5 = strongly agree), therefore, spearman's correlation tests were conducted to find the significant relations (Hauke & Kossowski, 2011; Khamis, 2008). The analysis of public perception involved the use of various demographic and contextual factors, including age (continuous), gender (1 = female, 0 = male), ethnicity (dummy variable: Asian, African, American, European, and Australian), educational status (low to high), occupational status (dummy variable: employed, unemployed, students), family setup (with children = 1, without children = 0), number of vehicles in the household (0, 1, 2, 3, 4, 5, 6+), gross income per month (low to high), and work-from-home (1 = yes, 0 = no). However, regarding the experts' perceptions, data for the two factors, (i.e., gender and country of residence) was available and was used in the analysis. Spearman's correlations were estimated using IBM SPSS Statistics software (version 26) to measure the significant correlation metrics between the demographic/contextual factors and the safety perceptions.

8.5. Results and Analysis

8.5.1 Road Crash Data

The crash data that was obtained from the National Traffic Safety Committee of the State of Qatar included total crashes, types of injuries, and different types of violations. The overall data is summarized in two different tables that are presented as appendices. Figure 8.2 presents the total crashes, causalities, and each causality's rate per 1000 crashes for each month, both as an average for 2015–2019 and separately for 2020. In addition, Figure 8.2 illustrates the overall number of road crashes per month in Qatar separately for each year from 2015 to 2020 and averaged for years 2015 to 2019. These crashes include all types of crashes, such as vehicle–pedestrian, vehicle-vehicle, and vehicle-street object crashes. The figure shows a gradual reduction in road crashes from 2015 to 2019 due to the successful implementation of the National Traffic Safety Strategy, 2013-2022, (Timmermans et al., 2019b). The crash data from 2015 to 2019 revealed a similar trend, with peak road crashes in May and the lowest road crashes from July to September. Early restrictions in Qatar resulted in a remarkable decrease in road crashes. In order to determine significance of the drop, a Z-test was conducted. The results showed that the average of the overall road crashes from 2015 to 2019 (mean: 20119, Standard deviation (SD): 1495) was significantly higher than the overall road crashes in 2020 (Mean: 12108, standard deviation (SD): 3066) (two-tailed: $z(9) = -7.427$, $p < .001$). The data used in all presented *Z*-tests in this section are for the period from March to December of each year, as COVID-19 started to spread in Qatar from March 2020 onwards. In particular, the highest reduction in road crashes reached up to 70% (Δ = 14,124 crashes) in April, when compared with the average road crashes from 2015 to 2019 in April. However, since the government lifted certain restrictions in different phases starting in July 2020, the overall number of road crashes increased after April 2020, reaching approximately 15,000 in December 2020.

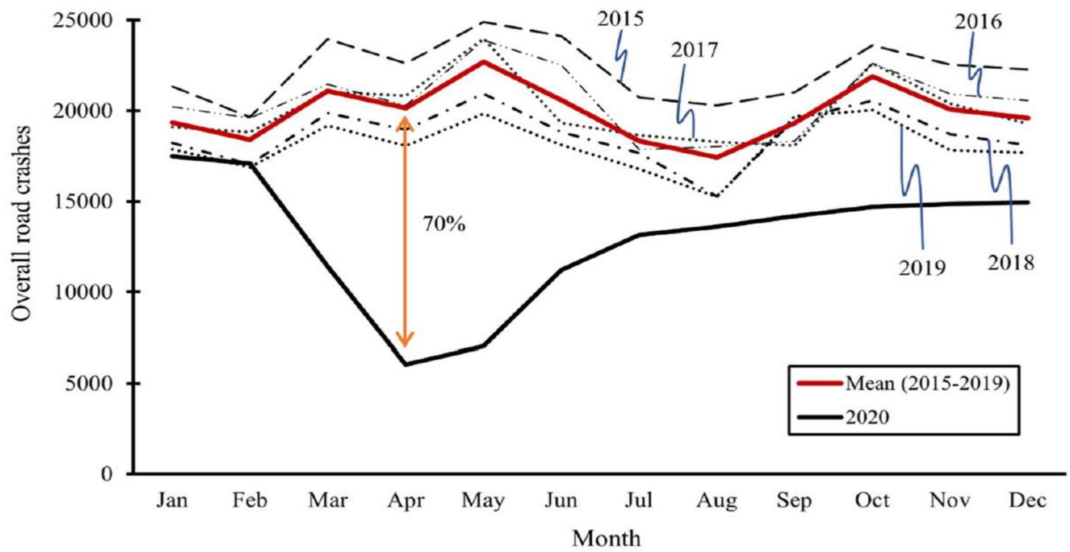
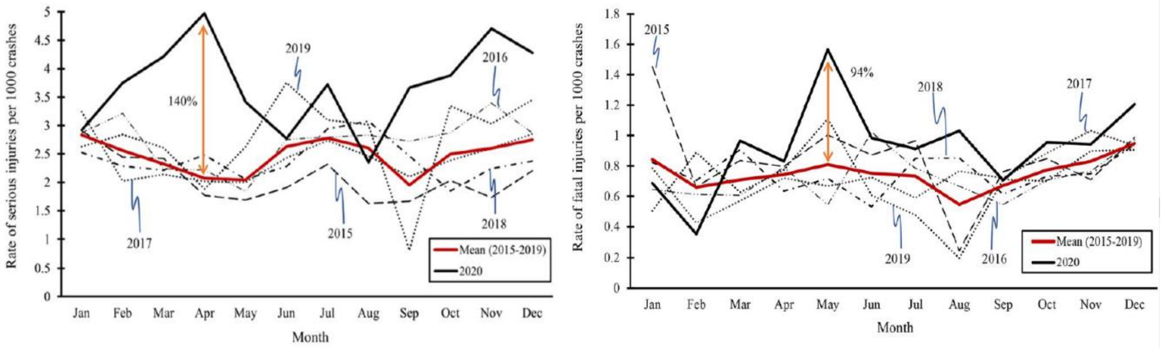


Figure 8.2 Overall number of road crashes per month in Qatar from 2010 to 2020

Despite the dramatic reduction in overall crashes in Qatar due to the pandemic, it's crucial to investigate whether the outcomes of these crashes also followed a similar trend. Based on the available data, the rate of serious injuries per 1000 crashes (Figure 8.3a) and the rate of fatal injuries per 1000 crashes (Figure 8.3b) were plotted. The figures present the injury rates separately for each year from 2015 to 2020, as well as the averaged injury rate for 2015–2019. The rates were calculated by dividing the injuries (serious or fatal) by the total number of crashes in the same month and year. Figure 8.3a demonstrates a steep increase in the rate of serious injuries per 1000 crashes in 2020, particularly during the peak restrictions period. April 2020 saw the highest rate of around five serious injuries per 10,000 crashes since the year 2015.

This was around a 140% increase in the rate of serious injuries per 1000 crashes compared to the mean rate of serious injuries per 1000 crashes (2015-2019) for the same month. To find out if the total rate of serious injuries per 1000 collisions in 2020 was substantially greater than the mean rate (2015-2019), a two-tailed Z-test was performed. The results confirmed that the mean rate of serious injuries per 1000 crashes in 2020 (Mean: 3.72, SD: 0.74) was significantly higher than the overall mean rate (2015-2019) (Mean: 2.45, SD: 0.29) ($z(11) = 5.51$, $p < .001$). Figure 8.3b illustrates a similar trend in the rate of fatal injuries per 1000 crashes. The highest escalation was observed in May 2020 (1.56 fatalities/1000 crashes), which was around 94% higher than the mean fatalities per 1000 crashes from 2015 to 2019 for the same month (Mean: 0.80 fatalities per 1000 crashes). The *Z*-test results showed that the overall mean rate of fatalities/1000 crashes in 2020 (Mean: 0.93, SD: 0.28) was significantly higher than the overall mean rate (2015-2019) (Mean: 0.75, SD: 0.09) ($z(11) = 2.05$, $p = .040$).

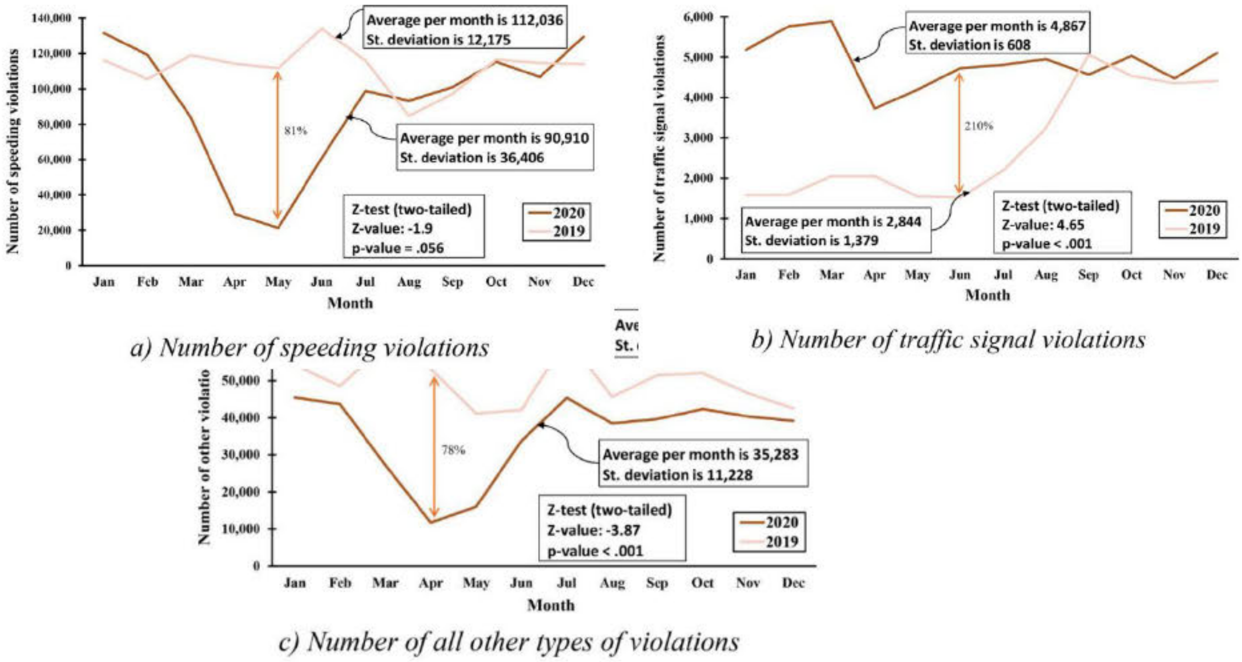


a) Rate of serious injuries per 1000 crashes *b) Rate of fatal injuries per 1000 crashes*

Figure 8.3 Proportion of Serious/Fatal Injuries per 1000 Total Crashes from 2015 to 2020.

Figure 8.4 plots the number of reported speeding tickets, passing traffic signal violations, and other violations to further analyse the situation during the pandemic. As shown in Figure 8.4a, the total number of speeding tickets in 2020 was higher than in 2019, prior to the appearance of COVID-19 in Qatar. However, a significant reduction in the number of speeding tickets was noticed in March and April 2020, with an 81% decrease in April 2020 compared to April 2019. To see if the difference was significant, a *Z*-test (two-tailed) was conducted between the two years. The results showed that the number of speeding tickets in 2020 (Mean: 90,910, SD: 36,406) was significantly different at the 1 level compared with 2019 (Mean: 112,036, SD: 12,175) (two-tailed: $z(11) = -1.9$, $p = .056$). It was observed that the number of red-light running (RLR) violations in 2020 consistently exceeded that of the same month in 2019 (Figure

8.4b). Despite a decrease from the previous month, the number of passing traffic signal violations in April 2020 remained higher than in April 2019. However, after a slight reduction in April 2020, the violations increased to reach a steady range that is equivalent to the same month in 2019. According to Qatar's National Traffic Safety Committee, the sharp increase in traffic signal violations between June and August 2019 could be due to the newly installed RLR violation cameras at many intersections during the third quarter of that year in Qatar. The results from *the Z-test* confirmed that the number of violations in 2020 (Mean: 4867, SD: 608) was significantly higher than the same month in 2019 (Mean: 2844, SD: 1379), (two-tailed: $z(10) = 4.65, p < .001$). Figure 8.4c shows the number of other violations for 2019 and 2020, such as overtaking violations, driving license-related violations, stand-and-wait rules, and obligations-related violations (excluding speeding and passing traffic signal violations). Once again, a steep reduction of around 78% was observed in the month of April in 2020 compared with the same month of 2019. The results from the *Z*-test showed that the reduction in other traffic violations in 2020 was significant (two-tailed: $z(10) = -3.87, p < .001$).



a) Number of speeding violations

b) Number of traffic signal violations

c) Number of all other types of violations

Figure 8.4 Comparison of Total Number of Violations between 2019 and 2020 for Each Month

8.5.2. General Public Perceptions of Traffic Safety during COVID-19

Figure 8.5 displays the percentages of the public's perceptions of traffic safety for the three different questions. Most of the respondents perceived that the roads had become safer during the pandemic. Out of the total respondents, 83% and 92% reported that the roads have become safer and the driving behaviour (i.e., less reckless or aggressive driving behaviour) has improved, respectively. Furthermore, 67% concurred that the pandemic also reduced road congestion. Table 8.2 presents the results from Spearman's correlation for the three main questions with the demographic and some other contextual factors such as age, gender, ethnicity, Educational/occupational status, family setup (with and without children), number of vehicles in the household, number of trips during COVID-19, gross income per month, and work-from-home.

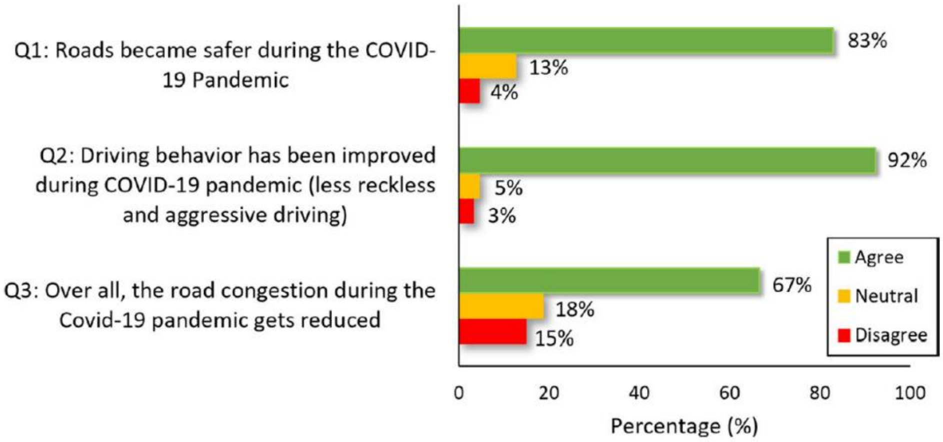


Figure 8.5 Results of the Road Safety Questions from the Questionnaire Survey

The table does not report the results of factors that were not significant at a 90% confidence level for any of the three main questions. In this regard, the factors 'family setup', 'number of trips during COVID-19', and 'work-from-home' had no significant correlations with any of the main questions. A consensus was found in the individuals' perceptions regarding road safety (Q1), driving behaviour (Q2), and road congestion (Q3), i.e., Q1 & Q2 ($r(402) = .557$, $p < .001$), Q1 & Q3 ($r(402) = .505$, $p <.001$), and Q2 & Q3 ($r(402) = .245$, $p < .001$). This indicates that the respondents who concurred that the pandemic has made roads safer also concurred that driving behaviour has improved and road congestion has decreased.

Table 8.2 Spearman's Correlations between Each Question from the Questionnaire

	Q1: Roads became safer during the COVID-19 pandemic			Q2: Driving behaviour has been improved during COVID-19 pandemic (less reckless and aggressive driving)			Q3: Overall, the road congestion during the COVID-19 pandemic gets reduced		
	Coefficient	P	N	Coefficient	P	N	Coefficient	P	N
Q1: Roads became safer during the COVID-19 Pandemic	1.00	.	404	.557	**<.001****	404	.505	**<.001****	404
Q2: Driving behaviour has been improved during COVID-19 pandemic (less reckless and aggressive driving)	.557	**<.001****	404	1.00	.	404	.245	**<.001****	404
Q3: Overall, the road congestion during the COVID-19 pandemic gets reduced	.505	**<.001****	404	.245	**<.001****	404	1.00	.	404
Age (low to high)	.154	**.002****	404	.072	.147	404	.278	**<.001****	404
Gender (0 = male, 1 = female)	–.016	.747	399	–.091	**.071***	399	–.114	**.022****	399
Ethnicity									
Asian	–.099	**.047****	404	–.003	.957	404	–.167	**.001****	404
African	.093	**.063***	404	.099	**.047****	404	.061	.220	404
American	.021	.668	404	–.027	.589	404	.080	.109	404
European and Australian	.024	.628	404	–.083	**.095***	404	.111	**.025****	404
Education level (low to high)	.049	.329	404	–.014	.783	404	.226	**<.001****	404
Occupational status									
Employed	.151	**.002****	404	.086	**.085***	404	.241	**<.001****	404
Unemployed	–.075	.134	404	–.041	.412	404	–.001	.980	404
Student	–.127	**.010****	404	–.073	.145	404	–.256	**<.001****	404
Gross income (low to high)	–.007	.892	331	–.130	**.018****	331	.061	.270	331
Number of vehicles (cars/motorbikes) in the household (low to high)	–.099	**.047****	404	–.122	**.014****	404	–.121	**.015****	404

*Significant at 0.1 level; **significant at 0.05 level.

Regarding the age of the respondents, the results showed positive correlations with Q1 ($r(402) = .154$, $p = .002$) and Q3 ($r(402) = .278$, $p < .001$). This indicates that, compared with younger people, older people have higher perceptions that the roads have become safer and less congested. Furthermore, compared with males, females showed higher disagreement on the statements that driving behaviour ($r(402) = -.091$, $p = .071$) and traffic flow ($r(402) = -.114$, $p = .022$) improved during the pandemic. When it comes to the different ethnic groups, Africans had higher perceptions that roads became safer ($r(402) = .093$, $p = .063$) and driving behaviour improved during the pandemic ($r(402) = .099$, $p = .047$). Different from that, Asians showed a higher disagreement on road safety improvement ($r(402) = -.099$, $p = .047$), while Europeans and Australians showed a higher disagreement on the improvement of driving behaviour during the pandemic ($r(402) = -.083$, $p = .095$).

Moreover, regarding the reduction in road congestion during the pandemic, Europeans and Australians showed a higher agreement ($r(402) = .111$, $p = .025$) while Asians showed a higher disagreement ($r(402) = -.167$, $p = .001$) both compared with the other ethnic groups. Respondents with higher educational levels indicated that the congestion level was reduced during the pandemic ($r(402) = .226$, $p < .001$). Regarding occupational status, respondents who were employed showed higher agreements with all of the statements (Q1: $r(402) = .151$, $p = .002$; Q2: $r(402) = .086$, $p = .085$; Q3: $r(402) = .241$, $p < .001$). On the contrary, the students showed higher disagreement that the roads became safer ($r(402) = -.127$, $p = .010$) or less congested ($r(402) = -.256$, $p < .001$) compared with the other groups. This is due to age, as younger participants showed a higher level of disagreement with the questioned improvements. Interestingly, respondents' gross income was negatively correlated with Q2 ($r(402) = -.130$, $p = .018$), indicating that respondents with higher income showed higher disagreement that driving behaviour was improved during the pandemic. Finally, the factor 'number of vehicles in the household' was negatively correlated with all of the statements (Q1: $r(402) = -.099$, $p = .047$; Q2: $r(402) = -.122$, $p = .014$; Q3: $r(402) = -.121$, $p = .015$). This indicates that respondents who possessed more vehicles had higher disagreements on the improvement of traffic safety, driving behaviour and traffic flow compared with those with no or fewer vehicles.

8.5.3. Experts' Perceptions of Traffic Safety during COVID-19 Pandemic

Figure 8.6 presents the percentages of the experts' perceptions of traffic safety for the three different questions that were asked during the webinar. Despite the fact that 47% of the respondents mentioned that the roads became safer during the pandemic, 55% indicated that driving behaviour had not improved. It is interesting to note that, unlike general public perceptions (Figure 8.5), a higher percentage of traffic safety experts disagreed with the statements about improving traffic safety and driving behaviour during the pandemic (Figure 8.6). Moreover, 70% of the respondents agreed that the pandemic has reduced attention to road safety. (Figure 8.6). Moreover, 70% of the respondents agreed that the pandemic has reduced attention to road safety. Figure 8.7 illustrates the percentages of the road safety experts' perceptions on three different questions, split by gender and country of residence. Females showed comparably higher disagreements for the first two statements than males. However, compared with males, they had higher perceptions that the COVID-19 pandemic reduced attention to road safety. Regarding the country of residence, experts from Asia had higher perceptions (54.8% agreed), followed by experts from Africa (50% agreed) on road safety during the pandemic. However, only 23.7% of the experts from Europe showed agreement with this statement. Furthermore, in terms of improving driving behaviour during the pandemic, experts from Africa showed the highest disagreement (68.8% disagreed), followed by Europe and Australia (60.6% disagreed). Regarding the third question, 97% of the experts from Europe and Australia concurred that the pandemic had an impact on the focus on road safety. To investigate the significant correlations between the three main questions and the factors 'gender' and 'country of residence', a Spearman's correlation was conducted. The results showed that gender was not significant for any of the three questions.

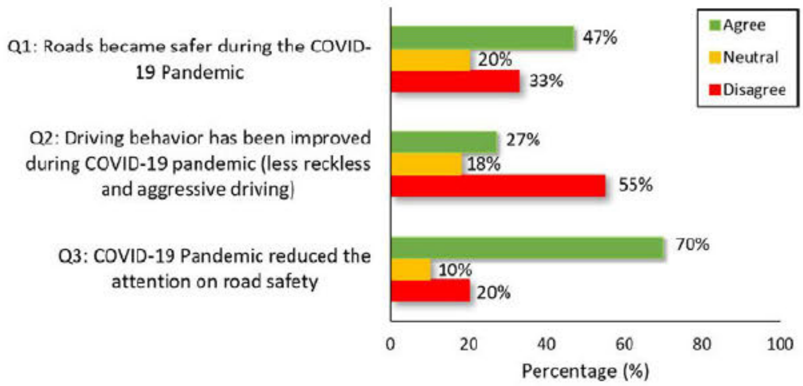
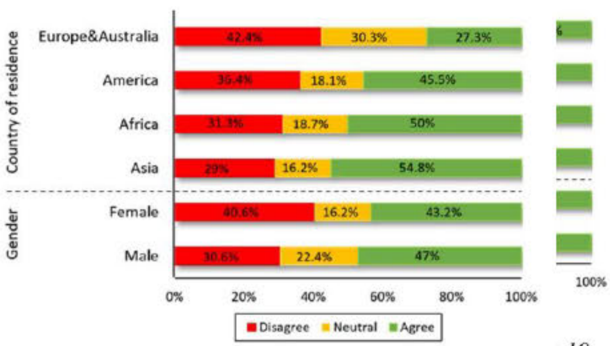
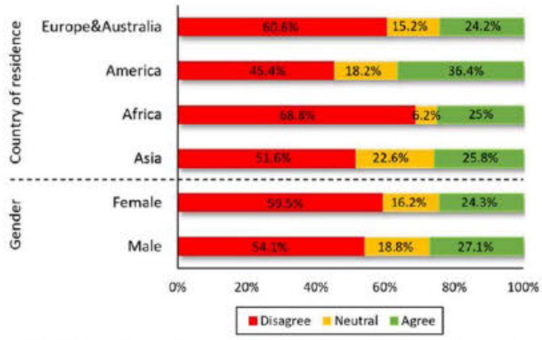


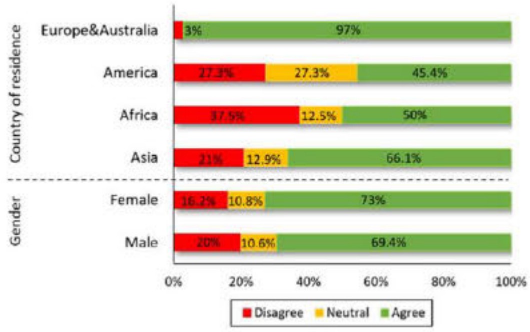
Figure 8.6 Percentages of the Experts' Perceptions on Traffic Safety for the Three Different Questions



a) Q1: Roads became safer during the COVID-19 Pandemic



b) Q2: Driving behavior has been improved during COVID-19 pandemic



c) Q3: COVID-19 pandemic reduced the attention on road safety

Figure 8.7 Percentages of the Experts' Perceptions on Traffic Safety by Gender and Country of Residence

Table 8.3 presents the results from Spearman's correlation for the three main questions and the factor 'country of residence'. Again, a consensus was found in the experts' perceptions regarding road safety and driving behaviour (Q1 vs. Q2: $r(402) = .385, p < .001$). This indicates that road safety experts, who concurred that the pandemic made roads safer, also concurred that driving behaviour improved. However, negative correlations were found between Q1 and Q3 ($r(402) = -.227$, $p = .012$), and Q2 and Q3 ($r(402) = -.199$, $p = .028$). This demonstrates the consistency among experts' opinions, where those who believed that traffic safety or driving behaviour had improved disagreed with those who believed that the COVID-19 pandemic had reduced attention to roads. Regarding the country of residence, experts living in Asia have shown higher agreement ($r(120) = .160$, $p = .078$) while experts living in Europe or Australia have shown higher disagreement ($r(120) = -.195$, $p = .031$) on Q1 (roads became safer during the COVID-19 pandemic), compared with the other regions.

Regarding the perceptions that the COVID-19 pandemic reduced attention to road safety, the experts living in Europe and Australia had higher agreements compared with the other regions ($r(120) = .344$, $p < .001$). Meanwhile, compared with the other regions, experts living in Africa ($r(120) = -.186$, $p = .040$) and America ($r(120) = -.155$, $p = .088$) have shown lower agreements on the statement that the pandemic reduced attention to road safety compared with other regions. Finally, it was observed that there were no significant differences in the perceptions of driving behaviour among the experts from different regions, indicating a consistent agreement among the surveyed experts from different continents that driving behaviour did not improve during the pandemic.

Table 8.3 Spearman's Correlations between Each Questions from the Webinar Questions

	Roads became safer during the COVID-19 Pandemic			Driving behaviour has been improved during COVID-19 pandemic (less reckless and aggressive driving)			COVID-19 pandemic reduced the attention on road safety		
	Coefficient	*P*	*N*	Coefficient	*P*	*N*	Coefficient	*P*	*N*
Roads became safer during the COVID-19 pandemic	1	–	122	.385	**<.001****	122	–.227	**.012****	122
Driving behaviour has been improved during COVID-19 pandemic (less reckless and aggressive driving)	.385	**<.001****	122	1	–	122	–.199	**.028****	122
COVID-19 pandemic reduced the attention on road safety	–.227	**.012****	122	–.199	**.028****	122	1	–	122
Country of residence									
Asia	.160	**.078***	122	.056	.539	122	–.092	.316	122
Africa	.029	.751	122	–.076	.404	122	–.186	**.040****	122
America	–.011	.908	122	.073	.421	122	–.155	**.088***	122
Europe and Australia	–.195	**.031****	122	–.053	.565	122	.344	**<.001****	122

*Significant at 0.1 level; **significant at 0.05 level.

8.6. Discussions

The main aims of this study were to investigate the traffic safety status (RTCs, rate of injuries, and violations) during the COVID-19 pandemic and to explore the general public and road safety experts' perceptions of traffic safety during the pandemic. In this study, three distinct research questions were formulated to address the stated objectives. The research questions will be repeated in this section for convenience and to formulate our findings subsequently.

The first research question was, 'To what extent did COVID-19 affect the RTCs and their severities in Qatar?' Section 5.1, 'Road crash data' for the period from 2015 to 2020, can be linked to the first research question. In this regard, a gradual reduction in RTCs from 2015 to 2019 was observed. This reduction is attributed to the National Traffic Safety Strategy, 2013-2022, which led to overall improvements in medical emergency response and treatments, advancements in traffic enforcement technology such as the installation of speed and RLR radars, and improvements in overall road infrastructure. However, the state of Qatar observed a significant reduction in RTCs during the pandemic, particularly in April and July. During that period, the highest governmental restrictions, including work-from-home, online education, social distancing, prohibiting social gatherings, and restricting other out-of-home activities, could have solely contributed to this steep reduction in RTCs. The literature (Aloi et al., 2020; Brodeur et al., 2021; Oguzoglu, 2020; Qureshi et al., 2020; Saladie et al., 2020) not only shows the reduction in overall RTCs in Qatar but also in many other countries in the world.

Although, RTCs were reduced dramatically, a completely opposite trend was observed in the outcomes of these crashes. In this regard, we found that the rates of minor, major, and fatal injuries per 1000 crashes climbed during the highest restriction period (see Appendix 1). This clearly shows that the main proportional reduction happened only in property damage-only (PDO) crashes, which commonly occur during traffic congestion periods. The steep increase in injury rates could be due to the fact that roads experienced significantly low traffic volumes during the peak restriction period, which resulted in increased aggressive and speeding behaviour (Benyei and Golarits, 2002; Doucette et al., 2021; Oskarbski et al., 2020). Therefore, increased speeding behaviour could have triggered more severe outcomes from crashes. Another reason could be the increase in social, financial, and psychological stress (Robillard et al., 2020), as well as anxiety and depression (Hou et al., 2021) levels during the COVID-19 pandemic. In this context, according to Kontogiannis, 2006, driver stress level has a strong correlation with unsafe driving behaviours as well as traffic crashes. In addition, a review study indicated that drivers with depression may encounter difficulties with divided attention, reaction time, changing speeds, and changing lanes (Wickens et al., 2014). Even with the lifting of most restrictions during the last quarter of 2020, our results showed higher injury rates compared to the same months in the previous few years, 2015-2019. According to Lally et al., 2010, exposure to repetitive travel behaviour for at least 1 month could shape an individual's future travel habits. As anticipated, there was a significant decrease in the number of speeding and other types of violations during the peak restriction periods. Despite the installation of new RLR cameras at many intersections in early 2020 and the last quarter of 2019, there was no steep reduction in RLR violations during the peak restriction period of 2020. Policymakers should use these trends to implement temporary traffic calming measures during the upcoming waves of COVID-19 or future epidemics.

The second research question was, 'How did the general public and traffic experts perceive road safety status and driving behaviour during the pandemic?' Most of the general public believed that road safety (83%) and driving behaviour (92%) improved during the pandemic. While comparing the differences in perception levels, certain groups showed higher agreement than others. For instance, compared to females, males expressed higher agreement that driving behaviour had improved and roads were less congested during the pandemic. It is important to mention here that males had higher exposure to the roads compared with females, i.e., a higher proportion of males were not working from home (35.8%) compared with females (11%), and males performed more trips per day (2.1 trips/day) compared with females (1.6 trips/day) during the peak restrictions period. Compared with young drivers, older drivers have a higher perception that the roads have become safer and less congested. Regarding ethnicity, compared with the other ethnic groups, Asians showed higher disagreement, while Africans showed higher agreement that the roads had become safer. Next, Africans had higher perceptions, while Europeans and Australians had lower perceptions that driving behaviour improved. Individuals with higher incomes had lower perceptions that their driving behaviour improved when it came to gross income.

Interestingly, the experts' perceptions about road safety and driving behaviour were different than the general public's perceptions. For instance, one-third of the experts did not agree that road safety improved during the pandemic, compared with 4% of the general public who disagreed. Furthermore, more than half of the experts disagreed that driving behaviour improved during the pandemic, compared with only 3% of the general public who disagreed.

The general public may associate traffic volume with overall road safety, whereas road safety experts analyse road safety more deeply and have access to updated data and information. For instance, this study found that, despite a reduction in overall RTCs, the rates of injuries during the pandemic were higher than in previous years. In general, the rates of injuries could provide a significant illustration of road safety, e.g., higher rates of injuries indicate lower proportional road safety and higher proportional unsafe driving behaviour. As a result, the opinions of traffic experts are more consistent with the reported road safety status during the pandemic than those of the general public. The results from Spearman's correlation confirmed that the gender of road safety experts was not a significant factor, meaning that both male and female experts had similar opinions regarding road safety and driving behaviour during the pandemic. The road safety experts from Asia had higher perceptions about the country of residence, while the experts from Europe and Australia had lower perceptions that roads became safer during the pandemic compared to the experts from other regions. Such findings about evaluating the differences between individuals' perceptions regarding road safety, driving behaviour, and congestion level are not yet reported in the literature and therefore, could contribute to improving policymakers' knowledge of public perceptions during the pandemic.

The third research question was, 'Did the COVID-19 pandemic affect attention to road safety: based on road safety experts' opinions?'. In this regard, we found that around 70% of the experts agreed that the pandemic reduced attention to road safety. This is quite logical, as government and public attention have shifted towards COVID-19-related issues. In addition, there should be high financial burdens due to the COVID-19 alleviation measures and economic crisis around the world, which could have exerted high pressures on funding at different levels, including road safety. However, relevant authorities must strike a more cost-effective balance between different issues, including road safety. In addition, this is a good time to inform the public about the importance of road safety in overcoming RTCs and resulting casualties. Furthermore, road traffic authorities should consider temporary strategies to curb risky driving behaviours in situations with lower traffic volumes. This could help not only save lives but also reduce pressure on health and other emergency services during these difficult times.

This study had some methodological limitations. The violation-related data presented in this study describes the overall violation for each category, e.g., RLR violations. It would be interesting to examine the differences in traffic violations identified by automated camera systems vs. tickets given in person by officers separately. Furthermore, the public questionnaire and webinar samples skewed more towards male respondents, with 62.9% and 69.9%, respectively. Samples containing a higher proportion of female respondents may produce slightly different results. Nonetheless, the actual population in Qatar includes a higher percentage of males (78.1%) (Planning and Statistics Authority of Qatar, 2019a). Future studies should focus on evaluating the long-term impacts of the COVID-19 pandemic on road safety and driving behaviour. In addition, future studies with larger sample sizes could use more sophisticated modelling techniques to draw different linkages between the public's and experts' perceptions and the real-world impacts that COVID-19 has had on various travel behaviour characteristics.

8.7. Conclusions and Recommendations

The objective of this case study (Case Study 5) was to investigate the impacts of the COVID-19 pandemic on traffic safety (RTCs, rate of injuries, and violations) using crash data in Qatar. In addition, the case study presents results from a questionnaire survey targeting the general public in Qatar and a webinar survey targeting international road safety experts to explore their perceptions regarding traffic safety during the pandemic. In this regard, the case study attempted to first investigate the trend of RTCs and rates of injuries during the pandemic and statistically compare them with the trends five years before the pandemic using Z-tests. The results showed that there was a significant reduction in overall RTCs in 2020, compared with the previous years. There was a 70% reduction in overall crashes during the peak restriction period in April 2020, overall crashes were reduced by 70%. Overall, crashes were reduced by 70%. Despite the drastic reduction in overall crashes, the rate of injuries per 1000 crashes significantly increased, particularly during the peak restrictions period, with rates of serious and fatal injuries increasing by 140% and 111% in April and May, respectively. This means that the main proportional reduction happened only in PDO crashes, which usually occur during high-traffic volume situations. The results further indicated that since the roads had low traffic volumes during the peak restriction period, this could have triggered unsafe driving behaviours such as speeding or reckless driving. Furthermore, the study used data from questionnaire surveys and a webinar survey to investigate public perceptions of road safety. The overall descriptive statistics showed that the majority of the respondents from the general public sample agreed that road safety and driving behaviour improved during the pandemic.

However, unlike the general public, higher percentages of road safety experts disagreed that the roads became safer (33%) or driving behaviour improved (55%) during the pandemic. The results from Spearman's correlation tests showed that there was no significant difference in perception levels about road safety and driving behaviour between male and female experts. However, experts from Europe and Australia showed higher disagreements, while those from Asia showed higher agreement that road safety improved during the pandemic in comparison to the experts from other regions. Around 70% of the experts agreed that the COVID-19 pandemic affected attention to road safety. In this regard, experts from American and African countries showed lower agreement, while experts from Europe and Australia showed significantly higher agreement.

The case study is important because it presents the RTCs and their casualties, as well as the public's and experts' perceptions regarding road safety during the pandemic. The findings of this case study could help policymakers understand the road safety status during the pandemic and the impacts that COVID-19 has had on the various aspects of road safety and driving behaviour. Policymakers could temporarily make appropriate adjustments in traffic laws and regulations to overcome risky driving behaviours during future epidemics, for example, by re-evaluating the posted speed limits and traffic fines. This could help not only reduce serious or fatal injuries, but also reduce pressure on health and other emergency services.

Chapter 9: Discussions and Conclusions

9.1 Introduction

This chapter, "Discussions and Conclusions," serves as the culmination of an in-depth exploration of five pivotal case studies concerning road safety and transportation management in Qatar. Each study sheds light on distinct facets of the broader discourse on road safety, collectively contributing to a nuanced understanding of the challenges and opportunities in Qatar's transportation landscape. The first case study delves into the "Impact of Road Safety Management Systems on Road Safety and Road Traffic Crashes, Fatalities, and Injuries in Qatar," offering insights into the effectiveness of existing road safety measures. Meanwhile, the second study examines "The Effects of Public Transport Infrastructure and Services on Road Safety in Qatar," highlighting the intricate relationship between transportation infrastructure and road safety outcomes. Moving beyond infrastructure, the third case study investigates "The Effect of Surveillance Cameras on Traffic Violations and Crashes in Qatar," highlighting the role of technology in enforcing traffic regulations and mitigating road incidents. In parallel, the fourth study scrutinizes "Pedestrian Signal Setting and Implementation in the State of Qatar," emphasizing the importance of pedestrian-friendly urban planning in fostering safer streets. Lastly, the fifth case study explores "Road Safety Status during the COVID-19 Pandemic: Exploring Public and Road Safety Expert's Opinions," providing valuable insights into the evolving dynamics of road safety amidst a global health crisis.

Drawing upon the findings and analyses from these diverse case studies, this chapter synthesizes key observations, identifies overarching themes, and offers actionable recommendations for policymakers, urban planners, and transportation authorities in Qatar. By integrating insights from multiple perspectives and addressing various dimensions of road safety management, this chapter seeks to inform evidence-based strategies aimed at enhancing road safety and promoting sustainable transportation practices in Qatar.

9.2 Final Discussions

As presented in the above chapters, a wide review of the existing literature on road safety management in Qatar recommended that little is known about the actual impact of the National Traffic Safety Strategy (NTSS) and road safety management interventions implemented on road safety in Qatar (Consunji, 2019; Consunji et al., 2018, 2020). Therefore, the purpose of this research is to investigate the road safety management systems in Qatar, the role and impact of the National Traffic Safety Strategy (NTSS), and the road safety schemes and policies that have been in place since the NTSS's establishment. The overall aim is to contribute to the existing realisation of road safety management systems in Qatar using some representative case studies as well as the regained personal experience in the field. Five (5) perspectives and case studies emerged upon an extensive review of the current state of knowledge in Road Safety Management in Qatar. Given the limited focus of earlier studies on investigating different aspects of Road Safety Management in Qatar, this doctoral research investigates the five related case studies of Road Safety Management to improve our understanding of:

- The impact of road safety management systems on road safety; road traffic crashes, fatalities, and injuries in Qatar.
- The effects of Public Transport infrastructure and services on road safety in Qatar
- The impact of CCTV/ speed cameras on road traffic violations in Qatar
- Setting and implementing pedestrian signals in Qatar
- The road safety system in Qatar and the impact of (the COVID) pandemic

Below, we discuss some methodological reflections along with the five cases mentioned above, which form the research objectives outlined in Section 1.4 and addressed by five research case studies reported in chapters four through eight of this thesis:

9.2.1 Impact of Road Safety Management Systems on Road Safety, Road Traffic Crashes, Fatalities, and Injuries in Qatar

Globally, road traffic crashes (RTCs) rank as the eighth leading cause of death. RTCs were the leading cause of death in children and young adults in 2016, according to the (World Health Organization, 2018). In 2016, 1.35 million deaths and about 50 million injuries and disabilities were reported by the World Health Organization to result from RTCs. In the same year, the Eastern Mediterranean Region recorded the world's third highest road traffic fatality rate, with 18.0 deaths per 100,000 people. Given the above, this study investigates the occurrence of RTCs in the state of Qatar between 2010 and 2020 with the aim of investigating the occurrence of RTCs and RTCs resulting in fatalities and severe and minor injuries to assess the impact of the Qatar Road Traffic Safety Strategies. The results of time series plots indicate that the occurrence of RTCs resulting in fatalities and severe injuries shows a decreasing trend from

2013 to 2020, corresponding to the period the NTSS has been in operation. The results indicate a rising trend in RTC injury severity between 2010 and 2016, followed by a downward trend from 2016 to 2020. Despite the improvements in the RTCs casualty rate, the implemented interventions did not appear to have a positive impact on the occurrence of RTCs that result in minor injuries. The results of the descriptive analysis of RTC victims reveal age, gender, and road user type variation in RTCs fatality and injury severity. Additionally, it was found that by comparing the age profiles of victims of RTCs fatalities for 0-10 years, 11-20 years, 20-30 years, 31-40 years and above 40 years, victims of RTCs fatalities are more likely to be young people between the ages of 20-30 years. Research studies also discovered a disproportionate representation of male victims in both RTC fatalities and severe injuries. Between 2016 and 2020, drivers and pedestrians face a higher risk of dying from RTCs, while motorists and passengers suffer severe injuries during this period.

9.2.2 The Effects of Public Transport Infrastructure and Services on Road Safety in Qatar

Analysis of responses from 316 survey respondents from Doha indicates that 88.9% of the 316 total respondents are active users of the public transportation services in Doha and enjoy the travel experience, particularly with the Qatar Metro. 96.5% of the participants (both sexes) expressed their willingness to use PT for their daily trips. It was also noted that the same age group (18 and 34 years) constitutes the majority of all public transport riders (70.6%) in Qatar. This observation has important implications for car travel and RTC reduction. It is expected that increasing the ridership of Qatar Metro and Karwa Bus could reduce the number of car trips made daily, which has implications for the annual vehicle kilometres travelled, reduced accident exposure levels, and consequently a reduction in RTCs rates and fatalities. Overall, at least 96% of the respondents expressed satisfaction with the safety and comfort of PT services, and approximately 92% expressed satisfaction with the level of safety offered by Doha's pedestrian infrastructure, expressing a sense of safety and confidence when walking. The findings also indicate that travel time and service reliability are essential factors affecting the mode-choice decisions of public transport users in Qatar. Participants were concerned about the reliability of public transport services, including Qatar Metro. The results further suggest that unpredictable PT travel conditions could be counterproductive. For the consideration of NTSC, the participants of the survey recommended the following measures to increase public transport ridership in Qatar;

"*Make PT services free. Could consider cess being levied from all people holding, say, more than two vehicles, which could fund free PT services.... It may also serve as a deterrence to hold more than two vehicles.... Sometimes, I feel there are more vehicles in Qatar than the people living in it."* ("*using different cards for bus and metro*").

These findings have great implications for car travel and RTC reduction. It is expected that increasing the ridership of Qatar Metro and Karwa Bus could reduce the number of car trips made daily, hence reducing distance exposure in terms of vehicle kilometres (VKM) or vehicle miles travelled (VMT), thereby reducing accident exposure levels and consequently a possible reduction in accidents and fatalities. Furthermore, 72.7% of cyclists, scooter riders, and 50% of motorbike riders in Qatar are likely to increase their RTC risk exposure if adequate, safe, and protective infrastructure is not in place. The accident statistics in Qatar show a disproportional representation of this age group among road traffic crash (RTC) casualties.

After analyzing participants' views and perceptions regarding the walkability and safety of Qatari streets and pedestrian and bicycle infrastructure, the results indicate that both sexes did not differ in opinion. Generally, there was a high level of satisfaction among the participants about the current state of road transport infrastructure. Despite the high level of user satisfaction and approval of the transport infrastructure's safety, the majority of participants expressed dissatisfaction with the indiscriminate parking of vehicles on the sidewalks and advocated for increased attention to the management and use of pedestrian sidewalks along the road corridors. Most respondents were also concerned about drivers' non-compliance with the traffic rules and lack of respect for pedestrians and pedestrian facilities.

The observations above provide the Qatar National Traffic Safety Committee (NTSC) with an opportunity to develop policies for the development of segregated bicycle infrastructure for the safety and protection of cyclists and scooter riders, as well as to reverse their high representation in Qatar's accident statistics.

9.2.3 The Impact of CCTV/ Speed Cameras on Road Traffic Violations in Qatar

Speeding is the primary cause of an increase in the frequency of accidents worldwide. Many countries are attempting to strengthen their traffic systems in order to curb this behaviour among drivers. Authorities in Qatar have implemented a speed camera enforcement system on some selected routes in order to reduce the number of speeding drivers and mobile phone use.

For this study, we examined a sample size of various highways in Qatar to better understand the variances in road traffic accidents, the effects of speed camera enforcement on driver behaviour, and the major factors driving the rising number of speed penalties. The study's findings indicate that from 2015 to 2021, there were more reported minor accidents than severe and fatal ones. Additionally, the study observed a significant difference in traffic offences between 2020 and 2021. Traffic Movement Violations, Stand and Wait Rules & Obligations Violations, Passing Traffic Signals, the number of speed cameras installed on the driver's routine roads, the driver's age, ignorance of the seatbelt rule, and covering the car's plate to hide from the speed camera, could all be contributing factors.

9.2.4 Pedestrian Signal Setting and Implementation in the State of Qatar

The investigation focused on the impact of pedestrian signal setting and implementation on traffic safety analysis in Qatar. Accident rates for pedestrians have been assessed using Analysis of variance techniques. The results show that the number of minor injuries fluctuated more than the number of fatal crashes over a seven-year period. Although traffic deaths and serious injuries decreased with time, the number of minor injuries that did not require hospitalization climbed. This could demonstrate better monitoring of minor injuries, or rapid population growth, which led to higher traffic density. Similarly, the number of passengers injured over the past six years is more varied than the number of pedestrians and drivers. Further study should be done to evaluate the variables that influence different accident kinds, different road types, and different injury types independently. Comparative analysis should also be done.

9.2.5 Road Safety Status during COVID-19 Pandemic: Exploring Public and Road Safety Expert’s Opinions

In this case study, the aim is to analyse the impacts of COVID-19 on traffic safety in the state of Qatar. A questionnaire also assesses the citizens' perceptions of road safety during the period. Three research questions have been designed and investigated, as follows:

- To what extent did COVID-19 affect the RTCs and severity of RTCs in the State of Qatar?
- How did the general public and road safety experts perceive road safety status and driving behaviour during the pandemic?

- Did the COVID-19 pandemic affect attention to road safety: based on road safety experts' opinions?

This investigation used Z-tests to assess and statistically compare the trend of RTCs and injury rates during the pandemic with the trends five years prior to the pandemic. The results showed that there was a significant reduction in overall RTCs during the period, 2020, compared with the previous years. A total of 70% reduction in overall crashes was observed. However, the rate of injuries per 1000 crashes significantly increased, especially during the peak restrictions period, i.e., the rates of serious and fatal injuries increased by 140% and 111% in April and May, respectively.

9.2.6 Overview of the Research Objectives

This section presents a summary of the methods adopted to achieve each objective.

Objective 1: *Assess the impact of the National Traffic Safety Strategy (NTSS) on road safety management in Qatar*

Chapters 4, 5, 6, 7, and 8 present the five case studies of this research and discuss some of the action plans or interventions resulting from the Qatar National Traffic Safety Strategy (NTSS). Overall, the results from the time series analysis of the accident data indicate that the occurrence of RTCs resulting in fatalities and severe injuries shows a decreasing trend from the year 2013 to 2020, which period corresponds to the development of the National Traffic Safety Strategy, 2013-2022, the operationalization of the first 5-year action plan, 2013 to 2017, and some period of the second 5-year action plan, 2018-2022. The first 5-year action plan period, specifically from 2013 to 2016, witnessed a rising trend in RTCs leading to severe injuries. However, the data analysis shows that the observed ascending trend halted and reversed in 2016, specifically between 2016 and 2020. It is believed that the measures implemented in the first 5-year and second 5-year action plans might have positively reflected on the recorded figures. Specific interventions like the installation of traffic cameras on some roads and intersections in Qatar, the review of the road traffic laws and penalties, and the improvement of the road transport infrastructure and public transport services, such as replacing the fleet of Karwa buses with modern buses with current technology and the introduction of Qatar Metro have been found to contribute towards the reduction of RTCs and their related fatalities and injuries. Notwithstanding the 55.2% increase in population from 2010 to 2020 and the 123% increase in the number of registered vehicles over the same period, the implementation of the National Traffic Safety Strategy, 2013-2022, has succeeded in halting and reversing the observed rising RTCs before the operationalization of the first 5-year action plan (National Traffic Safety Strategy, 2013-2017), from 2013.

Objective 1.1: *Select five case studies to represent some examples of the impacts of the national road safety strategy on the performance of road safety in Qatar.*

Objective 1.2*:* *Assessing the effectiveness of the road safety management interventions implemented and pandemics on reducing road traffic crashes, fatalities, and injuries in Qatar.*

Five case studies (1-5) have been designed to assess the effectiveness of road safety management interventions implemented in reducing road traffic crashes, fatalities, and injuries in Qatar in several aspects.

- ***The constitution of the Qatar National Traffic Safety Committee (NTSC),***

The Qatar National Traffic Safety Committee (NTSC) was established, the National Road Safety Strategy was developed, and the first and second National Road Safety Action Plans were implemented. The time series analysis results revealed that the total number of RTCs leading to fatalities shows a visible decreasing trend from 2013 to 2020. This observation coincides with the NTSC's establishment and operational period, which may indicate the effectiveness of the National Road Safety Action Plans in halting or reversing the predicted increase in road traffic fatalities in Qatar. Although Qatar has witnessed a substantial decrease in road traffic injuries and deaths in the past two decades, the gains between 2013 and 2020 have been very inspiring compared to the projection made in 2006 (see Figure 3.1) (Jamieson, 2008). The progress in road safety in Qatar (i.e., reduction in the occurrence of RTCs and the attendant fatalities and injuries) clearly demonstrates the effectiveness of the Qatar Bespoke Safe System in reducing road traffic crashes, fatalities, and injuries.

Objective 1.3*: Propose measures to improve the road safety management systems in Qatar*

The study found that the measures implemented by the NTSS have had a greater impact on reducing the occurrence of RTCs that lead to fatalities compared to minor injuries. The research also found variations in the occurrence of RTC fatalities and injury severity. Young people between the ages of 21 and 30 are more likely to die from RTCs compared to other age groups. Both RTC fatalities and severe injuries disproportionally represent males as victims. Therefore, the NTSC should prioritize addressing the observed age and gender variation by increasing awareness and implementing additional enforcement measures. Additionally, research suggests that public transport not only has a low environmental impact, producing fewer emissions per passenger mile than single-occupancy vehicles, but also serves as a sustainable mode of transportation that balances our current and future needs, reduces congestion by reducing the number of vehicles on the road, and ensures safety by reducing car use, vehicle kilometres travelled, and consequently, accident risk exposure. The research found that there is an increasing awareness of the benefits of public transportation and an increasing willingness to use them in Qatar.

Furthermore, despite the positive impact of the NTSS in reducing the occurrence of RTCs and their related fatalities and injuries in Qatar, the following specific recommendations are suggested for the consideration of the National Traffic Safety Committee (NTSC) based on the findings of the five case studies to reduce car use, promote PT ridership, and improve road traffic safety in Qatar:

- ❖ Implement car restrictions in the inner city, such as no car zones, congestion charges, increased toll fares, and the removal of parking spaces. There are many possible measures to be implemented and adopted by other nations. The most specific and tailored options and policies to the local conditions could be the most successful.
- ❖ Encourage more usage of public transportation modes of travel. This involves getting more car users to try PT for a limited time to induce attitudinal change. Follow-up and monitoring of such behavioural changes are very critical to their success.
- ❖ Integration of PT services (“using different means, for example, different types of cards for bus and metro," etc.) There are many successful examples in other neighbouring and world-class cities.
- ❖ Impose taxes on the price and use of private cars, use some of the revenues to fund PT services, and make PT services free and more attractive.
- ❖ Implementing innovative schemes to influence car users to use PT, even for a limited period, can change attitudes when the benefits of PT use are discovered. Raising awareness would be very helpful in achieving these targets.
- ❖ Encourage walking and cycling activities, where appropriate, and provide properly connected sidewalks and give pedestrians priority at un-signalised crossings to facilitate such activities.

- ❖ Implement measures that improve the safety and security of pedestrians on the road network. For example, apply more speed-calming measures and strengthen enforcement on vehicles for pedestrian right of way.
- ❖ Proper management and use of the pedestrian sidewalks along the road corridors, particularly the indiscriminate parking of vehicles on the sidewalks, is crucial for the success of such measures.
- ❖ Public education to reverse the current state of drivers' non-compliance with the traffic rules and lack of respect for pedestrians and pedestrian facilities.
- ❖ The provision and management of parking facilities at major terminals is very critical in order to encourage more metro use.
- ❖ Provision of real-time information for the use of public transportation options and ensure reliability of public transport options (waiting for pickup and trip to the drop-off point) as well as metro services.
- ❖ Ensure the safety and security of all road users while traffic management on road construction sites along road corridors is active.
- ❖ The provision of segregated or dedicated walkways, sidewalks, or footpaths for pedestrians in most local and residential areas is crucial for the success and encouragement of walking.

Objective 2: *Assess the effectiveness of Public Transport infrastructure and services on road safety in Qatar.*

Qatar has been experiencing increasing urbanisation and rapid population growth after the Gulf state found oil in commercial quantities, which put enormous stress on the nation's transport infrastructure, leading to increased levels of road traffic crashes (RTCs), fatalities, and injuries. This research found that to address this transportation challenge, the government of Qatar has made substantial investments to upgrade the nation's transportation infrastructure and services to modern standards by providing a safer and more sustainable transportation system to improve urban mobility and reduce RTCs and their related fatalities and injuries. Qatar has improved the infrastructure and services of its urban transport systems by improving Karwa bus services and stations, developing Qatar Metro under the management of Qatar Rail, etc.

A survey of 316 participants from Doha indicates that 88.9% of the 316 total respondents are active users of the public transportation services in Doha and satisfied with the level of services in aspects of the developed infrastructure and upgraded or introduced transport services, particularly the Qatar Metro. 96.5% of the participants (both sexes) expressed their willingness to use PT services to meet their urban mobility needs. The study could not establish how many respondents have reduced car use because of the improvements in Qatari transport services. However, it is expected that increasing the ridership of Qatar Metro and Karwa Bus will have implications for the reduction of car use, the number of car trips made daily, and vehicle kilometres travelled, reducing accident exposure levels and consequently a possible reduction in accidents and fatalities. The enhanced transport infrastructure and services could reduce road users' exposure to accident risk, leading to a decrease in RTC frequency and fatality rate.

Objective 3: *Assess the effectiveness of CCTV/ speed cameras on road traffic violations in Qatar.*

Speeding is a primary cause of RTCs worldwide. To enforce speed regulations and traffic regulations on the road, many countries across the globe have installed road traffic surveillance cameras to deter drivers and sanction violators. To sanitize the road environment and reduce the occurrence and/or severity of RTCs in Qatar, road traffic surveillance cameras were installed every two to four kilometres on major roads and major intersections in Qatar to deter drivers and identify and sanction violators. The installed cameras had the capability to capture speeding, safety belt violations, mobile phone use violations, and overtaking in the wrong lane. The study found that the number of tickets issued increased with an increasing number of cameras installed, leading to an immediate and dramatic reduction in the number of RTCs and their associated fatalities and injuries, which seems to suggest a positive impact of the cameras on road safety in Qatar the same year (see Figure 3.3). Mamtani et al., 2012, collaborated on this finding. Similar to the carrots and sticks analogy, the observed reduction in the frequency of RTCs immediately after the installation of the cameras supports the established proposition that individual behaviour can be influenced using elements of reinforcement and punishment; negative re-enforcement or sanctions, when applied, increase the likelihood of an individual performing the desired/targeted behaviour. Thus, the cameras induce an element of fear in the drivers, which causes them to refrain from violating the traffic rules (Carey, McDermott, and Sarma, 2013; Shen and Dillard, 2014) and delivering the desired outcome. The reduction in fatalities among young people aged 18 to 29, who were disproportionally represented among RTI casualties in Qatar, was more pronounced after the cameras were installed compared to other categories.

Objective 4: *Assess Qatar's Pedestrian signal setting and impacts on road safety.*

Pedestrian signal control is a major influence on the level of service of crossing facilities as well as road safety and performance, taking into account conflicts with vehicles. The characteristics and culture of the local population may lead to significantly different pedestrian behaviour in terms of crossing maneuvers and impact traffic accident patterns and rates. The empirical analysis showed that the 85th percentile crossing times were longer than the provided Pedestrian Flashing Green (PFG) intervals at the observed crosswalks. Additionally, the speed analysis indicated that the observed 15th percentile speed was 1.22 m/s, which is similar to the assumed design speed in the Qatar Traffic Control Manual, (QTCM, 2015). Furthermore, the analysis revealed that pedestrian crossing speeds during PFG or BI were significantly higher than those during PG.

Objective 5: *Demonstrate the ability of road safety system to cope with a pandemic (COVID).*

The case study presents results from a questionnaire survey targeting the general public in Qatar and a webinar survey targeting international road safety experts to explore their perceptions regarding traffic safety during the pandemic. The results showed that there was a significant reduction in overall RTCs in 2020, compared with the previous years. The peak restriction period in April 2020 accounted for a 70% reduction in overall crashes. Despite the drastic reduction in overall crashes, the rate of injuries per 1000 crashes significantly increased, particularly during the peak restrictions period, with rates of serious and fatal injuries increasing by 140% and 111% in April and May, respectively.

9.3 Recommendations for Future Work

The researcher envisages the need for further research in the following areas:

First, this study analysed aggregated RTC frequency data based on several categories. The researcher could not procure disaggregated crash data for statistical analysis. Therefore, it will be interesting for future research to procure disaggregated crash data to investigate the nature and extent of each intervention in reducing the RTCS in Qatar.

Secondly, the traffic violation data used for the research on the impact of the installation of traffic cameras on traffic safety was for 2019 and 2020. If the violation data and accident cases were also accessible prior to the installation of the cameras, a rigorous statistical before-and-after analysis might be undertaken to utilize quasi-experimental research. Additionally, it will be interesting to review road traffic management in other similar neighboring countries and assess the similarities, differences, and impacts of various schemes. Differences and similarities in attitudes, and cultural and population structures should also be noted. Comparative analysis with such countries, as well as with other world countries, could prove very useful and interesting. Road safety management frameworks in developing and developed countries could also be investigated and compared with road safety management in Qatar.

The work presented in this thesis attempted to indicate the integrated and extensive set of objectives related to road safety, vehicle safety, user behaviour, standards, and regulations that have been considered in the national strategy for the management of road safety. The five selected case studies in this research show applications in some of the areas that have been considered by Qatar's National Road Safety efforts. Further investigations in the other areas also need to be carried out. These include regulations, road engineering, auditing, further investigation of user studies, and more. Assessing the long-term impact of road safety education programs, especially in schools, is necessary to understand how early education influences behaviour and attitudes towards road safety. Investigating the role of cultural and societal factors in shaping road safety attitudes and behaviours is also very important. Understanding how cultural norms influence compliance with safety regulations can inform targeted interventions.

Exploring the intersection between climate change and road safety, considering the potential impact of extreme weather events on road infrastructure and safety, is relevant and needs further investigation. Addressing these research gaps can contribute to the development of more effective and targeted road safety strategies, policies, and interventions, ultimately reducing road accidents and improving overall transportation safety. Researchers, policymakers, and practitioners should collaborate to fill these gaps and advance our understanding of road safety management. Finally, the study could not establish how many people are likely to reduce car use because of the improvements in Qatari transport services. A study to investigate the implication of the improved public transport infrastructure and services on the percentage of the population likely to switch modes from car to public transport and its implication on the reduction in the number of car trips made daily and annual vehicle kilometres travelled.

9.4 Contribution to the Research

Although road safety management has been evolving, there are still gaps in several areas that require further research. This research contributes to addressing several gaps. The positioning of this research within the key bodies of literature on road safety, as well as its contribution and impact on various stakeholders such as academics, researchers, industry, policymakers, and the community at large, are evident in several distinct areas.

9.4.1 Behavioural Aspects

Understanding and addressing human behaviour about road safety is crucial. This research explores the attitudes of road users, pedestrians, and compliance with road safety measures (Case Studies 3-5). In terms of general road safety, the use of taxis is a key alternative to drink-driving, and hence taxis provide a service of potentially great indirect benefit to overall road safety (Dalziel J et al., 1997b). Many studies have shown that human behavioural factors collectively represent the main cause of road traffic crashes, and their remedial measures can go a long way towards helping prevent road traffic injuries (RTIs), (Bener A et al., 2007). A growing body of work is emerging that demonstrates the positive impact of using behavioural science approaches to both understand and reduce injury risk behaviours (Gielen AC et al., 2001). Evidence strongly suggests that road traffic accidents can be greatly minimised by bringing about changes in human behaviours and the associated psychological and structural factors. Around the world, researchers have successfully applied multiple behaviour change theories to various driving-related risky health behaviours. The health belief model is more appropriate for addressing human behaviours and educating drivers about risk as well as prevention (McGinnis JM et al., 2002).

9.4.2 Vulnerable Road Users

The literature review reveals a lack of research in the area of vulnerable road users (Case Study 4). It is required to concentrate more on vulnerable road users like pedestrians, cyclists, and motorcyclists. The current investigation examines the effects of pedestrian signals on road safety in Qatar. Speed mitigation policies benefit all Vulnerable Road Users (VRUs). These efforts may include setting speed limits using a Safe System approach, stronger speed limit enforcement, and infrastructure measures such as roundabouts, speed bumps, and other strategies (Retting, R. A et al., 2003). Urban and suburban areas, where pedestrian and cycling traffic is typically higher, particularly benefit from lowering the speed limit, which does not require new infrastructure. Even modest speed reductions could prevent many collisions and reduce the severity of injuries to VRUs (W.A. Leaf and D.F. Preusser., 1998). New York City has been successful in reducing pedestrian fatalities, which fell to the lowest level in a century in 2014 and have continued a downward trend since the city adopted new policies as part of its Vision Zero plan. Two effective policy changes were to reduce the city's default speed limit from 30 to 25 mph and increase enforcement of speeding laws, including the use of automated enforcement (Fitzsimmons, E., 2015). The progression of research in this area and its influences on travel safety will benefit academics, decision-makers, and planners.

9.4.3 Effectiveness of Public Transport Measures on Road Safety

Another gap in research is the lack of research on the effectiveness of public transportation measures on road safety, in particular in oil-rich countries. This research investigates a case study on the impacts of public transportation systems in Qatar (Case Study 2). The progression of research in this area and its influences on travel safety will benefit decision-makers, planners, and the community.

9.4.4 Evaluation of Road Safety Policies

Assessing the effectiveness of existing road safety policies and interventions to identify what works and what needs improvement, is an area that needs continuous research and updating. This research presents a case study that assesses the impacts of the implemented transport policies in Qatar on road safety (Case Study 1). This will have an impact on policymakers and guide them to make informed decisions based on evidence-based practices. The progression of research in this area and its influences on travel safety will benefit academics, decision-makers, and planners.

9.4.5 Road Safety in Low- and Middle-Income Countries

Focusing on road safety challenges in low and middle-income countries, where rapid urbanisation and increased motorization may outpace the development of safety measures. In this research, road safety in Qatar is assessed. Qatar is a fast-developing country that invests immensely in improving road safety (Case Study 1). The research on road safety in low- and middle-income countries and its impacts is very beneficial to various stakeholders, including academics, researchers, industry, policymakers, and the general public. Assessing road safety strategies and policies at a national level is a dimension for achieving improvements in the area of road safety and reducing road traffic crashes in rich countries. These improvements could provide lessons and experiences for other similar nations in the region and worldwide.

9.5 Study Limitations

This study had some methodological limitations. Firstly, the number of samples from both the public questionnaire and the webinar is limited. This was due to time and budget limitations. Larger samples would have been more favourable. In addition, the samplings were skewed more towards male respondents, i.e., 62.9% and 69.9%, respectively. This is due to cultural factors, which often make men more approachable than women for public surveys, particularly in this region. Samples containing a higher proportion of female respondents may produce slightly different results. However, the Planning and Statistics Authority of Qatar, 2019a, notes that the actual population in Qatar includes a higher percentage of males (78.1%).

The number of case studies that have been investigated in this research was limited to five. This is due to a lack of data, difficulty in getting data, and a lack of before and after periods since the implementation of the specific management scheme. Numerous case studies pertaining to auditing procedures, regulations, penalty systems, human acceptability, public transportation options, and vehicle types and designs require further investigation. Furthermore, the impact of additional socioeconomic characteristics on road safety and the acceptability of its strategies could enhance the work presented in this thesis. The perceptions of other stakeholders on the efficiency and impacts of different road safety strategies are relevant and could enhance the understanding and effectiveness of rod safety strategies. A comparison of longer-term and shorter-term impacts could also prove very valuable for improving road safety in Qatar and other similar countries. We should compare safe system schemes with those in both developing and developed countries.

The violation-related data presented in this study describes the overall violation for each category, e.g. RLR violations. It would have been interesting to examine the differences in traffic violations identified by automated camera systems vs. tickets given in person by officers separately. Moreover, different types of violations for each month that are reported separately for 2019 and 2020 have been investigated. It is important, however, to highlight that exposure data such as traffic volumes or vehicle-kilometre travelled was not available and thus it could not be considered in the analysis.

Furthermore, future studies should focus on evaluating the long-term impacts of the COVID-19 pandemic on road safety and driving behaviour. In addition, future studies could use alternative and more sophisticated modelling techniques to draw different linkages between public/experts' perceptions and the real-world impacts that COVID-19 has had on various travel behaviour characteristics.

References:

1. Abou-Amouna, M., Radwan, A., Al-Kuwari, L., Hammuda, A., & Al-Khalifa, K. (2014). Prediction of road accidents in Qatar by 2022. World Academy of Science, Engineering and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 8(2), 458–463. file:///C:/Users/User/Downloads/9997805.pdf

2. Al Mamun, A., Abouzeid, A., Al-Yafei, H., Hussain, S., Ahmad, A. M., Aseel, S., Kucukvar, M., & Onat, N. C. (2021). Sustainable Transportation in Qatar. 2021 IEEE 8th International Conference on Industrial Engineering and Applications, ICIEA 2021, 583–588. https://doi.org/10.1109/ICIEA52957.2021.9436707.

3. Al-Adhoobi, M. S., Jose, M., & Singh, A. V. (2017). A review of different road safety measures and enforcements. 2017 6th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), 691–697. 10.1109/ICRITO.2017.8342516

4. Al-Adhoobi, M. S., Jose, M., & Singh, A. V. (2018). A review of international practices of road safety audits. 2017 6th International Conference on Reliability, Infocom Technologies and Optimization: Trends and Future Directions, ICRITO 2017, 2018-Janua, 704–710. https://doi.org/10.1109/ICRITO.2017.8342518.

5. Alghnam, S., Alkelya, M., Alfraidy, M., Al-Bedah, K., Albabtain, I. T., & Alshenqeety, O. (2017). Outcomes of road traffic injuries before and after the implementation of a camera ticketing system: A retrospective study from a large trauma center in Saudi Arabia. Annals of Saudi Medicine, 37(1), 1–9. https://doi.org/10.5144/0256-4947.2017.1.

6. Alghnam, S., Towhari, J., Alkelya, M., Binahmad, A., & Bell, T. M. (2018). The effectiveness of introducing detection cameras on compliance with mobile phone and seatbelt laws: a before- after study among drivers in Riyadh, Saudi Arabia. Injury Epidemiology, 5(1), 1–8. 10.1186/s40621-018-0161-z

7. Alhajyaseen WKM, Hideki Nakamura H. (2010). Quality of pedestrian flow and crosswalk width at signalized intersections, IATSS Research, 34(1): 35-41. https://doi.org/10.1016/j.iatssr.2010.06.002.

8. Alhajyaseen WKM, Iryo-Asano M. (2017). Studying critical pedestrian behavioral changes for the safety assessment at signalized crosswalks. Safety Science, 91:351–360. https://doi.org/10.1016/j.ssci.2016.09.002

9. Alhajyaseen WKM. (2015). Pedestrian speed at signalised crosswalks: analysis and influencing factors. Int. J. Engineering Management and Economics, 5(3/4):258–272. https://doi.org/10.1504/IJEME.2015.072562

10. Alhajyaseen, W. K. M., Almukdad, A., Hussain, Q., Almallah, M., Al Malki, M. A., Singaravelu, J., & Zammataro, S. (2022). Road safety status during COVID-19 pandemic: exploring public and road safety expert's opinions. International Journal of Injury Control and Safety Promotion, 29(2), 135–151. https://doi.org/10.1080/17457300.2021.1962915.

11. Alhajyaseen, W., Adnan, M., Abuhejleh, A. *et al.* (2021). Travelers' preferences regarding autonomous mobility in the State of Qatar. *Pers Ubiquit Comput* **25**, 141–149. https://doi.org/10.1007/s00779-020-01407-1

12. Ali, G. A., Al-Alawi, S. M., & Bakheit, C. S. (1998). A comparative analysis and prediction of traffic accident causalities in the Sultanate of Oman using artificial neural networks and statistical methods. Sultan Qaboos University Journal for Science [SQUJS], 3, 11–20. http://dx.doi.org/10.24200/squjs.vol3iss0pp11-20

13. Al-Janahi, S. A., Ellabban, O., & Al-Ghamdi, S. G. (2020). Technoeconomic feasibility study of grid-connected building-integrated photovoltaics system for clean electrification: A case study of Doha metro. Energy Reports, 6,407–414. https://doi.org/https://doi.org/10.1016/j.egyr.2020.11.192.

14. AlKhereibi, A., AlSuwaidi, M., Al-Mohammed, R., Pokharel, S., & Ayari, M. (2021). An integrated urban-transport smart growth model around metro stations: A case of Qatar. Transportation Research Interdisciplinary Perspectives,10 (May),100392. https://doi.org/10.1016/j.trip.2021.100392.

15. Almallah, M., Alfahel, R., Hussain, Q., Alhajyaseen, W. K. M., & Dias, C. (2020). Empirical evaluation of drivers' start-up behavior at signalized intersection using driving simulator. Procedia Computer Science, 170, 227–234. https://doi.org/10.1016/j.procs.2020.03.034

16. Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echaniz, E., Gonzalez, F., Ladisa, C., Lezama- Romanelli, R., Lopez-Parra, A., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodriguez, A., & Sanudo, R. (2020). Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the city of Santander (Spain). Sustainability, 12(9), 3870. https://doi.org/10.3390/su12093870

17. Al-Thani, H., El-Menyar, A., Asim, M., Mollazehi, M., Abdelrahman, H., Parchani, A., Consunji, R., Castle, N., Ellabib, M., Al-Hassani, A., El-Faramawy, A., & Peralta, R. (2019). Evolution of the Qatar trauma system: The journey from inception to verification. Journal of Emergencies, Trauma and Shock, 12(3), 209–217. https://doi.org/10.4103/JETS.JETS_56_19

18. Al-Thawadi, F. E., Banawi, A. A. A., & Al-Ghamdi, S. G. (2021a). Social impact assessment towards sustainable urban mobility in Qatar: Understanding behavioral change triggers. Transportation Research Interdisciplinary Perspectives, 9(December 2020), 100295. https://doi.org/10.1016/j.trip.2020.100295.

19. Al-Thawadi, F. E., Banawi, A. A. A., & Al-Ghamdi, S. G. (2021b). Social impact assessment towards sustainable urban mobility in Qatar: Understanding behavioral change triggers. Transportation Research Interdisciplinary Perspectives, 9(January 2020). https://doi.org/10.1016/j.trip.2020.100295.

20. American Association of State Highway and Transportation Officials (AASHTO). "Road Safety Audit Guidelines." 2nd Edition, 2018.

21. Anaene Oyeka, I. C., & Ebuh, G. U. (2012). Modified Wilcoxon Signed-Rank Test. Open Journal of Statistics, 02(02), 172–176. https://doi.org/10.4236/ojs.2012.22019

22. Arbuckle, J. L. (2017). Amos 25 User 'S Guide. https://www.ibm.com/docs/en/SSLVMB_25.0.0/pdf/amos/IBM_SPSS_Amos_User_Guide.pdf

23. Austroads. (2013). Guide to Road Safety Part 1: Introduction and The Safe System. https://austroads.com.au/publications/road-safety/agrs01

24. Ayiei, A., Murray, J., & Wild, G. (2020). Visual flight into instrument meteorological condition: A post-accident analysis. Safety, 6(2), 19. https://doi.org/10.3390/safety6020019

25. B.P. Hughes, S. Newstead, A. Anund, C.C. Shu, T. Falkmer, (2015). A review of models relevant to road safety, Accident Analysis & Prevention, 74: 250-270, https://doi.org/10.1016/j.aap.2014.06.003.
26. Baklanova K, Voevodin E, Cheban E, Askhabov A, Kashura, A, (2021). Road Safety Audit as a Tool for Improving Safety on the Intercity Road Network, Transportation Research Procedia, 54,:682-691. https://doi.org/10.1016/j.trpro.2021.02.121.
27. Bavel, J. J. V., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., Crockett, M. J., Crum, A. J., Douglas, K. M., Druckman, J. N., Drury, J., Dube, O., Ellemers, N., Finkel, E. J., Fowler, J. H.,Gelfand, M., Han, S., Haslam, S. A., Jetten, J., Willer, R. (2020). Using social and behavioral science to support COVID-19 pandemic response. Nature Human Behavior, 4(5), 460–471. https://doi.org/10.1038/s41562-020-0884-z
28. Belwal. (2017). Public transportation in Oman: a strategic analysis. Advances in Transportation Studies, 42(3), 99–117. https://doi.org/10.4399/97888255035247.
29. Bendak, S. (2005). Seat belt utilization in Saudi Arabia and its impact on road accident injuries. Accident Analysis & Prevention, 37(2), 367–371. https://doi.org/10.1016/j.aap.2004.10.007
30. Bendak, S. (2007). Compliance with seat belt enforcement law in Saudi Arabia. International Journal of Injury Control and Safety Promotion, 14(1), 45–48. https://doi.org/10.1080/17457300600841726
31. Bener A, Al Humoud SMQ, Price P, et al. The effect of seatbelt legislation on hospital admissions with road traffic injuries in an oil-rich, fast-developing country. Int J Inj Contr Saf Promot 2007;14(2):103–107. https://doi.org/10.1080/17457300701212033
32. Bener, A., Hussain, S. J., Al-Malki, M. A., Shotar, M. M., Al-Said, M. F., & Jadaan, K. S. (2010). Road traffic fatalities in Qatar, Jordan and the UAE: Estimates using regression analysis and the relationship with economic growth. Eastern Mediterranean Health Journal, 16(3), 318–323. https://doi.org/10.26719/2010.16.3.318.
33. Bener, Abdulbari. (2005). The neglected epidemic: road traffic accidents in a developing country, State of Qatar. International Journal of Injury Control and Safety Promotion, 12(1), 45–47. https://doi.org/10.1080/1745730051233142225.

34. Bener, Abdulbari. (2012). A study on road traffic crashes and injuries in Qatar as reported by drivers. Journal of the Egyptian Public Health Association, 87(5–6), 85–89. https://doi.org/10.1097/01.EPX.0000421566.38407.94

35. Bennett S, Felton A, Akçelik R. Pedestrian movement characteristics at signalised intersections. In 23rd Conference of Australian Institute of Transport Research 2001, Clayton, Victoria, Australia. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=576a7430110e31966a3f1d3b4c633ac46d2b87b3

36. Benyei, A., & Golarits, P. (2002). Measurements to define relationship between traffic volume and traffic conditions in Hungary. Periodica Polytechnica Civil Engineering, 46(1), 83–94. https://pp.bme.hu/ci/article/view/622

37. Bíl, M., Bílová, M., Dobiáš, M., & Andrášik, R. (2016). Circumstances and causes of fatal cycling crashes in the Czech Republic. Traffic Injury Prevention, 17(4), 394–399. https://doi.org/10.1080/15389588.2015.1094183

38. Blincoe, L., Miller, T. R., Zaloshnja, E., & Lawrence, B. A. (2015). The economic and societal impact of motor vehicle crashes, 2010 (Revised). https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813403

39. Brodeur, A., Cook, N., & Wright, T. (2021). On the effects of COVID-19 safer-at-home policies on social distancing, car crashes and pollution. Journal of Environmental Economics and Management, 106, 102427. https://doi.org/10.1016/j.jeem.2021.102427

40. Caird, J. K., Johnston, K. A., Willness, C. R., Asbridge, M., & Steel, P. (2014). A meta-analysis of the effects of texting on driving. Accident Analysis & Prevention, 71, 311-318. https://doi.org/10.1016/j.aap.2014.06.005

41. CERTU. Guide de conception des carrefours à feux, technical report. Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques 2010. https://metropole.nantes.fr/files/pdf/espace-public/conception-carrefour-feux.pdf

42. Chen, G., Wilson, J., Meckle, W., & Cooper, P. (2000). Evaluation of photo radar program in British Columbia. Accident Analysis & Prevention, 32(4), 517–526. https://doi.org/10.1016/s0001-4575(99)00071-8

43. Chimba, D., Sando, T., & Kwigizile, V. (2010). Effect of bus size and operation to crash occurrences. Accident; Analysis and Prevention, 42(6), 2063–2067. https://doi.org/10.1016/j.aap.2010.06.018

44. Chin, H. C. (1999). An investigation into the effectiveness of the speed camera. Proceedings of the Institution of Civil Engineers-Transport, 135(2), 93–101. https://doi.org/10.1680/itran.1999.31375

45. Comparing transport infrastructure investment policies around the globe. Statistics Brief. Paris: International Transport Forum; 2023 (https://www.itf-oecd.org/sites/default/files/compare-transport-infrastructure-investment-statistics-brief.pdf accessed 15 June 2023).

46. Consunji, R. (2019). CIHT Qatar - Technical Seminar on "Is Road Safety in Qatar Getting Better or Worse?" | CIHT. https://www.ciht.org.uk/news/ciht-qatar-technical-seminar-on-is-road-safety- in-qatar-getting-better-or-worse/

47. Consunji, R., Alinier, G., Abeid, A. F., Murray, L. M., & Fildes, B. (2022). Recommendations to improve young and novice driver safety in the State of Qatar. Journal of Emergency Medicine, Trauma and Acute Care, 2022(2). https://doi.org/10.5339/jemtac.2022.4

48. Consunji, R., Malik, S., El-Menyar, A., Mollazehi, M., Al-Thani, H., & Peralta, R. (2020). Pediatric road traffic injuries in Qatar: Evidence for a developmental stage approach to road safety. Qatar Medical Journal, 2020(1), 1–8. https://doi.org/10.5339/QMJ.2020.3

49. Consunji, R., Mekkodathil, A., Abeid, A., El-Menyar, A., Al-Thani, H., Sekayan, T., & Peralta, R. (2018). Applying the five-pillar matrix to the decade of action for road safety in Qatar: Identifying gaps and priorities. Trauma Surgery and Acute Care Open, 3(1). https://doi.org/10.1136/tsaco- 2018-000233

50. Dalziel J, Job S. Taxi Drivers and Road Safety: A Report to the Federal Office of Road Safety 1997b. Retrieved on May 23, 2020. Available at: https://www.infrastructure.gov.au/roads/safety/publications/1997/pdf/taxi_drivers.pdf

51. DOT. Local Transport Note 2/95 The Design of Pedestrian Crossings. Department of Transport, The Welsh Office, The Scottish Office, The Department of the Environment for Northern lreland, 1995. https://assets.publishing.service.gov.uk/media/5a7d5cc0e5274a3356f2bc27/ltn-2-95_pedestrian-crossings.pdf

52. Doucette, M. L., Tucker, A., Auguste, M. E., Watkins, A., Green, C., Pereira, F. E., Borrup, K. T., Shapiro, D., & Lapidus, G. (2021). Initial impact of COVID-19's stay-at-home order on motor vehicle traffic and crash patterns in Connecticut: an interrupted time series analysis. Injury Prevention, 27(1), 3–9. https://doi.org/10.1136/injuryprev-2020-043945

53. Du, J., Rakha, H. A., Filali, F., & Eldardiry, H. (2021). COVID-19 pandemic impacts on traffic system delay, fuel consumption and emissions. International Journal of Transportation Science and Technology, 10(2), 184–196. https://doi.org/10.1016/j.ijtst.2020.11.003

54. Edvardsson Björnberg, K. (2022). Vision Zero and Other Road Safety Targets. In: Edvardsson Björnberg, K., Belin, MÅ., Hansson, S.O., Tingvall, C. (eds) The Vision Zero Handbook. Springer, Cham. https://doi.org/10.1007/978-3-030-23176-7_1-1

55. El Bcheraoui, C., Basulaiman, M., Tuffaha, M., Daoud, F., Robinson, M., Jaber, S., Mikhitarian, S., Wilson, S., Memish, Z. A., & Al Saeedi, M. (2015). Get a license, buckle up, and slow down: risky driving patterns among Saudis. Traffic Injury Prevention, 16(6), 587–592. https://doi.org/10.1080/15389588.2014.990090

56. Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. Transportation Research Record, 1595(1), 14–19. https://doi.org/10.3141/1595-03

57. Elvik, R. (2000). How much do road accidents cost the national economy? Accident Analysis & Prevention, 32(6), 849–851. https://doi.org/10.1016/S0001-4575(00)00015-4

58. Elvik, R. (2002). The importance of confounding in observational before-and-after studies of road safety measures. Accident Analysis & Prevention, 34(5), 631–635. https://doi.org/10.1016/S0001-4575(01)00062-8.

59. Enu, P. (2014). Road traffic accidents and macroeconomic conditions in Ghana. Social and Basic Sciences Research Review, 2(9), 374–393. Road_Traffic_Accidents_and_Macroeconomic.pdf

60. Ernstberger, A., Joeris, A., Daigl, M., Kiss, M., Angerpointner, K., Nerlich, M., & Schmucker, U. (2015). Decrease of morbidity in road traffic accidents in a high income country–an analysis of 24,405 accidents in a 21 year period. Injury, 46, S135–S143. https://doi.org/10.1016/S0020-1383(15)30033-4

61. European Transport Safety Council. (2020). The Impact of Covid-19 Lockdowns on Road Deaths in April 2020 (PIN Briefing). https://etsc.eu/pin-briefing-the-impact-of-covid-19- lockdowns-on-road-deaths-in-april-2020/

62. Federal Highway Administration (FHWA). "Road Safety Audit Guidelines." Report No. FHWA- SA-06-06, 2004. https://safety.fhwa.dot.gov/rsa/guidelines/documents/FHWA_SA_06_06.pdf

63. Feero S, Hedges JR, Simmons E, Irwin L., “Does out-of-hospital EMS time affect trauma survival?” Am J Emerg Med. 1995;13(2):133-135. 10.1016/0735-6757(95)90078-0

64. Fitzsimmons, E. (2015). New York City’s Pedestrian Fatalities Lowest on Record in 2014. The New York Times. https://www.nytimes.com/2015/01/02/nyregion/new-york-pedestrian-deaths-are-lowest-on-record.html

65. Fort, J. R., Díaz, J. A., Catalina, S. C., Boudet, J. M. C., & Herrero, M. P. (2017). Red Line South. Metro de Doha (Qatar). Estructuras singulares construidas in-situ de ancho o canto variable. Hormigón y Acero, 68(282), 129–138. https://www.elsevier.es/es-revista-hormigon-acero-394-articulo-red-line-south-metro-doha-S0439568917300268

66. Furlan, R. (2019). Doha, Qatar. In Parking: An International Perspective. INC.https://doi.org/10.1016/B978-0-12-815265-2.00010-8.

67. Gielen AC, Girasek DC. Integrating perspectives on the prevention of unintentional injuries. In: Schneiderman N, Speers MA, Silva JM, Tomes H, Gentry JH, eds. Integrating Behavioral and Social Sciences with Public Health. Washington, DC: American Psychological Association; 2001:203–230. https://doi.org/10.1037/10388-010

68. Givoni, M., & Rietveld, P. (2014). Do cities deserve more railway stations? The choice of a departure railway station in a multiple-station region. Journal of Transport Geography, 36, 89–97. https://doi.org/10.1016/j.jtrangeo.2014.03.004
69. Global status report on road safety 2023. Geneva: World Health Organization; 2023. Licence: CC BY-NC-SA 3.0 IGO. (https://iris.who.int/bitstream/handle/10665/375016/9789240086517)
70. Goniewicz, M., Nogalski, A., Khayesi, M., Lübek, T., Zuchora, B., Goniewicz, K., & Miskiewicz, P. (2012). Pattern of road traffic injuries in Lublin County, Poland. Central European Journal of Public Health, 20(2), 116. 10.21101/cejph.a3686
71. Google. (2021). Covid-19 Community Mobility Reports. https://www.google.com/covid19/mobility/
72. Government Communications Office. (2020a). Government Communications Office statement on the suspension of public and private schools and universities for all students until further notice as a precautionary measure to contain the spread of Coronavirus (COVID-19). https://www.gco.gov.qa/en/statement-on-the-suspension-of-public-and-private-schools-and-universities-for-all-students-until-further-notice-as-a-precautionary-measure-to-contain-the-spread-of-coronavirus/
73. Government Communications Office. (2020b). How you can stop the spread of COVID-1 https://www. gco. gov. qa/en/preventative-measures/
74. Governors Highway Safety Association. (2020). Pedestrian Traffic Fatalities by State: 2020 Preliminary Data. https://www.ghsa.org/sites/default/files/2021-03/Ped%20Spotlight%202021%20FINAL%203.23.21.pdf
75. Graham, D. J., Naik, C., Mccoy, E. J., & Li, H. (2019). Do speed cameras reduce road traffic collisions? PLoS ONE, 14(9), 1–15. https://doi.org/10.1371/journal.pone.0221267.
76. Guest, G., Namey, E., & McKenna, K. (2017). How many focus groups are enough? Building an evidence base for nonprobability sample sizes. Field Methods, 29(1), 3–22. https://doi.org/10.1177/1525822X16639015
77. Gulf Times. (2020a). Shops to remain closed till 30th; Ehteraz on phone mandatory. https://www.gulf-times.com/story/663527/shops-to-remain-closed-till-30th-ehteraz-on-phone-mandatory

78. Gulf Times. (2020b). Wearing of masks made mandatory outside home except when driving alone. https://www.gulf-times.com/story/663173/wearing-of-masks-made-mandatory-outside-home-except-when-driving alone#:~:text=It%20affirmed%20the%20continuation%20of,necessary%20measures%20in%20this%20regard.

79. Hadi, M. A., Aruldhas, J., Chow, L. F., & Wattleworth, J. A. (1995). Estimating safety effects of cross-section design for various highway types using negative binomial regression. In Transportation Research Record (Issue 1500, pp. 169–177).https://onlinepubs.trb.org/Onlinepubs/trr/1995/1500/1500-021.pdf

80. Harith, S. H., Mahmud, N., & Doulatabadi, M. (2019). A conceptual framework on the role of road safety management intervention in overcoming road accident. Proceedings of the International Conference on Industrial Engineering and Operations Management, 2019(MAR), 3375–3383. https://ieomsociety.org/ieom2019/papers/769.pdf

81. Hauer, E. (1997). Observational before-after studies in road safety. https://trid.trb.org/view/472973

82. Hauke, J., & Kossowski, T. (2011). Comparison of values of Pearson's and Spearman's correlation coefficients on the same sets of data. QUAGEO, 30(2), 87–93.https://doi.org/10.2478/v10117-011-0021-1

83. Hesse, C. A., & Ofosu, J. B. (2014). Epidemiology of road traffic accidents in Ghana. file:///C:/Users/User/Downloads/3069-Article%20Text-8887-1-10-20140331.pdf

84. Hou, W.K., Lee, T.MC., Liang, L. *et al.* (2021). Civil unrest, COVID-19 stressors, anxiety, and depression in the acute phase of the pandemic: a population-based study in Hong Kong. *Soc Psychiatry Psychiatr Epidemiol* **56**, 1499–1508. https://doi.org/10.1007/s00127-021-02037-5

85. Hukoomi Qatar e-Government. (2020). Cabinet: Reducing Number of Employees in Government Entities to 20%, While 80% To Start Working Remotely. https://www.gulf-times.com/story/658720/Cabinet-Reduce-number-of-employees-present-at- govt

86. Hussain, Q., Alhajyaseen, W. K. M., Brijs, K., Pirdavani, A., & Brijs, T. (2020).Innovative countermeasures for red light running prevention at signalized intersections: A driving simulator study. Accident; Analysis and Prevention,134, 105349. https://doi.org/10.1016/j.aap.2019.105349.
87. Hussain, Q., Alhajyaseen, W. K. M., Brijs, K., Pirdavani, A., Reinolsmann, N., & Brijs, T. (2019). Drivers' estimation of their travelling speed: a study on an expressway and a local road. International Journal of Injury Control and Safety Promotion, 26(3), 216–224. https://doi.org/10.1080/17457300.2019.1618342
88. Inada, H., Ashraf, L., & Campbell, S. (2021). COVID-19 lockdown and fatal motor vehicle collisions due to speed-related traffic violations in Japan: a time-series study. Injury Prevention, 27(1), 98–100. https://doi.org/10.1136/injuryprev-2020-043947
89. Iryo-Asano M, Alhajyaseen W, Nakamura H. (2014). Analysis and Modeling of Pedestrian Crossing Behavior during Pedestrian Flashing Green Interval. IEEE Transactions on Intelligent Transportation Systems. 16(2):958-969. https://ieeexplore.ieee.org/abstract/document/6899642
90. Iryo-Asano M, Alhajyaseen WKM (2014). Analysis of pedestrian clearance time at signalized crosswalks in Japan. Procedia Computer Science 2014;32:301–308. https://doi.org/10.1016/j.procs.2014.05.428
91. Ivan JN, McKernan K, Zhang Y, Ravishanker N, Mamun SA. (2017). A study of pedestrian compliance with traffic signals for exclusive and concurrent phasing. Accident Analysis and Prevention, 98:157–166. 10.1016/j.aap.2016.10.003
92. Jadaan, K., & Almatawah, J. (2016a). A Review of Strategies to Promote Road Safety in Rich Developing Countries: the Gcc Countries Experience. Journal of Engineering Research and Application, 6, 12–17. https://www.ijera.com/papers/Vol6_issue9/Part-5/C060905012017.pdf
93. Jafarpour, S., & Rahimi-Movaghar, V. (2014). Determinants of risky driving behavior: a narrative review. Medical Journal of the Islamic Republic of Iran, 28, 142. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4322337/

94. Jagnoor, J., Sharma, P., Parveen, S., Cox, K. L., & Kallakuri, S. (2020). Knowledge is not enough: barriers and facilitators for reducing road traffic injuries amongst Indian adolescents, a qualitative study. International Journal of Adolescence and Youth, 25(1), 787–799. https://doi.org/10.1080/02673843.2020.1746675

95. Jameel, A.K., Evdorides, H.T. (2023) REVIEW OF MODIFYING THE INDICATORS OF ROAD SAFETY SYSTEM. Journal of Engineering and Sustainable Development. 27(2):149-170. https://doi.org/10.31272/jeasd.27.2.1

96. Jamieson, J. (2007). Final Road Safety Strategy Plan for Qatar. In The Shock and Vibration Digest: Vol. 28/08/2007. https://doi.org/10.1177/058310247600800406

97. Jamieson, J. (2008). The Development of a Road Safety Strategy for the Gulf State of Qatar. November, 479–500. https://acrs.org.au/files/arsrpe/RS080010.pdf

98. Jeong-Gyu, K. (2002). Changes of speed and safety by automated speed enforcement systems. IATSS Research, 26(2), 38–44. https://doi.org/10.1016/S0386-1112(14)60041-8

99. JHU CSSE. (2021). COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. https://github.com/CSSEGISandData/COVID-19

100. Jones, Joshua Reid, (2013), A Method to Quantify Road Safety Audit Data and Results" All Graduate Theses and Dissertations. 1544. https://digitalcommons.usu.edu/etd/1544

101. Kaji, M., Barr, L., & Maile, A. (2020). Police see uptick in speeding, fatal crashes amid pandemic. ABC News. https://abcnews.go.com/US/police-uptick-speeding-fatal-crashes-amid-pandemic/story?id=70751844

102. Katrakazas, C., Michelaraki, E., Sekadakis, M., & Yannis, G. (2020). A descriptive analysis of the effect of the COVID-19 pandemic on driving behavior and road safety. Transportation Research Interdisciplinary Perspectives, 7, 100186. https://doi.org/10.1016/j.trip.2020.100186

103. Khamis, H. (2008). Measures of Association: How to Choose?Journal of Diagnostic Medical Sonography, 24(3), 155–162. https://doi.org/10.1177/8756479308317006

104. Khattak, Z. H., Magalotti, M. J., & Fontaine, M. D. (2018). Estimating safety effects of adaptive signal control technology using the Empirical Bayes method. Journal of Safety Research, 64, 121–128. https://doi.org/10.1016/j.jsr.2017.12.016

105. Khorasani-Zavareh, D., Mohammadi, R., Khankeh, H. R., Laflamme, L., Bikmoradi, A., & Haglund, B. J. A. (2009). The requirements and challenges in preventing of road traffic injury in Iran. A qualitative study. BMC Public Health, 9(1), 1–9. https://doi.org/10.1186/1471-2458-9-486
106. Kline, R. B. (2011a). Convergence of structural equation modeling and multilevel modeling. https://doi.org/10.4135/9781446268261.n31
107. Kline, R. B. (2011b). Principles and Practice of Structural Equation Modeling (T. D. Little (ed.); 3rd ed.). The Guilford Press. http://ndl.ethernet.edu.et/bitstream/123456789/74702/1/35.pdf
108. Kontogiannis, T. (2006). Patterns of driver stress and coping strategies in a Greek sample and their relationship to aberrant behaviors and traffic accidents. Accident Analysis & Prevention, 38(5), 913–924. https://doi.org/10.1016/j.aap.2006.03.002
109. Krug EG, Sharma GK, L. R. (2000).The global burden of injuries. American Journal of Public Health, 2000, 90:523–526., 523–526. https://doi.org/10.2105%2Fajph.90.4.523
110. Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How habits are formed: Modelling habit formation in the real world. European Journal of Social Psychology, 40(6), 998–1009. https://doi.org/10.1002/ejsp.674
111. Lockwood, M., Lahiri, S., Babiceanu, S. (2020). Traffic Trends and Safety in a COVID-19 World. What Is Happening in Virginia. Virginia department of Transportation (VDOT), Transportation Research Board. https://onlinepubs.trb.org/onlinepubs/webinars/200602.pdf
112. Ma W, Liao D, Liu Y, Lo HK. (2015). Optimization of pedestrian phase patterns and signal timings for isolated intersection. Transportation Research Part C, 58:502–514. https://doi.org/10.1016/j.trc.2014.08.023
113. Mamtani, R., Al-Thani, M. H., Al-Thani, A. A. M., Sheikh, J. I., & Lowenfels, A. B. (2012). Motor vehicle injuries in Qatar: Time trends in a rapidly developing Middle Eastern nation. Injury Prevention, 18(2), 130–132. https://doi.org/10.1136/injuryprev-2011-040147

114. Market research report: Automotive market size, share, growth, and global industry analysis, by type (passenger vehicle and commercial vehicle), by application (personal use, municipal use, and business use), regional insights and forecast to 2031. Business Research Insights. Maharashtra, India: Business Research Insights; 2023 (https://www.businessresearchinsights.com/market-reports/automotive-market-102183 accessed 2 November 2023).
115. Marvasti, A. (2018) 'Research methods', The Cambridge Handbook of Social problems, 1(3), pp. 23-37. https://pure.psu.edu/en/publications/research-methods
116. McGinnis JM, Williams-Russo P, Knickman JR. The case for more active policy attention to health promotion. Health Aff (Millwood) 2002;21(2):78–93. https://doi.org/10.1377/hlthaff.21.2.78
117. Mchugh, M. L. (2011). Multiple comparison analysis testing in ANOVA. Biochemia Medica, 21(3), 203–209. https://doi.org/10.11613/bm.2011.029
118. Mchugh, M. L. (2013). The Chi-square test of independence Lessons in biostatistics. Biochemia Medica, 23(2), 143–149. https://www.biochemia-medica.com/en/journal/23/2/10.11613/BM.2013.018
119. Molnar, A. (2019). SMARTRIQS: a simple method allowing real-time respondent interaction in qualtrics surveys. Journal of Behavioral and Experimental Finance, 22, 161–169. https://doi.org/10.1016/j.jbef.2019.03.005
120. Muley, D., Tahmasseby, S., Wink, B. W., & Tarlochan, F. (2020). Application of Vehicle Restraint Systems (VRSs) in the State of Qatar: A Case Study from Northern Roads. Cic, 462–467. https://doi.org/10.29117/cic.2020.0058
121. Mundfrom, D. J., Shaw, D. G., & Ke, T. L. (2005). Minimum sample size recommendations for conducting factor analyses. International Journal of Testing, 5(2), 159–168. https://psycnet.apa.org/doi/10.1207/s15327574ijt0502_4
122. Murray, C. J. L., Abraham, J., Ali, M. K., Alvarado, M., Atkinson, C., Baddour, L. M., Bartels, D. H., Benjamin, E. J., Bhalla, K., & Birbeck, G. (2013). The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. Jama, 310(6), 591–606. https://doi.org/10.1001%2Fjama.2013.13805
123. MUTCD. Manual on uniform traffic control devices for streets and highways 2009 Edition. U.S. Department of Transportation, Federal Highway Administration. 2009. https://mutcd.fhwa.dot.gov/pdfs/2009/mutcd2009edition.pdf

124. Mwale M, Mwangilwa K, Kakoma E, Iaych K.(2023). Estimation of completeness of road traffic mortality data in Zambia using a three source capture recapture method. Accident Analysis & Prevention. (186);107048. https://doi.org/10.1016/j.aap.2023.107048

125. Nafi, S., Furlan, R., Grosvald, M., Al-matwi, R., & Marthya, K. L. (2021). Transit-oriented development in doha: The case of the al sadd neighborhood and hamad hospital metro station. Designs, 5(4). https://doi.org/10.3390/designs5040061

126. Naser, A., Al-Jabery, A., Khan, O., & Choe, P. (2020). Modelling critical meteorological factors affecting public bus ridership in the state of Qatar: A case study. ACM International Conference Proceeding Series, 106–112. https://doi.org/10.1145/3416028.3416044

127. National Highway Traffic Safety Administration (NHTSA). (2018). Vehicle technologies. U.S. Department of Transportation. https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812981

128. National Traffic Safety Committee. (2012). National Road Safety Strategy 2013-2022. https://www.ashghal.gov.qa/ServicesLibrary/English/NRSS_Eng.pdf

129. National Traffic Safety Committee. (2018). Qatar Action Plan 2018-2022: National Road Safety Strategy. https://www.ashghal.gov.qa/ServicesLibrary/English/NRSS_Eng.pdf

130. Nussyba Eiraibe , ALMaha Ahmed AL-Malki , Raffaello Furlan , Exploration of Sustainable Urban Qualities of Al Sadd Area in Doha, *American Journal of Sociological Research,* Vol. 5 No. 4, 2015, pp. 101-118. 10.5923/j.sociology.20150504.02.

131. O'Brien, R. G., & Kaiser, M. K. (1985). MANOVA Method for Analyzing Repeated Measures Designs. An Extensive Primer. Psychological Bulletin, 97(2), 316–333. https://doi.org/10.1037/0033-2909.97.2.316

132. Oguzoglu, U. (2020). COVID-19 lockdowns and decline in traffic related deaths and injuries IZA Discussion Paper No. 13278. https://ssrn.com/abstract=3608527

133. Organization, W. H. (2013). Global status report on road safety. Injury Prevention,318.https://doi.org/http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/index. Html

134. Oskarbski, J., Kamiński, T., Kyamakya, K., Chedjou, J. C., Żarski, K., & Pędzierska, M. (2020). Assessment of the speed management impact on road traffic safety on the sections of motorways and expressways using simulation methods. Sensors, 20(18), 5057. https://doi.org/10.3390/s20185057

135. P. Puvanachandra C. Hoe , H. F. ElSayed , R. Saad , N. Al,Gasseer , M. Bakr & A. A. Hyder (2012). Road Traffic Injuries and Data Systems in Egypt: Addressing the Challenges, Traffic Injury Prevention, 13:sup1, 44 56. https://doi.org/10.1080/15389588.2011.639417

136. Paparella, N. (2020). Stunt driving increases with quieter streets during COVID-19 outbreak. https://london.ctvnews.ca/stunt-driving-increases-with-quieter-streets-during-covid-19-outbreak- 1.4907693

137. Peden, M., Scurfield, R., Sleet, D., Mathers, C., Jarawan, E., Hyder, A. A., Mohan, D., Hyder, A. A., & Jarawan, E. (2004). World report on road traffic injury prevention. World Health Organization. https://iris.who.int/bitstream/handle/10665/42871/9241562609.pdf?sequence=1

138. Peters D, Kim L, Zaman R, Haas G, Cheng J, Ahmed S, (2015). Pedestrian Crossing Behavior at Signalized Intersections in New York City. Transportation Research Record: Journal of the Transportation Research Board, 2519:179-188. https://doi.org/10.3141/2519-20

139. Pilkington, P. (2002). Increasing visibility of speed cameras might increase deaths and injuries on roads. Bmj, 324(7346), 1153. https://doi.org/10.1136%2Fbmj.324.7346.1153%2Fa

140. Pilkington, P., & Kinra, S. (2005). Effectiveness of speed cameras in preventing road traffic collisions and related casualties: systematic review. Bmj, 330(7487), 331–334. https://doi.org/10.1136/bmj.38324.646574.AE

141. Planning and Statistics Authority. (2019b). First Section Population and Social Statistics.https://www.psa.gov.qa/en/statistics/Statistical%20Releases/Population/Population/2019/Population_social_1_2019_AE.pdf

142. Planning and Statistics Authority. (2019c). Labor Force Sample Survey. https://www.psa.gov.qa/en/statistics/Statistical%20Releases/Social/LaborForce/2019/statistical_analysis_labor_force_2019_En.pdf

143. Planning and Statistics Authority. (2020). Qatar Monthly Statistics (Issue August). https://ghdx.healthdata.org/record/qatar-monthly-statistics-bulletin-issue-79-august-2020

144. Planning and Statistics Authority. (2019a). Education in Qatar Statistical Profile. https://www.psa.gov.qa/en/statistics/Statistical%20Releases/General/StatisticalAbstract/2019/Education_Statistical_Pro%EF%AC%81le_2019_En.pdf

145. Pons PT, Haukoos JS, Bludworth W, et al. (2005) "Paramedic response time: does it affect patient survival?" Acad Emerg Med. 12(7):594-600. https://doi.org/10.1197/j.aem.2005.02.013

146. Preacher, K. J., & MacCallum, R. C. (2002). Exploratory factor analysis in behavior genetics research: Factor recovery with small sample sizes. Behavior Genetics, 32(2), 153–161. https://doi.org/10.1023/A:1015210025234

147. QTCM. Qatar Traffic Control Manual, Volume 1, Part 5, Traffic Signals. Ministry of Municipality and Environment, State of Qatar 2015. https://dokumen.tips/documents/qatar-traffic-manual-volume-one.html?page=2

148. Qu, X., Yang, Y., Liu, Z., Jin, S., & Weng, J. (2014). Potential crash risks of expressway on- ramps and off-ramps: a case study in Beijing, China. Safety Science, 70, 58–62. https://doi.org/10.1016/j.ssci.2014.04.016

149. Qureshi, A. I., Huang, W., Khan, S., Lobanova, I., Siddiq, F., Gomez, C. R., & Suri, M. F. K. (2020). Mandated societal lockdown and road traffic accidents. Accident; Analysis and Prevention, 146, 105747. https://doi.org/10.1016/j.aap.2020.105747

150. Radwan, A., & Hammuda, A. (2015). Prediction of Road Accidents in Qatar by 2022. October. https://doi.org/10.5339/qfarf.2012.AHP31.

151. Rahoof, A., Singh, B. K., & Scholar, M. T. (2017). Road Safety and Road Safety Audit in India : a Review. 4(7), 1011–1014. https://ijtre.com/wp-content/uploads/2021/10/2017040713.pdf

152. Raj Ponnaluri, P. H. D., & Fred Heery SR, P. E. (2016). Wrong-Way Driving Mitigation: A Holistic Approach in Florida, USA. Institute of Transportation Engineers. ITE Journal, 86(5), 43.https://trid.trb.org/View/1426250

153. Ramasubramanian, V. (2014) ‘Intervention Based ARIMA Time Series Models’, Indian agricultural statistics research institute, New Delhi [Preprint]. http://cabgrid.res.in/cabin/publication/smfa/Module%20III/1.%20Intervention%20based%20ARIMA%20time%20series%20models_Rama.pdf

154. Rasoul, S. (2010). Why So Much oil in the Middle East ? The Qatar Oil Discoveries, 7(1), 42–46. https://geoexpro.com/why-so-much-oil-in-the-middle-east/

155. Richard A. Retting, Susan A. Ferguson, and Anne T. McCartt, 2003: A Review of Evidence-Based Traffic Engineering Measures Designed to Reduce Pedestrian–Motor Vehicle Crashes, American Journal of Public Health 93, 1456_1463, https://doi.org/10.2105/AJPH.93.9.1456

156. Richardson, A., Ampt, E., & Meyburg, A. (1995). Survey methods for transport planning. https://search.worldcat.org/title/32404041

157. Robillard, R., Saad, M., Edwards, J., Solomonova, E., Pennestri, M.-H., Daros, A., Veissiere, S. P. L., Quilty, L., Dion, K., Nixon, A., Phillips, J., Bhatla, R., Spilg, E., Godbout, R., Yazji, B., Rushton, C., Gifford, W. A., Gautam, M., Boafo, A., Swartz, R., & Kendzerska, T. (2020). Social, financial and psychological stress during an emerging pandemic: observations from a population survey in the acute phase of COVID-19. BMJ Open, 10(12), e043805. https://doi.org/10.1136/bmjopen-2020-043805

158. Royal Society for the Prevention of Accidents. (2017). Road Safety Factsheet (Issue November). https://www.rospa.com/rospaweb/docs/advice-services/road-safety/road-crashes-overview.pdf

159. Russell Griffin, Gerald McGwin, 2013, Emergency Medical Service Providers' Experiences with Traffic Congestion,The Journal of Emergency Medicine, 44, (2), 398-405, https://doi.org/10.1016/j.jemermed.2012.01.066.

160. Sadeghi Bazargani, H., Razzaghi, A., Atabak, A., Veisi, S., Yazdani, M. (2022). Setting research priorities to achieve long-term national road safety goals in Iran Open Access. Journal of Global Health https://doi.org/10.7189/jogh.12.09002

161. Saladie, O., Bustamante, E., & Gutierrez, A. (2020). COVID-19 lockdown and reduction of traffic accidents in Tarragona province, Spain. Transportation Research Interdisciplinary Perspectives, 8, 100218. https://doi.org/10.1016/j.trip.2020.100218

162. Salt, D., & Higham, E. (2013). Qatar launches National Road Safety Strategy (Vol. 11, Issue1). https://www.inhousecommunity.com/wp-content/uploads/2016/07/v11i1_JURIS_qatar.pdf

163. Savolainen, P., & Ghosh, I. (2008). Examination of Factors Affecting Driver Injury Severity in Michigan's Single-Vehicle–Deer Crashes. *Transportation Research Record*, *2078*(1), 17-25. https://doi.org/10.3141/2078-03

164. Shaaban, K., & Hassan, H. M. (2014). Modeling significant factors affecting Commuters' perspectives and propensity to use the new proposed metro service in Doha. Canadian Journal of Civil Engineering, 41(12), 1054–1064. https://doi.org/10.1139/cjce-2013-0595.

165. Shaaban, K., & Khalil, R. F. (2013). Investigating the customer satisfaction of the bus service in Qatar. Procedia-Social and Behavioral Sciences, 104, 865–874. https://doi.org/10.1016/j.sbspro.2013.11.181

166. Shaaban, K., & Kim, I. (2016a). Assessment of the taxi service in Doha. Transportation Research Part A: Policy and Practice, 88, 223–235. https://doi.org/10.1016/j.tra.2016.04.011

167. Shaaban, K., & Kim, I. (2016b). The influence of bus service satisfaction on university students' mode choice. Journal of Advanced Transportation, 50(6), 935–948. https://onlinelibrary.wiley.com/doi/epdf/10.1002/atr.1383

168. Shaaban, K., Shakeel, K., Rashidi, T. H., & Kim, I. (2021). Measuring users' satisfaction of the road network using structural equation modeling. International Journal of Sustainable Transportation, 0(0), 1–12. https://doi.org/10.1080/15568318.2021.1934916

169. Shilling, F., & Waetjen, D. (2020). Special report: Impact of COVID19 on California traffic accidents. https://trid.trb.org/view/1700419 Soliman, A., Alhajyaseen, W., Alfar, R., & Alkaabi, I. (2018). Changes in driving behavior across age cohorts in an Arab culture: The case of state of Qatar. Procedia Computer Science, 130, 652–659. https://doi.org/10.1016/j.procs.2018.04.116

170. Sidi, M. (2021). Cameras in Qatar to start monitoring seatbelt; mobile violations soon. The Peninsula https://thepeninsulaqatar.com/article/26/04/2021/Cameras-to-catch-seatbelt,-mobile-use-violations-soon-Traffic-official

171. Song, Y., & Zhang, M. (2019). Study on the gravity movement and decoupling state of global energy-related CO2 emissions. Journal of Environmental Management, 245, 302–310. https://doi.org/10.1016/j.jenvman.2019.05.094

172. Speed management: a road safety manual for decision-makers and practitioners, second edition. Geneva: Global Road Safety Partnership, International Federation of Red Cross and Red Crescent Societies; 2023 https://www.grsproadsafety.org/wp-content/uploads/2023/10/Green-Manual-Speed-revised-edition-16Oct23.pdf, accessed 15 June 2023).

173. Sperling, D., & Claussen, E. (2004). Motorizing the developing world. Access Magazine, 1(24), 10–15. https://www.accessmagazine.org/wp-content/uploads/sites/7/2016/07/Access-24-03-Motorizing-the-Developing-World.pdf

174. Sun, R. (2017). Road Safety and Intelligent Transport Systems. In: An Integrated Solution Based Irregular Driving Detection. Springer Theses. Springer, Cham, 9-19. https://doi.org/10.1007/978-3-319-44926-5_2

175. Tan, T., Al-Khalaqi, A., & Al-Khulaifi, N. (2014). Qatar national vision 2030. Sustainable Development: An Appraisal from the Gulf Region, 19, 65. https://doi.org/10.2307/j.ctt9qdd86

176. Tang, T., Guo, Y., Wang, H., Li, X., & Agrawal, S. (2023). Determinants of Helmet Use Intention Among E-Bikers in China: An Application of the Theory of Planned Behavior, the Health Belief Model, and the Locus of Control. *Transportation Research Record*, *0*(0). https://doi.org/10.1177/03611981231176290

177. Thompson, J. P. et al. (2013) ‘An examination of the environmental, driver and vehicle factors associated with the serious and fatal crashes of older rural drivers’, Accident Analysis and Prevention, 50, pp. 768–775. https://doi.org/10.1016/j.aap.2012.06.028.

178. Timmermans, C., Alhajyaseen, W., Al Mamun, A., Wakjira, T., Qasem, M., Almallah, M., & Younis, H. (2019). Analysis of road traffic crashes in the State of Qatar. International Journal of injury control and safety Promotion, 26(3), 242-250. https://doi.org/10.1080/17457300.2019.1620289.

179. Timmermans, C., Alhajyaseen, W., Al Mamun, A., Wakjira, T., Qasem, M., Almallah, M., & Younis, H. (2019b). Analysis of road traffic crashes in the State of Qatar. International Journal of InjuryControland Safety Promotion, 26(3), 242–250. https://doi.org/10.1080/17457300.2019.1620289

180. Timmermans, C., Alhajyaseen, W., Reinolsmann, N., Nakamura, H., & Suzuki, K. (2019a). Traffic safety culture of professional drivers in the State of Qatar. IATSS Research, 43(4), 286–296. https://doi.org/10.1016/j.iatssr.2019.03.004

181. Timmermans, C., Alhajyaseen, W., Ross, V., & Nakamura, H. (2020). Introducing a multi-variate classification method: Risky driving acceptance among different heterogeneous driver sub- cultures. Journal of Safety Research, 73, 81–91. https://doi.org/10.1016/j.jsr.2020.02.009

182. TSTM. 2008. Traffic Signal Timing Manual. U.S. Department of Transportation, Federal Highway Administration. Publication Number: FHWA-HOP-08-024.https://nacto.org/docs/usdg/signal_timing_manual_fhwa.pdf

183. United Nations. (2011a). Decade of Action for Road Safety 2011-2020.https://www.who.int/publications/m/item/decade-of-action-for-road-safety-2011-2020---global-launch

184. United Nations. (2011b). Global Plan for Decade of Action for Road Safety 2011-2020. https://www.who.int/publications/m/item/global-plan-for-the-decade-of-action-for-road-safety-2011-2020

185. Urban Planning & Development Authority. (2007). Transportation Master Plan for Qatar: Road Safety Strategy Plan for Qatar. https://www.yumpu.com/en/document/read/10563724/the-transport-master-plan-for-qatar#google_vignette

186. Vingilis, E., Beirness, D., Boase, P., Byrne, P., Johnson, J., Jonah, B., Mann, R. E., Rapoport, M. J., Seeley, J., Wickens, C. M., & Wiesenthal, D. L. (2020). Coronavirus disease 2019: What could be the effects on Road safety?Accident; Analysis and Prevention, 144, 105687.https://doi.org/10.1016/j.aap.2020.105687

187. Violence, W. H. O. D. of, Prevention, I., Violence, W. H. O., Prevention, I., & Organization, W. H.O (2009). Global status report on road safety: time for action. https://www.afro.who.int/publications/global-status-report-road-safety-time-action

188. W.A. Leaf and D.F. Preusser (1998), Literature Review on Vehicle Travel Speeds and Pedestrian Injuries, National Highway Traffic Safety Administration, USDOT https://nacto.org/docs/usdg/literature_review_on_vehicle_travel_speeds_leaf.pdf

189. Wang, S., Yu, D., Kwan, M.-P., Zheng, L., Miao, H., & Li, Y. (2020). The impacts of road network density on motor vehicle travel: An empirical study of Chinese cities based on network theory. Transportation Research Part A: Policy and Practice, 132, 144–156. https://doi.org/10.1016/j.tra.2019.11.012

190. Warne, R., (2014) "A Primer on Multivariate Analysis of Variance (MANOVA) for Behavioral Scientists", *Practical Assessment, Research, and Evaluation* 19(1): 17. https://doi.org/10.7275/sm63-7h70

191. Wickens, C. M., Smart, R. G., & Mann, R. E. (2014). The impact of depression on driver performance. International Journal of Mental Health and Addiction, 12(4), 524–537. https://doi.org/10.1007/s11469-014-9487-0

192. Wijnen, W., & Stipdonk, H. (2016). Social costs of road crashes: An international analysis. Accident Analysis & Prevention, 94, 97–106. https://doi.org/10.1016/j.aap.2016.05.005

193. Williams, A. F., Preusser, D. F., Ulmer, R. G., & Weinstein, H. B. (1995). Characteristics of fatal crashes of 16-year-old drivers: implications for licensure policies. Journal of Public Health Policy, 16(3), 347–360. World Gulf. (2020). COVID-19: 3 years jail for not wearing masks in Qatar.https://gulfnews.com/world/gulf/qatar/covid-19-3-years-jail-for-not-wearing-masks-in- qatar-1.71541538

194. Wilson, E. M. (2000). Adapting the Road Safety Audit Review for Local Rural Roads (Issue July). https://www.ugpti.org/resources/reports/downloads/mpc00-114.pdf

195. World Health Organization (WHO). (2018). Global status report on road safety 2018. https://www.who.int/publications/i/item/9789241565684

196. World Health Organization (WHO). (2021a). Road traffic deaths - Data by country. In Global Health Observatory data repository. World Health Organization. https://apps.who.int/gho/data/view.main.51310?lang=en

197. World Health Organization (WHO). (2021b). Road traffic deaths - Data by country. In Global Health Observatory data repository. World Health Organization https://apps.who.int/gho/data/node.main.A997

198. World Health Organization. (2013). Road safety in the Eastern Mediterranean Region Highlights from the Global Status Report on Road Safety 2013. https://policycommons.net/artifacts/463230/road-safety-in-the-eastern-mediterranean-region/1436372/

199. World Health Organization. (2015a). Global Status Report on Road Safety 2015 (Issue 2015). https://www.afro.who.int/sites/default/files/2017-06/9789241565066_eng.pdf

200. World Health Organization. (2015b). Road safety in the Eastern Mediterranean Region Facts from the Global Status Report on Road Safety 2018. https://applications.emro.who.int/docs/WHOEMHLP123E-eng.pdf?ua=1#:~:text=The%20overall%20road%20traffic%20death,Asia%20(20.7%20per%20100%20000

201. World Health Organization. (2018). Global status report on road safety 2018 (Vol. 1, Issue 1).https://doi.org/10.29333/aje.2019.423a.

202. World Health Organization. (2020). WHO Timeline – COVID 19. https://www.who.int/news/item/27-04-2020-who-timeline---covid-19

203. World Health Organization. (2021a). WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/

204. World Health Organization. (2021b). WHO Coronavirus Disease (COVID-19) Dashboard. https://covid19.who.int/region/emro/country/qa

205. Xiao M, Zhang L, Hou Y, Chuan S. (2013). An adaptive pedestrians crossing signal control system for intersection. Procedia - Social and Behavioral Sciences, 96:1585–1592.https://doi.org/10.1016/j.sbspro.2013.08.180

206. Xu, B., Tian, H., Sabel, C. E., & Xu, B. (2019). Impacts of road traffic network and socioeconomic factors on the diffusion of 2009 pandemic influenza A (H1N1) in mainland China. International Journal of Environmental Research and Public Health, 16(7), 1223.https://doi.org/10.3390/ijerph16071223

207. Yu C, Ma W, Han K, Yang X. (2017). Optimization of vehicle and pedestrian signals at isolated intersections. Transportation Research Part B, 98:135–153.https://doi.org/10.1016/j.trb.2016.12.015

208. Zeger, S.L., Irizarry, R. and Peng, R.D. (2006) 'On time series analysis of public health and biomedical data', Annu. Rev. Public Health, 27, pp. 57–79.10.1146/annurev.publhealth.26.021304.144517

209. Zhang, Y., Zhang, Y., & Liu, Z. (2011). The role of different transportation in the spreading of new pandemic influenza in mainland China2011 19th International Conference on Geoinformatics, 1–6. https://doi.org/10.1109/GeoInformatics.2011.5981012

210. Zhao, S., Bauch, C. T., & He, D. (2018). Strategic decision making about travel during disease outbreaks: a game theoretical approach. Journal of the Royal Society Interface, 15(146), 20180515. https://doi.org/10.1098/rsif.2018.0515

211. Zijun Du, Min Deng, Nengchao Lyu, Yugang Wang, (2023). A review of road safety evaluation methods based on driving behavior, Journal of Traffic and Transportation Engineering 10(5):743-761. https://doi.org/10.1016/j.jtte.2023.07.005.

Appendix 1: Questionnaire-Case Study 2

Introduction

You are kindly invited to participate in our survey on Public Transport Perception studies in Qatar. The survey will take approximately 5 minutes to complete. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. To ensure anonymity, no personally identifiable information will be collected and associated with your response. If you have questions at any time about the survey or the procedures, you may contact NTSC on +97450707392 or by email at ncommittee@moi.gov.qa Thank you very much for your time and support. Thank you very much for your time and support.

The survey is also available for online completion at https://forms.gle/nKYKS4Ty973RchPz6

Transport Characteristics

1. Which of these applies to you?
   Currently hold a valid Qatar Driving Licence (car or motorcycle)
   - License for one week
   - Temporary license for 3 months
   - International driving license for 6 months
   - None - Never held a Qatari driving licence

2. Which of the following do you have?
   - Bus Card
   - Metro Card
   - Karwa smartcard
   - None

3. Which of these applies to you? I am ….
   - Employed full-time
   - Employed part-time
   - Student
   - Retired
   - Unemployed

4. In total, how many cars or vans are owned, or are available for private use or by members of your household?
   (*Include any company cars or vans available for private* use)
   - None
   - One
   - Two
   - Three and above

5. Please how do you travel around for the following activities?

	How many times do you make this trip in a week	I drive a car/van	Passenger (someone drives me)	I get a Bus/ Metro/Tram	I ride a Bicycle/ scooter	I ride a motorbike	Hire (Limousine /Car)	Karwa Taxi, Uber, Get2Go, Ryde	Other, please indicate _____
Work									
School (students)									
Supermarket/shopping									
Leisure/entertainment									
See family / friends									
Hospital/ medical appointments/bank									
Other, please tell us									

6. Have you changed your means of transport in recent times?
- Yes
- No

7. Why did you change your means of travel to your current means of travel, if you have?
- Not applicable (not changed)
- I Changed job
- I live within walking distance
- I moved home
- I bought a car / I got a company car
- I lost my job
- Cost saving
- For Convenience
- I drop off/pickup children on the way
- Health reasons
- Other (please indicate) ______________________

8. Which of the following transport modes have you changed to
- I drive a car/van
- Passenger (someone drives me)
- I get a Bus/ Metro/Tram
- I ride a Bicycle/ scooter
- I walk
- I ride a motorbike Hire (Limousine /Car)
- Ride hailing (Karwa Taxi, Uber, Get2Go, Ryde)
- Other, please indicate ___________________

9. How long would it take to walk to the nearest bus/metro-stop/station from your home?
- 5 minutes walk or less
- Within 6-10 minutes walk
- Within 11-20 minutes walk
- Within 21-30 minutes walk
- More than 30 minutes walk
- Don’t know

10. How long would it take to walk to the nearest bus/metro-stop/station from your trip destination?
- 5 minutes walk or less
- Within 6-10 minutes walk
- Within 11-20 minutes walk
- Within 21-30 minutes walk
- More than 30 minutes walk
- Don’t know

11. Please indicate how much you agree with each of the following statements about transportation in Qatar?

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
I feel safe using PT (Bus/Metro / Tram) services in Qatar					
I feel comfortable using PT (Bus/Metro / Tram) services in Qatar					
The transport infrastructure adequately supports walking in Qatar					
Pedestrian facilities (pedestrian lanes and crossings) in Qatar encourages walking and cycling					
I feel confident walking around in Doha					
I feel safety walking around in Doha					

12. How important are the following when choosing a transport mode for your trips

	Not Important at all	Not Important	Not Applicable	I don't Know	Important	Very Important
Cost						
Reliability						
The time it takes						
Convenience						
Comfort						
Weather						
How good it is for the environment?						
Health and fitness						
Safety						
Things I have to carry						

13. Have you used public transport services (Bus, Metro, Tram) in the past

	Very Unpleasant	Unpleasant	Average	Pleasant	Very Pleasant	I have no idea
Yes, it						
No, it						

14. Are you currently using public transport services (Bus, Metro, Tram)

	Very Unpleasant	Unpleasant	Average	Pleasant	Very Pleasant	I have no idea
Yes, it .						
No, it .						

15. Are you willing to use public transit services (Bus, Metro, Tram) for your trips, if you answered no to question 14 above

- Yes, for what purpose____

- No, please give reason/s____

16. What challenges do you have with the pedestrian facilities in Qatar you?

____

____

17. What intervention do you think should be considered in Qatar to make walking and cycling attractive to you?

---

18. What challenges do you have with PT (Bus / Metro / Tram) services and infrastructure in Qatar?

---

19. What intervention do you think should be considered in Qatar to make PT (Bus / Metro / Tram) services attractive to you

---

Demographics

20. What is your gender?
    - Female
    - Male

21. What is your age?
    - 18 to 24 years
    - 25 to 34 years
    - 35 to 44 years
    - 45 to 54 years
    - 55 to 60 years
    - 60 years or older

22. What is your Marital Status?
    - Married
    - Unmarried / Single

23. Nationality
    - Qatar
    - India
    - Bangladesh
    - Nepal
    - Egypt
    - Philippines
    - Pakistan
    - Sri Lanka
    - Sudan
    - Syria
    - Lebanon
    - United States
    - Kenya
    - Iran
    - United Kingdom
    - Other

24. Please what is the size of your household including yourself and children?
    - 1
    - 2
    - 3
    - More than 3

25. Please could you indicate the highest educational qualifications you have?
    - No formal education
    - Primary
    - Secondary
    - College
    - Bachelor's degree
    - Master's degree
    - PhD

26. Which of these best represents your monthly income?
    - Less than 10,000 Riyal
    - 10,000 to 15,000 Riyal
    - 15,000 to 20,000 Riyal
    - 20,000 to 25,000 Riyal
    - 25, 000 to 30,000 Riyal
    - 30,000 to 40,000 Riyal
    - 40,000 to 50,000 Riyal
    - Above 50,000 Riyal

27. Do you have any comments/suggestions, or recommendations on Sustainable Public Transportation in Qatar