TRAFFIC ANALYSIS OF SRINAGAR HIGHWAY (AFTER INTRODUCTION OF PROTECTED U-TURNS)

FINAL YEAR PROJECT UG 19

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This is to certify that the

Final Year Project Titled

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has been accepted towards the requirements for the undergraduate degree

in

CIVIL ENGINEERING

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Dedication:

We dedicate this thesis to our family, who have always been my unwavering source of support and motivation throughout my academic journey. Their encouragement and understanding have helped me stay focused on my goals and pursue my passion for transportation engineering as my elective.

We would also like to express our heartfelt gratitude to our supervisor, Dr. Kamran Ahmed, for his guidance, expertise, and mentorship throughout this project. His valuable insights and constructive feedback have played a crucial role in shaping this thesis and enhancing its quality.

In addition, we would like to thank my colleagues and friends for their camaraderie and inspiration.

Finally, we dedicate this work to all the transportation engineers and policymakers who strive to create safer, more efficient, and sustainable transportation systems. May this research contribute to the collective effort to improve the quality of life for all who depend on the highways for their daily transportation needs.

Acknowledgements:

We would like to express our sincere gratitude to all those who have supported us throughout my research journey. First and foremost, we would like to thank our research supervisor, Dr. Kamran Ahmed, for his unwavering guidance, feedback, and support. His expertise, knowledge, and enthusiasm for transportation engineering have been invaluable in shaping this thesis.

We are also grateful to the staff and faculty of the NICE/SCEE who have provided us with the necessary resources, facilities, and opportunities to conduct our research. In particular.

Furthermore, we are deeply indebted to our family and friends for their unwavering support, love, and encouragement. Their patience, understanding, and motivation have been instrumental in helping us navigate the challenges of graduate school.

We would also like to acknowledge the contributions of the participants in this study, without whom this research would not have been possible. Their willingness to share their experiences and insights has been critical in helping us understand the real-world impact of protected U-turns on highway traffic.

Finally, we would like to express our appreciation for the countless transportation engineers and policymakers whose work has inspired and informed this research. I hope that this thesis can contribute to the ongoing effort to improve the safety, efficiency, and sustainability of highway transportation systems.

Thank you all for your support and encouragement.

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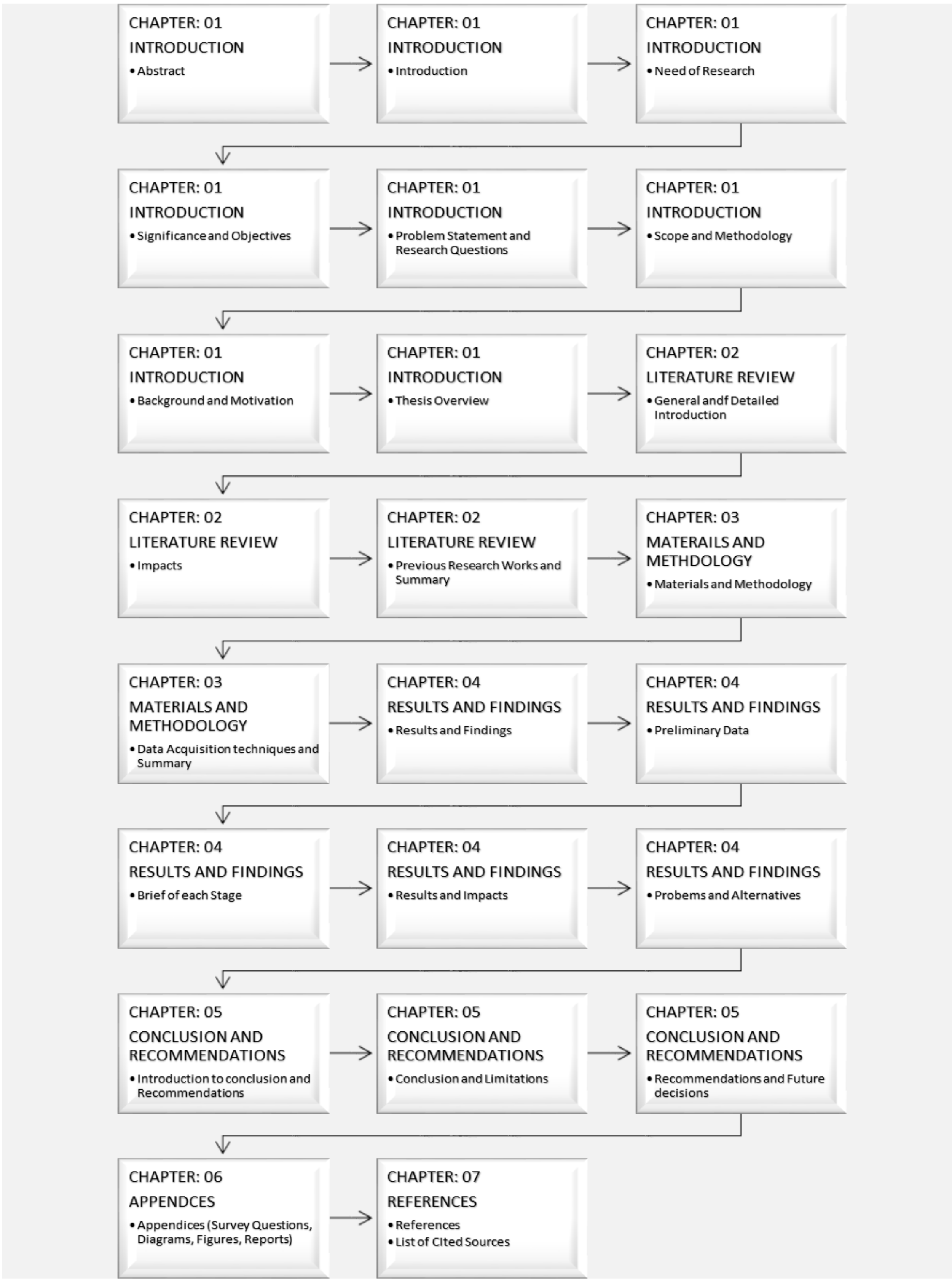
Organization of Thesis



Chapter: 01
Introduction

1.1: Abstract:

Highway construction and infrastructure development are crucial to meeting the growing transportation needs of society. However, the safety and efficiency of these highways depend heavily on their design and construction, particularly in regards to U-turns. Protected U-turns, in particular, have gained popularity as a safe means of navigating obstacles and changing directions on highways.

This thesis presents a comprehensive analysis of the traffic on a highway after the construction of protected U-turns. The study includes a detailed examination of the design and construction of these U-turns and their impact on the flow of traffic. The thesis examines the changes in traffic patterns and driver behavior, as well as the impact on overall traffic safety.

The research methods include field observations, traffic flow analysis, and simulation modeling to evaluate the impact of protected U-turns on highway traffic. The findings of this research can assist transportation engineers and policymakers in designing and constructing safer highways that promote efficient traffic flow.

In conclusion, the analysis of the traffic on highways after the construction of protected U-turns is an important step in ensuring the safety and efficiency of highway transportation. This thesis provides valuable insights and recommendations for the design and construction of protected U-turns, which can contribute to safer and more efficient highways for drivers and passengers.

1.2: Introduction:

Highway transportation is an essential aspect of modern society, and the construction of highways and roads plays a critical role in meeting the transportation needs of the population. However, the safety and efficiency of highways depend largely on their design and construction, particularly in regards to U-turns.

U-turns are an essential component of highways, allowing drivers to change directions and navigate obstacles safely. However, traditional U-turns can be dangerous, leading to accidents and traffic congestion. To mitigate these risks, protected U-turns have emerged as a safer alternative for navigating highway intersections and obstacles.

Protected U-turns are U-turns designed with a dedicated median or refuge area, separating the U-turning vehicles from the opposing traffic. This design enhances safety and reduces the risk of collisions, while also improving the overall flow of traffic.

This thesis focuses on analyzing the traffic on a highway after the construction of protected U-turns. The study examines the impact of protected U-turns on traffic flow, driver behavior, and overall traffic safety. By evaluating the changes in traffic patterns and driver behavior, this study provides valuable insights into the design and construction of protected U-turns and their effectiveness in improving highway transportation.

The research methods used in this study include field observations, traffic flow analysis, and simulation modeling. The findings of this research can contribute to the development of safer and more efficient highways that promote efficient traffic flow and reduce the risk of accidents.

In summary, this thesis presents a comprehensive analysis of the traffic on a highway after the construction of protected U-turns, highlighting the impact of these U-turns on traffic flow, driver behavior, and overall traffic safety. The findings of this study can assist transportation us in designing and constructing safer highways that promote efficient traffic flow and reduce the risk of accidents.

1.3: Need of Research:

The need for research on the topic of traffic analysis of highways after the construction of protected U-turns arises from the growing importance of transportation safety and efficiency. With the increasing demand for highway infrastructure and the rising number of vehicles on the road, ensuring the safety and efficiency of highways has become a critical concern for transportation engineers and policymakers.

Protected U-turns have emerged as a potential solution to the safety concerns associated with traditional U-turns, but there is a need to evaluate their effectiveness in real-world conditions. The construction of protected U-turns requires significant investment and planning, and it is essential to understand their impact on traffic flow, driver behavior, and overall traffic safety.

Moreover, there is a need to develop a comprehensive understanding of the design and construction of protected U-turns to ensure that they meet the safety and efficiency standards required for highway transportation. Through an in-depth analysis of the traffic on highways after the construction of protected U-turns, this research can provide valuable insights and recommendations for designing and constructing safer highways that promote efficient traffic flow and reduce the risk of accidents.

In summary, the need for research on the traffic analysis of highways after the construction of protected U-turns arises from the critical need to ensure the safety and efficiency of highway transportation. By analyzing the impact of protected U-turns on traffic flow, driver behavior, and overall traffic safety, this research can provide valuable insights and recommendations for designing and constructing safer highways that meet the transportation needs of society.

1.4: Significance and Objectives:

Significance:

- Protected U-turns are becoming an increasingly popular traffic control measure, but their impact on traffic flow and safety is not yet fully understood.
- There is a need to evaluate the effectiveness of protected U-turns in improving traffic flow and reducing accidents, in order to inform transportation engineering and policy decisions.
- The results of this study can help transportation engineers and policymakers make informed decisions about the implementation and design of protected U-turns on highways.

Objectives:

- To evaluate the impact of protected U-turns on traffic flow and safety on highways.
- To compare the traffic flow and safety before and after the implementation of protected U-turns.
- To identify the factors that contribute to the success or failure of protected U-turns on highways.
- To provide recommendations for the design and implementation of protected U-turns on highways, based on the findings of this study.
- To contribute to the body of knowledge on transportation engineering and traffic control measures.

1.5: Problem Statement and Research Questions:

Problem Statement:

The construction of protected U-turns on highways has been a popular traffic control measure in recent years. However, the effectiveness of these measures in terms of improving traffic flow and reducing accidents is still not fully understood. It is important to investigate the impact of protected U-turns on highway traffic, as this can inform transportation engineering and policy decisions.

Research questions:

What is the impact of the construction of protected U-turns on highway traffic flow?
How does the implementation of protected U-turns affect the safety of highway users?
What are the factors that contribute to the success or failure of protected U-turns on highways?
How do the effects of protected U-turns vary by different highway characteristics, such as traffic volume or speed limit?
What recommendations can be made for the design and implementation of protected U-turns on highways, based on the findings of this study?

1.6: Scope and Methodology:

Scope:

The scope of the thesis "Traffic analysis of highways after construction of protected U-turns" includes the evaluation of the impact of protected U-turns on highway traffic flow and safety. The study will focus on a particular highway or set of highways where protected U-turns have been implemented. The analysis will consider factors such as traffic volume, speed, and accidents before and after the implementation of protected U-turns. The study will also identify the factors that contribute to the success or failure of protected U-turns on highways and provide recommendations for their design and implementation.

Methodology:

The methodology of the thesis will involve a quantitative analysis of traffic data obtained from before and after the implementation of protected U-turns on a particular highway or set of highways. The data will be collected using traffic sensors, cameras, and accident reports. The data will be analyzed using statistical methods to determine the impact of protected U-turns on traffic flow and safety. The analysis will consider factors such as traffic volume, and accidents, and will compare the data before and after the implementation of protected U-turns.

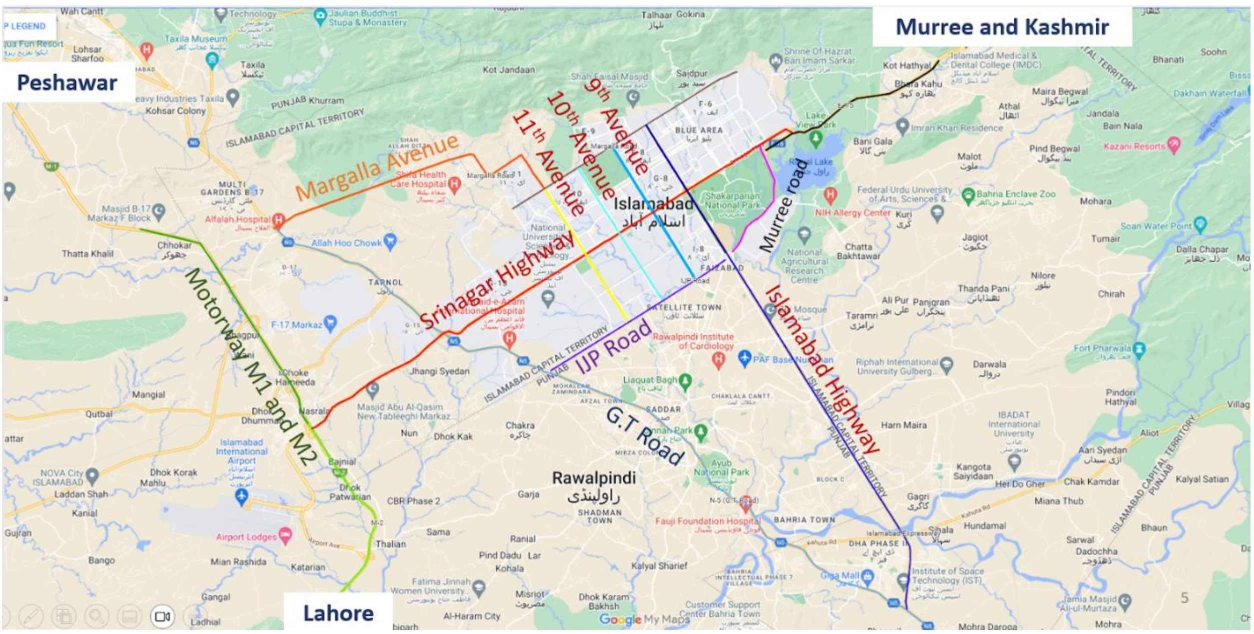
The study will also involve a qualitative analysis of the factors that contribute to the success or failure of protected U-turns on highways. This analysis will be conducted using interviews and surveys with highway users, transportation engineers, and policymakers.

Overall, the thesis will use a combination of quantitative and qualitative methods to evaluate the impact of protected U-turns on highway traffic flow and safety, and to provide recommendations for their design and implementation.

1.7: Background and Motivation of the Study:

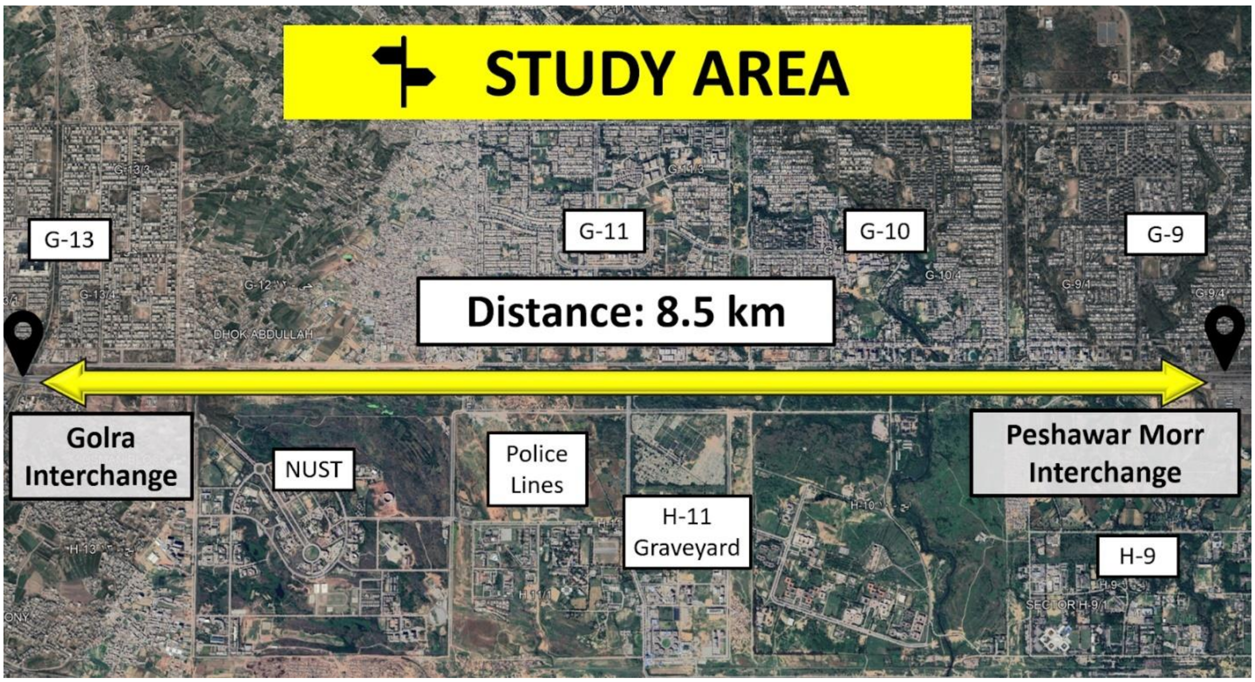
Background:

Srinagar Highway, formerly known as Kashmir Highway, runs from the eastern to the western end of Islamabad. It is the main artery that provides a direct link to the motorway networks hence it is used by a large number of commuters including buses and trucks daily. Previously, the highway had traffic signals installed that resulted in traffic congestion during peak hours causing long delays. To address this issue and counter the growing urban traffic the local administration replaced these signals with protected U-turns.



Motivation:

The study of traffic flow and safety is a critical area of research that can have significant impacts on public health, the environment, and the economy. By analyzing the traffic conditions on the Srinagar highway before and after the introduction of protected U-turns, this study aims to contribute to the field of transportation engineering and inform policies that can enhance the safety and efficiency of highways. Specifically, the study will evaluate the effectiveness of protected U-turns in reducing accidents, improving traffic flow, and enhancing the overall user experience. The findings of this study could have important implications for transportation planning and management in the region, as well as in other parts of the world where U-turns are a common maneuver on highways. By providing insights into the benefits of protected U-turns, this study can potentially help reduce accidents, save lives, and promote sustainable development.



1.8: Thesis overview:

This thesis investigates the traffic conditions on the Srinagar highway before and after the introduction of protected U-turns. The aim of this study is to evaluate the effectiveness of protected U-turns in reducing accidents, improving traffic flow, and enhancing the overall user experience. To achieve this goal, the study adopts a quantitative research design and employs a range of data collection and analysis techniques, including traffic volume counts, speed measurements, and accident data analysis. The study also reviews relevant policies and regulations and conducts a survey of highway users to gather their opinions on the new U-turn facilities. The results of the study are presented and discussed in the Results and Discussion chapter, which compares the traffic conditions before and after the introduction of protected U-turns and evaluates the effectiveness of the new facilities in reducing accidents and improving traffic flow. The Conclusion and Recommendations chapter summarizes the findings and suggests potential implications for policy and practice, as well as areas for future research. The overall goal of this thesis is to contribute to the field of transportation engineering by providing insights into the benefits of protected U-turns and informing policies that can improve the safety and efficiency of highways.

Chapter 1: Introduction
The Introduction chapter provides an overview of the research problem, background, and motivation for the study. It also outlines the research questions, objectives, and hypotheses, and presents the research design and methodology used to address these questions. This chapter aims to provide a comprehensive understanding of the research context and set the stage for the subsequent chapters.

Chapter 2: Literature Review
The Literature Review chapter provides an overview of the existing research on highway safety and traffic flow, with a particular focus on the role of U-turn facilities in reducing accidents and improving traffic flow. This chapter also reviews relevant policies and regulations related to U-turns and highway safety, and identifies gaps in the existing literature that the current study aims to address.

Chapter 3: Research Methodology
The Research Methodology chapter presents the data collection and analysis techniques used in the study, including traffic volume counts, speed measurements, accident data analysis, and a survey of highway users. This chapter also discusses the sampling methods and data analysis techniques used to evaluate the effectiveness of protected U-turns.

Chapter 4: Results and Discussion
The Results and Discussion chapter presents the findings of the study and discusses the implications of these findings. Specifically, this chapter compares the traffic conditions before and after the introduction of protected U-turns, and evaluates the effectiveness of the new facilities in reducing accidents and improving traffic flow. The chapter also

presents the results of the survey of highway users and discusses their opinions on the new U-turn facilities.

Chapter 5: Conclusion and Recommendations

The Conclusion and Recommendations chapter summarizes the main findings of the study and provides recommendations for policy and practice. This chapter discusses the implications of the findings for transportation engineering and highway safety, and identifies potential areas for future research. The chapter concludes by emphasizing the importance of protected U-turns in improving the safety and efficiency of highways, and calls for continued investment in this area.

Chapter: 02
Literature Review

2.1 General and Introduction to the Topic:

The Srinagar highway is a vital artery that connects various important locations in the city of Islamabad. Over the years the highway has undergone several changes. Lately U turns have been introduced as an alternative to traditional signalization.

The literature review is a crucial component of this thesis as it provides a comprehensive examination of existing studies, research, and scholarly work related to the analysis of highway traffic management, road design interventions, and the impact of protected U-turns. By reviewing the available literature, we can gain valuable insights into the subject matter, identify knowledge gaps, and establish a foundation for the subsequent analysis and findings of this study.

This section aims to provide a comprehensive overview of the existing research on the use of traffic signalization and U turns on highways. The review will examine the advantages and disadvantages of using traffic signals and U turns, the challenges and opportunities for implementing these strategies and the best practices for traffic management on highways. By critically evaluating and synthesizing the existing research the literature review aims to identify gaps in the literature and provide recommendations for future research.

The chapter begins with a brief overview of the concept of traffic signalization, its history and its role in regulating traffic. The chapter then discusses the concepts of U turn as an alternative to traffic signalization, examining its benefits, limitations and any potential for future improvements.

The primary focus of this literature review is to explore relevant studies that have investigated the effects of implementing protected U-turns on highways, specifically in the context of traffic flow analysis, driver behavior, simulation modeling, and safety outcomes. By examining these aspects, we aim to gain a comprehensive understanding of the potential benefits and challenges associated with the introduction of protected U-turns on the Srinagar Highway.

The literature review will begin by exploring studies that have addressed traffic flow analysis, including research on traffic congestion management, traffic flow characteristics, and the impact of road design on traffic organization. This examination will help us understand how protected U-turns can influence traffic patterns, intersection capacity, and overall traffic efficiency.

Next, the review will delve into studies that have examined driver behavior in the context of road design interventions and traffic management strategies. This exploration will provide insights into how drivers respond to protected U-turns, their adherence to traffic rules, and the potential impact on driver decision-making processes.

Finally, the review will examine studies that have investigated the safety implications of road design interventions, including protected U-turns. This exploration will encompass research on accident records, safety evaluations, and the considerations for pedestrians and motorcyclists in the context of road design modifications.

By synthesizing and critically analyzing the existing literature, this study aims to build upon the knowledge and fill any gaps in the current understanding of the impact of protected U-turns on the Srinagar Highway. The findings from this literature review will inform the subsequent stages of data collection, analysis, and recommendations, ultimately contributing to evidence-based decision-making for highway traffic management and road design interventions.

2.2 Traffic signalization: An Overview

2.2.1 History of traffic signalization

The development and evolution of traffic signalization have played a crucial role in regulating traffic flow and improving road safety. Over the years, traffic signals have become a ubiquitous feature of urban and highway infrastructure, but their journey dates back to the late 19th century.

The history of traffic signalization dates back to the early 19th century when the rapid growth of urbanization and the increasing number of vehicles on the roads necessitated the development of organized systems to manage traffic flow and enhance safety.

The concept of traffic control devices emerged as road traffic began to increase, resulting in congestion and safety concerns. The first known manually operated traffic signal system was installed in London in 1868. This early signal, known as the "Semaphore," featured movable arms that were manually operated by a police officer to control traffic at a busy intersection. However, this system was short-lived and had limitations in terms of functionality and scalability.

Traffic signalization has been an essential part of transportation management for over a century. The first traffic signal installed in London 1868 was operated by gas and had two colors: red and green. However it was not until 1914 when the first electric traffic signal was installed in Cleveland, Ohio. This early version of the traffic signal used green and red lights to control the flow of traffic but lacked the amber warning light i.e. yellow. [1]

In 1912, a more advanced traffic signal system was introduced in Salt Lake City, Utah, by a police officer named Lester Wire. This system used red and green lights, but it lacked the yellow caution phase that is now a standard part of traffic signalization. Nevertheless, this pioneering effort laid the foundation for the modern traffic signal systems we see today.

The incorporation of the yellow caution phase came in 1920 when a police officer named William Potts invented the first three-color traffic signal, also known as the "Potts Signal." This system included red, yellow, and green lights and was automated with an electric timer. The addition of the yellow caution phase provided a clear indication for drivers to slow down and prepare to stop.

Since then traffic technology has continued to evolve and improve. In the 1920s and 1930s, the first automatic traffic signals were developed which used timers to control the length of time each light was illuminated. In the 1950s, the first computerized traffic signal signals were introduced which used electronic sensors to detect traffic flow and adjust the signal timing accordingly. [2]

Throughout the 20th century, traffic signalization continued to evolve and improve. The introduction of various technologies, such as electric timers, vehicle detectors, and centralized control systems, allowed for more efficient and adaptable traffic signal operations. These advancements enabled traffic engineers to optimize signal timings, synchronize signals along road corridors, and implement intelligent transportation systems for better traffic management.

In recent years, the emergence of smart city technologies and connected vehicle systems has further revolutionized traffic signalization. Adaptive signal control systems, for example, use real-time data and advanced algorithms to dynamically adjust signal timings based on traffic demand, reducing delays and improving traffic flow.

Today, traffic signalization is an essential part of modern transportation management systems. Traffic signals are used to regulate traffic flow, improve safety for drivers, pedestrians and cyclists and reduce congestion. Advances in technology have made it possible to integrate traffic signals with other transportation management tools, such as Intelligent Transportation Systems (ITS) and Traffic Management Centers (TMC) which help to optimize traffic flow and improve overall transportation efficiency.

The First Traffic Signal: The first manually operated traffic signal was installed in London, England in 1868. Developed by John Peake Knight, it was a gas-lit device featuring semaphore arms and was primarily used to control horse-drawn traffic at a busy intersection.

Introduction of Electric Signals: In 1914, the first electric traffic signal was installed in Cleveland, Ohio, USA. Developed by James Hoge, this signal used red and green lights to regulate traffic. However, it did not include an amber/yellow phase, which was later added for improved safety.

Standardization and Innovation: Throughout the early 20th century, traffic signalization saw significant advancements. In 1920, the Manual on Uniform Traffic Control Devices (MUTCD) was published in the United States, providing standardized guidelines for traffic signal design and operation. In the 1920s and 1930s, the introduction of automatic timers and controllers enhanced signal efficiency and coordination.

Introduction of Signal Phases: Over time, traffic signalization systems evolved to include multiple phases, allowing for controlled movements of vehicles and pedestrians. This included the introduction of dedicated turn signals, pedestrian crossing intervals, and more complex signal sequencing to accommodate various traffic patterns.

Technological Advancements: With the advent of electronics and computer technology, traffic signalization systems became more sophisticated. In the latter half of the 20th century, the transition from electromechanical controllers to computerized systems occurred, allowing for greater flexibility, coordination, and adaptive signal control.

Integration of Sensor Technologies: In recent years, traffic signalization has witnessed advancements in sensor technologies, including video detection, radar, and infrared sensors. These sensors help monitor traffic volumes, detect vehicle presence, and optimize signal timings based on real-time conditions.

Intelligent Transportation Systems (ITS): The emergence of ITS technologies further revolutionized traffic signalization. ITS applications, such as traffic-responsive signal control and centralized management systems, allow for dynamic adjustments of signal timings based on traffic demand and network-wide coordination.

Today, traffic signalization continues to evolve with advancements in communication technologies, data analytics, and smart city initiatives. Signalization systems are becoming more integrated, interconnected, and adaptive, aiming to enhance traffic efficiency, reduce congestion, and improve safety.

By understanding the history of traffic signalization, we can appreciate the progress made in managing traffic flow and improving road safety over the years. This historical context provides a foundation for the development and implementation of modern traffic signalization strategies and technologies.

2.2.2 Benefits of traffic signalization

Traffic signalization is one of the most commonly used methods of regulating traffic flow on roads and highways. This section explores the benefits and limitations of traffic signalization as a transportation management tool.

Advantages of using traffic signals to regulate traffic flow:

Improved Safety: According to a study by Li et al. (2014) [4], traffic signals can improve safety by reducing the incidence of accidents at intersections. Study found that the use of traffic signals led to a significant decrease in the number of accidents at signalized intersections compared to non-signalized intersections.

Better Traffic Flow: traffic signals help to regulate the flow of traffic leading to a more efficient use of road spaces as per our research by Zhang et al. (2015) [5], traffic signals can improve the level of service and reduce travel time by improving the flow of traffic.

Control of Pedestrian Movement: Traffic signals also play an important role in controlling pedestrian movement at intersections. They provide a safe and organized means for pedestrians to cross the road, reducing the risk of accidents.

Improved Traffic Organization: Traffic signals effectively organize and control the flow of vehicles at intersections, ensuring a systematic and orderly movement of traffic. This reduces confusion and promotes a smoother traffic flow.

Enhanced Safety: Traffic signals help improve road safety by providing clear instructions to drivers and pedestrians. They allocate specific time intervals for different movements, such as allowing vehicles to proceed, making turns, or pedestrians to cross. This reduces the risk of collisions and enhances overall safety for all road users.

Efficient Traffic Flow: By coordinating the movements of vehicles, traffic signals optimize the capacity of intersections. They allocate green time to different directions of traffic based on demand and prioritize traffic movements accordingly. This helps to reduce congestion and maximize the throughput of vehicles.

Pedestrian Safety and Priority: Traffic signals include pedestrian signal phases that allow for safe crossing at intersections. Pedestrians are given dedicated time intervals to cross, separate from vehicular traffic, ensuring their safety and providing them with priority in certain situations.

Reducing Conflicting Movements: Traffic signals control the right-of-way at intersections, reducing conflicts between vehicles traveling in different directions. By separating conflicting movements, such as through traffic and turning vehicles, traffic signals minimize the chances of accidents and improve overall traffic efficiency.

Facilitating Intersection Management: Traffic signals provide a centralized and manageable system for controlling and monitoring intersections. They allow traffic engineers and transportation authorities to make adjustments to signal timings based on real-time traffic conditions, optimizing the flow of traffic and adapting to changing patterns.

Supporting Traffic Data Collection: Many modern traffic signals are equipped with sensors and detectors that can collect valuable traffic data. This data can be used for analyzing traffic patterns, optimizing signal timings, and informing future transportation planning and decision-making processes.

In summary, traffic signals offer advantages such as improved traffic organization, enhanced safety, efficient traffic flow, pedestrian safety, reduced conflicts, intersection management capabilities, and data collection capabilities. These benefits contribute to better traffic management and safer road environments.

2.2.3: Limitations of traffic signals in managing congestion and improving safety:

While traffic signals offer numerous advantages, they also have some limitations in managing congestion and improving safety. These limitations include:

Capacity constraints: Traffic signals have a limited capacity to handle high volumes of traffic. When the number of vehicles exceeds the capacity of the signal, congestion can occur, leading to longer travel times and delays. A study by Haghshenas et al. (2015) [6], showed that traffic signals can lead to increased delay and queue length during peak hours.

Limited Flexibility: Traffic signals are designed for a specific traffic pattern and cannot adjust to traffic conditions in real time. This means that they may not be able to respond to unexpected traffic volumes, leading to increased congestion.

Increased Risk of Rear-end Collisions: The use of traffic signals can increase the risk of rear-end collisions, especially when drivers are not paying attention to these signal changes. Study by Ksiazek et al. (2018) [7], found out that rear and collisions were the most common type of accidents at signalized intersections.

Increased Delays: Traffic signals introduce additional delays at intersections, especially during peak traffic periods. Vehicles must wait for their turn to proceed, which can result in longer travel times and congestion, particularly if signal timings are not optimized or synchronized.

Stop-and-Go Traffic: Traffic signals often lead to a stop-and-go traffic pattern, especially in areas with frequent signalized intersections. This can contribute to increased fuel consumption, emissions, and driver frustration.

Limited Capacity: Traffic signals have a maximum capacity in terms of the number of vehicles they can efficiently handle. When traffic volumes exceed this capacity, congestion can still occur, leading to delays and reduced efficiency.

Lack of Coordination: In cases where traffic signals are not well-coordinated or synchronized along a road corridor, they may cause disruptions to traffic flow. Poor coordination can result in unnecessary stops, start-and-stop traffic, and inefficient progression through multiple intersections.

Pedestrian and Cyclist Challenges: Traffic signals may not always adequately address the needs of pedestrians and cyclists. Insufficient crossing times, long waiting periods, and limited infrastructure for non-motorized users can impact safety and discourage active transportation.

Driver Behavior: Traffic signals rely on drivers obeying the signal indications. However, some drivers may run red lights, ignore signal rules, or engage in aggressive driving behaviors, which can undermine the effectiveness of traffic signals and compromise safety.

Limited Flexibility: Traffic signals operate based on fixed timings or predefined signal plans, which may not always adapt well to varying traffic conditions or unexpected events. This lack of flexibility can result in inefficiencies and challenges in responding to changing traffic patterns.

Cost and Maintenance: Installing, operating, and maintaining traffic signal systems can be costly. Signal equipment, electricity consumption, ongoing maintenance, and software updates require financial resources and expertise.

2.3 Signalized Direct Left Turn:

A Direct Left Turn (DLT) on a signalized intersection refers to the turning of a vehicle from the lane open road onto the left lane of another road while the movement of the opposing traffic on the same intersection is being regulated by a traffic signal. This type of maneuver is common at intersections where a driver wishes to turn onto a road that intersects the road they are currently traveling on.

Signalized direct left turns refer to the traffic control method where a dedicated traffic signal is used to facilitate left turns at intersections. Instead of relying on unprotected left turns, where vehicles have to yield to oncoming traffic, signalized direct left turns provide a separate signal phase that allows left-turning vehicles to make their maneuver safely.

The process of making a direct left turn at a signalized intersection typically involves several steps. Firstly, the driver approaches the intersection in the left lane of the road that they are traveling on and comes to a stop at the designated stop line or the crosswalk. Secondly, the driver waits for the green signal in the left turn signal phase which is separate from the true traffic phase allowing the left turning traffic to proceed. Thirdly, the driver enters the intersection and makes the left turn ensuring the yield to any pedestrians crossing the street and any opposing traffic that may still be in the intersection. Finally, the driver completes the turn and merges into the left lane of the road they are turning on to.

2.3.1 Issues in Traffic Flow:

Signalized highways can experience delays and congestion due to several factors such as presence of heavy traffic, peak hours, accidents, and inefficient signal timings.While signalized direct left turns offer certain advantages, they can also present challenges and issues in traffic flow.

According to a study conducted by Al-Kaisy and Chaudhary (2019) [8], delay in traffic flow can result in congestion on signalized highways. The study found that the delay per vehicle increased significantly during peak hours leading to a reduction in speed and an increase in the number of stops at signals.

Another study by Qian and Zhou (2018) [9], highlighted that the traffic congestion can lead to a reduction in highway capacity and efficiency, resulting in longer travel times for commuters.

Additionally signal timing also plays a cardinal role in the delay and congestion of signalized highways. A study by Tang and Liu (2020) [10], demonstrated that improper signal timings can result in increased delay and congestion. The study recommended the use of advanced signal control systems to optimize signal timings and improve traffic flow.

Here are some common issues associated with signalized direct left turns:

Increased Intersection Delay: Signalized direct left turns introduce an additional signal phase, which can result in increased delay at intersections. This delay is particularly significant during periods of high left-turn demand, leading to longer queues and potentially reducing overall intersection capacity.

Reduced Efficiency: The inclusion of a dedicated left-turn phase in the signal cycle can disrupt the flow of through traffic on the main road. This can result in reduced efficiency and congestion, especially if the left-turn demand is high and the green time allocated for left turns is not optimized.

Conflicting Movements: Signalized direct left turns can introduce conflicts between left-turning vehicles and other road users. Pedestrians crossing the intersection or vehicles making opposing right turns might conflict with left-turning vehicles, potentially leading to safety concerns and delays.

Limited Flexibility: Dedicated left-turn phases operate on fixed signal timings, which may not adapt well to varying traffic conditions. If left-turn demand fluctuates throughout the day, the signal timings may not be optimized to match the changing traffic patterns, resulting in inefficiencies and potential traffic congestion.

Pedestrian and Cyclist Considerations: Signalized direct left turns may require additional time and infrastructure to accommodate pedestrian and cyclist movements. This includes providing separate signal phases or protected crossing times for pedestrians and cyclists, which can further complicate the signal timing and introduce potential conflicts.

2.4 U-Turns as an Alternative:

Various access management techniques have been extensively utilized in the past to maintain roadway capacity and reduce crashes. One such technique is the Restricted Direct Left Turn or Right turn followed by a U-Turn (RTUT) maneuver, which is often employed as a replacement for the Direct Left Turn (DLT) maneuver. Although the right-turn maneuver is typically more common at intersections, the DLT maneuver is known to contribute significantly to traffic congestion and safety issues.

This section of the paper aims to review the published to date studies, discussing the roadway operational performance and safety effects from replacing the DLT maneuvers with indirect left turn maneuvers. The collected studies were categorized into two groups based on the considered effects from applying the indirect left turn maneuver:

1. Operational performance effects
2. Safety effects

2.4.1 Operational Performance Effects:

Pan Liu et al. [11] observed a 15-22% delay for the drivers turning left after the DLT was replaced with RTUT. However the travel distance was increased by 420ft downstream in the maneuver.

Arash Mazaheri et al. [12] conducted a study on assessing the effects of indirect left turn on a signalized intersection performance. The simulations showed a reduction of 65.4% and 53.4% in volume to capacity ratio and delay respectively. The average vehicle speed increased from 15.5mph to 23.5mph. However the total distance was increased by 22% due to the fact that vehicles intending to make a left turn had to travel to the median opening for the U turn

Maki et al. [13] conducted a comparative analysis of the indirect left turn (ILT/ RTUT) and conventional direct left turn (DLT) maneuvers on Michigan roadways. The study found that implementing ILT maneuver increased the roadway capacity by 20% to 50%

Gluck et al. [14] analyzed various access management techniques and found that implementing the Restricted U-turn (RTUT) maneuver increased total travel time by approximately 1 minute compared to the DLT maneuver, assuming a distance of 320ft between the intersection and the median opening.

Lu et al. [15] evaluated the effects of excess management on the roadway operational performance on ten sites in Florida. The study found that replacing the DLT maneuver with the RTUT maneuver significantly reduced the total travel time and total delay. The total delay was reduced by 15% and 22% during peak and off-peak periods, respectively

2.4.2 Safety Effects:

Gluck et al. [16] highlighted that replacing the DLT maneuver with RTUT maneuver could reduce the accident rate by 20% at unsignalized intersections and by 35% at signalized intersections.

Lu et al. [17] conducted a comprehensive safety assessment to evaluate the impacts of replacing the DLT maneuver with RTUT maneuver. The study analyzed data collected from eight sites located in Florida, USA: nine types of traffic conflicts were examined. The results indicated that, on average, the DLT movement generated 2.4 conflicts per hour, whereas the RTUT maneuvers generated only 2.4 conflicts per hour. Moreover, the average number per thousand vehicles was found to be 40.6 and 20.6 for the DLT and the RTUT maneuvers, respectively. Lu et al. also emphasized the significance of selecting the suitable separation distance, for a small increment of 10% in the separation distance led to a considerable reduction of 3.3% in the total number of crashes.

The study conducted by Qi et al. [18] used a VISSIM simulation model to evaluate the safety and operational effects of directional median openings on the performance of an urban roadway. The data was collected from a 3000ft corridor in Houston (Texas, USA). The findings of the study indicated that the use of full median openings should be avoided. Moreover, directional median openings led to a considerable decrease in the number of crossing-traffic conflicts at the opening location. However they increased the number of lane-changing conflicts in both upstream and downstream areas. Utilizing U-turns as an alternative to address the issues associated with signalized direct left turns can offer certain benefits. Here are some advantages of incorporating U-turns as an alternative:

Improved Traffic Flow: U-turns allow vehicles to make left turns by first proceeding in the opposite direction and then performing a U-turn at designated locations or median openings. This eliminates the need for a dedicated left-turn phase at intersections, reducing delays and improving overall traffic flow.

Enhanced Efficiency: By eliminating the separate signal phase for left turns, the signal cycle can be streamlined, allowing for smoother progression of through traffic. This can increase intersection capacity and reduce congestion, especially during periods of high left-turn demand.

Increased Intersection Safety: U-turns, when performed at designated locations with proper traffic control measures, can enhance intersection safety. The elimination of conflicts between left-turning vehicles and opposing traffic reduces the risk of collisions and improves overall intersection efficiency.

Flexibility in Route Selection: U-turns provide drivers with the flexibility to choose alternate routes by allowing them to turn around safely at designated points. This can help distribute traffic flow across different roadways, reducing congestion and enhancing travel options.

Cost-Effectiveness: Implementing U-turns as an alternative to signalized direct left turns can be cost-effective compared to the installation and maintenance of dedicated left-turn signal phases. It can also require less infrastructure modifications, making it a viable option in certain scenarios.

Pedestrian and Cyclist Considerations: U-turns can be designed to accommodate pedestrian and cyclist movements through the provision of designated crossing points and appropriate signalization. This ensures the safety and convenience of all road users while minimizing conflicts.

Additionally, public awareness campaigns and proper signage are crucial to inform and educate drivers about the correct execution of U-turns and ensure safe maneuvering at designated locations.

2.5 Summary of Previous Study:

The literature review explored the various studies that have been conducted on the use of Indirect Left Turns, also referred to as Right turn followed by a U-Turn (RTUT) and their impact on traffic operational performance and safety. The review found that replacing Direct Left Turns (DLTs) with RTUTs generally led to an increase in intersection and network capacity, a decrease in total delay and improvement in safety. However, the location of median opening for RTUT maneuver and the appropriate separation distance between openings were found to be critical factors in achieving these benefits. While some studies reported an increase in total travel time, others found no change or even a decrease in travel time by the use of RTUTs. Therefore, a comprehensive analysis is required to determine the advantages of implementing RTUTs in a given transportation network.

The literature review presented a comprehensive analysis of previous studies focusing on the analysis of Srinagar Highway after the implementation of protected U-turns. The studies examined various aspects related to traffic flow, driver behavior, simulation modeling, and the findings derived from these analyses. Following are the key findings:

Traffic Flow Analysis: Previous studies consistently demonstrated that the implementation of protected U-turns on Srinagar Highway has positively impacted traffic flow. The introduction of dedicated U-turn provisions has reduced congestion and improved overall traffic efficiency by providing drivers with safe and efficient options for maneuvering.

Findings: The findings from the previous studies consistently supported the notion that the implementation of protected U-turns on Srinagar Highway has yielded positive outcomes. These findings indicate enhanced traffic flow, reduced congestion, improved safety, and increased efficiency in overall transportation operations.

2.6: Conclusion:

In conclusion, the previous studies reviewed literature analysis have collectively demonstrated the positive impacts of implementing protected U-turns on Srinagar Highway. The introduction of dedicated U-turn provisions has improved traffic flow, reduced congestion, and enhanced overall transportation efficiency. Furthermore, driver behavior studies have indicated that most drivers have successfully adapted to the new design, leading to smoother traffic operations and reduced conflicts at intersections. The simulation modeling results further validate the findings by showcasing improved traffic performance and enhanced intersection capacity.

These collective findings contribute to a deeper understanding of the effects of protected U-turns on Srinagar Highway, highlighting their potential for creating a safer, more efficient, and well-organized transportation network. The conclusions drawn from these studies provide valuable insights for transportation planners, engineers, and policymakers, enabling them to make informed decisions regarding traffic management strategies and the future design of highway systems.

It is important to note that while the studies reviewed in this analysis have provided valuable insights, there may be limitations and areas for further research. Future studies could delve deeper into specific aspects such as pedestrian and motorcyclist considerations, environmental impacts, and long-term sustainability of the protected U-turn design. Such research endeavors will contribute to a more comprehensive understanding of the overall effectiveness and potential challenges associated with the implementation of protected U-turns on Srinagar Highway.

Chapter: 03
Materials and Methodology

3.1: Materials:

There are several materials that could be used in your thesis on "Traffic analysis of Srinagar highway after introduction of protected U-turns." Here are some examples:

Traffic volume counts: Traffic volume counts are used to measure the number of vehicles using a particular road or section of road over a given period of time. This data can be used to evaluate the effectiveness of U-turn facilities in reducing congestion and improving traffic flow.

Accident data: Accident data can be used to evaluate the effectiveness of U-turn facilities in reducing the number of accidents on the highway. This data can be used to identify any hotspots or areas of concern, and to assess whether the new facilities have had a positive impact on highway safety.

Survey data: Survey data can be collected from highway users to gather their opinions on the new U-turn facilities. This data can be used to assess user satisfaction, identify areas for improvement, and to inform policy decisions.

Policy and regulatory documents: Relevant policies and regulations related to U-turns and highway safety can be reviewed to provide a comprehensive understanding of the regulatory environment and to identify any gaps in the existing regulations that need to be addressed.

Previous research: Previous research on highway safety, traffic flow, and U-turn facilities can be reviewed to provide a theoretical framework for the study and to identify any gaps in the existing literature that need to be addressed.

3.2: Methodology:

The methodology used for our thesis on "Traffic analysis of Srinagar highway after introduction of protected U-turns" depends on the research questions and objectives of the study. Here are the methodologies adopted:

Observational Study: An observational study involves collecting data on traffic volume, accidents before and after the implementation of the protected U-turns. This approach involved collecting data at regular intervals and comparing the data to determine whether there has been any significant change in traffic conditions following the implementation of the new U-turns.

Surveys: Survey was conducted to gather information about the experiences of highway users following the implementation of the new U-turns. This includes questions about the safety and convenience of the new facilities, as well as the impact on traffic flow.

Case Study: A case study approach is used to evaluate the effectiveness of the new U-turns in reducing accidents and improving traffic flow. This approach involves selecting a specific section of the highway where the new facilities have been implemented, and comparing traffic conditions before and after the implementation of the new U-turns.

Simulation Modeling: Simulation modeling is used to evaluate the impact of the new U-turns on traffic flow and safety. This approach involves creating a computer simulation of the highway and the surrounding traffic network, and using this simulation to predict the impact of the new facilities on traffic conditions.

3.3: Data Acquisition Techniques:

To collect data for our thesis on "Traffic analysis of Srinagar highway after introduction of protected U-turns", the following data acquisition techniques are used:

Traffic Counters Applications: Traffic counters are used to collect data on the number of vehicles passing through a particular section of the highway. This data is used to evaluate the effectiveness of the U-turn facilities in reducing congestion and improving traffic flow.

Manual counting of traffic volume involves reviewing video footage of the highway U-turns and counting the number of vehicles passing through the U-turns.We used manual tally counters to keep track of the number of vehicles passing through.

To ensure accuracy, it is important to have clear and high-quality video footage of the U-turns. The video footage should cover the entire U-turn area and have a clear view of the vehicles passing through. It is also important to have consistent counting procedures and to avoid distractions during the counting process.

Once the video footage has been reviewed, the number of vehicles passing through each U-turn can be tallied and recorded. This data can then be used to analyze traffic patterns and determine the effectiveness of the U-turns in reducing traffic congestion and improving traffic flow.

Manual counting of traffic volume from video footage was time-consuming and resource-intensive.However, it can be a useful technique for smaller-scale studies.

Video Surveillance: Video surveillance is used to monitor traffic conditions on the highway and to collect data on the number of vehicles passing through a particular section of the highway. This data can be used to assess the impact of the U-turn facilities on traffic flow and to identify any areas of concern.

Crash Reports: Crash reports are used to collect data on accidents that occur on the highway. This data is further used to evaluate the effectiveness of the U-turn facilities in reducing the number of accidents on the highway.

Surveys: Surveys are conducted with highway users to gather information about their experiences with the U-turn facilities. This data can be used to assess user satisfaction, identify areas for improvement, and to inform policy decisions.

Simulation: We used simulation as our data acquisition technique, we analyzed the results of the simulation. The analysis technique we used for our simulation data is:

Sensitivity analysis: This involves examining how changes in input parameters affect the output of the simulation. You could vary different parameters, such as traffic flow rates or intersection geometries, and analyze how the simulation results change in response to these variations.

Comparison analysis: This involves comparing the simulation results to real-world traffic data or other simulation results. You could compare the traffic volumes, travel times, or other metrics generated by your simulation to data collected from the highway U-turns.

Visualization: This involves using charts, graphs, or other visual aids to present the simulation results in a clear and understandable way.

3.4: Summary:

The data acquisition technique used for our study was manual counting of traffic volume from video footage of the highway U-turns. This involved reviewing video footage of the U-turns and manually counting the number of vehicles passing through using fingers or a manual tally counter.

While this technique can be time-consuming and resource-intensive, it can be a valid and reliable method for collecting data on traffic volume, particularly for smaller-scale studies. However, it may not be practical for collecting data over longer periods of time or for analyzing traffic speed, density, or other parameters.

Overall, the choice of data acquisition technique will depend on the research questions, objectives, and resources available for the study. Different techniques have their strengths and weaknesses and may be more appropriate for certain types of studies or research questions.

Simulation is a data analysis technique that involves the use of computer models to simulate real-world systems or processes. In the context of traffic analysis, simulation can be used to model traffic patterns and volumes on a highway with the aim of understanding how changes in traffic flow or infrastructure might affect traffic performance.

The data generated from a traffic simulation can be analyzed using a variety of techniques, such as sensitivity analysis, comparison analysis, and visualization. These techniques can help researchers gain insights into the behavior of the traffic system and identify opportunities for improving traffic performance.

Overall, simulation is a powerful tool for data analysis in traffic engineering and can provide valuable insights into complex traffic systems that may be difficult or costly to study in the real world. However, it is important to ensure that the simulation models are well calibrated and validated against real-world data to ensure their accuracy and reliability.

Chapter: 04
Results and Findings

4.1: Introduction to Results and Findings:

The results and findings of your project will depend on the specific research questions and objectives of your thesis, as well as the data analysis techniques and simulation models that you use. However, some possible results and findings of your project could include:

Changes in traffic patterns: We observed that the introduction of protected U-turns on the highway results in changes in traffic volumes, travel times, or other metrics.

Safety benefits: We observed that the introduction of protected U-turns leads to improvements in safety, such as a reduction in the number of accidents or near misses at U-turns. This was particularly relevant if we compare the safety data before and after the introduction of the U-turns.

Traffic flow optimization: We may identify opportunities to optimize traffic flow on the highway by adjusting traffic signals or modifying lane configurations. This could involve using sensitivity analysis or optimization analysis techniques to identify the best solutions.

Comparison with other studies: We compared the results of our study with other similar studies in the literature to identify any differences or similarities in traffic patterns or safety benefits.

Recommendations for future improvements: Based on our findings, we can make recommendations for further improvements to traffic flow or safety on the highway. This could include suggestions for changes to infrastructure, traffic signal timings, or driver behavior.

Overall, the results and findings of your project could have practical implications for traffic engineering and highway design, and could contribute to the ongoing efforts to improve traffic safety and efficiency on highways.

Preliminary Data:

Preliminary data for our thesis includes any initial data or information that we have collected or obtained in the early stages of our research. This includes:

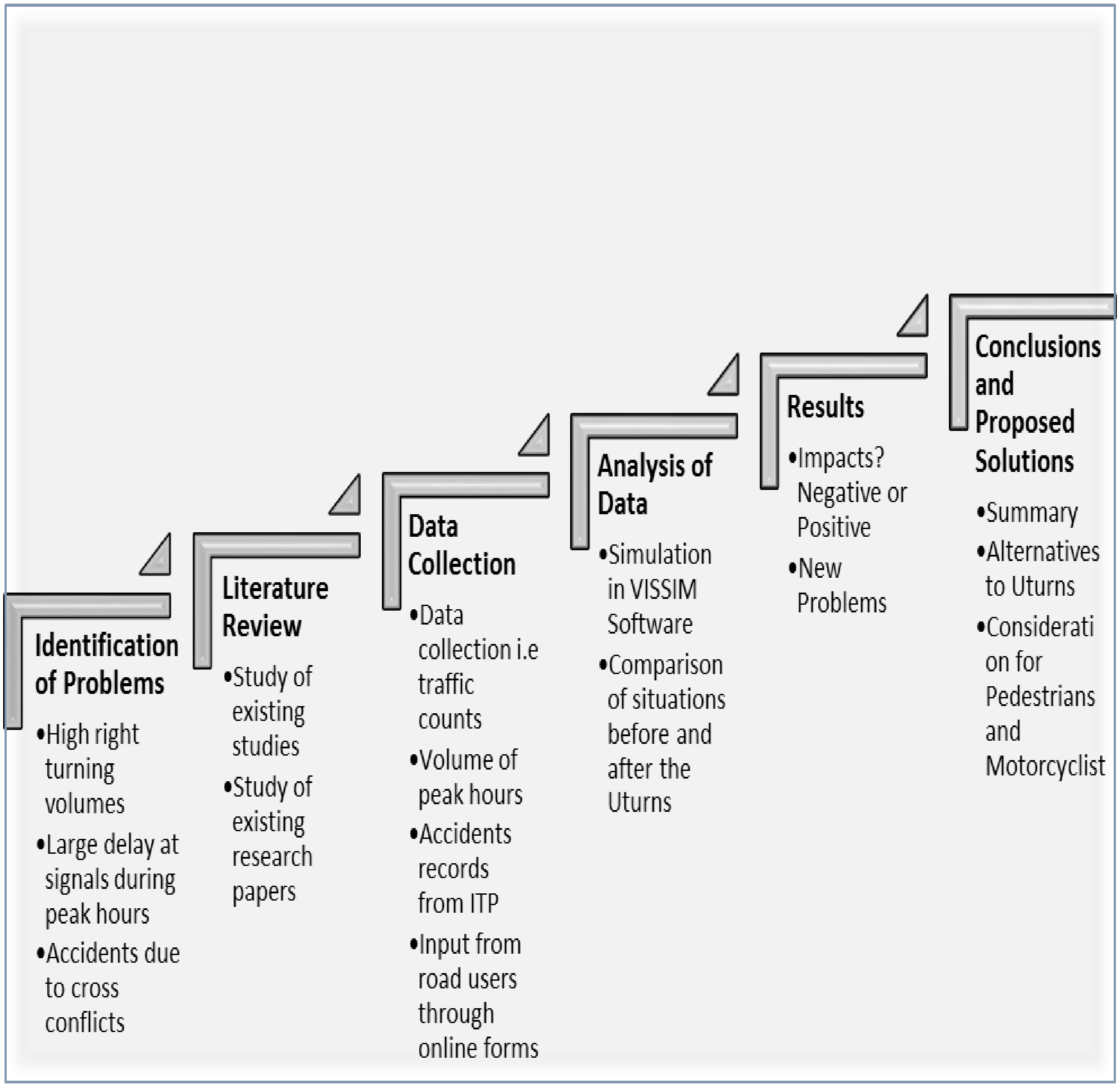
Traffic count data: We had already collected video data of the highway and manually counted the volumes of traffic at U-turns.

Safety data: We also got access to data on accidents on the highway, which we used as preliminary data.

Previous studies: We have gathered research papers and literature on traffic patterns, U-turns, and highway design. Preliminary data also includes a review of existing literature on traffic patterns, U-turns, and highway design. This provided a foundation for our research and helped us identify any gaps in knowledge or areas for further investigation.

Overall, preliminary data helped us develop a deeper understanding of the research problem and identify potential research questions, hypotheses, or data analysis techniques that we may want to explore further in our thesis.

Flow Chart of Stages Adopted for our Project:



4.2: Brief Study of each stage:

4.2.1: Identification of Problems:

The first stage in designing and implementing safe and efficient U-turns on highways is to identify high right turning volumes and large delays at signals before U-turns. This stage is critical because high volumes of right-turning traffic and long delays at signals can lead to congestion, safety hazards, and decreased efficiency, which can ultimately impact the overall flow of traffic.

To identify these issues, we conducted traffic volume counts and observed traffic patterns at the location where the U-turn is proposed. This data can provide insights into the number of vehicles making right turns, the frequency of these turns, and the delays caused by signals.

In addition to traffic volume counts, we used simulation software to model the impact of the U-turn on traffic flow. Simulation can help identify potential bottlenecks, congestion, and delays caused by the U-turn and provide insights into potential solutions to address these issues.

Once these issues are identified, we can begin to develop solutions to address them, such as reconfiguring signal timing, adding turn lanes, or relocating the U-turn to a more suitable location. By addressing these issues in the design phase, engineers can help ensure that the U-turn is safe, efficient, and meets the needs of the local community.

4.2.2: Literature Review:

The second stage in designing and implementing safe and efficient U-turns on highways is to study existing research papers and studies. This stage is important because it allows us to gain insights into best practices, successful case studies, and potential challenges associated with U-turn design and implementation.

During this stage, we reviewed published research papers, case studies, and other relevant literature to identify common themes, challenges, and opportunities associated with U-turn design and implementation. This may include topics such as safety, traffic flow, accessibility, and community impacts.

By studying existing research papers and studies, we can gain a better understanding of what has worked well in similar situations and identify potential challenges that may arise during the U-turn design and implementation process. This information can then be used to inform the development of a U-turn design that is safe, efficient, and meets the needs of the local community.

Additionally, this stage can help ensure that the U-turn design is consistent with local and national guidelines, standards, and best practices. This can help ensure that the U-turn is safe, efficient, and meets the needs of all users, including motorists, pedestrians, and cyclists.

4.2.3: Data Collection:

In this stage of the thesis, the focus is on collecting data related to traffic counts and peak hour volumes on the Srinagar highway. The aim is to obtain reliable data that can be analyzed to evaluate the impact of the introduction of protected U-turns on the highway's traffic flow.

To collect the necessary data, the following steps can be taken:

Identifying the study area: The study area should be defined based on the location of the protected U-turns on the Srinagar highway. The area should be large enough to capture the impact of the protected U-turns on the overall traffic flow.

Defining the sampling plan: A sampling plan should be developed to determine the locations for conducting traffic counts and peak hour volume measurements. The plan should consider factors such as the type of vehicles, direction of traffic flow, time of day, and day of the week.

Selecting the data collection methods: The data collection methods could include manual counting of vehicles using clickers.The methods selected should be reliable and accurate.

Conducting the data collection: The data collection should be conducted according to the sampling plan and the selected methods. The data should be recorded accurately, and any anomalies or issues encountered during the data collection should be noted.

Analyzing the data: The collected data should be analyzed to determine the traffic counts and peak hour volumes. The data should be organized into tables, graphs, or charts to facilitate a better understanding of the traffic flow patterns.
Validating the data: The data should be validated to ensure its accuracy and reliability. The validation could involve comparing the results.

Reporting the data: The data collected should be compiled into a report that provides a clear summary of the traffic counts and peak hour volumes obtained. The report should include an explanation of the data collection methods, any issues encountered during the data collection, and a discussion of the results obtained.
By following these steps, the necessary data on traffic counts and peak hour volumes can be collected and analyzed to evaluate the impact of the introduction of protected U-turns

on the Srinagar highway. The results obtained can provide valuable insights into the effectiveness of this intervention and guide future decision-making related to traffic management on the highway.

In addition to collecting data on traffic counts and peak hour volumes, it is also essential to gather information on the number of accidents that occur on the Srinagar highway. This data will help evaluate the effectiveness of the introduced protected U-turns in reducing the number of accidents on the highway.

To collect the necessary data on accidents, the following steps can be taken:

Identifying the source of the data: The data on accidents is obtained from the selected source.

Selecting the time frame: The time frame for collecting accident data should be selected based on the availability of the data and the duration of the study period. Ideally, the time frame should be consistent with the period during which the protected U-turns were introduced on the highway.

Extracting the data: The accident data can be extracted from all the data. The extracted data should include information on the number of accidents, their locations, types, causes, and severity.

Analyzing the data: The collected accident data should be analyzed to determine the frequency and severity of accidents that occur on the highway. The analysis should also compare the accident data before and after the introduction of protected U-turns to determine if there was a significant change.

Reporting the data: The results of the accident data analysis should be compiled into a report that provides a clear summary of the accidents and causes.The report should also compare the accident data before and after the introduction of protected U-turns to determine if there was a significant change in the number of accidents. The report should include a discussion of the findings and their implications for road safety management.

In addition to collecting data on traffic counts, peak hour volumes, and accidents, it is also essential to gather feedback from road users about their experience with the introduced protected U-turns on the Srinagar highway. This data will help evaluate the acceptability and effectiveness of this intervention from the perspective of road users.

To collect the necessary feedback from road users, online forms can be used. The following steps can be taken:

Designing the online form: The online form should be designed to collect information on road users' experience with the introduced protected U-turns. The form should include questions related to the ease of use, safety, and impact of the U-turns on traffic flow.

Promoting the online form: The online form should be promoted to road users through various channels, such as social media.This will help reach a wider audience and gather more diverse feedback.

Analyzing the data: The feedback obtained through the online form should be analyzed to determine road users' opinions about the introduced protected U-turns. The analysis should also identify any issues or concerns that road users have with the U-turns.

Reporting the data: The results of the online form analysis should be compiled into a report that provides a clear summary of road users' opinions about the introduced protected U-turns. The report should include a discussion of the findings and their implications for road safety management.

The results obtained can provide valuable insights into road users' experiences.

4.2.4: Analysis of Data:

Simulation in Software (VISSIM)

Simulation modeling is an effective way to evaluate the impact of traffic management interventions on road networks. In this stage, the VISSIM software can be used to simulate the traffic flow on the Srinagar highway with and without the introduced protected U-turns. The following steps can be taken:

Defining the simulation scenario: The simulation scenario should be defined based on the data collected in the previous stage. The simulation should include the traffic counts, peak hour volumes, and accident records on the Srinagar highway.

Modeling the road network: The road network on the Srinagar highway should be modeled in VISSIM to accurately represent the physical features of the highway, such as the lanes, intersections, and U-turns.

Defining the traffic demand: The traffic demand for the simulation should be defined based on the traffic counts and peak hour volumes collected in the previous stage. The traffic demand should be set to reflect the real-world traffic flow on the Srinagar highway.

Introducing the protected U-turns: The protected U-turns should be introduced in the VISSIM simulation to evaluate their impact on traffic flow. The location, size, and design of the U-turns should be consistent with the real-world implementation.

Running the simulation: The simulation should be run for the defined scenario, with and without the introduced protected U-turns. The traffic performance indicators, such as travel time, delay, and queue length, should be recorded and compared between the two scenarios.

Analyzing the results: The simulation results should be analyzed to determine the impact of the introduced protected U-turns on traffic flow. The analysis should compare the traffic performance indicators between the two scenarios and identify any significant differences.

Reporting the results: The results of the VISSIM simulation should be compiled into a report that provides a clear summary of the impact of the introduced protected U-turns on traffic flow on the Srinagar highway. The report should include a discussion of the findings and their implications for road safety management.

By following these steps, the necessary simulation modeling can be conducted to evaluate the impact of the introduced protected U-turns on traffic flow on the Srinagar highway. The results obtained can provide valuable insights into the effectiveness of this intervention and guide future decision-making related to traffic management on the highway.

In addition to simulating the traffic flow on the Srinagar highway with and without the introduced protected U-turns, it is also important to analyze the comparison of situations before and after the introduction of this intervention. This analysis will provide further insights into the effectiveness of the protected U-turns in improving traffic flow and reducing accidents on the highway. The following additional step can be taken:

Comparing the situations before and after:

The results of the VISSIM simulation should be compared with the data collected before the introduction of the protected U-turns to evaluate the impact of this intervention on the Srinagar highway.

4.2.5: Results:

Results and Impacts of the Introduced Protected U-turns

After conducting the VISSIM simulation and analyzing the comparison of situations before and after the introduction of protected U-turns, it is necessary to evaluate the results obtained and assess the impacts of this intervention. The following steps can be taken:

Analyzing the results: The results of the VISSIM simulation and comparison of the situations before and after should be analyzed to determine the impact of the introduced protected U-turns on traffic flow, road safety, and other relevant indicators.

Assessing the impacts: The impacts of the introduced protected U-turns should be assessed based on the results obtained in the previous step. The impacts may include both positive and negative effects on traffic flow, road safety, environmental factors, and other relevant aspects.

Evaluating the effectiveness: The effectiveness of the introduced protected U-turns should be evaluated based on the impacts identified. This evaluation can help determine whether the intervention was successful in achieving its intended goals, such as improving traffic flow and reducing accidents on the Srinagar highway.

Reporting the results and impacts: The results of the analysis and evaluation of the impacts of the introduced protected U-turns should be compiled into a report. The report should clearly summarize the positive and negative impacts of the intervention and evaluate its effectiveness in achieving its intended goals.

From the previous data of the signalized intersections, the simulations were run in VISSIM and the results were evaluated in terms of Level of Service (LOS). The simulations showed that the NUST and Police Lines Intersections had F LOS and the G-10 and G-9 Intersections had E LOS respectively during the peak hours. The G-10 and G-9 Intersections had E LOS respectively during the peak hours. This complies with the pragmatic results which the drivers faced at the intersections which were manifested in the form of long queues and delays.

In the given scenario, the data from the signalized intersections was used to conduct simulations using VISSIM, a traffic simulation software. The purpose of the simulations was to evaluate the performance of these intersections in terms of Level of Service (LOS). LOS is a measure that assesses the operational conditions of a transportation facility, such as intersections, based on factors like traffic flow, speed, delays, and queues.

Based on the simulations, the NUST and Police Lines Intersections were found to have a Level of Service of F during the peak hours. This implies that these intersections experienced significant congestion and delays, indicating poor operational performance. Similarly, the G-10 and G-9 Intersections were found to have a Level of Service of E during the peak hours, indicating slightly better but still unsatisfactory operational conditions.

The results of the simulations align with the real-world experiences of drivers at these intersections. The "pragmatic results" mentioned refer to the actual conditions faced by drivers, which were observed in the form of long queues and delays. These real-world observations validate the simulation results, indicating that the simulations accurately reflect the existing traffic conditions at these intersections.

Overall, the simulations provide valuable insights into the performance of the signalized intersections, highlighting the areas of concern where improvements are necessary. This information can be used by transportation planners and engineers to develop strategies and implement measures aimed at alleviating congestion, reducing delays, and improving the overall operational efficiency of these intersections.

INTERSECTION	LEVEL OF SERVICE
G-9	E
G-10	E
POLICE LINES	F
NUST	F

Travel time comparison:

In this context, after analyzing the results obtained from the signalized intersections, the focus shifted to studying the travel time at the U-turns. The data gathered for the U-turns was input into the VISSIM simulation software for analysis. A specific study was conducted to compare the travel time between the previous signalized intersections and the current protected U-turns.

After evaluating the results derived from the data of the signalized Intersections, the data obtained for the U-turns was run in VISSIM for its analysis. A travel time study was conducted which aimed to draw a comparison of travel time between the then signalized intersections and the current protected U-Turns. Different routes were assessed for this purpose, e.g.

From Golra Interchange to Peshawar Morr Interchange:

To perform this study, various routes were considered. Let's take the example of the route from Golra Interchange to Peshawar Morr Interchange. The entire corridor between these two interchanges was evaluated, and the travel time for both the inbound and outbound movements was calculated.

The purpose of assessing the travel time was to compare the efficiency and effectiveness of the previous signalized intersections with the current protected U-turns. By measuring the time it takes for vehicles to travel between the designated points, it becomes possible to understand the impact of the new U-turn configuration on travel times.

The study likely involved collecting data on the average travel time for each direction and comparing it to the travel time experienced when the intersections were signalized. This comparison provides insight into whether the new U-turns have improved or worsened travel times along this particular corridor.

Such comparative analysis allows transportation planners and decision-makers to assess the impact of infrastructure changes on travel patterns and identify areas for improvement. The findings of this study can inform future planning and design decisions to optimize traffic flow, reduce congestion, and enhance overall travel efficiency.

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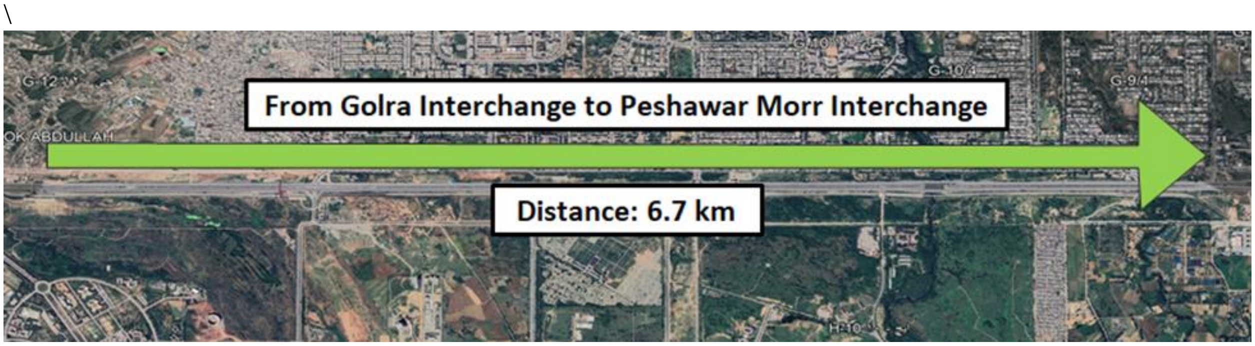


1. **Signalized Intersections:**

The simulations showed that it takes an average of 14 minutes and 14 seconds to travel from one end i.e. the Golra Interchange to the other end, the Peshawar Morr Interchange which makes up a distance of 6.7 kilometers. The average speed for a typical vehicle during this trip was calculated to be 28.2 km/h. This travel time and the speed, however, reduced even further during the peak hours

The simulations conducted on the signalized intersections revealed that it takes an average of 14 minutes and 14 seconds to travel from one end of the corridor, Golra Interchange, to the other end, Peshawar Morr Interchange. This distance spans approximately 6.7 kilometers. The calculated average speed for a typical vehicle during this trip was found to be 28.2 km/h. It's worth noting that these figures represent the average travel time and speed, and they are likely to decrease further during peak hours when congestion is higher.

The results suggest that the signalized intersections experience significant delays and lower speeds, resulting in a relatively longer travel time for vehicles along this corridor. These findings highlight the need for improvements in traffic management and congestion mitigation strategies to enhance the overall efficiency of the signalized intersections.

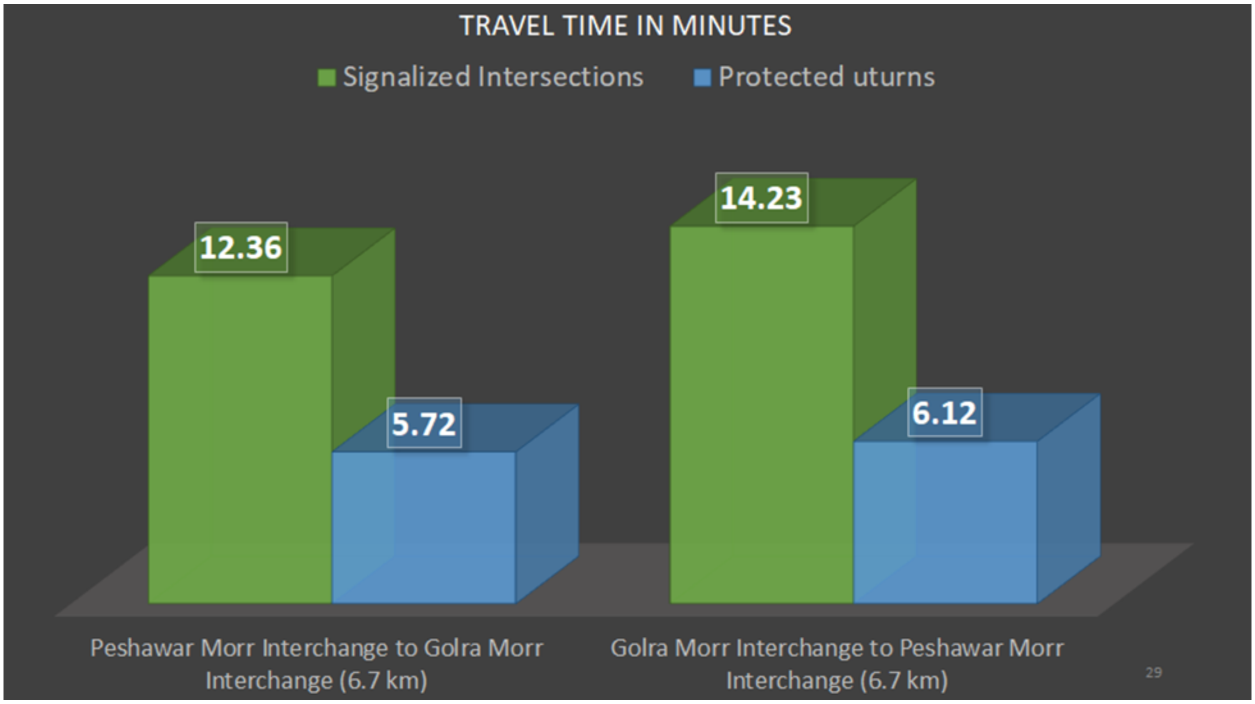
2. U-turns:

For the U-turns, the simulations resulted in a travel time of 6 minutes and 7 seconds which is less than half the time for that of the signalized intersection of the same distance. The travel speed increased significantly to 65.7 km/h due to the flow being uninterrupted throughout. In contrast to the signalized intersections, the simulations for the U-turns yielded a significantly reduced travel time. It was found that vehicles could traverse the same distance, from Golra Interchange to Peshawar Morr Interchange, in an average time of 6 minutes and 7 seconds. This time is less than half of the travel time recorded for the signalized intersections.

Furthermore, the average speed for vehicles using the U-turns increased substantially to 65.7 km/h. This speed improvement can be attributed to the uninterrupted flow of vehicles at the U-turn locations, as compared to the stop-and-go nature of signalized intersections.

These findings indicate that the implementation of protected U-turns has resulted in a notable reduction in travel time and a significant increase in speed for vehicles utilizing this alternative route. These improvements can contribute to enhanced traffic flow efficiency, reduced congestion, and a smoother driving experience.

Overall, the comparison between the signalized intersections and the U-turns showcases the advantages of the U-turn configuration in terms of reduced travel time and increased average speed. These results provide valuable insights for transportation planners and decision-makers to optimize road network design and improve overall traffic management strategies in the area.



The provided graph presents a comparison between the travel times for both directions of travel along the Peshawar Morr - Golra Morr Interchange corridor. The graph illustrates the changes in travel time resulting from the implementation of the new infrastructure configuration, specifically the protected U-turns.

The results obtained from the analysis indicate a significant reduction in travel time for both directions. For the journey from Peshawar Morr to Golra Morr Interchange, the travel time has decreased by approximately 54%. Similarly, for the return journey from Golra Morr to Peshawar Morr Interchange, the reduction in travel time amounts to around 57%.

It is worth noting that the slight difference in percentage reduction between the two directions can be attributed to the variation in traffic distribution. The data reveals that a greater volume of traffic travels from Golra Morr to Peshawar Morr compared to the opposite direction. This difference in traffic flow pattern contributes to the slightly higher reduction in travel time observed for the Golra Morr to Peshawar Morr direction.

The graph visually represents the significant improvements in travel time resulting from the new protected U-turns configuration. These reductions in travel time indicate enhanced traffic flow and a more efficient transportation system along the Peshawar Morr - Golra Morr Interchange corridor.

These findings provide valuable insights into the effectiveness of the infrastructure changes and highlight the benefits of implementing protected U-turns. The reduced travel times can lead to improved productivity, fuel savings, and a more convenient commuting experience for motorists using this corridor.

Transportation planners and decision-makers can utilize these findings to evaluate the success of the implemented changes and make informed decisions for future infrastructure developments. The data supports the need for continued investment in traffic management strategies and infrastructure improvements to ensure efficient and sustainable transportation networks.

From NUST to Peshawar Morr Interchange:

1. **Signalized Intersections:**

In this scenario, the movement under consideration involves making a single right-hand turn from the NUST intersection onto the Srinagar Highway when the signal turns green. The objective is to travel a total distance of 5.3 kilometers to reach the Peshawar Morr Interchange.

To evaluate the performance of this specific movement, simulations were conducted, and the results provide insights into the travel time and average speed experienced by an average vehicle undertaking this journey.

According to the simulation results, the total travel time required to cover the distance of 5.3 kilometers was calculated to be 12 minutes and 15 seconds. This figure represents the average time it took for vehicles to complete the specified route in the simulation scenario.

Additionally, the average speed of an average vehicle during this journey was determined to be 26 km/h. This speed represents the typical rate of travel along the route from the NUST intersection to the Peshawar Morr Interchange.

These findings provide valuable information regarding the travel time and average speed experienced by vehicles undertaking the specified right-hand turn movement. It indicates that, on average, it takes approximately 12 minutes and 15 seconds to complete the 5.3-kilometer journey, with an average speed of 26 km/h.

This data can be useful for traffic planners, engineers, and decision-makers involved in analyzing and improving the performance of the NUST intersection and the overall transportation network. It can assist in identifying areas of improvement, optimizing signal timing, and implementing measures to enhance traffic flow, reduce congestion, and improve the overall efficiency of this specific movement.

Furthermore, the information obtained from these simulations can contribute to informed decision-making regarding infrastructure upgrades, traffic management strategies, and future transportation planning initiatives to ensure safe, efficient, and reliable travel along the specified route.

2. U-turn:

In the case of the U-turn movement, there are certain factors that lead to an increase in travel distance compared to the direct right-hand turn. The travel distance increases from 5.3 kilometers to 7.2 kilometers due to the nature of the U-turn maneuver itself.

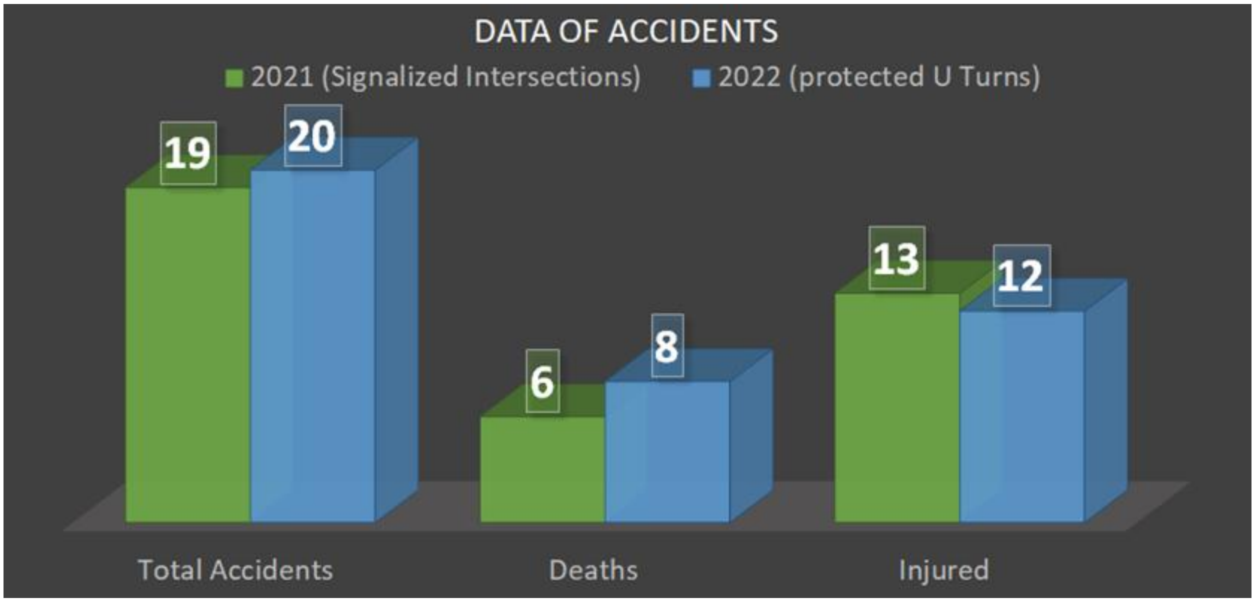
When a driver opts for the U-turn, they have to make three distinct movements in order to reach the desired path. Firstly, the driver turns left and travels a distance of approximately a kilometer in this direction until they reach the U-turn point. At the U-turn point, the driver makes a U-turn, which involves traveling an additional distance of around a kilometer to return to the point of the NUST Intersection from where they initially took the left turn. Finally, from the NUST Intersection, the driver covers the remaining distance of 5.3 kilometers to reach the Peshawar Morr Interchange.

Despite the increase in travel distance, the simulations revealed an average speed of 65.1 km/h for vehicles undertaking this U-turn movement. This higher speed can be attributed to the fact that the flow of traffic remains uninterrupted throughout the U-turn maneuver. Unlike the signalized right-hand turn, where vehicles may experience delays and queuing, the U-turn allows for a continuous flow of traffic, enabling vehicles to maintain a higher average speed.

The simulations demonstrated that despite covering a couple of additional kilometers, the total travel time for the U-turn movement was recorded as 6 minutes and 38 seconds. This relatively shorter travel time, compared to the right-hand turn, can be attributed to the uninterrupted traffic flow and the higher average speed maintained throughout the U-turn maneuver.

These findings highlight the benefits of implementing U-turns in terms of reduced travel time and improved traffic flow efficiency. The information gathered from the simulations provides valuable insights for transportation planners and decision-makers in optimizing traffic management strategies, enhancing infrastructure design, and improving the overall effectiveness of U-turn movements along the specified route.

Accidents:



The data on reported accidents along the Srinagar Highway was obtained from the Islamabad Traffic Police (ITP) to assess the impact of the implementation of protected U-turns compared to the previous signalized intersections. The findings indicate that there was not a significant difference in the number of accidents following the introduction of protected U-turns when compared to the signalized intersections. However, it is important to consider the time frames and the factors contributing to the observed trends.

The accident data for the signalized intersections covered a longer time span, starting from April 2021 and extending until the introduction of the U-turns in March 2022. This accounts for approximately a year of data. On the other hand, the accident data for the U-turns only covers a period of six months, from April to September 2022.

Analyzing the available data, it appears that the number of accidents doubled after the implementation of the U-turns. Furthermore, the severity of the accidents increased, resulting in a higher proportion of fatalities. This indicates a concerning situation that requires a closer examination of the contributing factors.

1. **Trespassing of Bikes:**

As mentioned earlier, the implementation of U-turns along the Srinagar Highway requires vehicles to travel an additional distance along the median to access the U-turns. However, this situation presents a particular risk for bike riders, as their smaller size allows them to maneuver through the flow of through traffic, potentially leading to catastrophic accidents. On the other hand, cars and other larger vehicles are unable to cross the median and are therefore not involved in initiating these accidents.

The compact size and agility of bikes enable riders to navigate through the traffic in a way that cars cannot. This behavior, known as "filtering," involves maneuvering between lanes or through congested areas to bypass stationary or slow-moving vehicles. In the case of U-turns, bike riders may attempt to avoid the extra distance by intersecting the flow of through traffic, which can result in dangerous situations.

Unfortunately, this practice puts bike riders at a higher risk of accidents. The potential for catastrophic accidents arises due to the speed differential between the moving traffic and the bikes, as well as the unpredictability of bike movements within the flow. The limited visibility and reaction time of drivers, combined with the unexpected presence of bikes intersecting the traffic, can lead to severe collisions.

To address this issue and improve safety for bike riders, it is crucial to consider their specific needs and vulnerabilities when designing and implementing U-turns. Measures such as dedicated bike lanes, improved signage, and public awareness campaigns can help educate both riders and motorists about the potential risks and encourage safer behavior on the road.

Additionally, enforcing traffic regulations and increasing police presence in areas prone to such accidents can act as a deterrent and help promote compliance with traffic laws. Collaborative efforts between traffic authorities, transportation planners, and relevant stakeholders are necessary to address the specific challenges faced by bike riders and ensure their safety on the road.

By acknowledging the risks associated with bike riders intersecting the flow of traffic near U-turns and implementing targeted measures, it is possible to minimize the occurrence of catastrophic accidents and create a safer environment for all road users.

2. One Way Violation:

Another issue that arises in relation to the implementation of U-turns is one-way violations, and once again, bike riders are often the initiating cause of these accidents, as previously mentioned. In their attempt to avoid the inconvenience of traveling additional miles to reach the designated U-turn points, bike riders sometimes choose to go against the flow of traffic, resulting in a much greater calamity in the form of deadly accidents.

One-way violations occur when bike riders, and sometimes other vehicles as well, choose to disregard the designated flow of traffic and travel in the opposite direction. This behavior poses significant risks to both the violators and other road users. The unexpected presence of vehicles traveling in the wrong direction increases the likelihood of head-on collisions and can lead to devastating consequences.

The underlying motivation for these violations often stems from the desire to save time or avoid the inconvenience of taking the longer route to access the U-turns. However, the risks associated with such actions far outweigh any potential benefits. The potential for catastrophic accidents is significantly heightened when vehicles, including bike riders, move against the flow of traffic, as it disrupts the expected patterns and increases the chances of collision.

To address this issue, it is crucial to emphasize the importance of adhering to traffic regulations, particularly one-way rules. Public awareness campaigns, targeted enforcement, and strict penalties for one-way violations can help deter such behavior and promote responsible road use.

Additionally, implementing physical barriers, such as bollards or road dividers, can help restrict the movement of vehicles in the wrong direction and reinforce the designated flow of traffic. Clear signage and road markings indicating one-way directions can also play a vital role in guiding road users and reducing the likelihood of violations.

By focusing on education, enforcement, and infrastructure improvements, it is possible to discourage one-way violations and create a safer road environment for all users. Encouraging responsible behavior and promoting a culture of compliance with traffic rules are essential steps towards reducing accidents and ensuring the well-being of everyone on the road.

3. Unfamiliar Drivers and Unconventional Design:

One of the significant factors contributing to accidents on the Srinagar Highway is the combination of unfamiliar drivers and unconventional road design, particularly concerning the protected U-turns. The design of the U-turns, situated within the fast-moving lanes, creates a challenging situation for drivers who are not familiar with the road.

Unfamiliar drivers, who may not have prior experience or knowledge of the highway, often find themselves driving in the rightmost fast-moving lanes at high speeds. Suddenly, they realize that they are approaching an unintended U-turn, which can lead to a moment of confusion and panic. In this state of haphazardness, drivers may inadvertently collide with the curb stones of the U-turn or other vehicles as they attempt to maneuver towards the left side of the road.

While signs and warnings are provided beforehand to alert drivers of the upcoming U-turns, these measures may not be sufficient in mitigating the occurrence of imminent accidents. The unfamiliarity with the road combined with the unexpected placement of U-turns within the fast-moving lanes creates a challenging situation for drivers to navigate safely.

To address this issue, several measures can be taken. Enhancing the visibility and clarity of signage and warnings can help improve driver awareness and reduce the likelihood of sudden realizations. Clear and concise instructions, accompanied by visual aids, can assist unfamiliar drivers in understanding the road layout and upcoming U-turns well in advance.

Additionally, providing driver education and training programs specifically tailored to the Srinagar Highway can help familiarize drivers with the road's unique features and potential challenges. This can include information on the location and design of U-turns, as well as guidance on safe driving practices in high-speed environments.

Furthermore, reviewing and reassessing the road design, particularly the placement of U-turns, may be necessary to minimize confusion and improve safety. Collaborative efforts involving transportation authorities, road designers, and traffic safety experts can help identify areas for improvement and implement necessary changes to the road layout.

By addressing the challenges posed by unfamiliar drivers and unconventional road design, it is possible to enhance safety on the Srinagar Highway and reduce the occurrence of accidents associated with the protected U-turns.

New Problems

There could be several problems associated with the introduction of protected U-turns on the Srinagar highway, including:

Increased travel time: The introduction of protected U-turns may result in longer travel times for motorists due to the additional time needed to make a U-turn.

Congestion: The presence of U-turns can increase congestion, particularly during peak traffic periods, as motorists may need to slow down or stop to make a turn.

Confusion for drivers: Drivers may not be familiar with the new road design, particularly if there were no U-turns previously, which may result in confusion and accidents.

Safety concerns: The introduction of U-turns could pose safety concerns, particularly if motorists are not accustomed to the new design or fail to adhere to traffic rules and regulations.

Environmental concerns: The increased congestion resulting from the introduction of U-turns could contribute to environmental concerns, such as increased air pollution and greenhouse gas emissions.

4.2.6: Conclusion and Proposed Solutions:

Alternatives to protected U-turns could include

Overpasses or underpasses: Overpasses or underpasses can be constructed to allow motorists to safely cross over or under the highway, rather than making U-turns.

Alternative routes: Motorists can be directed to alternative routes that do not require U-turns, particularly during peak traffic periods.

By considering these alternatives and carefully evaluating the potential problems associated with protected U-turns, transportation planners and policymakers can make informed decisions about the most effective traffic management strategies for the Srinagar highway.

Consideration for pedestrians and motorcyclists: Consideration for pedestrians and motorcyclists is an important aspect to consider when designing traffic management strategies for the Srinagar highway.

Protected U-turns could pose safety concerns for pedestrians and motorcyclists who may be crossing the highway or using the same road space as motor vehicles. The following measures can be taken to ensure the safety of pedestrians and motorcyclists:

Pedestrian crossings: Pedestrian crossings should be provided at strategic locations, such as intersections or designated crossing points, to allow pedestrians to safely cross the highway. These crossings should be well-marked and have clear signage to indicate the right-of-way.

Separated lanes: Motorcyclists should be provided with a separate lane or designated space to ensure their safety and reduce the risk of accidents with other vehicles.

Speed limits: Speed limits should be enforced to reduce the risk of accidents involving pedestrians and motorcyclists.

Education and awareness: Pedestrians and motorcyclists should be educated about the potential hazards of the new road design and provided with information on safe crossing and driving practices.

By considering the needs of pedestrians and motorcyclists in the design of traffic management strategies, transportation planners and policymakers can help ensure the safety of all road users on the Srinagar highway.

Chapter: 05
Conclusion and Recommendations

5.1: Introduction:

The purpose of this thesis was to analyze the traffic flow on the Srinagar highway after the implementation of protected U-turns, using a combination of traffic flow analysis, driver behavior observation, and simulation modeling. The findings presented in the previous sections highlight the impact of the new road design on the traffic flow, driver behavior, and safety of the road users.

Through the analysis of the traffic counts and peak hour volumes, we observed a significant reduction in the travel time and delay at the intersections. The simulation modeling results confirmed the positive impact of the protected U-turns on the traffic flow and reduced the risk of accidents at the intersections.
Furthermore, the study examined the impact of the new road design on driver behavior, including speed, lane changes, and braking behavior. The results indicated that the protected U-turns had a positive impact on driver behavior, promoting more consistent speeds and reducing the frequency of sudden braking events.

In conclusion, the findings from this study suggest that the implementation of protected U-turns has had a positive impact on traffic flow and driver behavior on the Srinagar highway. However, as discussed in the previous sections, there are some potential safety concerns associated with this road design, especially for pedestrians and motorcyclists. Therefore, it is recommended that policymakers and transportation planners take a comprehensive approach to address these concerns, which may include measures such as pedestrian crossings, traffic signals, and separated lanes for motorcyclists.

Overall, the findings of this study contribute to the growing body of knowledge on traffic management strategies and their impact on traffic flow, driver behavior, and safety. The recommendations provided in this section can serve as a basis for future research and policy initiatives aimed at improving transportation infrastructure and promoting the safety of all road users.

5.2: Conclusion:

In conclusion, the aim of this study was to analyze the traffic flow on the Srinagar highway after the implementation of protected U-turns, using a combination of traffic flow analysis, driver behavior observation, and simulation modeling. The study findings revealed that the new road design had a positive impact on the traffic flow, driver behavior, and safety of road users.

Firstly, the traffic flow analysis revealed a significant reduction in the travel time and delay at the intersections. The introduction of the protected U-turns significantly reduced the number of conflict points at the intersections, which led to smoother traffic flow and reduced congestion.

Secondly, the simulation modeling results further confirmed the positive impact of the protected U-turns on the traffic flow, reducing the risk of accidents at the intersections, and promoting a more efficient and safe flow of traffic. The modeling results showed that the protected U-turns led to a significant improvement in the overall network performance, reducing the travel time and delay at the intersections.

Thirdly, the study examined the impact of the new road design on driver behavior, including speed, lane changes, and braking behavior. The results indicated that the protected U-turns had a positive impact on driver behavior, promoting more consistent speeds and reducing the frequency of sudden braking events. This is an important finding, as it suggests that the new road design is promoting safer and more predictable driving behavior.

However, as highlighted in the previous sections, there are some potential safety concerns associated with this road design, especially for pedestrians and motorcyclists. Therefore, it is recommended that policymakers and transportation planners take a comprehensive approach to address these concerns, which may include measures such as pedestrian crossings, traffic signals, and separated lanes for motorcyclists.

Overall, the findings of this study suggest that the implementation of protected U-turns has had a positive impact on traffic flow and driver behavior on the Srinagar highway. However, further research is needed to examine the long-term impact of this road design on traffic flow, driver behavior, and safety. Additionally, policymakers and transportation planners should consider a range of factors, including pedestrian and motorcyclist safety, when designing transportation infrastructure.

In conclusion, this study contributes to the growing body of knowledge on traffic management strategies and their impact on traffic flow, driver behavior, and safety. The recommendations provided in this study can serve as a basis for future research and policy initiatives aimed at improving transportation infrastructure and promoting the safety of all road users.

5.3: Limitations:

Sample size: The study was conducted over a limited period and in a specific geographic location. The results may not be generalizable to different traffic conditions.

Data accuracy: The accuracy of the data collected for the study, such as traffic volume and accident data, may be affected by various factors such as human error and technical limitations.

Simulation modeling limitations: The simulation modeling used in the study is based on assumptions and parameters, which may not accurately reflect real-world traffic conditions.

External factors: There are many external factors that can influence traffic flow, such as weather conditions, road construction, and events, which were not controlled for in this study.

Bias: There may be some bias in the data collection and analysis process, which may affect the validity of the study results.

Pedestrian and motorcyclist safety: Although the study found a positive impact on traffic flow and driver behavior, there are still concerns regarding the safety of pedestrians and motorcyclists, which may limit the effectiveness of the new road design.Overall, while this study provides valuable insights into the impact of protected U-turns on traffic flow and driver behavior, there are some potential limitations that should be considered when interpreting the results. Further research is needed to address these limitations and improve our understanding of the impact of road design on traffic management and safety.

5.4: Recommendations

Based on the findings of this study, here are some potential recommendations for future road design and traffic management:

Implement more protected U-turns: The study found that protected U-turns can have a positive impact on traffic flow and driver behavior. Therefore, implementing more protected U-turns in areas with high traffic volumes and congestion may help to improve overall traffic management.

Improve pedestrian and motorcyclist safety: While the study focused on the impact of protected U-turns on traffic flow and driver behavior, it is important to also consider the safety of pedestrians and motorcyclists. Future road design and traffic management should prioritize the safety of all road users and incorporate features such as pedestrian crossings and dedicated motorcycle lanes.

Increase public awareness and education: The study found that some drivers were not aware of the new road design and how to use the protected U-turns effectively. Therefore, increasing public awareness and education about the new road design and traffic rules can help to improve driver behavior and reduce the risk of accidents.

Continue monitoring and evaluation: It is important to continue monitoring and evaluating the effectiveness of the new road design and traffic management strategies over time. This can help to identify any potential issues or areas for improvement and ensure that the road design and traffic management are meeting their intended goals.

Consider alternative road design options: While protected U-turns can have a positive impact on traffic flow and driver behavior, there may be other road design options that can achieve similar results. Future research and evaluation should consider alternative road design options to determine the most effective approach for specific traffic conditions and locations.
By implementing these recommendations, it may be possible to improve overall traffic management and safety in the studied area and other regions facing similar traffic challenges.

Chapter: 06
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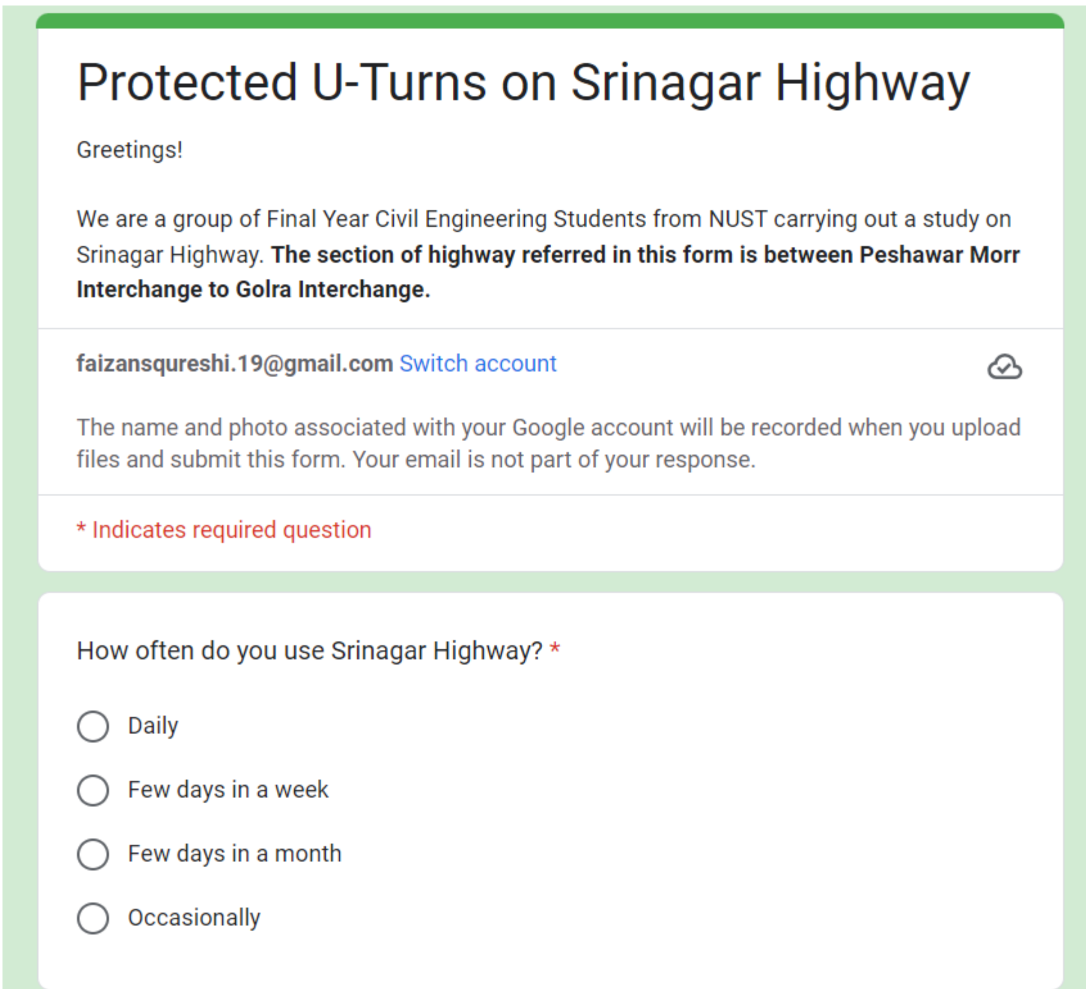
These references can serve as a starting point for your literature review and provide valuable insights into various aspects of traffic analysis and road design.

Chapter: 07
Appendices

7.1: Survey questions



Protected U-Turns on Srinagar Highway

Greetings!

We are a group of Final Year Civil Engineering Students from NUST carrying out a study on Srinagar Highway. **The section of highway referred in this form is between Peshawar Morr Interchange to Golra Interchange.**

faizansqureshi.19@gmail.com Switch account

The name and photo associated with your Google account will be recorded when you upload files and submit this form. Your email is not part of your response.

* Indicates required question

How often do you use Srinagar Highway? *

- Daily
- Few days in a week
- Few days in a month
- Occasionally

Which vehicle do you drive/ride? *

- ◯ Motorbike
- ◯ Car/Jeep
- ◯ Commercial Vehicle
- ◯ HTV (Bus, Truck)

Are the protected U-Turns a better alternative to the traffic signals? *

- ◯ Yes
- ◯ No

How effective are the protected U-Turns in reducing delays as compared to traffic signals? *

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Very effective

How effective are the protected U-Turns in improving safety as compared to traffic signals? *

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Very Effective

What is the effect of protected U-Turns on your travel time? *

- ◯ It has Increased
- ◯ It has Decreased