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Comparative Analysis of Speed Limits on Urban Roads: Balancing Safety and Mobility

May 2024

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Master of Planning (Transport Planning and Logistics Management)

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Thesis submitted in partial fulfillment of the requirements for the award of the degree of

Master of Planning
(Transport Planning and Logistics Management)

By

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Declaration

I **Shubham Barman**, Scholar No. **2022MTPLM007** hereby declare that the thesis titled **"Comparative Analysis of Speed Limits on Urban Roads: Balancing Safety & Mobility"** submitted by me in partial fulfilment for the award of **Master of Planning**, at the School of Planning and Architecture, Bhopal, India is a record of bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Signature of the Student

Date: _______________

Certificate

This is to certify that the declaration of **Shubham Barman** is true to the best of my knowledge and that the student has worked under my guidance in preparing this thesis.

RECOMMENDED

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Signature of the Guide

Dr. Mayank Dubey

ACCEPTED

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Prof. Saurabh Popli

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Abstract

In today's rapidly urbanizing world, cities are confronted with the dual challenge of enhancing mobility to accommodate growing vehicle populations while also prioritizing safety on urban roads. This delicate balance is directly influenced by the posted speed limits (PSLs) on roads. Typically, PSLs are determined based on the 85th percentile speeds of vehicles on roads, as well as other considerations such as road characteristics, geometric design, traffic flow, and safety measures. However, some PSLs may not effectively align with existing road design and traffic patterns, resulting in inconsistencies. These inconsistencies can disrupt traffic flow; excessively low PSLs on high-capacity roads can lead to congestion, while high PSLs on low-traffic roads might compromise safety. This study aims to understand speed limit behavior and provide recommendations for improving road safety and mobility. The research focuses on the comparative analysis of speed limits across diverse zones of urban areas to comprehend existing conditions and variations within and across cities. For comparison, four cities are selected: Agra, Lucknow, Bhopal, and Indore, which are ranked 2nd, 6th, 25th, and 28th, respectively, in accidents according to the Accident Report 2022 by MoRTH. The study is conducted on higher hierarchy roads, including arterial, sub-arterial, and ring roads of urban areas. Data is collected from both primary and secondary sources to gather valuable information, including details such as PSL value, location, direction, signage type, reason for the upcoming PSL, continuity, and mutual relatedness.

Spatial factors such as distance from the city center, proximity to intersections, geometrical factors like right-of-way width, land use pattern changes, and transition zones are analyzed to understand different PSL behaviors. Additionally, this research examines how different speed limits impact travel times and delays in urban areas, along with speed distribution, aiding in the analysis of speed variations by examining existing traffic conditions and speed limits. The results indicate that PSLs are highly influenced by right-of-way and less influenced by land use, increasing as one moves outward from the city center.

Through comparative analysis, this research provides evidence-based recommendations for implementing optimal speed limits or improving existing speed limit policies in urban areas. Safe transition distances have been recommended in transition zones for different PSLs based on the findings of this research.

Keywords: Posted Speed Limits, Road Safety, Landuse, Right of Way, Transition Zone, Travel time, Road Geometry

सारांश

आज की तेजी से शहरीकरण की दुनिया में, शहरों को बढ़ती वाहन आबादी को समायोजित करने के लिए गतिशीलता बढ़ाने के साथ-साथ शहरी सड़कों पर सुरक्षा को प्राथमिकता देने की दोहरी चुनौती का सामना करना पड़ता है। यह संतुलन सड़कों पर निर्धारित गति सीमा (पी.एस.एल.) से सीधे प्रभावित होता है। आमतौर पर, पोस्ट की गई गति सीमाएं सड़कों पर वाहनों की 85वीं प्रतिशत गति और सड़क विशेषताओं, ज्यामितीय डिजाइन, यातायात प्रवाह और अन्य सुरक्षा उपायों जैसे अन्य विचारों के आधार पर निर्धारित की जाती हैं। कुछ पीएसएल मौजूदा सड़क डिजाइन और यातायात पैटर्न के साथ प्रभावी ढंग से संरेखित नहीं हैं जिससे विसंगतियां पैदा हो सकती हैं। ये विसंगतियाँ यातायात प्रवाह को बाधित कर सकती हैं क्योंकि उच्च क्षमता वाली सड़कों पर अत्यधिक कम पीएसएल भीड़भाड़ का कारण बन सकती है, जबकि कम यातायात वाली सड़कों पर उच्च पीएसएल सुरक्षा को प्रभावित कर सकती है। यह सड़क उपयोगकर्ताओं की सुरक्षा के बारे में सवाल उठाता है, इस प्रकार, यह शोध गति सीमा व्यवहार को समझने में मदद करता है और बेहतर सड़क सुरक्षा और गतिशीलता के लिए सिफारिशें प्रदान करता है। यह शोध शहरों के भीतर और बाहर मौजूदा स्थितियों और विविधताओं को समझने के लिए शहरी क्षेत्रों के विभिन्न क्षेत्रों में गति सीमाओं के तुलनात्मक विश्लेषण पर केंद्रित है। तुलना के लिए, अध्ययन क्षेत्र के लिए चार शहरों को चुना गया है: आगरा, लखनऊ, भोपाल और इंदौर। ये शहर दुर्घटनाओं में दूसरे, छठे, 25वें और 28वें स्थान पर हैं (दुर्घटना रिपोर्ट 2022- MoRTH)। यह शोध शहरी क्षेत्रों की मुख्य, उप-धमनी और रिंग सड़कों सहित उच्च पदानुक्रम वाली सड़कों पर किया गया है। पीएसएल मूल्य, स्थान, दिशा, साइनेज प्रकार, आगामी पीएसएल का कारण, निरंतरता और पारस्परिक संबंधितता जैसे विवरणों सहित बहुमूल्य जानकारी इकट्ठा करने के लिए प्राथमिक और माध्यमिक दोनों स्रोतों से डेटा एकत्र किया गया है। शोध में, विभिन्न पीएसएल व्यवहारों को समझने के लिए स्थानिक कारकों जैसे शहर के केंद्र से दूरी, चौराहों से निकटता, रास्ते की चौड़ाई जैसे ज्यामितीय कारक, और भूमि उपयोग पैटर्न में बदलाव और संक्रमण क्षेत्र का विश्लेषण

किया गया है। यह शोध इस बात की भी जांच करता है कि गति वितरण के साथ-साथ विभिन्न गति सीमाएं शहरी क्षेत्रों में यात्रा के समय और देरी को कैसे प्रभावित करती हैं, जो मौजूदा यातायात स्थितियों और गति सीमाओं की जांच करके गति भिन्नता के विश्लेषण में मदद करती है। नतीजे बताते हैं कि पीएसएल रास्ते की चौड़ाई से अत्यधिक प्रभावित होते हैं और भूमि उपयोग से कम प्रभावित होते हैं और शहर के केंद्र से बाहर जाने पर बढ़ते हैं। तुलनात्मक विश्लेषण के माध्यम से, यह शोध शहरी क्षेत्रों में इष्टतम गति सीमा लागू करने या मौजूदा गति सीमा नीतियों में सुधार के लिए साक्ष्य-आधारित सिफारिशें प्रदान करने में मदद करता है। इस शोध के माध्यम से, विभिन्न पीएसएल के लिए संक्रमण क्षेत्रों में सुरक्षित संक्रमण दूरी का भी सुझाव दिया गया है।

कीवर्ड: पोस्ट की गई गति सीमाएं, सड़क सुरक्षा, भूमि उपयोग, रास्ते का अधिकार, संक्रमण क्षेत्र, यात्रा समय सड़क ज्यामिति।

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Abbreviations

PSL	Posted Speed Limits
RoW	Right of Way
MoRTH	Ministry of Road Transport and Highway
V85	85th Percentile speed
IRC	Indian Road Congress

CHAPTER 1: INTRODUCTION

This chapter serves as an introduction to the concept of speed limits and their significance in enhancing urban road safety and mobility. Alongside providing background information, it delineates the aim, objectives, scope, limitations, and detailed methodology employed in the research. This segment lays the foundational framework for investigating the establishment of speed limits in urban areas.

Traffic accidents represent a significant concern, and speed limits are perceived as a tool to ameliorate road safety. Nonetheless, a disparity exists between posted speed limits and actual road conditions, impacting both safety and traffic flow. The primary objective of this research is to bridge this gap by formulating data-driven guidelines. The study will concentrate on both core and outer urban areas, scrutinizing speed limits on arterial, sub-arterial roads, and expressways. Although local residential roads are not encompassed, the dynamic nature of urban development is acknowledged as a potential influencing factor.

The methodology entails several phases: initial background research, comprehensive literature review, meticulous data collection (on speed limits, road characteristics, accidents, and traffic flow), and rigorous analysis to discern speed variations and safety considerations. The expected outcome is a set of evidence-based suggestions for improving road safety and urban mobility. This includes recommendations for appropriate speed limit intervals, transition zones, and valuable insights for policymakers

1. Background

In contemporary urban development, the creation of sustainable and liveable urban spaces involves various essential components, including housing facilities, transport systems, and resilient infrastructure. As urban development progresses, continuous enhancement of road infrastructure and transportation systems is crucial to accommodate the increasing demands of a growing population. One of the significant challenges associated with urban road infrastructure is the safety of road users. In India, mixed traffic conditions prevail with different types of vehicles, ranging from 2-wheelers to heavy-duty trucks, moving on the road, posing critical safety concerns. To address this issue and reduce the occurrence of road accidents and congestion while maintaining efficient mobility, various countermeasures are taken by the concerned authorities. Traffic calming measures, such as the enforcement of speed limits, play a pivotal role in enhancing road safety within urban areas. Speed limits represent the legally maximum speeds at which vehicles can operate on public roadways. These limits are set based on local factors, leading to variations in different locations (Silvano & Bang, 2016). A prevalent method frequently utilized to identify an appropriate speed limit for a specific road involves closely aligning it with the V85, which is defined as the speed at which 85 percent of vehicles are moving on roads. Road characteristics and design, including lane width, curvature, grade, and intersections, as well as the overall condition of the road, including surface quality, signage, and lighting, are also taken into consideration while setting speed limits on specific stretches of road (Nalla & Dhobale, 2023).

The determination of speed limits is principally governed by the Ministry of Road Transport and Highways, which establishes statutory speed limits. However, as roads are a state subject, the setting of these limits is subsequently delegated to state governments or local authorities. This decentralized approach allows for the customization of speed limits based on local geographic conditions and is set according to comprehensive traffic studies. It is imperative to note that these locally defined speed limits must not exceed the statutory limits established by the central ministry. By imposing speed restrictions, authorities aim to create safer environments for pedestrians, cyclists, and motorists alike. Adjusting speed limits helps mitigate the severity of accidents and reduces the likelihood of collisions. While imposing speed limits for safety, there is also a negative impact since it affects vehicular speed, directly influencing mobility. In urban areas, numerous stretches exist where speed limits do not align with existing road and traffic conditions. There is a pressing need to rectify these stretches and establish optimal speed limits that enhance both safety and mobility.

1.1 Need of the Study

Posted Speed Limits (PSLs) are regarded as a cornerstone of traffic safety, yet discrepancies between these limits and actual road conditions can pose significant dangers. Moreover, such inconsistencies have the potential to disrupt traffic flow, with excessively low PSLs on high-capacity roads leading to congestion, while high PSLs on low-traffic roads may encourage speeding and result in road accidents. This research delves into these disparities, focusing on how road hierarchy and operating speeds may be influenced by PSLs. By identifying areas where PSL adjustments can ensure smoother traffic movement, this research aims to optimize traffic flow. Ultimately, the goal is to develop data-driven guidelines for setting PSLs, enhance enforcement strategies, and raise public awareness about the importance of adhering to PSLs and the dangers of inconsistencies.

Additionally, it has been proposed by the Ministry of Road Transport and Highways (MoRTH) to raise the current speed limits. However, as per the Accident Report of 2022 published by MoRTH, a substantial 72% of all road accidents are attributed to instances of overspeeding.

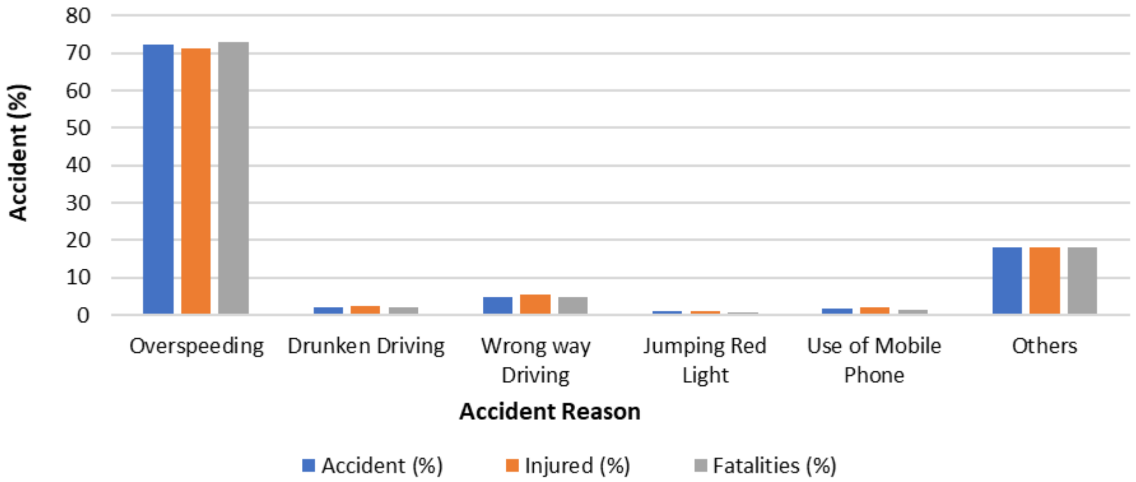


Figure 1: No. of Accidents as per different Reason in 2022
Source: Accident Report 2022 (MoRTH)

The percentage of accidents attributed to speeding far outweighs those caused by other factors, which are comparatively minor. This data underscores the importance of cautious deliberation and comprehensive analysis before implementing any adjustments to speed limits, ensuring that road safety remains a paramount consideration. In response to this proposal, a study has been commissioned to investigate the feasibility of implementing higher speed limits on urban roads. The study considers the varying conditions of road geometry and mixed traffic to assess whether such an increase in speed limits is practical and safe. By examining these factors, valuable insights into the potential benefits and risks associated with higher speed limits will be provided, helping inform future policy decisions regarding road safety in India

1.2 Aim

The aim of this research is to analyze different speed limits across diverse zones of urban areas to enhance road safety and mobility.

1.3 Objectives

To achieve the aim of the research, the following objectives are formulated that help in the enhancement of road safety and mobility:

- **To examine existing speed limits on urban roads in different cities**

  The first objective entails examining the current speed limits implemented on urban roads across various cities. This involves comprehensively reviewing speed limits to understand the distribution, variability, and consistency of posted speed limits (PSLs) on higher hierarchy roads.

- **To investigate how spatial and geometric factors influence safety due to speed limits in urban areas**

  The second objective investigating how spatial factors such as distances from the city center, proximity to intersections, and abutting land use impact speed limits. Additionally, geometric factors such as right of way and transition zones are considered to analyze their influence on road safety with speed limits. This analysis also correlates these factors with PSLs for safety effectiveness.

- **To analyze the impact of different speed limits on traffic flow, travel time, and delay**

  The third objective seeks to determine the impact of different speed limits on traffic flow; travel time, and delays. This involves comparing travel time under ideal speed conditions (near to free flow speed) and with PSLs on roads by identifying reasons for specific stretches. It also examines how varying speed limits affect overall traffic patterns, including congestion levels and journey times, to identify optimal speed limits for enhancing mobility without compromising safety.

- **To provide evidence-based recommendations that balance road safety and mobility through speed limits**

  The final objective is to create well-founded recommendations that strike a balance between road safety and traffic flow by establishing suitable speed limits. This involves synthesizing findings from the analysis of existing speed limits, correlation studies with spatial factors, and traffic impact analysis to suggest guidelines that optimize both safety and mobility on urban roads.

1.4 Scope

1. The study primarily focuses on urban roads, encompassing both core and outer regions within urban areas. A comprehensive analysis of speed limits applicable to roads within city limits is conducted, considering factors specific to urban environments.
2. The research specifically concentrates on higher hierarchy roads, namely Arterial, Sub-arterial roads, and ring roads. These road types constitute critical components of urban transportation networks and are integral to understanding speed limit dynamics in urban settings.

1.5 Limitations

1. Lower hierarchy roads (Collector and local residential roads) were not considered in this research.
2. The dynamic nature of urban development and transportation systems may reduce the long-term applicability of the findings.

1.6 Methodology

The research methodology comprises several phases that are crucial for the successful execution of the study. It commences with the Research Design, followed by the Literature Review, Data Identification, Data Collection, and concludes with the analysis of data collected during site visits. During the Research Design phase, an extensive background study on speed limits is conducted. This involves gathering foundational information about speed limits and formulating a comprehensive research framework. The research aim, objectives, scope, limitations, and expected outcomes of the study are clearly defined.

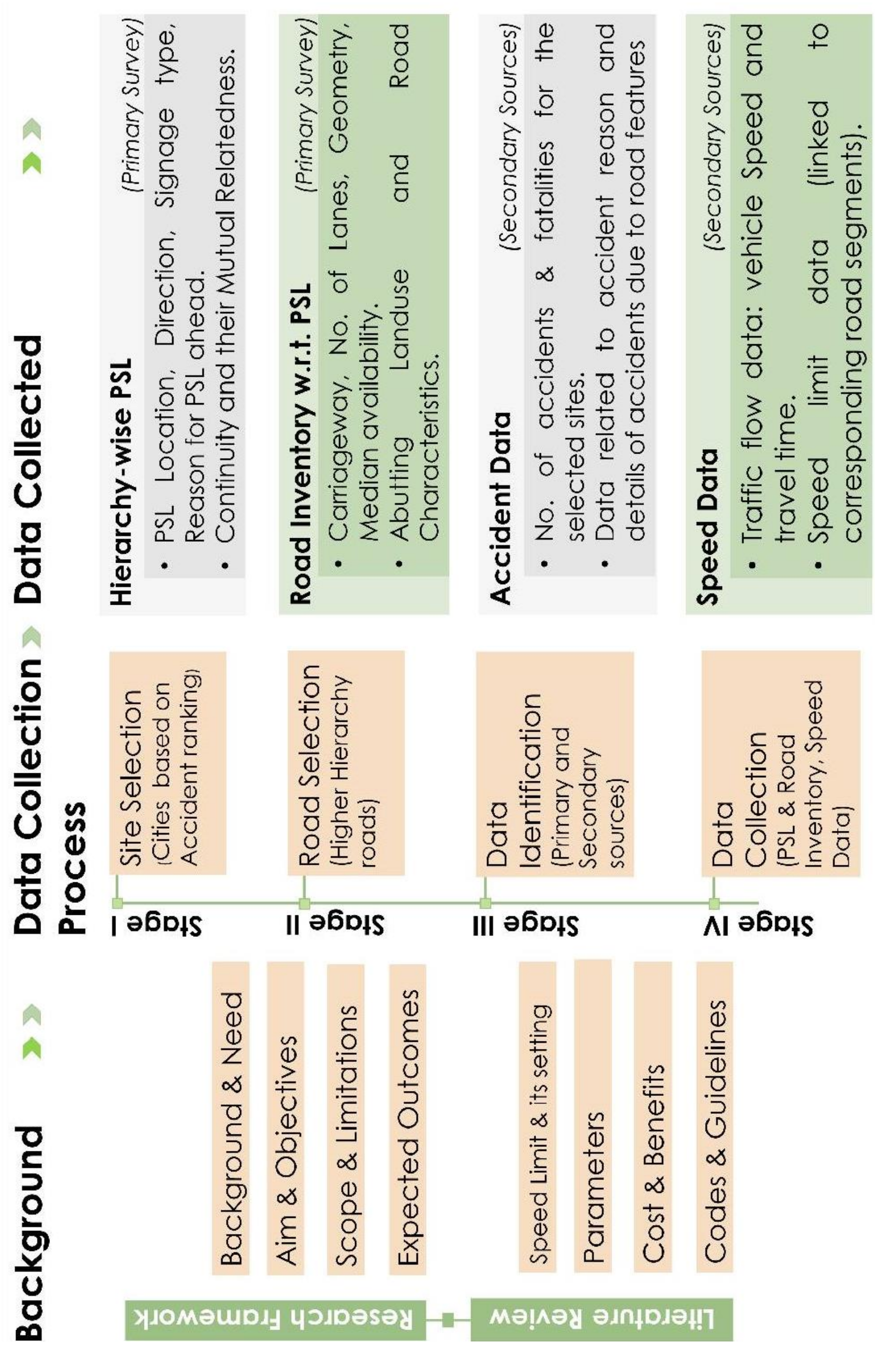


Figure 2: Methodology of the research

Subsequently, the Literature Review entails a thorough examination of existing literature on speed limits. This review encompasses basic concepts and terminologies related to speed limits, the methodologies employed in establishing and regulating these limits, and standards and guidelines related to speed limits. Adhering to this methodological approach provides a solid basis for investigating and understanding the dynamics of speed limits and their broader implications in the context of road safety and transportation management.

The second step involves data identification for the study, encompassing both primary and secondary data sources. Following this, a methodology for the data collection process is developed, which includes site selection and the identification of road hierarchies to be studied. The data collection phase begins with gathering primary data, including the PSL Inventory. This inventory captures PSL locations, directions, reasons for PSL placement, and the continuity and mutual distances between PSLs. Additionally, Road Inventory data is collected for each PSL, detailing Right-of-Way (RoW), number of lanes, median availability, abutting land use, and other road characteristics. Secondary data comprises Accident data for each city, documenting accident reasons and geometric factors contributing to accidents. Furthermore, speed data from Google Traffic under ideal conditions is also collected as part of the secondary data sources. Moving on to find the impacts of speed on travel behavior, the study entails the collection of traffic flow data, including travel speed and time. This is done with the secondary source (Google Traffic).

Further analysis methodology is framed, which includes a comprehensive examination of speed variations, their impacts, safety considerations, and the subsequent formulation of recommendations. The initial phase encompasses a meticulous review of existing speed limits. This will be done with the primary survey of urban areas where the road characteristics and geometric design differ significantly. To further refine the analysis, urban zones are delineated based on factors such as road hierarchy, land use, and road characteristics.

With safety considerations in mind, various spatial factors such as distance from the city center, proximity to intersections, and land use patterns, along with geometric characteristics like Right of Way (RoW) and Transition Distance, are correlated with PSLs to understand their behavior.

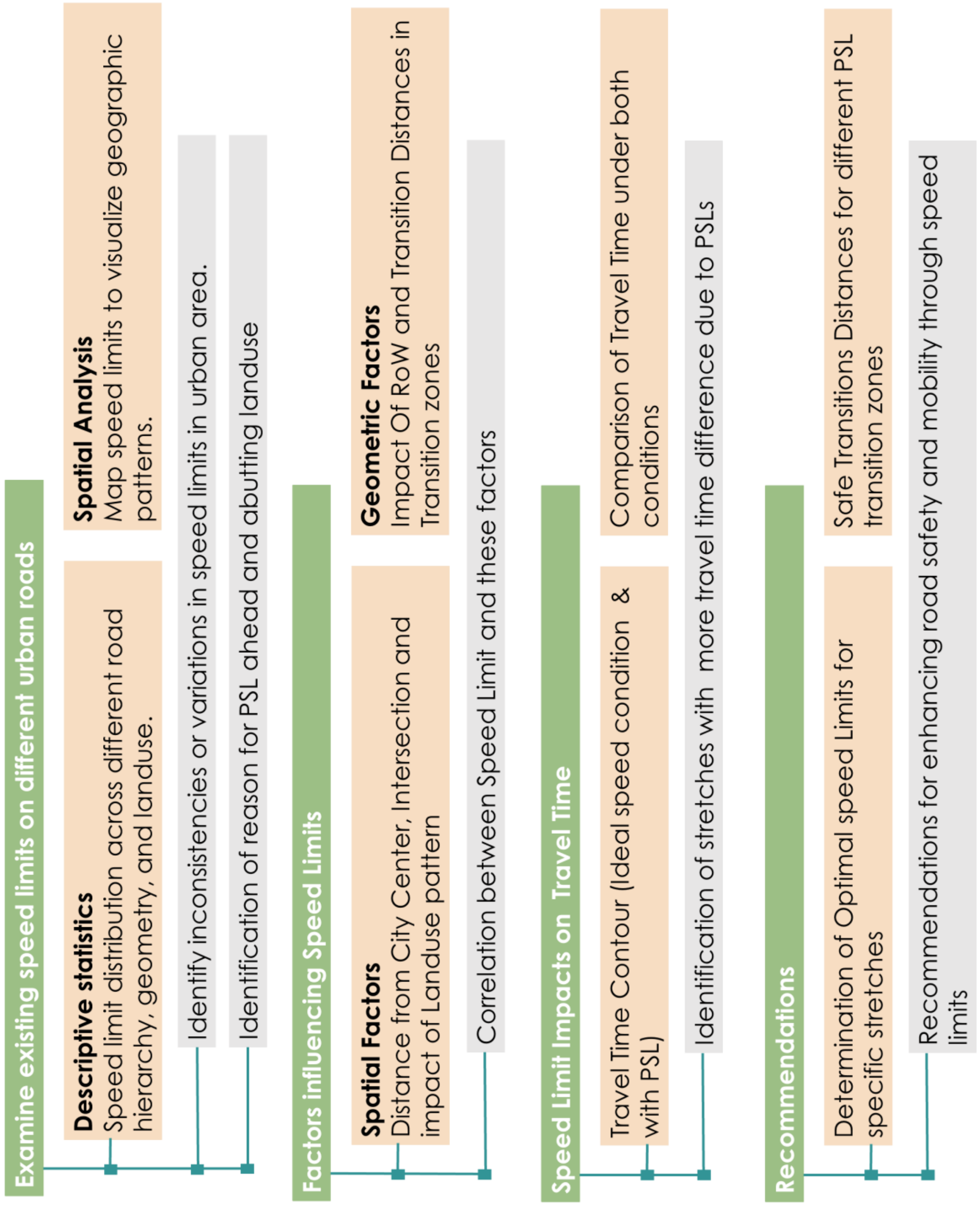


Figure 3: Analysis Methodology for each Objective

The focus is on discerning trends and variations in the implementation of speed limits across diverse zones within urban areas.

Following this, in alignment with the third objective, the impact of PSLs on travel time and delays is assessed. Travel time contours are generated under free-flow conditions and with PSLs on each stretch for all cities. These contours are then compared to identify stretches where significant differences in travel time exist between the two scenarios. By conducting this analysis, the study evaluates how the implementation of PSLs influences travel time and traffic delays along specific road segments.

Finally, based on the analysis findings, the outcomes of the study will be presented along with insightful recommendations for potential adjustments to speed limits.

1.7 Expected Outcomes

The study tried to provide evidence-based suggestions that can enhance road safety while ensuring efficient mobility within urban areas. Firstly, it suggests placing PSLs at suitable and regular intervals along road stretches to effectively inform road users about the permissible speed limit. This approach aims to enhance awareness among drivers and promote compliance with speed regulations, thereby improving overall road safety.

Secondly, the study recommends establishing proper and safe transition zones for speed limits. These transition zones should be designed to facilitate gradual speed adjustments, reducing the need for sudden deceleration. Implementing well-designed transition zones contributes to road user safety by minimizing abrupt changes in driving speed and promoting smoother traffic flow.

By presenting these outcomes and recommendations, stakeholders and policymakers will be equipped with valuable insights to inform decision-making processes related to speed limit regulations and traffic management strategies. This ultimately strives to create safer and more suitable transportation systems that prioritize both safety and efficient mobility for all road users.

1.8 Structure of the Research

This thesis report has been majorly divided into 5 chapters:

Chapter 1: Introduction

This chapter lays out the foundational aspects of the study, including an overview of the research framework and a detailed explanation of the research methodology.

Chapter 2: Literature Review

In this chapter, an extensive review of relevant literature is presented, covering research papers, identification of gaps, and exploration of keywords such as the impact of road characteristics and driver behavior. Additionally, the merits and drawbacks associated with higher and lower speed limits are discussed, drawing upon references from papers. IRC codes and guidelines are also referred to understand the norms for the speed limits.

Chapter 3: Site Selection and Data Collection

This chapter introduces the site for the research with the key parameters for site selection. Additionally, the data identification and the collected data for the research are discussed in this chapter, outlining the methodologies employed.

Chapter 4: Data Analysis

This chapter focuses on the analysis phase of the research, wherein the gathered data is examined with the research questions formulated based on the objectives of the research. Further, the process of each analysis is described along with the involved procedures.

Chapter 5: Findings and Recommendations

In Chapter 5, the findings derived from the analyses conducted in Chapter 4 are presented. Moreover, the chapter offers recommendations aligned with the overarching aims and objectives of the research.

CHAPTER 2: LITERATURE REVIEW

The literature review is broadly categorized into three main parts. The first part focuses on the fundamental concepts related to speed limits, including the process of setting speed limits and the factors that influence them. It also examines the current scenario of speed limits in India, specifically urban areas, considering different road types. The second part of the literature review explores the impact of speed limits on safety and mobility. Mobility aspects are further analyzed by considering vehicle operating speeds and how congestion levels may be affected by speed limits. Safety parameters such as accident rates, severity of accidents, and emergency response readiness are also evaluated concerning different speed limits. Additionally, this section discusses the benefits and losses of higher and lower speed limits on roadways. The third part of the literature review focuses on standards related to speed limits (IRC Codes), covering criteria for placing speed limit signs on various types of roads, determining mutual distances between signs, considering sign repetition, and assessing the influence of intersections on speed limits. This provides a proper understanding of different aspects of speed limit regulations and their implications for better road safety and mobility.

1.1 Speed Limits and its setting

Speed limits are legally defined maximum speeds at which vehicles can travel on roads, typically expressed in km/h or miles per hour (mph). They are established to provide motorists with clear directions to drive at a speed that facilitates the safe and orderly flow of traffic under normal conditions. Speed limits can be influenced by various factors, including the type of nearby development, pedestrian and bicycle activity, roadside conditions, reported collision history, and the 85^{th} percentile speed of traffic (Speed Limits Basics, n.d.). The 85^{th} percentile speed or V85 refers to the speed at which 85 percent of motorists are traveling at or below a given road. Traditionally, speed limits have been established with a dual focus on safety and mobility, aiming to strike an optimal balance between these two considerations. Safety considerations are taken because of high accident rates due to overspeeding and other factors. Conversely, mobility considerations are taken because of travel time, delays, and other impacts like congestion due to speed limits

Speed Limits are majorly categorized into two types, statutory speed limits and Posted Speed limits. Statutory speed limits are the limits that set by state legislatures for particular categories of roads, such as interstate, rural highways, or urban streets, and these limits can differ from one state to another (Speed Limits Basics, n.d.). They are legally binding and enforceable so that drivers must comply with them regardless of whether speed limit signs are posted. These speed limits are established to promote safety and regulate traffic flow on different types of roads across states. In India, these limits are broadly formulated under the guidelines of the Ministry of Road and Transport and established by the local or state transportation authorities within a given region.As per the revision by MoHRT (2018), the maximum speed for the class of motor vehicles is specified in the table.

Table 1: Existing Maximum Statutory Speed limits as per MoRTH

Maximum speed per hour in kilometres on roads in India					
S. No.	**Class of Motor Vehicles**	**Expressway with Access Control**	**4 lane and above divided carriageway (roads with Median strips/Dividers)**	**Road within Municipal Limits**	**Other Roads**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
1.	Motor vehicles used for carriage of passengers comprising not more than eight seats in addition to the driver's seat (M1 category vehicles)	120	100	70	70
2.	Motor vehicles used for carriage of passengers comprising nine or more seats in addition to the driver's seat (M2 and M3 category Vehicles)	100	90	60	60
3.	More vehicles used for carriage of goods (All N category Vehicles)	80	80	60	60
4.	Motor Cycles	80*	80	60	60
5.	Quadricycle	-	60	50	50
6.	Three wheeled vehicles	-	50	50	50
* If permitted to ply on Expressway.					

Source: Ministry of Road Transport Authority and Highways

The above table shows that the maximum permissible statutory speed limit for expressways is 120 km/h and 100km/h for National highways. It is noted that this provided limit is not imposed forcefully on any roads, rather traffic studies are conducted and road characteristics are taken into consideration for actual speed limit regulation for that specific road stretch i.e. Statutory speed limits are broadly set for the country or state but the final speed limit is decided based on actual road conditions. In urban areas, the speed limit is typically 70 km/hr within municipal limits and for all types of roads. However, the speed limit may be higher for roads that fall into higher hierarchies within the urban area. Roads are further categorized within urban limits based on their hierarchy, including arterial, sub-arterial, collector, and local roads, arranged from higher to lower classifications. Each category has its own designated speed limit based on the road's function and importance within the urban road network.

Another type of speed limit is the Posted Speed Limit (PSL) which is displayed on road signs and is legally enforceable. PSLs are placed along the road either on the shoulder side or at the median, sometimes these are placed overhear and on the lane as lane marking. These limits can either match the statutory speed set by the state legislature or be established by a city, county, or state transportation agency as an adjustment to the statutory speed limit (Speed Limits Basics, n.d.). These limits may differ from statutory speeds but are always under the umbrella, these are never exceeded them. When the posted speed limit differs from the statutory speed limit, the posted speed limit takes precedence and is determined through an engineering speed study. This study assesses factors like road conditions and traffic patterns to ensure safe and appropriate speed limits for specific road segments.

1.1.1 Setting of Speed Limits

Speed limits are determined through a process that combines traffic studies, road characteristics, and legal considerations. The process typically begins with an engineering study, where the operating speeds of vehicles on a specific road are measured by identifying the speed at which 85% of vehicles travel, known as the 85th percentile speed (Pdxscholar et al., 2020). This speed serves as a baseline for setting the speed limit, reflecting the behavior of most drivers under normal conditions. This study also considers various roadway characteristics, including the number of lanes, the presence of curves, hills, intersections, and surrounding development (John Lu et al., 2003). These factors help assess the safe speed at which vehicles can travel on the road. Crash and injury rates on the road are also considered; if rates are higher than expected, the speed limit may be reduced to enhance safety (Schaefer, n.d.). Following the engineering study, the recommended speed limit undergoes review by legal authorities such as state legislatures or local governments. These authorities finalize the speed limit, considering factors like overall traffic flow and community needs. Once approved, the speed limit is posted along the road using traffic signs and becomes legally enforceable, and applicable. Once posted, then for regulations, various enforcement practices are done like traffic police marshal, CCTV surveillance, and overspeeding Challan to ensure the safety and efficient mobility on roads.

1.1.2 Factors Affecting Speed Limits

Various factors contribute to the determination of speed limits on roads. These factors encompass a range of considerations that influence the safe and efficient operation of vehicles. Firstly, the design speed of a road is critical, representing the intended speed at which the road can be safely navigated based on its geometric alignment, surface condition, and overall design features. Complementing this is the posted speed limit, which establishes the legal maximum speed for vehicles on a given road section and is indicated by traffic signs. Traffic characteristics also play a pivotal role in speed limit decisions. This includes analyzing the 85th percentile speed, which reflects the speed at or below which 85% of vehicles typically travel, as well as assessing speed variance among vehicles sharing the road. Furthermore, the geometric alignment of the highway, encompassing factors like curves, hills, and intersections, is instrumental in determining the appropriate speed limit to ensure driver safety. Moreover, traffic volume is a critical consideration, as higher volumes can impact vehicle speeds and influence accident risks. Evaluating the accident history of a road segment provides insights into safety performance and informs potential adjustments to speed limits or other traffic control measures. Additionally, the presence of pedestrians and bicyclists near the road necessitates lower speed limits to enhance safety for vulnerable road users.

Environmental impacts, such as noise, vibration, and emissions associated with vehicle speed, are increasingly considered in speed limit decisions to mitigate adverse effects. Community needs and preferences also contribute to the speed limit-setting process, incorporating local safety concerns and requests for speed adjustments. Lastly, adherence to legal requirements and regulations governing speed limits ensures the appropriate procedures are followed following jurisdictional laws and standards. These factors collectively inform the comprehensive process of determining speed limits to promote safe and efficient traffic flow on roadways.

1.2 Impact of Speed Limits

When speed limits are adjusted on different types of roadways, there are both positive and negative impacts on safety and mobility. Firstly, the safety aspect is carefully evaluated, which includes assessing how reducing or increasing speed limits affects accidents and fatalities. This involves considering the impact of speed changes on road safety, such as whether lowering speed limits reduces accidents or if higher limits lead to more fatalities.

1.2.1 Safety

Numerous studies have explored the effects of different speed limits on safety, focusing on two key aspects. The first aspect is the impact of speed limits on accidents and road safety. Researchers analyze how varying speed limits influence the frequency and severity of accidents on different types of roadways (Gonzalo-Orden et al., 2021). The second aspect is driver compliance with speed limits. Studies examine how drivers adhere to and comply with different speed limits across various road conditions and environments. Higher speeds take longer time for a vehicle to come to a stop. This means that drivers need more distance to stop safely. Higher speeds result in longer reaction times, making it harder for drivers to respond quickly to unexpected events. Driving at higher speeds also increases the risk of skidding when turning or going around curves. Another important factor is kinetic energy, which increases with speed (Wilmot & Khanal, 1999). This means that vehicles traveling faster have more energy associated with their movement, which can lead to more severe consequences in case of accidents. Whereas reduced speed limits can significantly improve safety in urban areas, leading to a large positive impact and also have a relatively minor effect on average journey times for individuals (Archer et al., 2008). One study by Silvano & Bang, (2016) showed that reducing the posted speed limit (PSL) from 50 to 40 km/h decreases the mean speed level by 1.57 km/h, representing a reduction of 4% in speed. This speed reduction is associated with an 11%

decrease in accidents. Whereas increasing the PSL from 50 to 60 km/h raises the mean free flow speed by 2.59 km/h. However, this increase in speed is correlated with a 14% increase in accidents. There is another study that reviewed altered speed limits and assessed changes in accident rates before and after interventions and found that for every 1 km/hr change in mean speed, there was approximately a 3% change in accident risk (Archer et al., 2008). This suggests a direct relationship between speed changes and the likelihood of accidents occurring.

Another factor is the impact of speed limits on driver's behavior. According to many traffic engineers, most drivers tend to drive at a speed that feels comfortable and safe, regardless of the posted speed limit (Pline et al., 1992). If this perspective is accurate, raising the speed limit may not significantly impact the driving speeds of most people. Instead, it could mainly influence the behavior of the minority of drivers who adhere strictly to the speed limit, creating speed variance that leads to accident severity (Ossiander & Cummings, 2002). One of the studies (Yannis et al., 2013) showed that exceeding speed limits is common because of inappropriate or unreasonable speed limits and this was found to be significant primarily on urban roads.

1.2.2 Mobility

The influence of speed limits on transportation efficiency is influenced by various factors such as road type, traffic volume, and driver behavior. Studies have revealed that speed limits can impact both mobility and safety, particularly in uncongested traffic scenarios. A reduction in the citywide speed limit from 30 mph to 25 mph led to a decrease in overall speeding and significantly reduced instances of excessive speeding (Tarko et al., 2019). Similarly, in Toronto, measurable safety improvements were observed after lowering speed limits from 40 km/h (~25 mph) to 30 km/h (~20 mph) on several local streets (Tarko et al., 2019). However, the effect of speed limits on mobility can vary based on road type and traffic conditions. Driver behavior also plays a role in how speed limits influence mobility. Research indicates that drivers tend to drive more cautiously on rural interstates with varying speed limits, while drivers on urban roadways may exhibit more aggressive lane-changing behaviors to maintain their desired speeds (Tarko et al., 2019). Some Research has shown that when speed limits are adjusted within a range of 15 mph (24 kph) above or 20 mph (32 kph) below the initial limit, the average speed changes by less than 4 mph (6.4 kph) (Wilmot & Khanal, 1999). Similarly, the 85th percentile speed, which represents the speed at or below which 85% of motorists travel, changes by less than 2 mph (3.2 kph) within this range of speed limit adjustments (Wilmot & Khanal, 1999). This shows that the speed changes when speed limits are altered.

Speed limits can affect travel time, although their impact varies depending on the situation. In Outer regions of urban areas, higher speed limits can save time over long distances, but these time savings are often small. Increasing the speed limit from 100 km/h to 110 km/h could save about 5.5 minutes when traveling 100 km, assuming no delays occur because 5.5 min is very small as compared to the whole travel time [1]. However, in urban core areas with frequent stops and starts, higher speed limits generally don't lead to significant time savings, especially for short trips [1]. In congested traffic, the impact of speed limits on travel time is limited. Factors like traffic signals, congestion, parked vehicles, and turning vehicles play a bigger role in determining travel time than speed limits. Studies have shown that speed limits have little effect on travel time in congested conditions (Tarko et al., 2019). Lower travel speeds can sometimes reduce travel times by preventing flow breakdown. Flow breakdown happens when traffic volumes approach the road's capacity, causing disruptions in the steady flow of vehicles [1]. Erratic driving behaviors like sudden lane changes or braking can lead to stop-and-go traffic, which affects overall travel times.

1.3 Codes and Guidelines

To ensure consistency and uniformity, road signs must be placed and maintained according to specific guidelines. These signs should be positioned at the start of any road section or near structures where there are restrictions or prohibitions, facing incoming traffic. Additionally, at intersections where there are no restrictions, extra signs should be placed within the restricted area to inform drivers of the rules. When it comes to speed limits, repeat signs may also be installed at appropriate intervals if needed. To provide clear guidance to drivers approaching a junction, a speed limit sign should be positioned 25 meters away from the intersection, reassuring them about the speed limit on the upcoming road (IRC Code: 067, 2012). This systematic approach helps ensure road safety and compliance with traffic regulations. The table below shows the speed-wise distance between two consecutive PSLs:

Table 2: Maximum Distance between consecutive Speed Limit Sign Boards

Speed Limit (kmph)	Maximum Distance (m) between		
	Consecutive Signs on alternate sides of the carriageway	Consecutive Signs on the same sides of the carriageway	Terminal Sign & First Repeater
Below 40	200	300	200
50	250	400	200
60	350	500	250
80	900	700	350

Source: IRC Code: 067-2018

It's important to avoid abrupt changes in posted speeds on a road stretch. Instead, changes should be implemented gradually, increasing or decreasing speeds in increments of 10 kmph at a time (IRC Code: 067, 2012). This approach helps to ensure smoother transitions for drivers and enhances road safety. By making changes gradually, drivers have more time to adjust to the new speed limits, reducing the likelihood of confusion or sudden braking. Gradual changes minimize disruptions to traffic flow and contribute to a more predictable driving environment.

Another important consideration in determining the placement of posted speed limits (PSLs) is the stopping distances required at different speeds. These stopping distances vary depending on the speed of the vehicle.

Table 3: Safe Stopping Distance for Different Speed Limits

S.No.	Speed (km/h)	Safe Stopping Distance (m)
1	20	20
2	30	30
3	40	45
4	50	60
5	60	80
6	70	105
7	80	120

Source: IRC Code: 86, 2018

For instance, at higher speeds, it takes longer for a vehicle to come to a complete stop compared to lower speeds. Therefore, when deciding where to place PSLs, it's essential to consider the distance required for a vehicle to stop safely in response to the posted speed limit (IRC Code: 86, 2018). By considering stopping distances, authorities can ensure that PSLs are positioned appropriately to allow drivers enough time to react and safely slow down when necessary. This factor also plays a crucial role in promoting road safety and preventing accidents by providing drivers with adequate warning to adjust their speed accordingly.

To ensure driver safety and awareness, it's recommended to install transition speed limit signs at a distance of 500 to 750 meters before significant changes in speed limits along highways (IRC Code: 86, 2018). These signs should be repeated as necessary and accompanied by other warning signs. Additionally, warning signs should be placed along highways to alert drivers of upcoming cross traffic and changes in speed limit to 30 km/hr. In highway corridors, speed limit signs of 40 km/h should be provided, with transition speed limits of 70 or 60 km/h (IRC Code: 99, 2018).

Other warning and informative signs should also be installed as needed. At railroad intersections on highways, drivers should reduce their speed to 50 kmph 250 meters before reaching the railroad intersection. Similarly, on arterial and sub-arterial roads, vehicle speeds should be decreased to 30 kmph from a distance of 100 meters before intersections with roads of the same hierarchy (IRC Code: 99, 2018). These measures help promote safer driving conditions and prevent accidents on the roads.

CHAPTER 3: SITE AREA & DATA COLLECTION

This chapter comprises site selection and the process involved in it by identifying the various parameters considered during the site selection phase. It also discusses the rationale behind choosing specific cities and outlines the factors considered during this decision-making process.

Furthermore, it provides a comprehensive exploration of the data identification process, detailing the methods used to identify and gather relevant data essential for the research. The chapter also discusses the data collection methodology in-depth, highlighting the specific types of data collected and the procedures employed to ensure comprehensive information gathering. Overall, it systematically describes the steps undertaken to gather crucial information needed to fulfill the research's objectives effectively.

3.1 Site Selection

The site selection process was conducted according to the core theme of the research: "Comparative Analysis of Speed Limits on Urban Roads: Balancing Safety and Mobility". The objective was to ensure a comprehensive comparison by carefully selecting four cities that could provide meaningful insights into the identified factors, ultimately leading to valuable and applicable recommendations for cities with similar characteristics. The selection of these cities was based on fundamental parameters of safety and mobility. The chosen cities were evaluated to represent a diverse range of urban contexts, considering variables such as land use, road infrastructure, road hierarchy, and existing speed limit regulations. The fundamental parameters considered for selection were safety and mobility, and are outlined as follows:

3.1.1 Safety Criterion

The primary criterion for city selection was safety. Cities with varying safety records and approaches to road safety interventions were chosen to highlight effective strategies and challenges. To ensure a comprehensive analysis, accident rankings for the top 50 million-plus cities were derived from the Ministry of Road Transport and Highways (MoRTH) 2022 Accident Report. Two cities were selected from the top, and two from the midway rankings to capture a diverse range of accident rates. This approach aims to facilitate a nuanced examination of how speed limits impact safety outcomes.

Various factors that contribute to road accidents were taken into consideration during the examination process. This included analyzing the accident rates, identifying the types of accidents such as pedestrian-related incidents or collisions, and determining the reasons behind the accidents including overspeeding, drunk driving, and road geometrical issues.

3.1.2 Mobility Criterion

To gain a better understanding of speed limits on urban roads, the focus was on higher hierarchy roads, specifically Arterial and Sub-arterial roads, and Ring roads, in the selected cities. By examining these variables across multiple cities, the research aimed to identify best practices and solutions for optimizing mobility without compromising safety.

3.1.3 Geographical Spread:

The four chosen cities are strategically located in different regions of India. This deliberate selection ensures that the study considers potential geographical influences on speed limits, traffic patterns, and road safety. These fundamental parameters ensured that the selected cities would provide valuable insights into the relationship between speed limits, safety, and mobility in urban settings. This strategic approach to site selection enhances the credibility and applicability of the research outcomes.

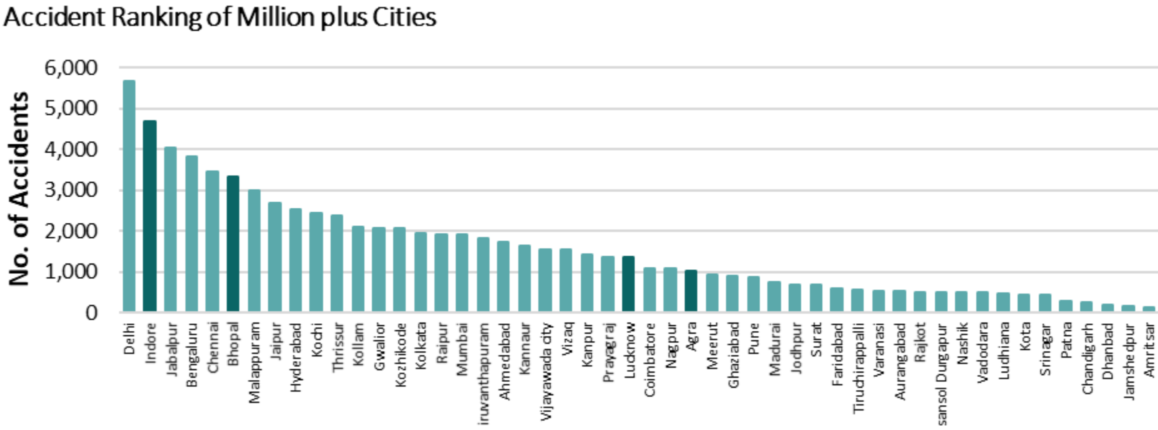


Figure 4: Accident Ranking of top 50 million plus cities in 2022
Source: Accident Report 2022 (MoRTH)

Study Area

The cities selected for the research sites are Indore, Bhopal, Agra, and Lucknow. Their selection is based on their rankings in a list of the top one million plus 50 cities. Indore and Bhopal are ranked 2nd and 6th, respectively, indicating a higher incidence of traffic accidents. Meanwhile, Lucknow and Agra hold rankings of 25th and 28th, positioning them in the middle range with comparatively lower accident rates. This selection facilitates a comprehensive examination of how speed limits can significantly impact safety in urban areas with varying levels of traffic accidents. Below is a table summarizing the key characteristics of the chosen cities:

Table 4: Comparison of cities for site study

S.No.	City	Area (Sq.km)	Population (2011)	Road Length (km)	Surveyed Road Length (km)
1	Agra	121	1585704	610.16	109.2
2	Lucknow	631	2902920	1468.77	213.2
3	Bhopal	463	1886100	894.64	225.8
4	Indore	530	2167447	585.13	177.3

Source: DPRs, Census 2011, Open Street Map

In Agra, covering an area of 121 km² with a population of 1,585,704 according to the 2011 Census, the total road length is 610.16 km, primarily comprising higher hierarchy roads excluding local residential streets. Out of this total road length, 109.2 km has been surveyed, consisting mainly of arterial and sub-arterial roads within the city's planning boundary.

In Lucknow, the total surveyed road length amounts to 213.2 km out of a total road network spanning 1468.7 km. Lucknow has the largest area within the planning boundary compared to the other three cities. Its road network includes arterial, sub-arterial, and ring roads, making it an ideal location to study how speed limits impact safety in urban environments with significant traffic challenges. This strategic selection of cities enables a detailed exploration of how speed regulations can play a critical role in enhancing safety within densely populated urban areas prone to frequent traffic accidents. The differences in city characteristics and road infrastructure will provide valuable insights into effective speed limit strategies that can be applied to improve road safety and mobility in similar urban settings.

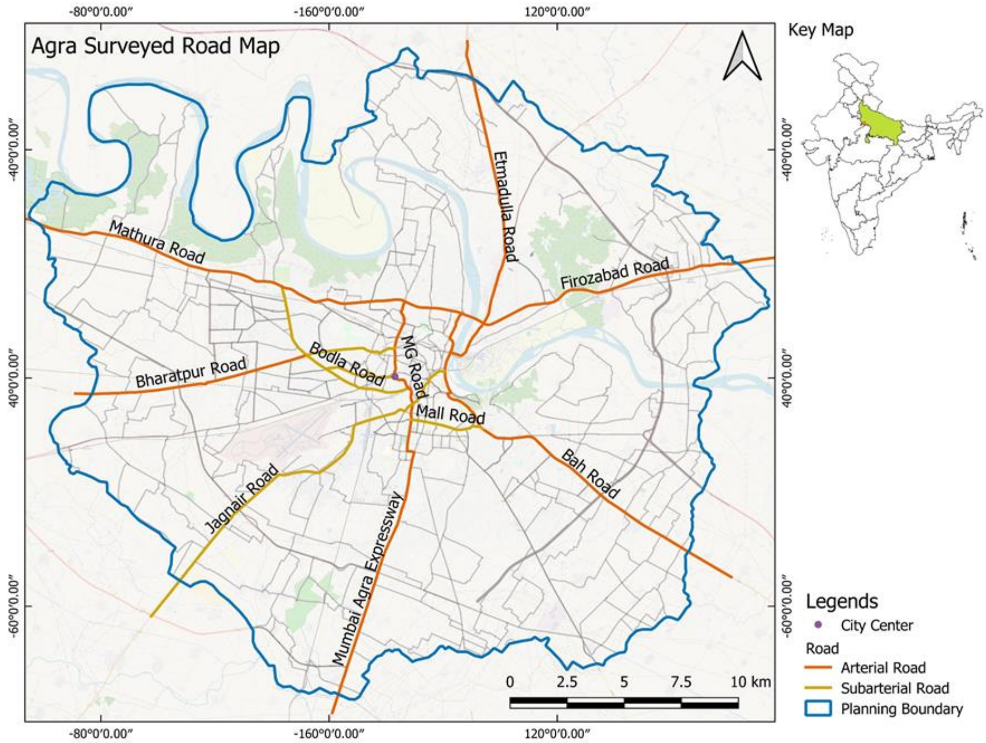


Figure 4: Surveyed Road Map of Agra
Source: Author Generated

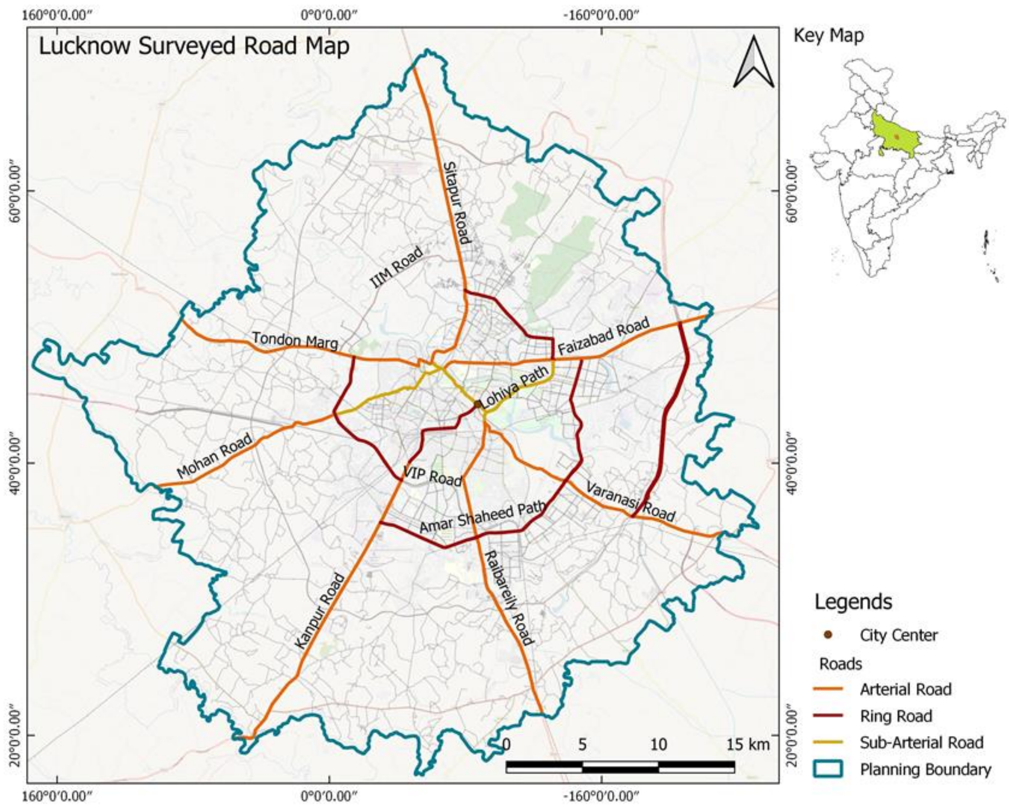


Figure 5: Surveyed road map of Lucknow
Source: Author Generated

On the other hand, Bhopal and Indore are representative of cities facing higher accident rates. Bhopal spans an area of 463 km² within its planning boundary and has a population of 1,886,100. The city has a total road length of 894.6 km, excluding local residential streets, with 225.8 km of these roads surveyed for the research. These surveyed roads include arterial, sub-arterial, and ring roads within the planning boundary.

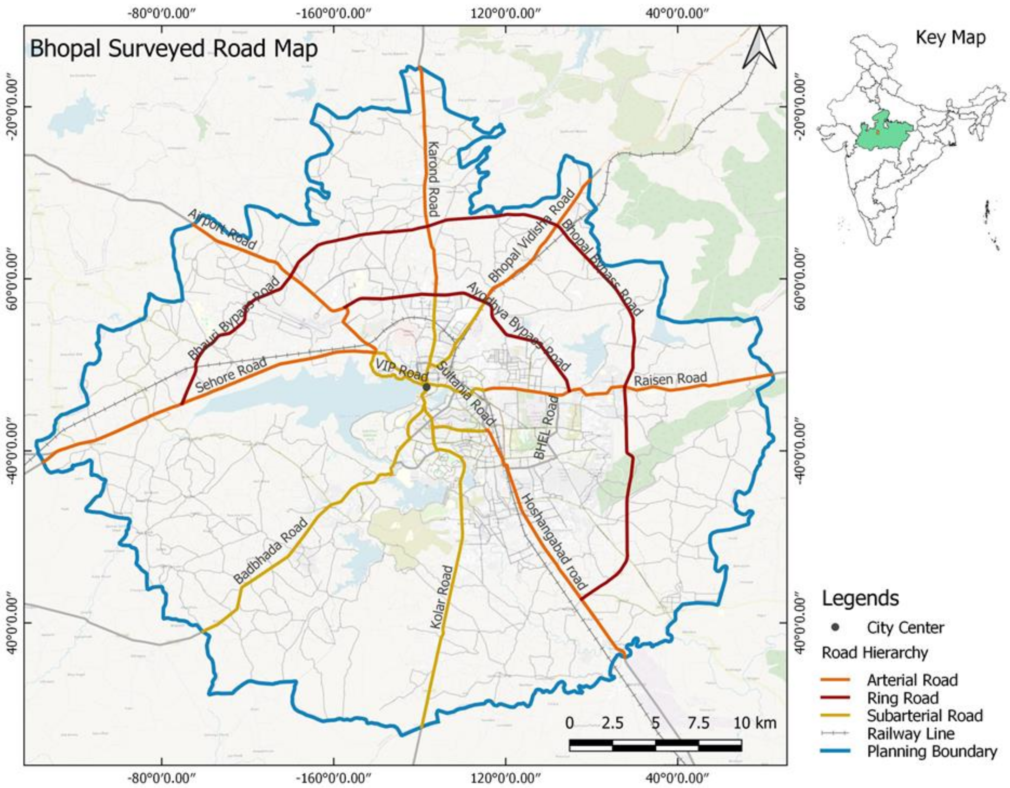


Figure 6: Surveyed Road Map of Bhopal
Source: Author Generated

Similarly, Indore covers an area of 530 km² within its planning boundary and has a population of 2,167,447. The city has a total road length of 585.13 km (excluding local roads), with 177.3 km of these roads surveyed for the research. Examining these cities provides information on how speed limits can be strategically optimized in contexts with a higher number of accidents. By analyzing cities with varying accident rates and road infrastructures, a nuanced understanding of effective speed limit policies and their impact on urban road safety can be gained.

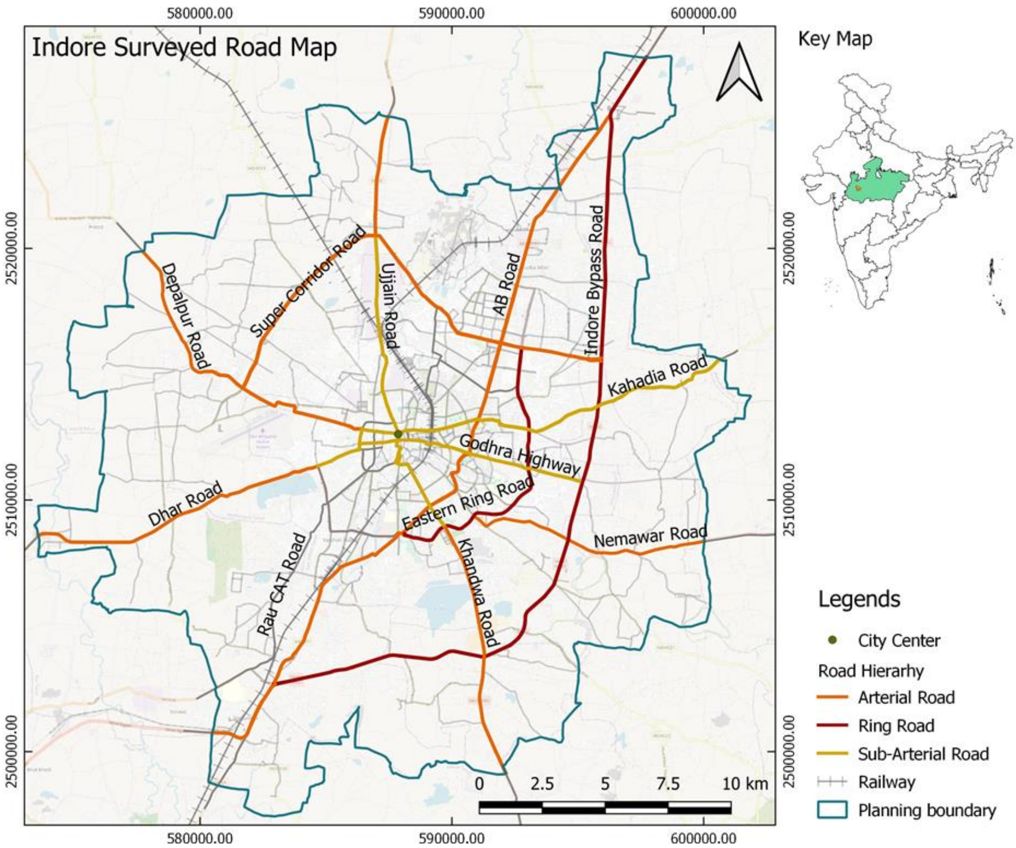


Figure 7: Surveyed Road Map of Agra
Source: Author Generated

The selection of cities with diverse accident rates, geographical locations, and population sizes is deemed integral to the study's overarching goal of conducting a comprehensive analysis. It focuses on how speed limits can impact safety and mobility concerns in Indian urban environments. By including cities with varying accident rates, ranging from high to moderate, the study aims to explore the impact of speed limits on road safety outcomes across different contexts. Geographical diversity is ensured by considering regional factors such as urban layout, which can influence traffic patterns and safety measures. Additionally, cities with different population sizes are considered to gain insights into how urban density and traffic volume interact with speed regulations.

Through this approach, evidence-based recommendations for optimizing speed limits to enhance safety without compromising mobility in Indian cities are sought to be provided by the study. By analyzing a range of urban environments, the research outcomes are expected to be more comprehensive and applicable. The outcomes lead to informed policy and planning decisions aimed at improving road safety and overall quality of life in urban areas across India.

3.2 Data Collection & Process

This section of the research outlines the data collection process and the specific data collected for this study.

3.2.1 Hierarchy-wise Posted Speed Limit (PSL)

- **PSL Location, Direction, Signage Type, and Reason for PSL:** The data is collected through field observations, encompassing the location of speed limit signs, the direction to which they apply, the type of signage employed (e.g., static signs, variable message signs), and the specific rationales for implementing the speed limit (e.g., proximity to a junction, alignment along a horizontal curve, or due to ongoing construction activities).
- **Continuity and Their Mutual Relatedness:** The PSL data is spatially collected to comprehend the continuity and transitions in posted speed limits along roads and within road networks. This entails identifying patterns such as abrupt speed limit changes or sections of roads exhibiting frequent alterations in speed limits.

3.2.2 Road Inventory w.r.t. Posted Speed Limit (PSL)

- **Carriageway, No. of Lanes, Geometry, Median availability:** This data is obtained through primary surveys and field measurements. It includes recording the number of lanes, lane widths, presence of a median, and any other pertinent geometric characteristics of the road.
- **Abutting Landuse and Road Characteristics:** This data is also gathered through field observation, capturing the type of land use adjacent to the road (e.g., residential, commercial, industrial), along with any other pertinent characteristics of the road environment (e.g., presence of sidewalks, lighting, traffic signals).

3.2.3 Speed Data

- **Vehicle observed speed and travel time:**
- Speed data is collected using secondary sources such as Google Traffic. Observations are conducted during both peak and non-peak traffic periods to

distinguish between free-flowing speeds and speeds observed during congested conditions. This data aids in comprehending how speed fluctuates under diverse traffic conditions.

- **PSL Data to Corresponding Road Segments:** Speed limit data is recorded and linked to specific road segments where the speed limit applies. This enables an analysis of observed speeds relative to posted speed limits on each segment of the road, offering insights into compliance and potential safety implications.

PSL inventory and corresponding road inventory are attached in Annexures. By systematically collecting and analyzing these data, correlations between posted speed limits, road characteristics, and actual vehicle speeds were sought to be established by the research. This data also contributed to a comprehensive understanding of how speed limits influence traffic flow, delay, and overall road safety and mobility in urban areas.

CHAPTER 4: DATA ANALYSIS

This chapter delves into the data analysis process and examines various parameters analyzed with PSLs for each selected city. Subsequently, the data from each city is aggregated to compare these parameters across all selected cities. To begin, data decoding for each parameter is carried out using primary and secondary sources, as well as Geographic Information System (GIS) applications.

4.1 Parameters for Analysis

The parameters considered for the data decoding process include:

4.1.1 PSL Location

During the primary survey, the precise locations of PSLs were observed and recorded. Subsequently, these locations were inputted into GIS to discern spatial patterns. By mapping these distinct PSL locations, the running length for each PSL was calculated across different hierarchies of roads. The utilization of GIS aids in visualizing and analyzing the distribution and arrangement of PSLs along road networks within each city. This spatial analysis offers insights into how speed limits are positioned and organized across different road types and areas. Furthermore, the running length associated with each PSL facilitates understanding the coverage and effectiveness of speed limits.

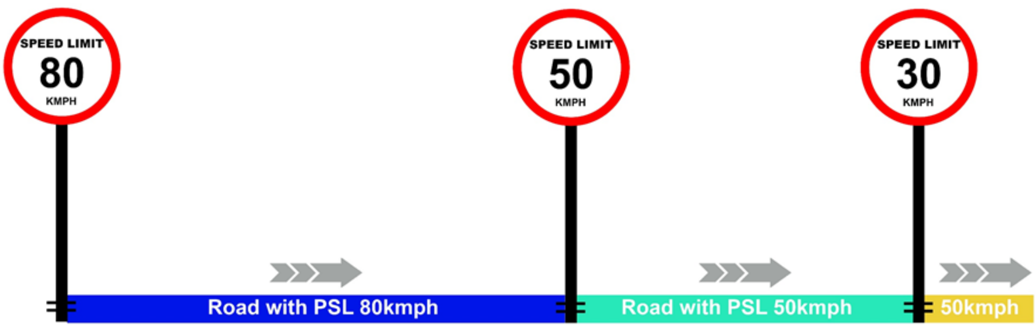


Figure 8: Illustration showing PSL Locations
Source: Author generated

4.1.2 Distance from City Center

In this process, the city center is identified within each city, and using the exact location data of each PSL in GIS, the distance of each PSL from the city center is calculated. This involves the pinpointing of the geographic center or central business district (CBD) of each city, which serves as a reference point for measuring distances to PSL locations. With GIS, precise spatial measurements are obtained to quantify the proximity of PSLs to the city center. This distance analysis provides an understanding of the spatial distribution of speed limits relative to urban cores and peri-urban areas, highlighting variations in speed limit placement across different city contexts.

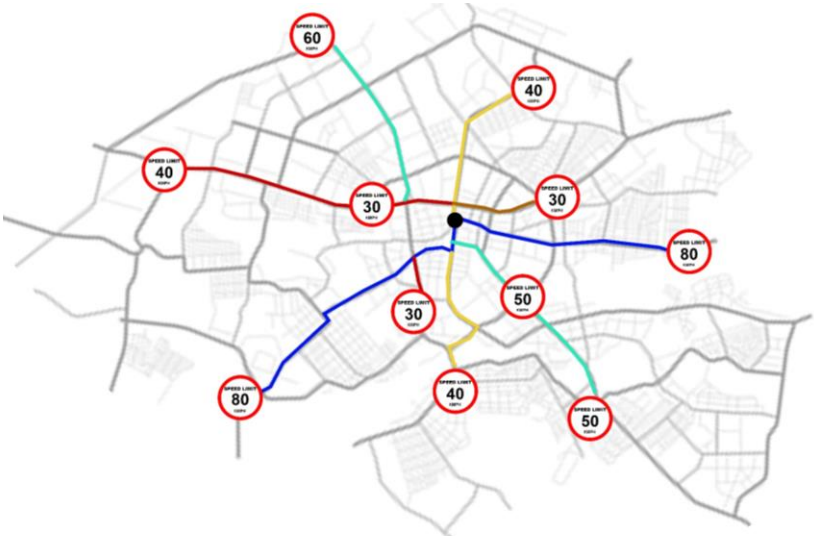


Figure 9: Illustration of PSL location from city center
Source: Author Generated

4.1.3 Proximity to Intersections

To analyze this parameter, the upstream distance from each PSL towards the nearest upstream intersection is determined using GIS. This process involves the identification and measurement of the distance from each PSL location to the closest intersection located upstream along the road network. This helps in examining the relationship between the placement of higher and lower PSLs and their proximity to intersections ahead along the road corridors.

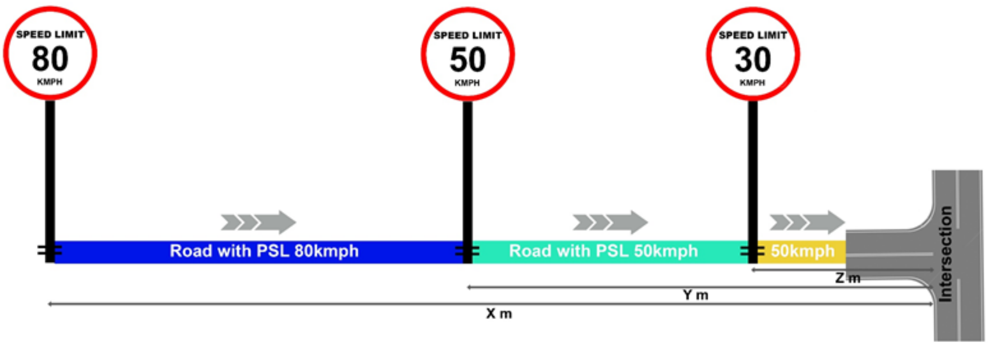


Figure 10: Illustration of Proximity of PSL to Intersection
Source: Author generated

To conduct data analysis for the research and successfully achieve all the objectives, specific research questions are formulated that align with the research's objectives. The research questions are as follows:

4.2 Research Question 1- Existing PSLs

What are the variations in speed limits on urban roads?

The distinctive approach to regulating speeds in each city is examined by analyzing the existing speed limits in the selected cities. The existing condition of speed limits in each city is individually analyzed.

4.2.1 Agra

Delving into the situation in Agra, a comprehensive assessment was conducted along 109.2 km of roadways, representing approximately 18% of Agra's entire road network, excluding residential streets.

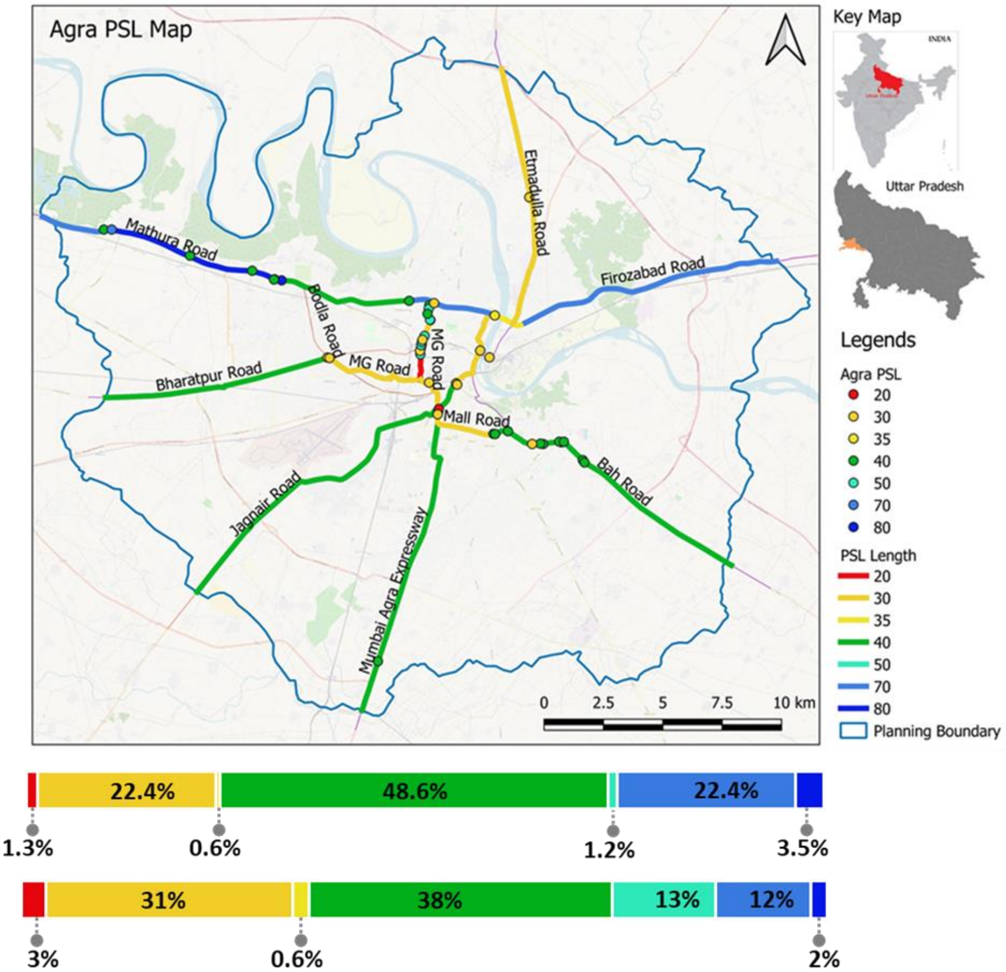


Figure 11: PSL map of Agra with %age of PSL boards and PSL Running Length
Source: Primary Survey, Author Generated

Within the surveyed stretch, the roads were further classified: a significant 66% were categorized as arterial roads, vital for the city's transportation flow, while the remaining 34% fell under the classification of sub-arterial roads, playing a crucial role in connecting different parts of the city. During the inventory survey for the posted speed limit (PSL) signs, it was observed that out of the total length of roads surveyed, only 68 PSL boards were present. This translates to an average of 3 PSL boards per 10 km for both arterial and sub-arterial roads.

From the data visualized in the graph, it's evident that PSL values of 20, 35, and 80 are the least frequent, while 40 and 30 are the most common. Additionally, the analysis includes calculating the running PSL length, highlighting that 40 has the longest continuous stretch, whereas 20 has the shortest. The lengths for 30 and 70 are relatively similar. When analyzing the distribution of PSL boards per km, it's noted that 30 has the highest density of PSL boards on its running length. Conversely, 40 and 70 exhibits lesser PSL boards than their running lengths.

1. PSL Reason and Abutting Landuse

When examining each PSL individually based on their location and reason ahead, it became apparent that PSLs 30 and 40 are primarily placed to indicate upcoming junctions. Conversely, higher PSLs such as 50, 70, and 80 are strategically positioned along stretches of road where visibility is clear and traffic flow is unobstructed. These signs serve a vital role in communicating the maximum permissible speed limit to drivers, enhancing road safety and compliance.

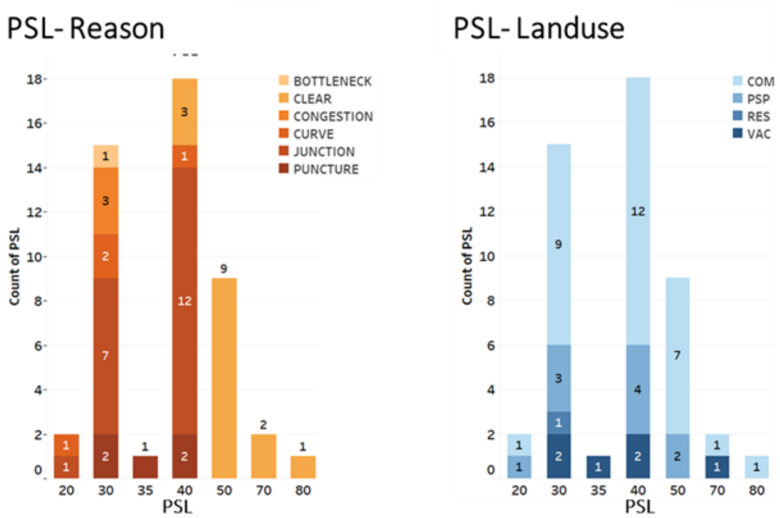


Figure 12: No. of PSL boards as per PSL Reason and Landuse in Agra
Source: Primary Survey, Author Generated

Fewer PSLs are installed for reasons such as bottlenecks, congestion, curves, and roadside hazards. Moreover, a comprehensive analysis of PSL distribution based on abutting land use reveals that the majority of PSLs are predominantly clustered around commercial zones, where traffic density tends to be higher and adherence to speed limits is crucial for pedestrian safety and efficient traffic management. Residential areas exhibit a lower density of PSLs, focusing on pedestrian and local road users' safety within such regions. Additionally, areas characterized by higher speed limits often coincide with vacant or undeveloped land.

2. Average Spacing

From the analysis, it is observed that the average distance between PSLs of 40 and 50 km/h typically ranges from 500 to 1000 meters. There are also some stretches where transitioning from a 50 km/h zone to a 30 km/h zone has a distance of 150 to 200 meters before encountering another sign indicating the reduced speed. Then, within around 50 meters, there is a junction. On highways where PSLs were set higher, like at 70 or 80 km/h, the average distance between consecutive signs is more than 2 km.

4.2.2 Lucknow

In Lucknow, a thorough examination was conducted on 213.2 km of roadways, representing about 14.5% of Lucknow's total road network, excluding residential streets. It was noted that a significant portion, approximately 61.6%, consisted of arterial roads, which serve as the main arteries of the city's transportation system, ensuring smooth traffic flow. It was observed that these arterial roads had an average of 3 PSLs per 10 km, contributing to safe driving conditions. Moreover, sub-arterial roads, comprising around 9.4% of the surveyed network connecting different parts of Lucknow, were found to have a higher density of PSLs, with an average of 6 signs per 10 km, emphasizing the importance of driver awareness and safety on these connecting routes. Additionally, the ring roads, making up approximately 29% of the surveyed area, served as vital conduits for circumferential travel around the city. Along these routes, an average of 4 PSLs per 10 km were observed, striking a balance between efficient traffic flow and the need to ensure compliance with speed limits for enhanced safety.

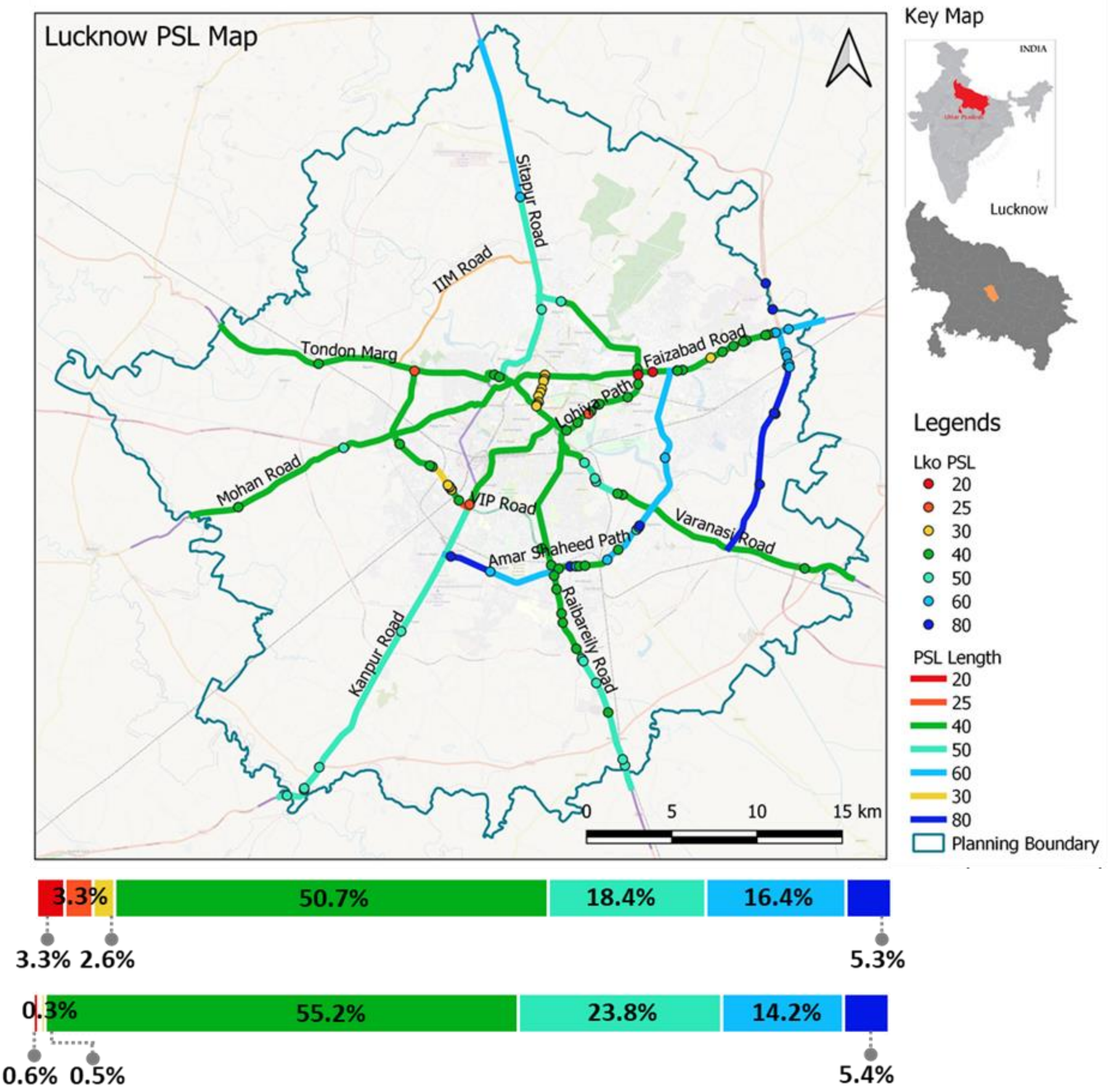


Figure 13: PSL map of Lucknow with %age of PSL boards and PSL running length
Source: Primary Survey, Author Generated

From the data depicted in the graph, it is observed that PSL values of 20, 30, and 80 are the least frequent, while 40 is the most common. Additionally, the analysis includes calculating the running PSL length, highlighting that 40 has the longest continuous stretch (55.2%), whereas 20 has the shortest (0.3%) of the total running length. The lengths for 50 and 60 have moderate lengths, accounting for 23.8% and 14.2%, respectively.

When analyzing the distribution of PSL boards per km, it is noted that lower PSLs 20, 30, and 35 have a greater number of PSL boards compared to their running length. Conversely, 40, 50, 60, and 80 exhibit PSL boards proportional to their running lengths.

1. PSL Reason and Abutting Landuse

When examining each PSL individually based on their location ahead, it becomes apparent that higher PSLs such as 50, 60, and 80 are strategically positioned along stretches of road where visibility is clear and traffic flow is unobstructed. These signs serve a vital role in communicating the maximum permissible speed limit to drivers, enhancing road safety and compliance. All other PSLs, including 20, 30, 35, and 40, are primarily installed to indicate upcoming junctions, bottlenecks, congestion, curves, and roadside hazards.

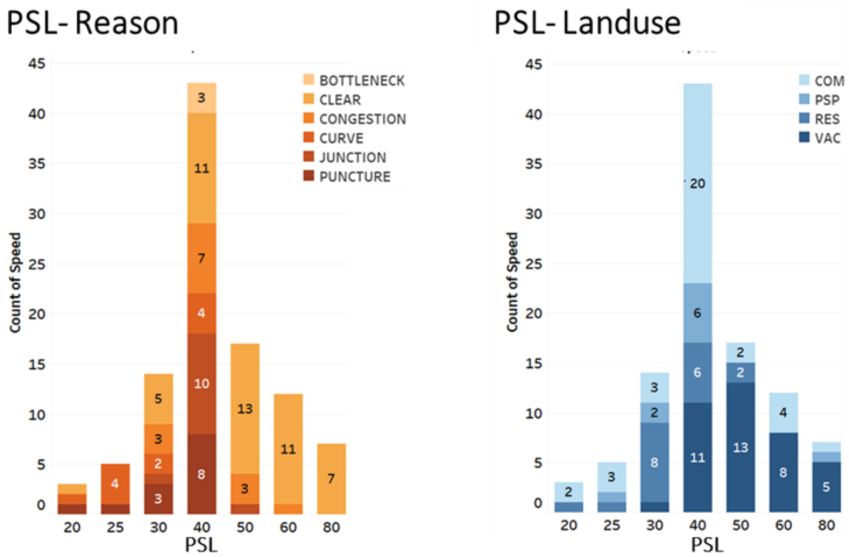


Figure 14: No. of PSL boards as per PSL Reason and Landuse in Lucknow
Source: Primary Survey, Author Generated

On analysis of PSL distribution based on abutting land use, it is observed that the majority of PSLs are predominantly clustered around commercial zones, where traffic density tends to be higher and adherence to speed limits is crucial for pedestrian safety and efficient traffic management. Additionally, areas characterized by higher speed limits often coincide with vacant or undeveloped land.

2. Average Spacing

From the analysis conducted in Lucknow, it's observed that the average distance between PSLs set at 30 km/h is typically between 200 to 500 meters. For PSLs where the same signage is repeated at 40 km/h, the average distance ranges from 500 to 1000 meters, other than this there is an overall average distance of 3 km between signs. Additionally, it was noted that for higher PSLs such as 50 and 60 km/h, the distance between signs is typically above 4 km.

4.2.3 Bhopal

During the road survey for the posted speed limit (PSL) inventory, which covered 225.8 km (25.2% of the total road network), a total of 79 PSL boards were found along the major roads. The survey revealed that 40.3% of the surveyed roads were main arterial roads, where an average of 2 PSL boards were found per 10 km. Sub-arterial roads, accounting for 29.5% of the surveyed roads, had an average of 3 PSL boards per 10 km, indicating a higher density of PSL signboards. On the ring road, which made up 30.2% of the total surveyed road length, 1 PSL board was found per 10 km. This suggests that sub-arterial roads have a higher number of PSL signboards, likely due to safety considerations and traffic congestion levels on these road sections.

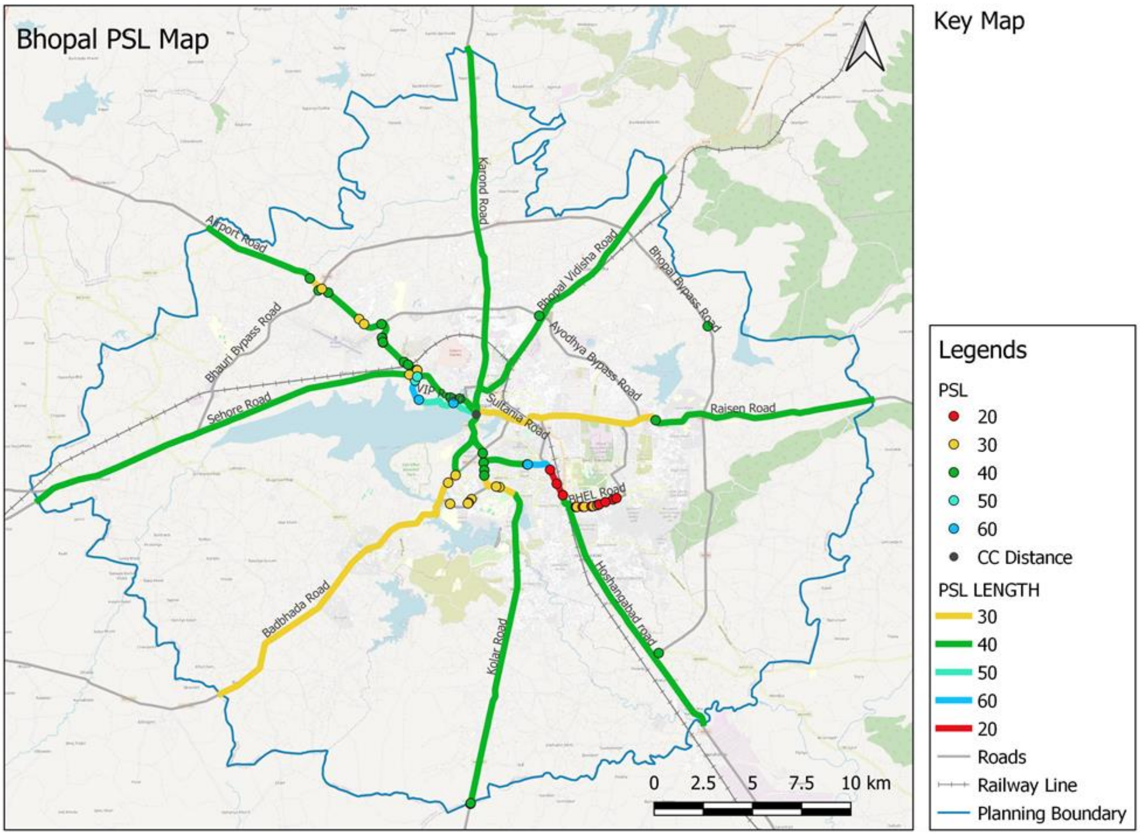


Figure 15: PSL map of Bhopal
Source: Primary Survey, Author Generated

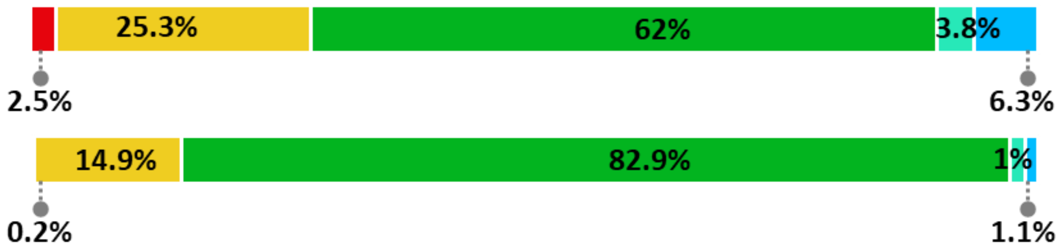


Figure 16: Percentage of PSL Boards and PSL running length in Agra
Source: Primary Survey, Author Generated

As per the above graphs, it is observed that a significant portion of the total road length, roughly 62%, falls under the 40 km/h speed limit zone, indicating that most roads have this designated speed limit. Interestingly, this category also boasts the highest number of speed limit signs, making up 83% of all installed signs. This means that there are more speed limit signs per km in the 40 km/h zones compared to other speed zones. 30 km/h limit covers 25.3% of the total running length but only accounts for 20% of the total boards, suggesting fewer boards per km for this limit. Similarly, the 20 km/h, 50 km/h, and 60 km/h limits also have fewer boards per running km, as they cover a higher percentage of the total road length but a lower percentage of total PSL boards. This may be due to high-speed zones being designed for efficient traffic movement with fewer intersections. Since drivers are expected to maintain consistent speeds, fewer signs are needed to remind them of the designated limit. Conversely, lower speed zones (like 40 kmph) often have frequent intersections and require more frequent reminders of the reduced speed limit for safety reasons

1. PSL Reason & Abutting Landuse

While understanding the PSL of Bhopal more deeply, it is observed that PSL also changes as per the reason ahead and the abutting landuse. PSL of 40 has maximum signage in clear road conditions followed by road geometry whereas 30 PSL has maximum signage due to junctions.

While examining the posted speed limits (PSL) in Bhopal, it is observed that the placement of speed limit signs varies based on specific factors such as road conditions and surrounding land use. Major roads with a speed limit of 40 km/h have the most signage in clear road conditions, emphasizing the importance of road geometry and visibility.

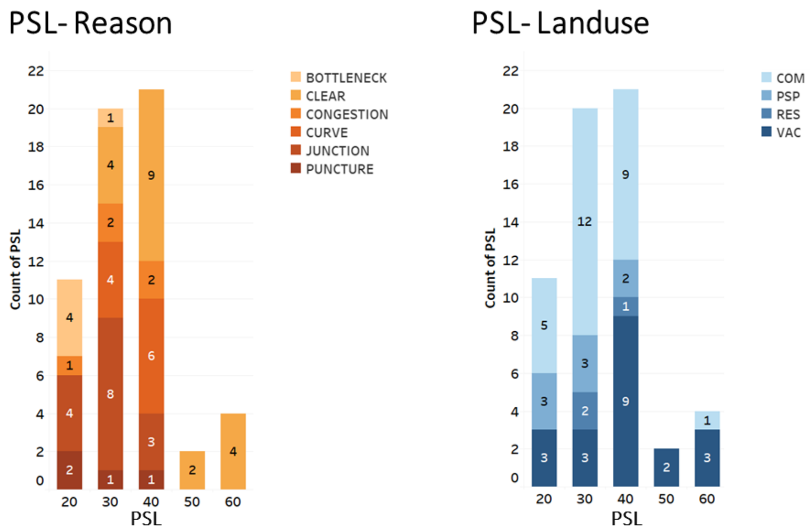


Figure 17: No. of PSL boards as per PSL Reason and Landuse in Agra
Source: Primary Survey, Author Generated

In contrast, speed limits of 30 km/h often have signage near junctions to alert drivers to upcoming intersections. Similar patterns are observed for speed limits of 20 km/h and 30 km/h, where the majority of signs are placed before junctions. Higher speed limits of 50 km/h and 60 km/h are typically placed in clear conditions to provide advanced warning to drivers.

In addition to road conditions, the type of abutting land use also influences the placement of speed limit signs. Lower speed limits of 20 km/h, 30 km/h, and 40 km/h are commonly found near commercial areas and vacant land. Conversely, higher speed limits are more prevalent in vacant land areas. Speed limit signage placement considers both road conditions and surrounding land use to effectively communicate speed regulations and enhance road safety for drivers.

2. Average Spacing

The average spacing of speed limit signs in Bhopal varies depending on the designated speed limit. For roads with a speed limit of 40 km/h, the typical spacing between speed limit signs ranges from 200 meters to 500 meters. This spacing is designed to ensure drivers have adequate notice and comply with the speed limit in clear road conditions. On roads with a speed limit of 30 km/h, the spacing between signs is generally between 200 meters and 250 meters. However, the spacing is reduced to 50 meters near junctions to alert drivers of upcoming intersections and the reduced speed limit. For higher speed limits, such as 50 km/h and 60 km/h, the spacing between speed limit signs increases significantly to over 2 km. This wider spacing reflects the expectation of drivers to maintain higher speeds over longer stretches of road. The placing of speed limit signs at appropriate intervals based on the designated speed and road conditions aims to enhance road safety and ensure drivers are aware of and adhere to the specified speed limits.

4.2.4 Indore

In Indore, the surveyed road covered 177.3 km of road, which accounts for approximately 30.3% of the total road length excluding local residential streets, a total of 192 PSL signs were identified. Among these, 51.4% of the signs were located on arterial roads, where an average of 7 speed limit signs were found per 10 km. Sub-arterial roads constituted 22.6% of the total road length and had an average of 5 speed limit signs per 10 km. Additionally, the ring road, comprising 26% of the surveyed roads, had an average of 3 speed limit signs per 10 km.

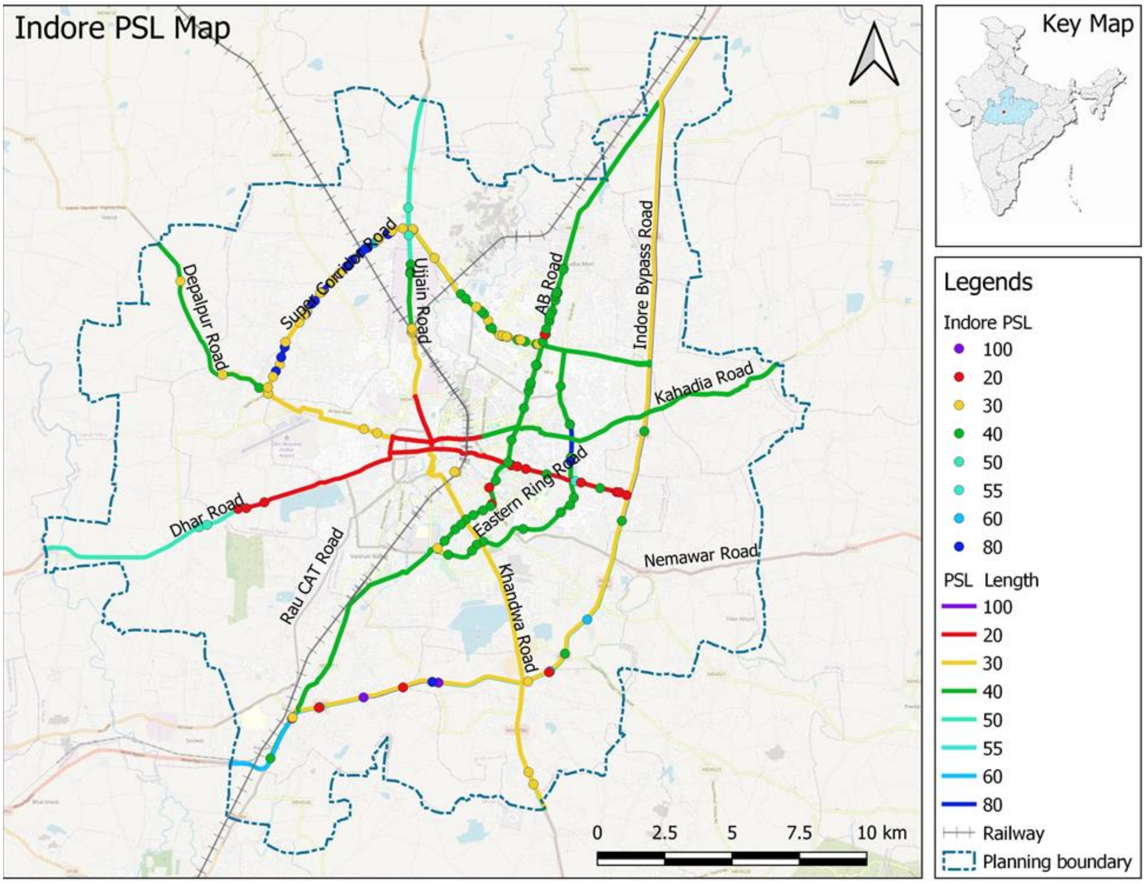


Figure 18: PSL map of Indore
Source: Primary Survey, Author Generated

It is inferred that arterial roads have the highest density of speed limit signs, followed by sub-arterial roads and ring roads. The distribution of speed limit signs reflects varying traffic conditions and road classifications within the surveyed area.

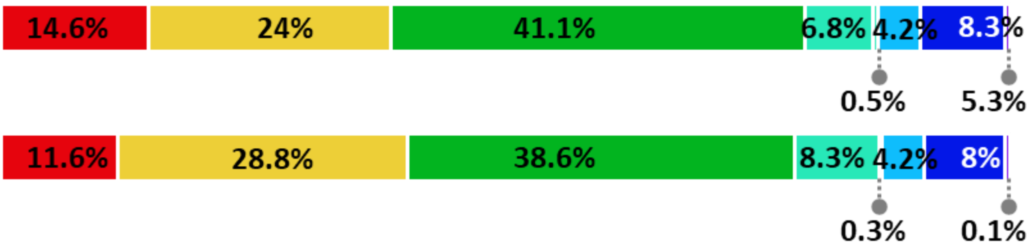


Figure 19: Percentage of No. of PSL boards and PSL running length
Source: Primary Survey, Author Generated

Based on the running length analysis of identified road types shown in the graphs above, it is evident that roads with a PSL of 40 km/h cover approximately 41.1% of the total road length, followed by roads with a PSL of 30 km/h and 20 km/h, which account for 24% of the road length each. Roads with higher speed limits like 50 km/h, 60 km/h, and 80 km/h constitute smaller proportions of the road length, at 6.8%, 4.2%, and 8.3%, respectively. The distribution of speed limit signs across these PSL categories appears to be proportional, indicating a relatively uniform distribution of signs throughout the city's road network. The prevalence of different speed limits across various road types in the city is reflected in the corresponding signage consistently.

1. PSL Reason & Landuse

As per analysis, it is observed that out of the total PSL boards, the maximum is 40 and that is placed on clear road sections providing a repetition of the board to aware the drivers. Lower PSLs like 20 and 40 are due to junctions and punctures ahead on the road. Higher PSL is also placed on clear roads for information on the maximum legal limit on the respective road.

Upon analyzing the adjacent land use with speed limits (PSLs), it is observed that PSLs of 40 km/h and 30 km/h are proportionally installed in areas zoned for commercial use, public service providers (PSP), and vacant land. PSLs 20 km/h have a relatively smaller share across all land uses. Higher speed limits are predominantly located in areas designated as vacant land use.

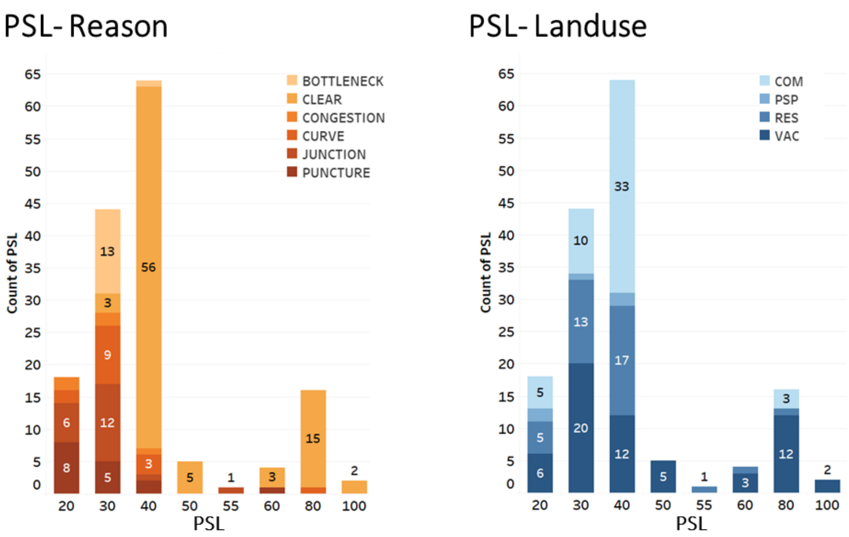


Figure 20: No. of PSL boards as per PSL Reason and Landuse in Indore
Source: Primary Survey, Author Generated

2. Average Spacing

For speed limits of 20 km/h and 30 km/h, the average distance between signs ranges from 300 to 350 meters whereas for higher speed limits like 50 km/h, 60 km/h, 80 km/h, and 100 km/h, the spacing between signs increases to over 2 km. Specifically, for speed limits set at 40 km/h and 80 km/h, the average distance between signs extends to approximately 500 meters. The variation in sign spacing reflects the diverse speed limits observed across different road sections, ensuring effective communication of speed regulations along the road network.

4.3 Research Question 2- Variation in PSLs

Does PSL differ in core middle and Outer regions in Urban Areas?

In this research question, it's hypothesized that posted speed limits (PSLs) are lower in the city center and increase as you move away from it. The study aims to examine the relationship between different PSLs and their distances from the city center. The process involved in establishing this relationship is outlined below:

Firstly, various PSLs were identified throughout the city and got their respective distances from the city center. This involved collecting data on speed limits along different roads radiating out from the city's central area.

Then, the gathered data is analyzed to determine if there is a discernible pattern or trend between the PSLs and their corresponding distances from the city center. This analysis is done with statistical techniques to identify any correlations between the variables.

- Identification of City Center Area
- Locate the PSL in the city (On Arterial & Sub- Arterial roads)
- Distance from City Center to each PSL (Along Identified Roads)
- Relate All PSL's to Distance from City Center

Figure 21: Process of relation of PSL with Distance from City Center

The relationship between posted speed limits (PSL) and their distance from the Central Business District (CBD) was plotted for all four cities. It is noticed that there's a positive correlation between PSL and distance from the CBD. In CBD areas, speed limits tend to be lower, but they increase as move outward from the city, especially on higher-hierarchy roads. The relation is then combined for all cities to compare the conditions for all four cities

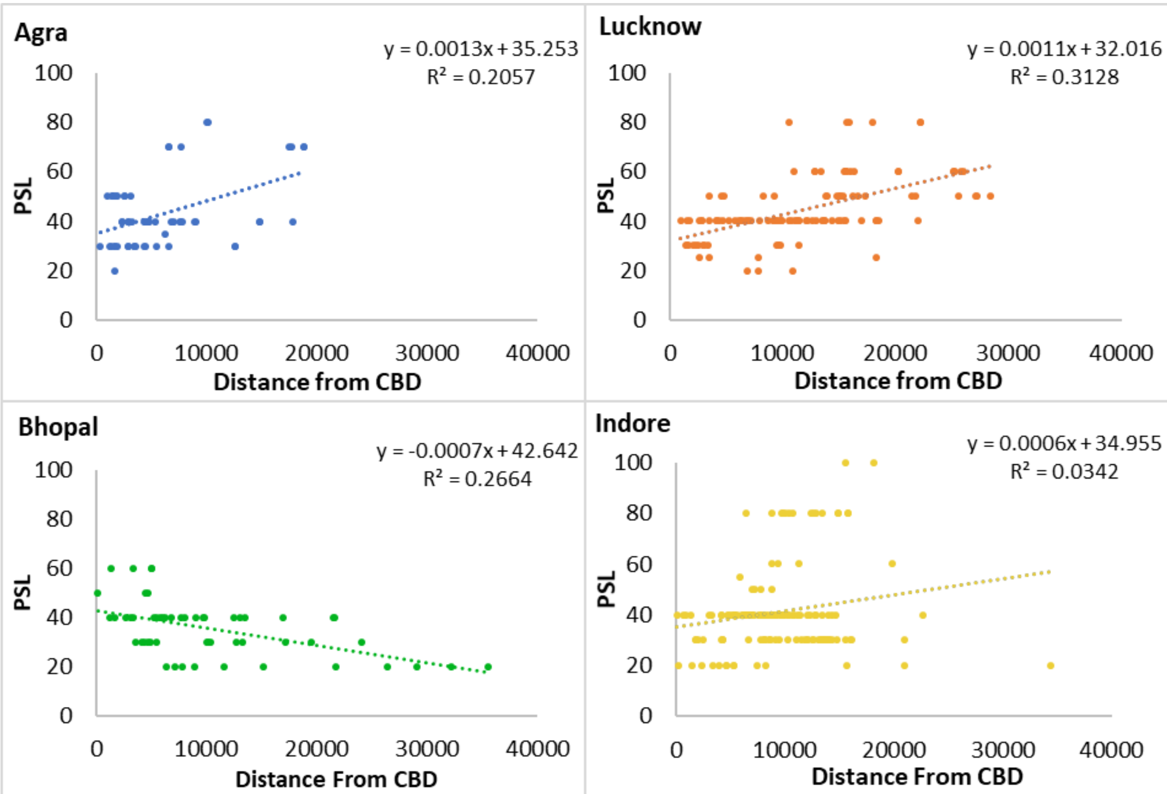


Figure 22: Graph of PSL vs Distance from City Center for all four Cities
Source: Primary Survey, Author Generated

From the combined graph, it is observed that Agra, Lucknow, and Indore exhibit a common trend: PSL values tend to increase as move away from the city center. This suggests that roads farther from the central area generally allow for higher speeds, catering to the flow of traffic on wider thoroughfares.

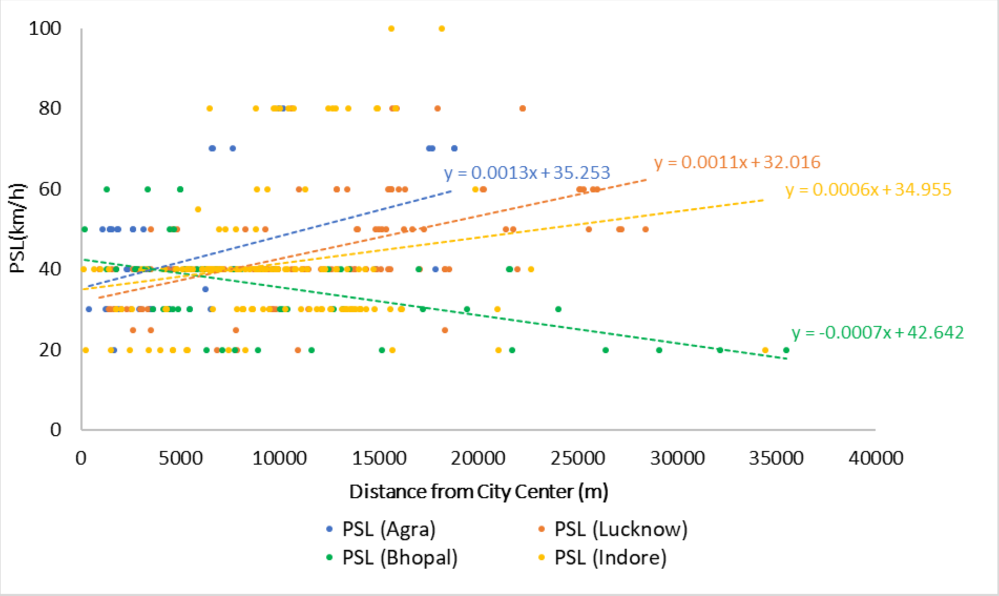


Figure 23: Graph of PSL vs Distance from City Center (Combined)
Source: Primary Survey, Author Generated

However, Bhopal presents a contrasting picture. Here, near the city center, particularly along VIP Road, speed limits are notably higher, but other roads have comparatively lower speed limits even in outer regions.

A notable exception to this trend is observed in Indore, where PSL reaches its peak around 15 km from the city center before decreasing along certain roads. Factors such as bottlenecks and road conditions contribute to this fluctuation. Meanwhile, Bhopal's outer regions stand out with a relatively low PSL of 20 km per hour, attributed to ongoing road construction work. The dynamic nature of speed limit distributions in urban settings is influenced by a multitude of factors including city layout, traffic flow patterns, and infrastructure development projects.

4.4 Research Question 3- Proximity to Intersection

What is the impact of Intersection on different PSLs?

This research question is to find the relationship between posted speed limits (PSL) and their proximity to upstream intersections. The assumption is that as the distance between a PSL sign and an intersection decreases, the corresponding speed limit decreases, and vice versa. The process for establishing this relationship is outlined below:

- Identification of Intersection (Along Identified Roads)
- Locate the PSL in the city (On Arterial & Sub- Arterial roads)
- Distance from each PSL to upstream Intersections
- Relate All PSL's to Distance from upstream Intersections

Figure 24: Process of relation of PSL with Distance from Intersection

Firstly, intersections were identified along the chosen roads within the city. Following this, the locations of posted speed limit (PSL) signs on both arterial and sub-arterial roads were determined. Subsequently, the distance from each PSL sign to the nearest upstream intersection was measured. Then, the gathered data is analyzed to determine if there is a relationship or trend between the PSLs and their upstream distances from the city center.

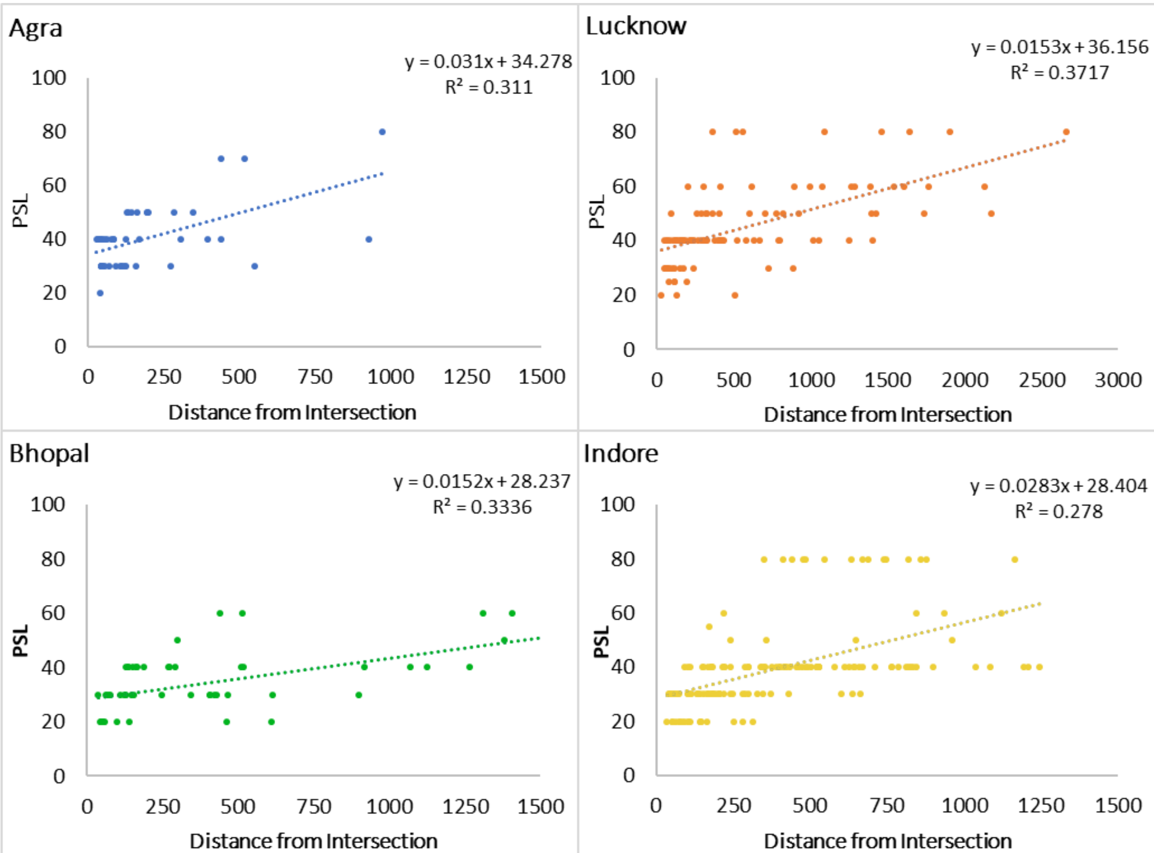


Figure 25: Relation of PSLs with Upstream Intersection for all four cities
Source: Primary Survey, Author Generated

The posted speed limits (PSL) and their distance from the intersection were plotted for all four cities. It is observed that PSL and its Upstream distance to the intersection have a positive relation. PSL decreases as the vehicle moves toward the Intersections. The relation is then combined for all cities to compare the conditions for all four cities

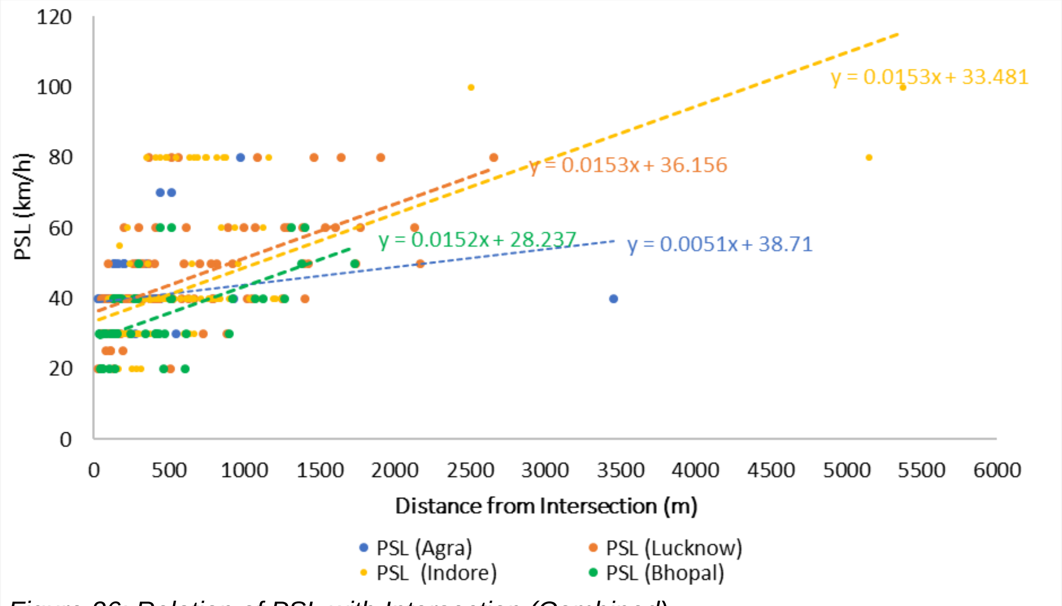


Figure 26: Relation of PSL with Intersection (Combined)
Source: Primary Survey, Author Generated

While comparing all four cities, and analyzing the relationship between posted speed limits (PSLs) and their distance from intersections, consistent trends in Lucknow, Bhopal, and Indore are observed. However, Agra's data deviates slightly, indicating less variation in PSLs as the distance from intersections increases, suggesting a unique pattern in speed regulation compared to the other cities. When considering the distance from intersections, Bhopal emerges with the shortest distance, approximately 1.7 km, while Indore stands out with the longest distance, approximately 5.4 km.

Interestingly, Indore displays a distinct feature with its PSL distribution, featuring values of 30, 40, and 80. Many of these PSLs are placed near consecutive signs, indicating a systematic approach to speed regulation along its roads.

4.5 Research Question 4- PSL vs RoW

Does PSLs and Right of Way are related?

In this research question, it is tried to understand if the width of the Right of Way (RoW) plays a role in determining the placement of posted speed limits (PSLs) on roads. The assumption is that PSLs are higher in areas with wider RoW and lower in areas with narrower RoW. To explore this relationship, a systematic process is followed. Initially, various locations along the road where PSL signs are installed are identified. Subsequently, the width of the RoW at each of these locations is measured. Corresponding speed limits indicated by the PSL signs are recorded.

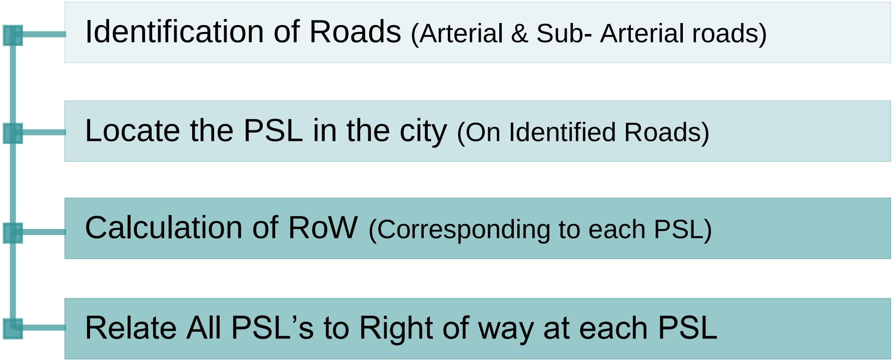


Figure 27: Process for relation of PSLs with RoW

Through careful analysis of the collected data, it is ascertained if a consistent pattern emerges: whether PSLs indeed tend to be higher in wider RoW and lower in narrower RoW. The relation is plotted for all four cities and then tried to find the relation between them.

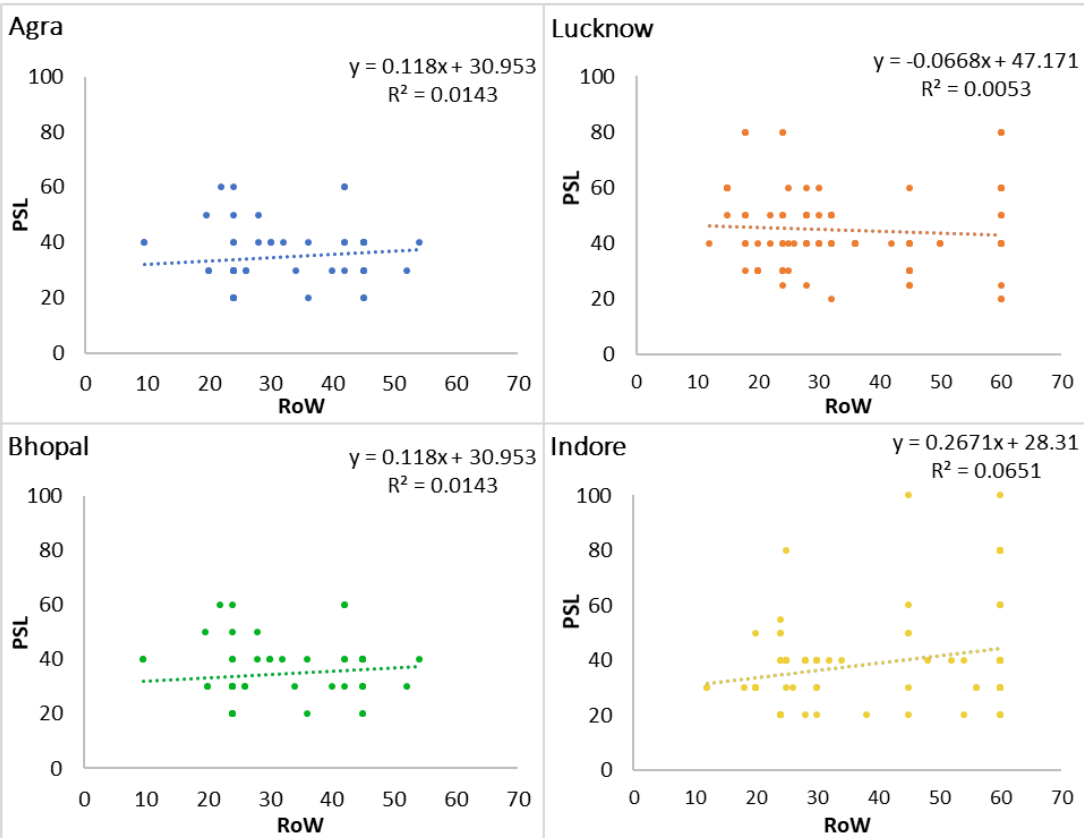


Figure 28: Relation of PSLs with RoW for all four cities
Source: Author Generated

From the above plotted graphs, it is inferred that there is a positive relationship between them, but it's not particularly strong. The data suggests that posted speed limits (PSLs) are somewhat influenced by the width of the Right of Way (RoW) in the city. However, it's observed that PSLs tend to increase as the width of the road increases, but it's not the sole determinant of speed limit placement. The data is also compared among the four cities.

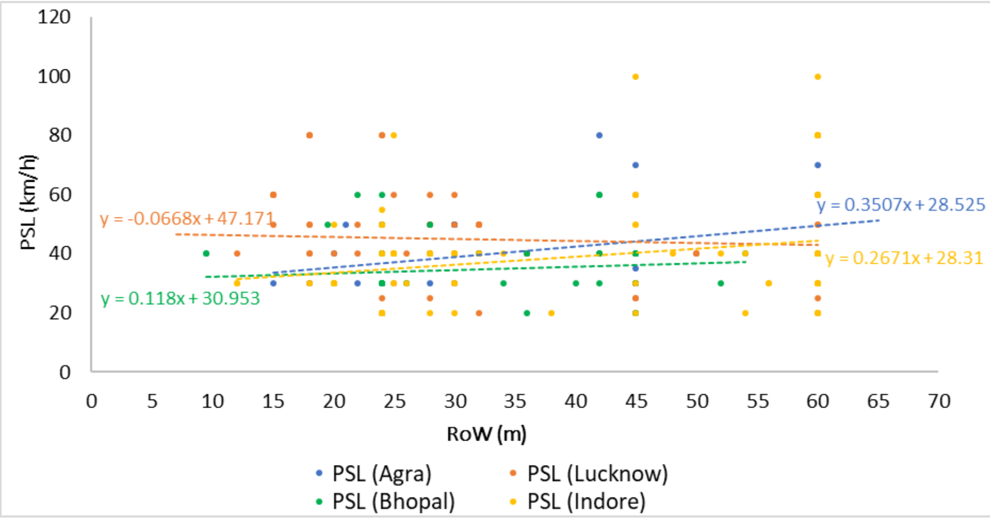


Figure 29: Relation of PSLs with RoW (Combined)
Source: Primary Survey, Author Generated

In Agra, Bhopal, and Indore, the increase in posted speed limit (PSL) values is less noticeable with an increase in the width of the Right of Way (RoW) along the roads. However, in Lucknow, a different trend is observed where roads with higher RoW tend to have mostly uniform PSLs of 40 km/h. Across all cities, PSLs were predominantly found at RoW widths of 18m, 24m, 45m, and 60m. Additionally, lower speed limits are commonly observed near sections where lanes merge or diverge. In Lucknow, higher PSLs are observed at lower RoW widths of 18m, attributed to the implementation of one-way traffic regulations.

Furthermore, the right-of-way (RoW) is classified into four main ranges: up to 20 meters, 20-30 meters, 30-40 meters, and above 40 meters. Then, the behavior of speed limits (PSL) is analyzed across different zones of the city from the core to the outer regions. When examining PSLs with Right of Way (RoW) across the core, middle, and outer regions of urban areas, distinct patterns emerge. Firstly, it is observed that PSLs tend to increase as one moves outward from the city center, reflecting a gradual adjustment of speed limits to accommodate changing traffic conditions and road characteristics.

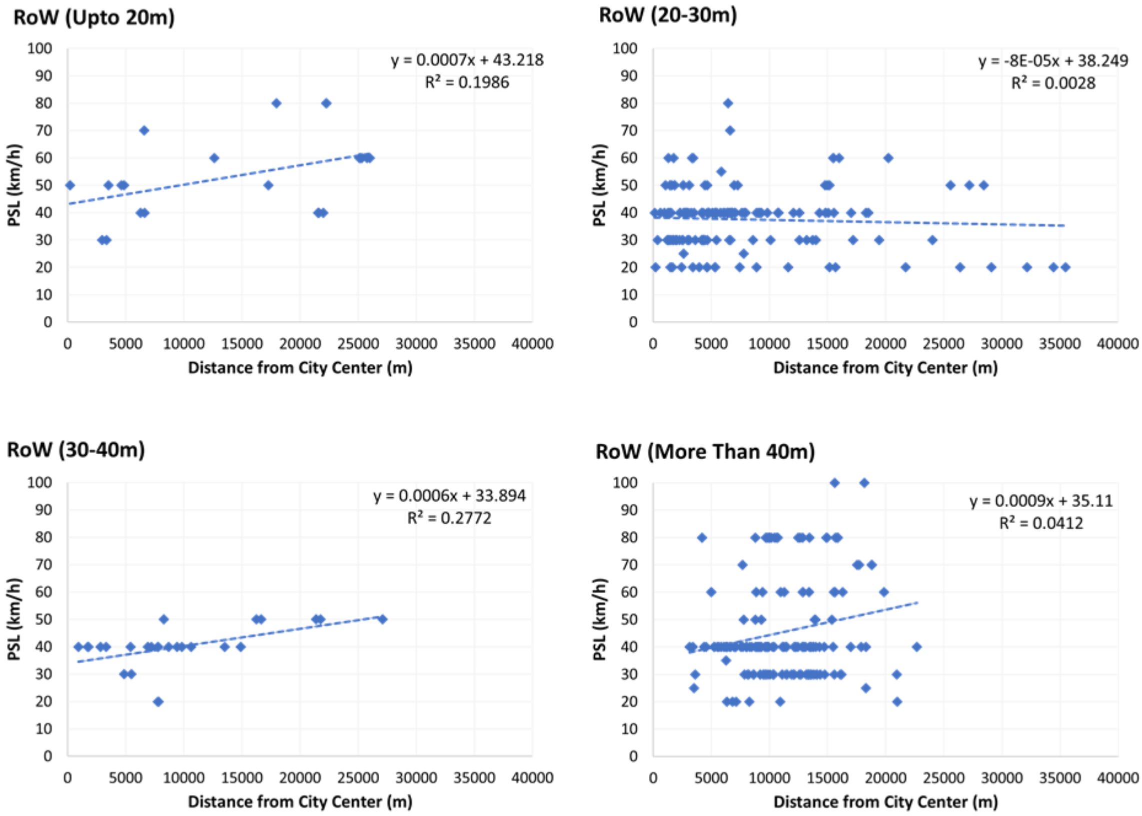


Figure 30: PSL variation from core to outer region for all four cities
Source: Primary Survey, Author Generated

However, within a RoW range of 20-30 meters, no significant variation in PSLs is observed across different regions, indicating consistent speed limit enforcement irrespective of road width within this range. Notably, PSL values are notably higher in areas with RoW exceeding 40 meters, suggesting a correlation between wider road infrastructure and elevated speed limits to accommodate higher traffic volumes and facilitate smoother traffic flow. In the core area specifically, where space constraints may limit road width, major PSLs such as 20, 30, and 40 km/h are predominantly observed on RoW of 20-30 meters, highlighting the prioritization of road safety and traffic management measures in densely populated urban cores.

4.6 Research Question 5- PSL vs Landuse

How does abutting landuse affect PSLs in urban areas?

This research question explores the relationship between different land use patterns and associated posted speed limits (PSLs). The assumption is that there's a connection between land use types and the corresponding PSLs. Based on the parking scenario, it's hypothesized that commercial land use typically has lower PSLs compared to other land use types, followed by PSP, residential, and vacant land use. the focus is to gain insights into how land use patterns influence speed limit regulations on roads. The process involved in finding the relationship is as follows: Firstly, roads including arterial and sub-arterial were identified, and then the posted speed limit (PSL) signs along these roads were located.

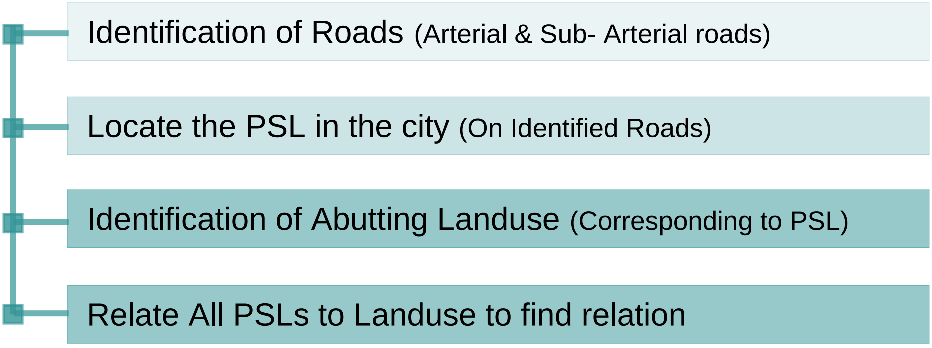


Figure 31: Process of relating PSLs with Landuse

The types of land use adjacent to each PSL location were determined. By systematically relating all PSLs to their corresponding land use types, an examination of any existing relationship between them will be conducted.

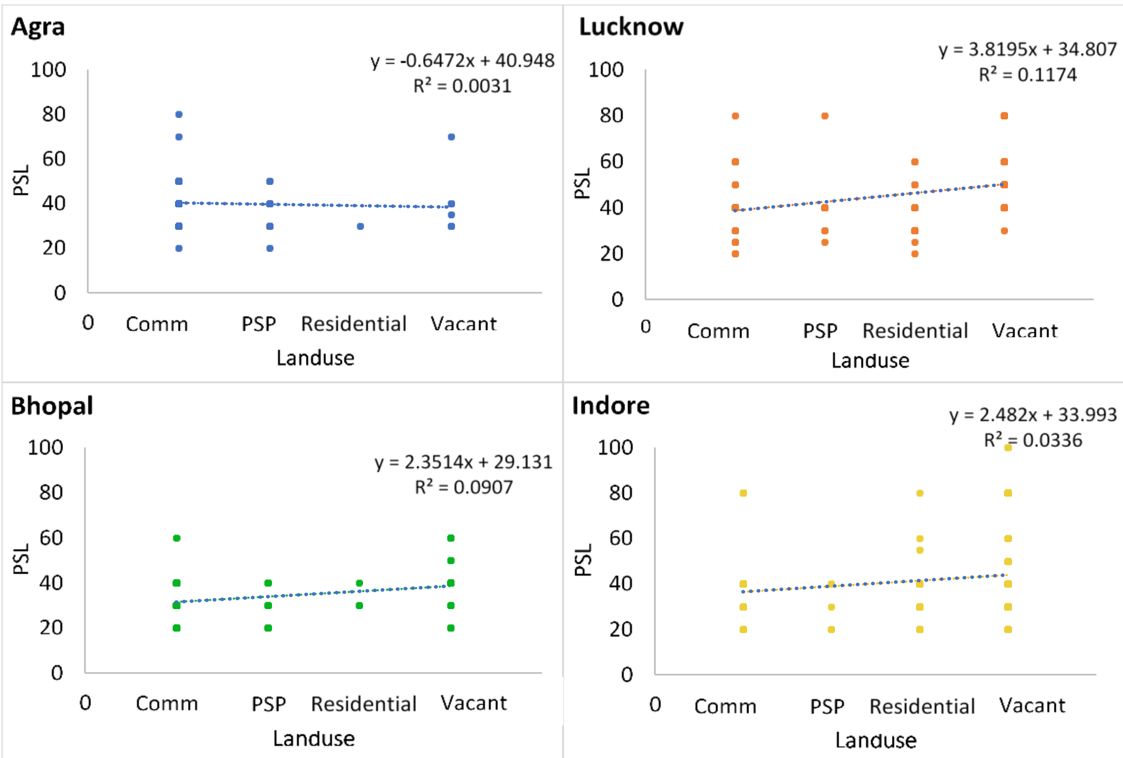


Figure 32: PSLs for different Landuse for all four cities
Source: Primary Survey, Author Generated

While plotting PSLs and their abutting landuse for all four cities, a positive relationship is observed, although it's not particularly strong. The graph indicates that commercial land use tends to have lower posted speed limits (PSL), while vacant land use tends to have higher PSLs. Following this pattern, PSP areas typically have lower speed limits compared to residential land use. This relation is also combined for all cities to compare among them.

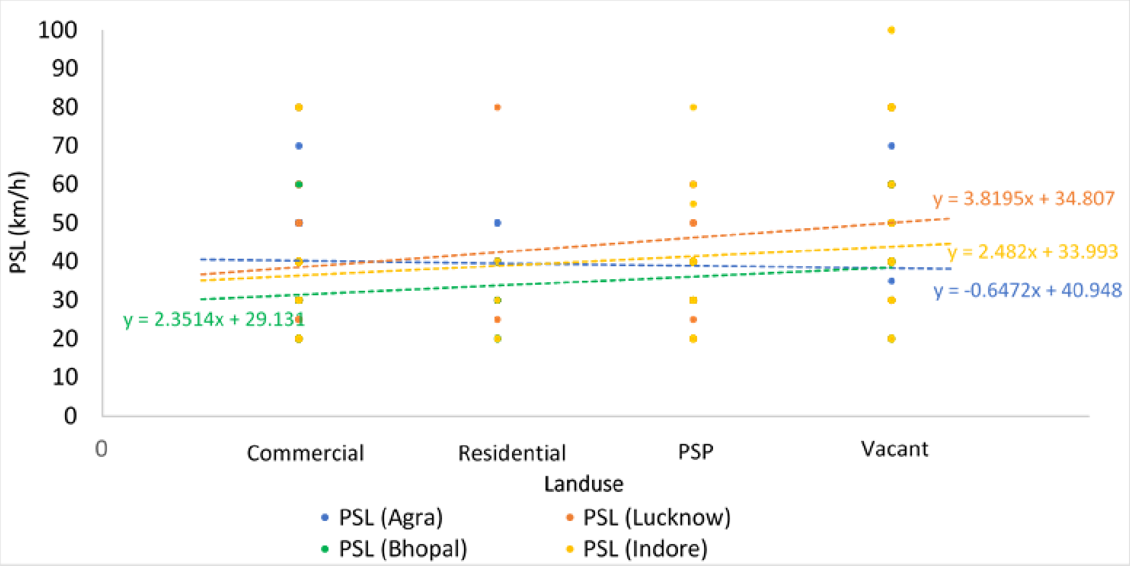
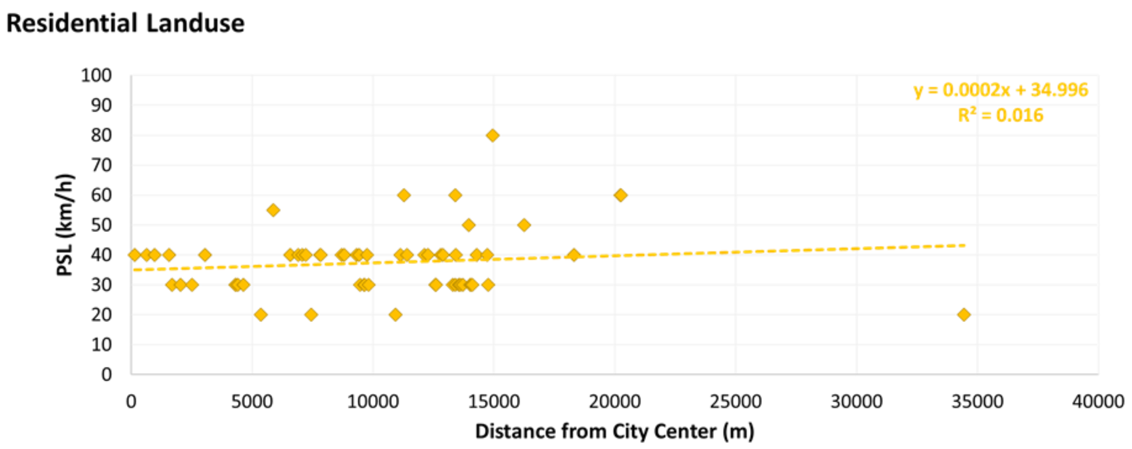


Figure 33: PSLs for different Landuse (Combined)
Source: Primary Survey, Author Generated

In Lucknow, Bhopal, and Indore, it's observed that commercial areas tend to have lower posted speed limit (PSL) values, while vacant areas have higher PSLs. Conversely, in Agra, commercial land use has higher PSL values, with other land use types having relatively similar PSLs. Among these cities, Lucknow stands out with higher PSL values, followed by Indore and then Bhopal. Interestingly, in Agra, Lucknow, and Indore, the lowest PSL values are found in areas designated for PSP landuse.

These different types of land use are grouped into three main categories: residential landuse, non-residential and vacant landuse After that, PSL behavior is analyzed for each of these categories in the city from city center, the middle parts, and the outer edges.



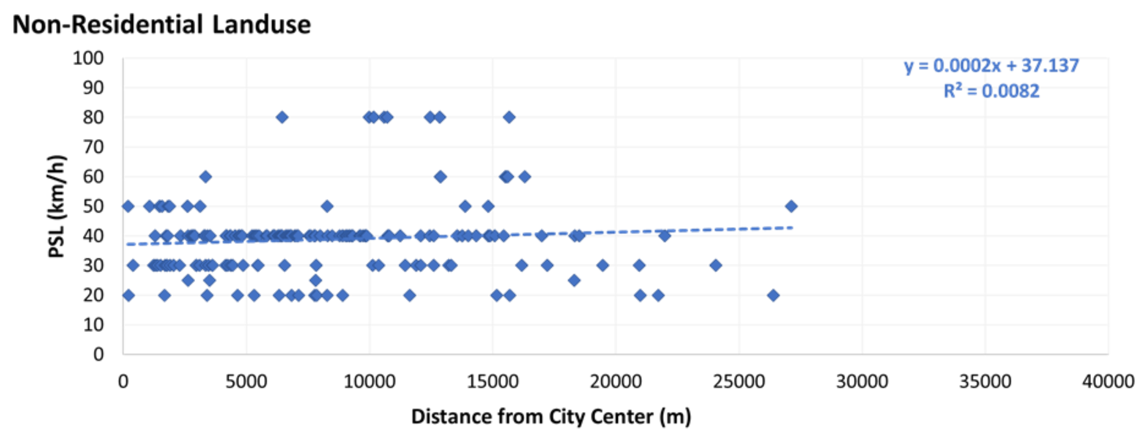


Figure 34: Variation of PSL in residential and Non-residential Landuse across urban area
Source: Primary Survey, Author Generated

When plotted PSL with the distance from the city center it is observed that across residential and non-residential land use categories in the core, middle, and outer regions of the city, there is minimal variation in PSLs. This suggests consistent speed limit enforcement regardless of land use zoning, emphasizing uniformity in speed regulations to maintain road safety and traffic flow within urban neighborhoods.

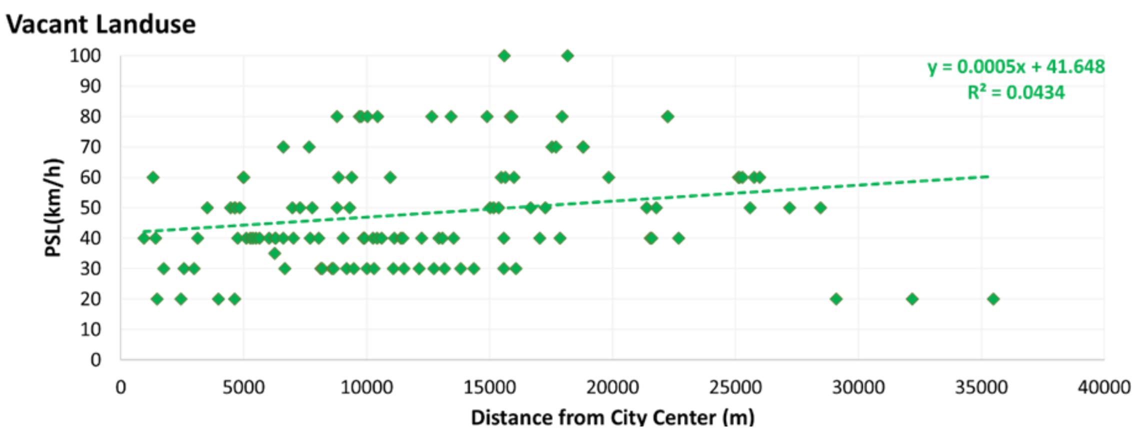


Figure 35: Variation of PSLs in Vacant Landuse across urban area
Source: Primary Survey, Author Generated

However, in areas characterized by vacant land use, a notable trend emerged wherein PSLs increased progressively moving outward from the city center. This observation indicates a correlation between land development and speed limit adjustments, possibly reflecting changing traffic dynamics and infrastructure demands as urban areas expand.

4.7 Research Question 6- PSLs in Transition Zones

How two consecutive PSLs & their mutual distances are related to each other?

The research question is focused on examining the relationship between two consecutive posted speed limits (PSLs) and the distance between them. It is assumed that smaller changes in PSL correspond to shorter mutual distances traveled between them, while larger changes in PSL result in greater mutual distances. Through this relationship, it is tried to understand how changes in PSL influence the distance between consecutive speed limit signs aiding in a deeper understanding of speed limit transitions on roadways. The process involved is as follows:

The identification of roads, including arterial and sub-arterial ones, marks the initial step of the study. Then, the posted speed limit (PSL) signs along these roads will be located. Following this, stretches of road containing consecutive pairs of PSL signs will be identified.

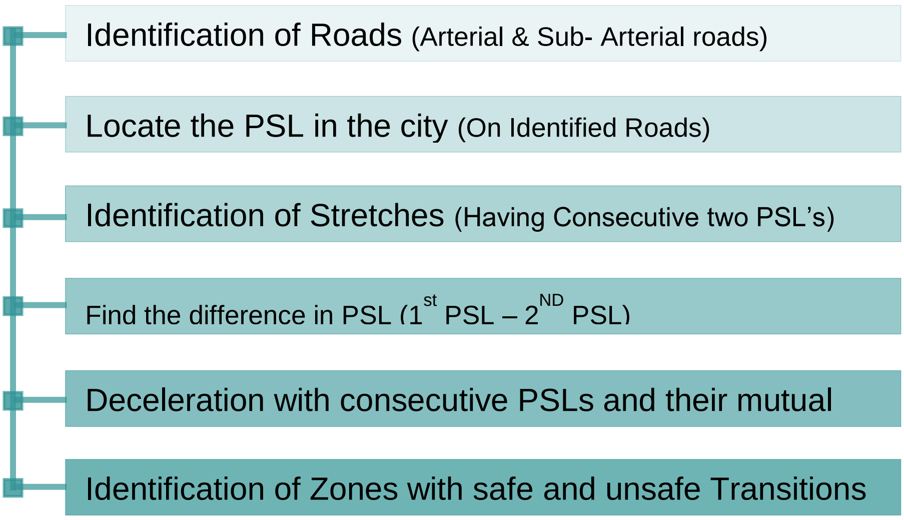


Figure 36: Process of identification of safe and unsafe transition zones

The difference in speed between the first and second PSL signs in each pair will then be determined. Afterward, the mutual distance between the two PSL signs in each pair will be calculated. Finally, an analysis will be conducted to relate all the differences in PSLs to their corresponding mutual distances and deceleration.

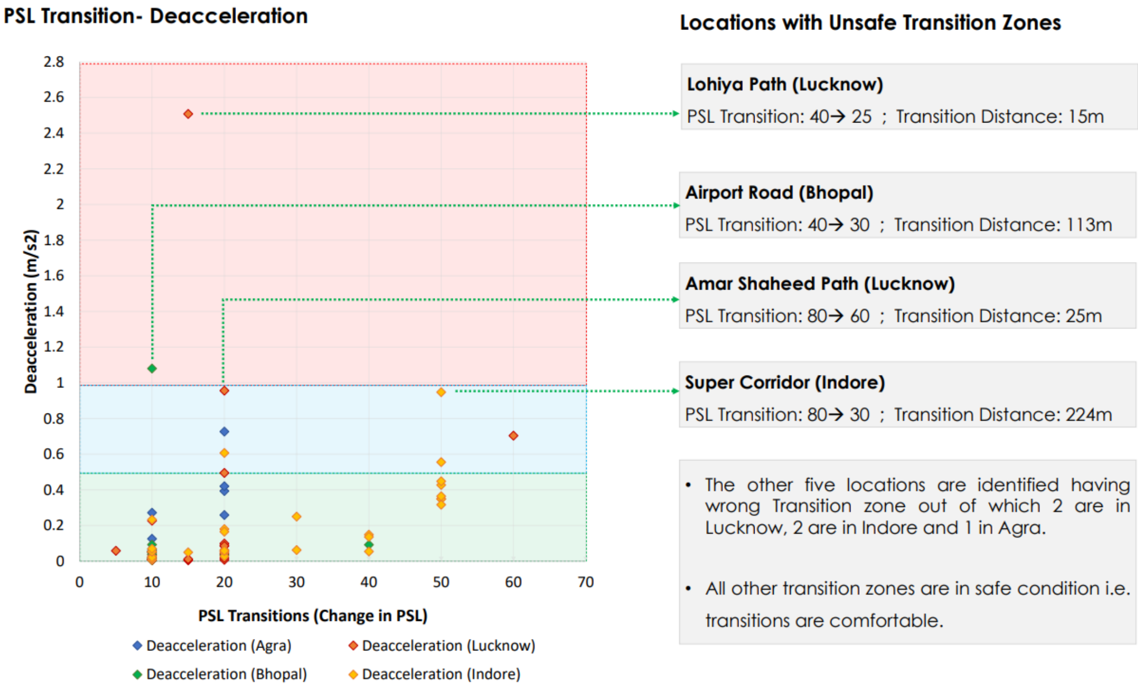


Figure 36: Decelerations in PSL Transition with safe and unsafe zones
Source: Primary Survey, Author Generated

When both variables are analyzed, it is observed that significant changes in posted speed limits (PSLs) often occur at 10 or 20 km/h. For instance, decreases from 40 to 30 or 20 to 10 kmph are common over shorter distances, indicating lower speed limits. Conversely, higher speed limits, such as 100 to 80 or 70 to 60 kmph, are typically associated with longer distances between consecutive signs. This pattern suggests that larger changes in speed limits are often spread out over greater distances, while smaller changes tend to occur within shorter distances.

While considering the deacceleration within transition zones, it is found that a range of calculated deceleration rates, varying from 0.0053 to 2.5 m/s^2. In the majority of cases, transition zones are deemed safe, with deceleration rates typically falling within the range of up to 0.3 m/s^2. However, in cities like Indore and Lucknow, transition zones with slightly higher deceleration rates of 0.5-1.0 m/s^2 are also identified, indicating relatively quicker speed adjustments for drivers. Notably, one location in Lucknow and Bhopal stands out for having unsafe transition zones, characterized by significantly higher deceleration rates of 1.1 and 2.5 m/s^2, respectively. These elevated deceleration rates pose safety concerns for motorists, highlighting the need for targeted interventions to mitigate risks associated with abrupt speed changes.

4.8 Research Question 7- PSL Impact on Travel Time

What impacts do Posted Speed Limits have on Travel Time and Delay?

This research question analyzes the influence of various speed limits on travel time and delays, specifically investigating the underlying causes of delays. For each city, a comparison is made between travel times under ideal speed conditions (near to free flow speed) and with posted speed limits to identify differences. This difference in travel times is then examined with factors such as congestion levels, road geometry, and other potential contributors to delays. This seeks to provide information on how speed limits impact travel time variations. The process involves identifying roads in each of the four cities under study. Then travel times are calculated under ideal speed conditions and the posted speed limits (PSLs) are set for each road.

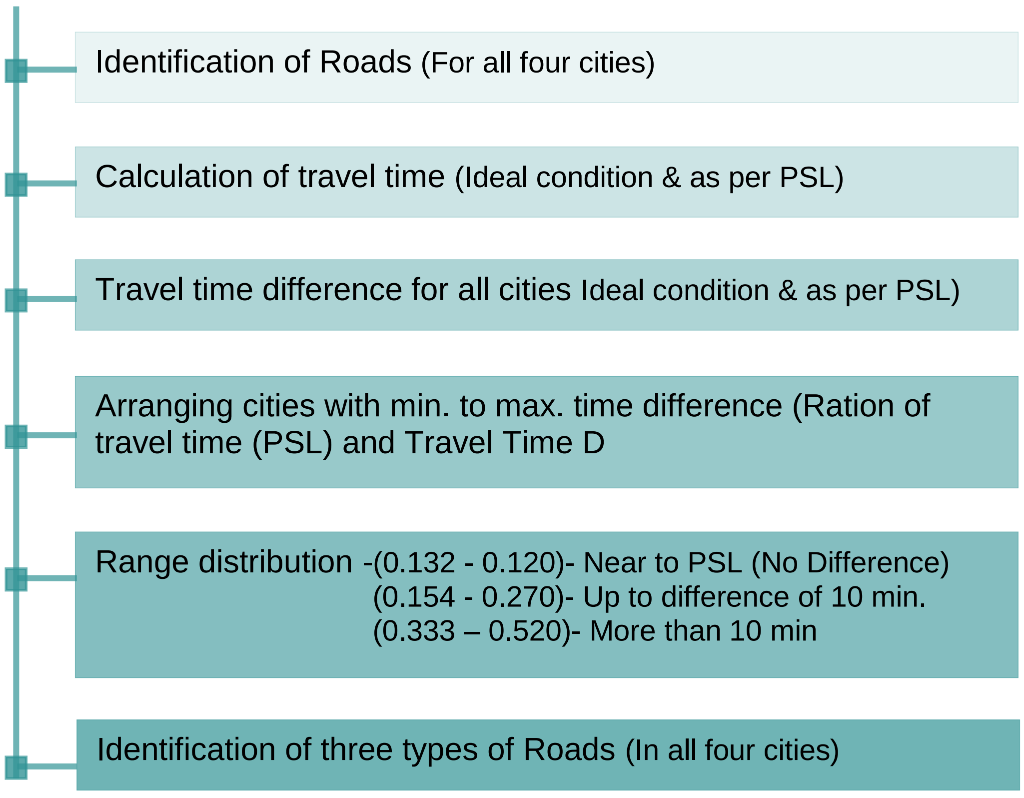


Figure 37: Process of identification of roads with travel time differences

By comparing travel times under these conditions, the study understands the impact of speed limits on travel time and potential delays. Then, the ratio of travel time due with PSLs to the difference in travel times is calculated to categorize the stretches in order of delay that ranges from -0.132 to 0.520. This range is further categorized into specific groups based on the ratio values, delineating the nature and extent of travel time differences observed.

The first category pertains to stretches where the ideal speed closely matches the posted speed limit (PSL). The second category included stretches where there is a travel time difference of up to 10 minutes between ideal conditions and PSL conditions. The third category includes road stretches where the time difference exceeds 10 minutes. By identifying these different categories of road stretches, targeted recommendations are developed to address specific issues related to speed limits and travel time variations.

Agra

In Agra, when calculating the free-flow speed for major stretches originating from the city center, speeds range from 20 km/h to 58 km/h. The slowest free-flow speed was observed on Bah Road, while Mathura Road recorded the highest speeds. On other roads, the average free-flow speed was around 47 km/h. Travel time contours are then created based on these free-flow speeds to visualize the variations in travel time across different road segments.

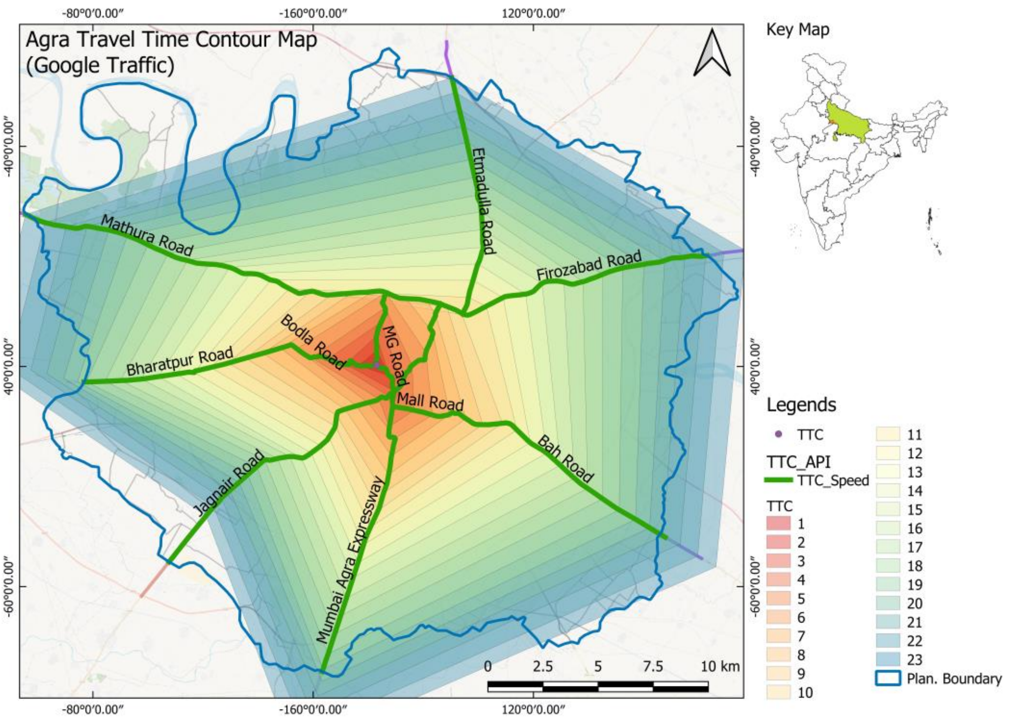


Figure 38: Travel Time Contour map of Agra under ideal speed condition
Source: Primary Survey, Author Generated

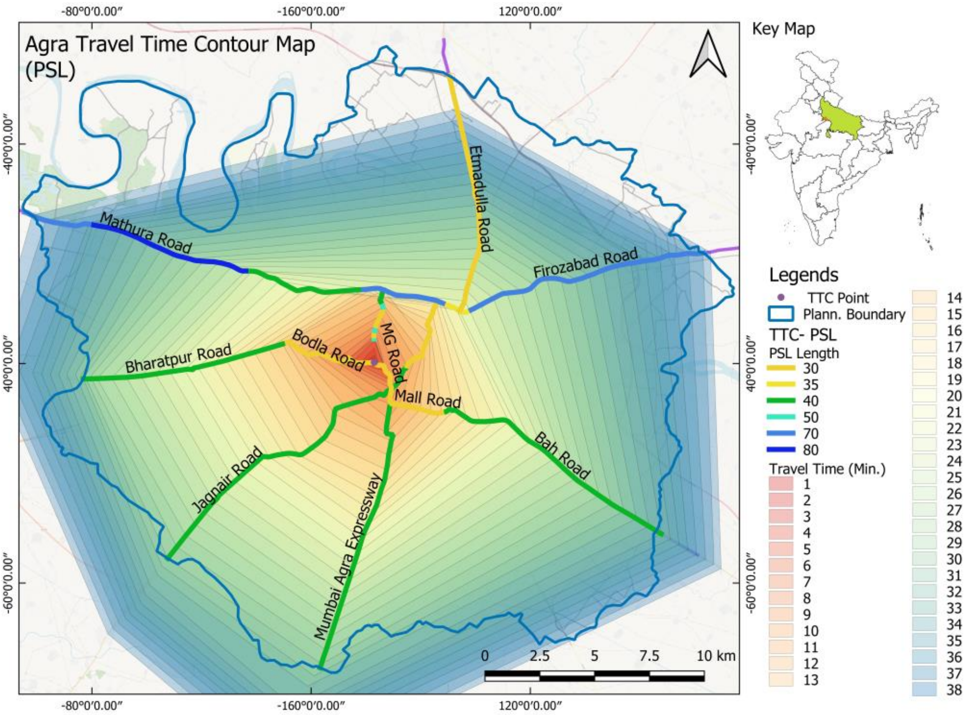


Figure 39: Travel Time Contour map of Agra under PSL
Source: Primary Survey, Author Generated

Another travel time contour is created using the posted speed limits (PSL) for each road, considering the different PSLs assigned to various areas within the city. Bharatpur Road, Jagnair Road, and Bah Road have a PSL of 40 in peri-urban areas, whereas the PSL is 30 near the city center. The travel times with free-flow speed and PSL reveals variations influenced by these speed limits across different road segments within the city. The time taken free flow speed and PSLS are as in the following table:

Table 5: Travel Time under ideal condition and PSL for Agra

Road Name (Agra)	Time (min.) Ideal Speed	Time (min.) As per PSL	Time Diff (min.)	Reason
Mumbai-Agra Expressway	18	27	9	Commercial Zone in Core Area
Bah Road	31	31	0	-
Jagnair Road	28	27	-1	Less Traffic
Bharatpur Road	20	26	6	Commercial Zone in Core Area
Mathura Road	25	38	13	Junction & High Traffic
Faizabad Road	27	37	10	Junction & High Traffic
Hathras Road	23	41	18	On-road Parking & High Traffic

Lucknow

In Lucknow, similar to Agra, speeds are measured near to free flow speed along major roads. The speeds varied considerably, with Mohan Road recording the lowest speed at 32 km/h, while Lohiya Path and Sitapur Road exhibited the highest speeds at 53 km/h. Other roads maintained an average speed of around 45 km/h. A travel time contour was generated to visualize these speed variations, providing a comprehensive overview of the travel times for each road segment. This data allows for a detailed analysis of speed dynamics across different routes within the city, facilitating informed decision-making for urban planning and traffic management strategies.

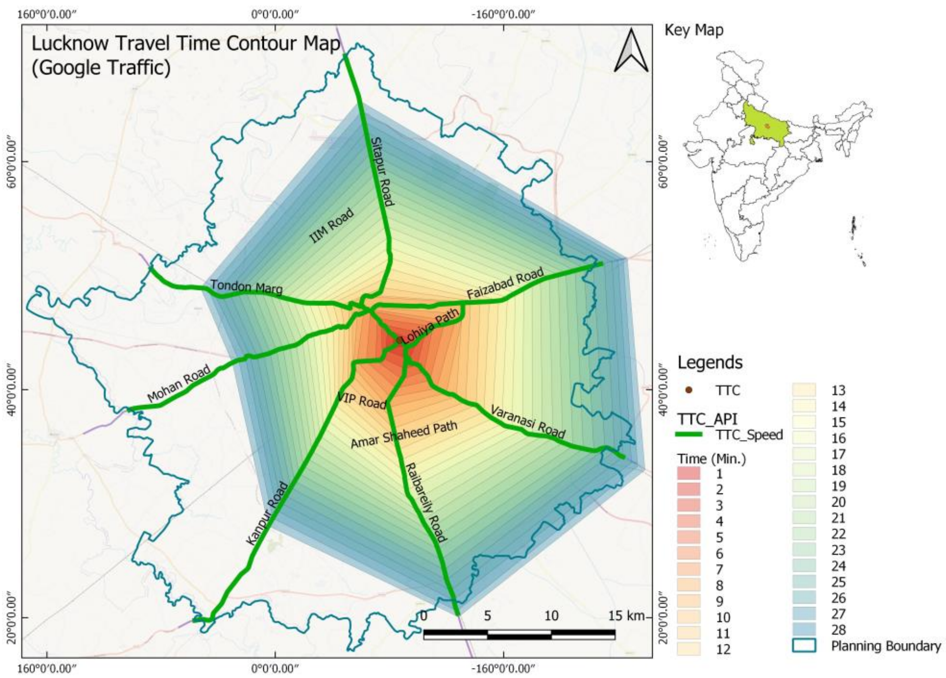


Figure 40: Travel Time Contour map of Lucknow under ideal speed condition
Source: Primary Survey, Author Generated

While analyzing travel time contours with respect to posted speed limits (PSL), it is noted that most roads in the area have a speed limit of 40 km/h. However, Kanpur Road, Raebareilly Road, Sitapur Road, and the outer region of Faizabad Road have higher speed limits ranging from 50 to 60 km/h. A travel time contour was developed based on these speed limits, providing insights into the corresponding travel times for each road segment. This visualization aids in understanding the impact of varying speed limits on travel efficiency and congestion levels across different parts of the city.

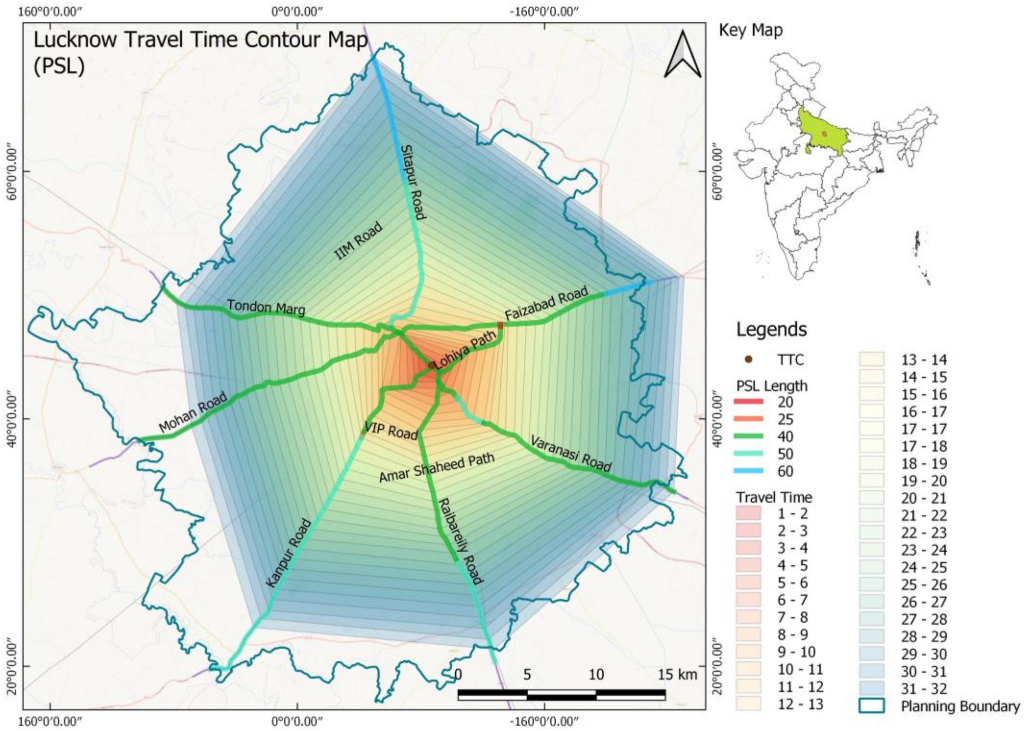


Figure 41: Travel Time Contour map of Lucknow under PSL
Source: Primary Survey, Author Generated

In the table below, the ideal travel time represents the time it would take to travel along each road segment under ideal conditions without any external factors affecting traffic flow. The travel time with PSL reflects the actual travel time considering the posted speed limits and any delays caused by factors such as congestion, construction work, heavy traffic, road repairs, frequent intersections, traffic lights, accidents, and ongoing road maintenance.

Table 6: Travel Time under ideal condition and PSL for Lucknow

Road Name (Lucknow)	Time (min.) Ideal Speed	Time (min.) PSL	Time Diff (min.)	Reason
Kanpur Road	43	38	-5	High Traffic in Core Area
Raebareilly Road	26	32	6	Less Puncture
Varanasi Road	24	30	6	Less Puncture & Res. Density
Tondon Road	35	34	-1	-
Mohan Road	40	38	-2	Less & Undivided Carriageway
Sitapur Road	24	31	7	No Res. Density along Road
Faizabad Road	26	26	0	-

Bhopal

Similarly, in Bhopal, a comprehensive analysis of travel time contours was conducted, encompassing both ideal speed conditions and those dictated by posted speed limits (PSL) across various road segments within the city. The findings unveiled nuanced differences in travel durations, shedding light on the factors influencing traffic flow and efficiency. Along Hoshangabad Road, the transition from an ideal travel time of 24 minutes to 36 minutes under PSL conditions accentuated the substantial 12-minute delay attributed to persistent high traffic volumes. Similarly, Raisen Road exhibited a notable extension from an ideal 30-minute travel duration to 38 minutes under PSL constraints, indicating an 8-minute delay primarily caused by congestion in the core area. Conversely, Karond Road demonstrated minimal variance between ideal and PSL travel times, with a marginal 1-minute difference.

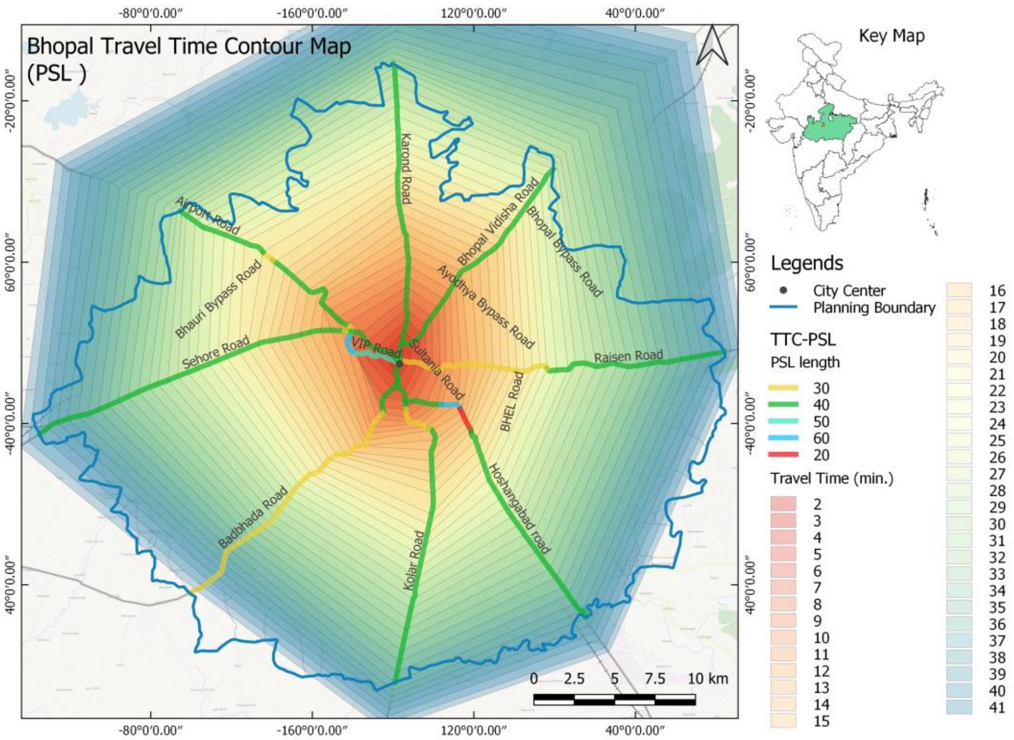


Figure 42: Travel Time Contour map of Bhopal under ideal speed condition
Source: Primary Survey, Author Generated

Further analysis revealed that Vidisha Road experienced a 2-minute delay at a railway crossing, while Sehore Road encountered a substantial 13-minute delay due to a combination of junctions and heavy vehicular traffic. Meanwhile, Airport Road saw a 4-minute delay, chiefly attributable to its layout featuring horizontal curves and multiple junctions. Notably, Bhadbhada Road exhibited a significant

14-minute delay, possibly owing to the absence of speed limit boards, whereas Kolar Road showcased negligible deviation between ideal speed and PSL travel times. These detailed observations underscore the multifaceted dynamics influencing travel durations across Bhopal's diverse road network, ranging from traffic congestion and infrastructure design to regulatory signage and road maintenance practices.

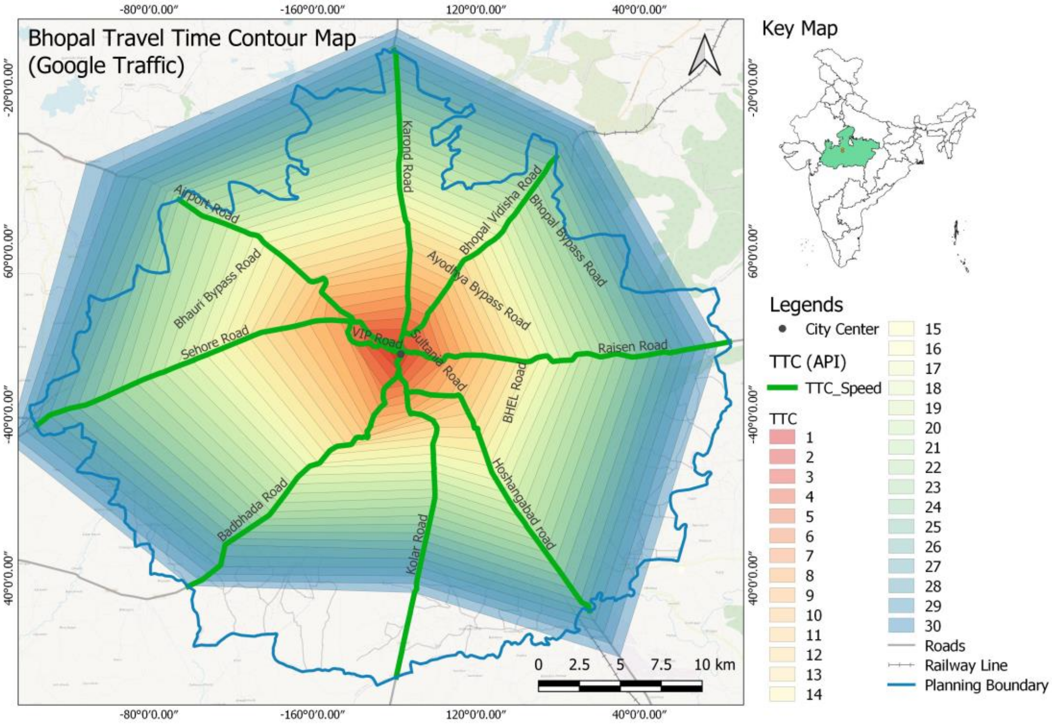


Figure 43: Travel Time Contour map of Bhopal under PSL
Source: Primary Survey, Author Generated

The travel time under ideal speed conditions and with PSLs are shown in the table below:

Table 7: Travel Time under ideal conditions and PSL for Bhopal

Road Name (Bhopal)	Time (min.) Ideal Speed	Time (min.) PSL	Time Diff. (min.)	Reason
Hoshangabad Road	24	36	12	High Traffic
Raisen Road	30	38	8	High Traffic in Core Area
Karond Road	27	28	1	-
Vidisha Road	22	24	2	Railway Crossing
Sehore Road	26	39	13	Junctions & Vehicular Traffic
Airport Road	22	26	4	Horizontal Curve and Junction
Bhadbhada Road	28	42	14	No Speed Limit Board
Kolar Road	35	34	-1	-

Indore

Similar to the other three cities, travel time difference analysis is done also for the Indore city. The travel time contour for Indore City under both ideal speed conditions and posted speed limits (PSL) provides a comprehensive insight into the diverse factors influencing travel durations across different road segments within the city. Delving into the specifics, Ujjain Road illustrates a 5-minute delay under PSL conditions compared to ideal travel times, stemming from challenges associated with its limited width and undivided carriageway. Similarly, Depalpur Road experiences a notable 9-minute deviation from ideal travel times, highlighting the impact of narrow width and absence of division on travel efficiency. Moving on to Kahadia Road, a 3-minute disparity between ideal and PSL travel times reflects the road's inherent limitations in accommodating traffic flow effectively. AB Road, being a major thoroughfare, encounters an 8-minute delay, primarily attributed to junctions and high traffic density. Meanwhile, Khandwa Road stands out with a significant 26-minute deviation under PSL conditions, mainly due to its two-way carriageway and ongoing construction activities, contributing to traffic congestion and delays.

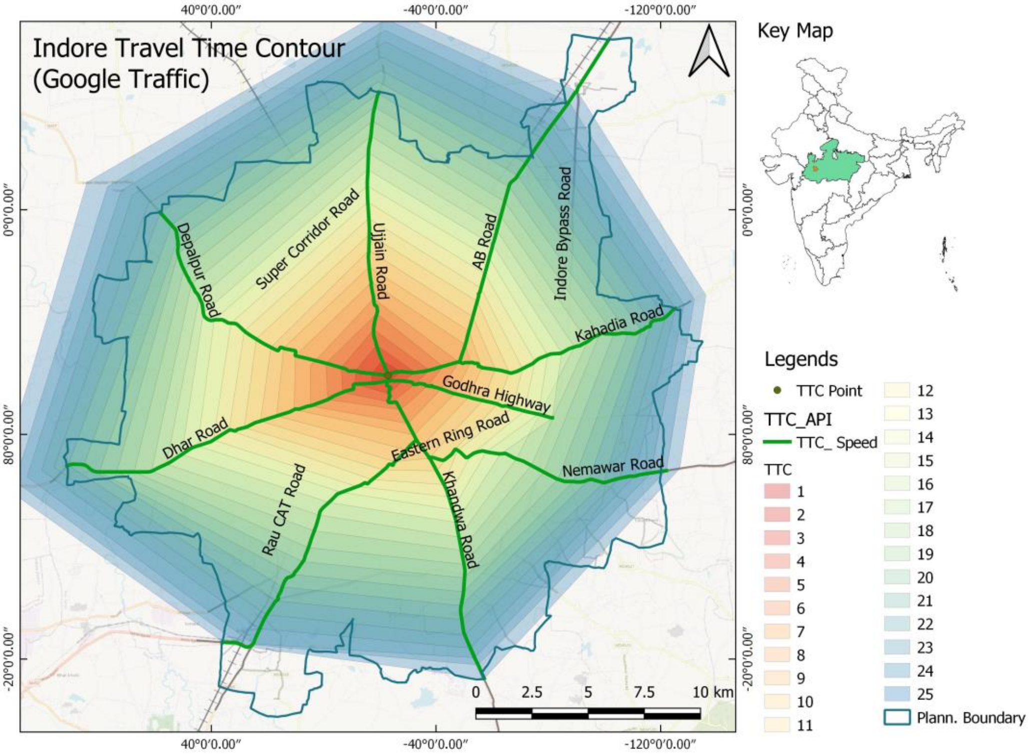


Figure 44: Travel Time Contour map of Indore under ideal speed condition
Source: Primary Survey, Author Generated

The Mumbai Agra National Highway records a 15-minute delay, largely influenced by junctions and heavy traffic volume along the route. Nemawar Road faces a substantial 16-minute delay, primarily due to the presence of challenging road features such as horizontal curves and frequent punctures. Pipiliyahana Road and Dhar Road also demonstrate noteworthy delays of 12 and 13 minutes, respectively, chiefly driven by high traffic congestion within their core areas.

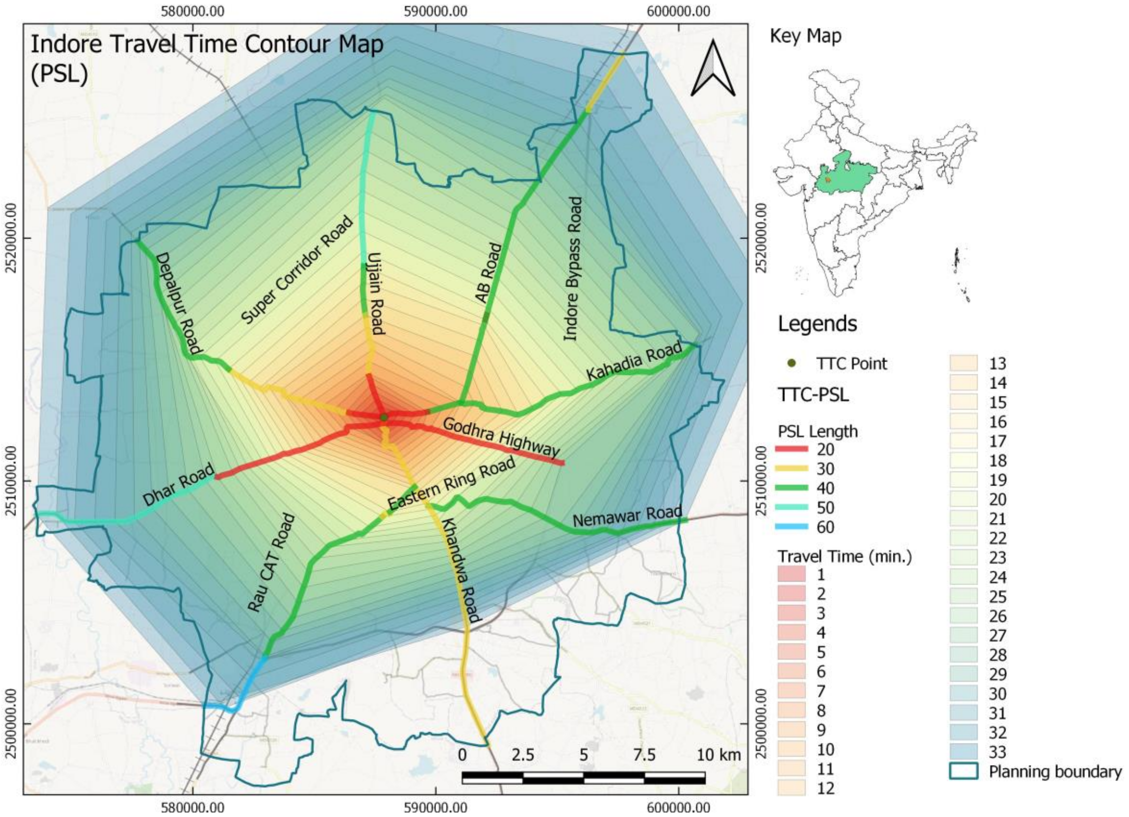


Figure 45: Travel Time Contour of Indore under PSL
Source: Primary Survey, Author Generated

These findings underscore the intricate dynamics shaping travel durations across Indore's diverse road network, highlighting the need for strategic traffic management and infrastructure development initiatives to mitigate delays and enhance overall travel efficiency. The table below displays the travel time under ideal speed conditions and as per the posted speed limit, along with the reason associated with the time difference for each road. It is also noted that the major delay in both conditions is maximum in the case of Indore city. This is attributed to heavy traffic on the road and mismanagement of drivers' behavior in mixed traffic on roads.

Table 8: Travel Time under ideal condition and PSL for Indore

Road Name (Indore)	Time (min.) Ideal Speed	Time (min.) PSL	Time Diff (min.)	Reason
Ujjain Road	18	23	5	Less & Undivided Carriageway
Depalpur Road	18	27	9	Less & Undivided Carriageway
Kahadia Road	22	25	3	Less & Undivided Carriageway
AB Road	24	32	8	Junction & High Traffic
Khandwa Road	24	50	26	2-way Carriageway/ Construction
Mumbai Agra NH	18	33	15	Junction & High Traffic
Nemawar Road	16	32	16	Horizontal Curves & Punctures
Pipiliyahana Road	12	24	12	High Traffic
Dhar Road	20	33	13	High Traffic in Core Area

After getting the travel time for each road for all four cities, stretches are segregated into three categories:

Type I Road	Travel Time (TT) with PSL **=** TT with Ideal Speed
Type II Road	TT (PSL) **>** TT (Ideal Speed) up to 10min.
Type III Road	TT (PSL) **>** TT (Ideal Speed) more than 10min.

The analysis of speed limits (PSL) compared to ideal speeds reveals distinct patterns across different cities. In Indore, a significant portion of roads exhibit ideal speeds higher than the posted speed limits, indicating potential opportunities to adjust PSLs to better align with actual traffic conditions and road characteristics. Conversely, in Lucknow, major roads predominantly adhere to PSLs that closely match ideal speeds, suggesting effective speed limit enforcement and alignment with optimal traffic flow. Bhopal and Agra fall somewhere in between these extremes, with fewer roads exhibiting large disparities between ideal speeds and PSLs. This variation underscores the importance of tailored approaches to speed limit management and enforcement, considering the unique traffic dynamics and infrastructure characteristics of each city. By closely analyzing these patterns and implementing targeted interventions, authorities can enhance road safety and optimize traffic flow for improved urban mobility.

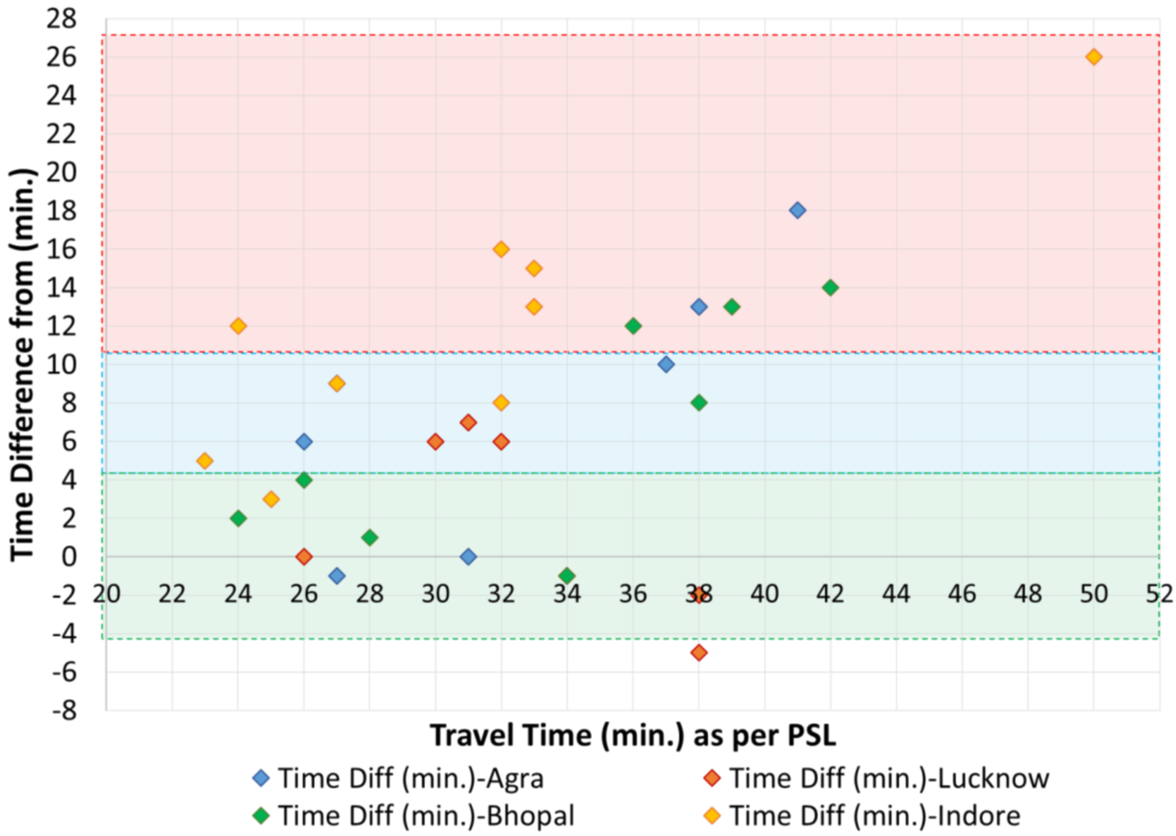


Figure 46: Identification of roads with time travel differences
Source: Primary Survey, Author Generated

Table 9: No. of roads under each category for all cities

City	I Type Roads	II Type Roads	III Type Roads
Agra	2	2	3
Lucknow	4	3	0
Bhopal	3	2	3
Indore	1	2	6

Notably, Lucknow also features stretches where PSLs exceed the ideal speeds of the respective road segments, potentially leading to suboptimal traffic management and safety concerns. Additionally, on one road each in Agra and Lucknow, equal travel times are observed between ideal speeds and PSLs, highlighting the potential for adjusting speed limits to optimize travel efficiency without compromising safety. These findings underscore the importance of regularly evaluating and adjusting speed limits to ensure optimal traffic flow and road safety in urban areas. Regular assessments and adaptations of speed limits based on evolving traffic conditions and infrastructure developments are essential for maintaining efficient and safe transportation systems within cities.

CHAPTER 5: FINDINGS AND RECOMMENDATIONS

In this chapter, significant findings are derived from the analyses conducted in the previous chapter regarding speed limits, with a focus on highlighting their variations across different cities. The analysis explored factors influencing posted speed limits (PSL), encompassing proximity to city centers, intersections, land use types, and Right-of-way considerations. By examining these factors, both direct and indirect influences on posted speed limits were identified. Furthermore, the impact of transition zones between different speed limits on comfortability and safety was investigated, which is crucial for understanding the complexities of speed limit determinants in urban areas, thereby paving the way for targeted improvements in road safety and traffic management.

Based on the findings, several recommendations are proposed to enhance safety and mobility in urban areas. These include adjusting speed limits where necessary to improve safety, ensuring smooth and safe transitions between different speed zones, strategically placing signage to reinforce speed limits, and defining appropriate transition distances between speed zones. Implementing these recommendations can significantly contribute to optimizing urban traffic systems and making roads safer for all users.

5.1 Overall Findings

From the analysis based on research questions derived in the initial stage, the following findings are derived:

5.1.1 PSL Distribution

Firstly, the outcomes are derived from the distribution of posted speed limits within and across the surveyed cities:

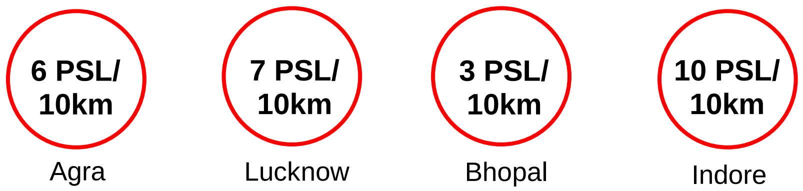


Figure 47: PSL Distribution in all four cities
Source: Primary Survey, Author Generated

The analysis of speed limit distributions across cities reveals notable variations in the placement and frequency of speed limit (PSL) signboards. The highest density of PSLs is observed in Indore, where an average of 10 PSL boards per 10 km is recorded, while the lowest density is exhibited in Bhopal, with only 3 PSL boards per 10 km. This disparity underscores the importance of consistent PSL distribution for effective traffic management and driver awareness. Interestingly, a proportional relationship between the number of PSL boards and their respective running road lengths is demonstrated by Indore and Lucknow, suggesting a systematic approach to PSL placement. In contrast, this proportional alignment is lacking in Agra and Bhopal, potentially leading to inconsistencies in speed regulation enforcement.

5.1.2 Higher PSL %age

Examining the percentage of higher PSLs (more than 40 km/h) relative to road length provides additional insights into speed limit trends across these cities. A significant proportion of roads with higher PSLs, accounting for 43.4% of its total surveyed running length, is observed in Lucknow.

27%	43.4%	2.8%	21%
Agra	Lucknow	Bhopal	Indore

Figure 48: Percentage of higher PSLs in all four cities
Source: Primary Survey, Author Generated

In contrast, the lowest percentage is recorded in Bhopal at 2.8%, indicating a predominance of lower speed limits within the city. Most roads in Bhopal maintain a uniform PSL of 40 km/h, except for specific roads like VIP Road and Link Road-1, which deviate from this standard and have higher PSLs of 40 and 50. Besides these two cities, higher speed limits on 27% and 21% respectively of their higher hierarchical roads are observed in Agra and Indore.

5.1.3 Landuse

The impact of land use on PSL distributions reveals intriguing patterns. Lower PSLs are found in commercial zones, whereas higher PSLs are observed in vacant land use areas. When comparing PSLs in core, middle, and outer regions in urban areas, variations are observed based on land use. In residential and non-residential areas, minimal variation in PSLs is noted, suggesting consistent speed limit enforcement irrespective of land use zoning.

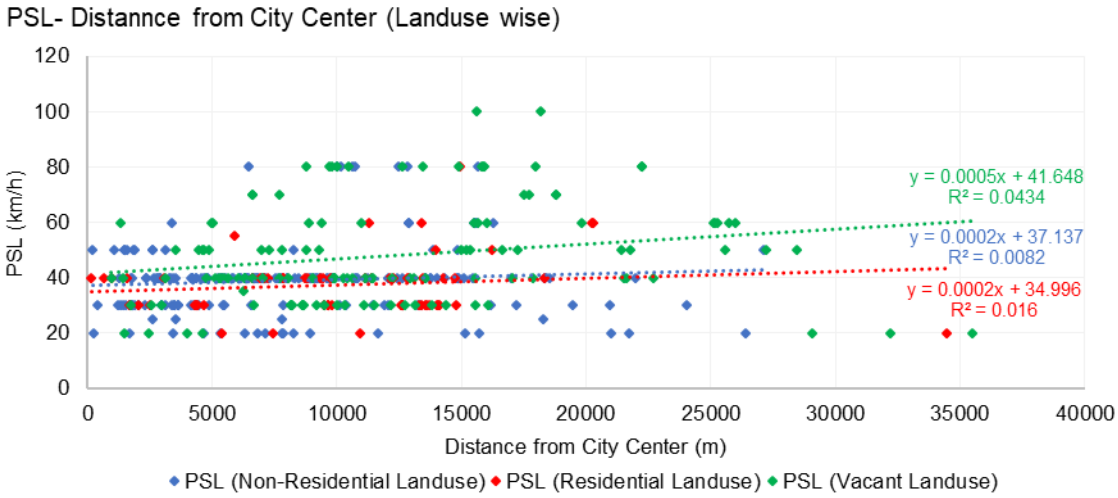


Figure 49: Landuse-wise impact on PSLs in core and outer region
Source: Primary Survey, Author Generated

However, in areas characterized by vacant land use, PSLs tend to increase while moving outward from the city center, reflecting a potential correlation between land development and traffic management strategies.

5.1.4 Right of Way

Furthermore, the influence of right-of-way (RoW) on PSLs underscores the relationship between road infrastructure and speed regulations.

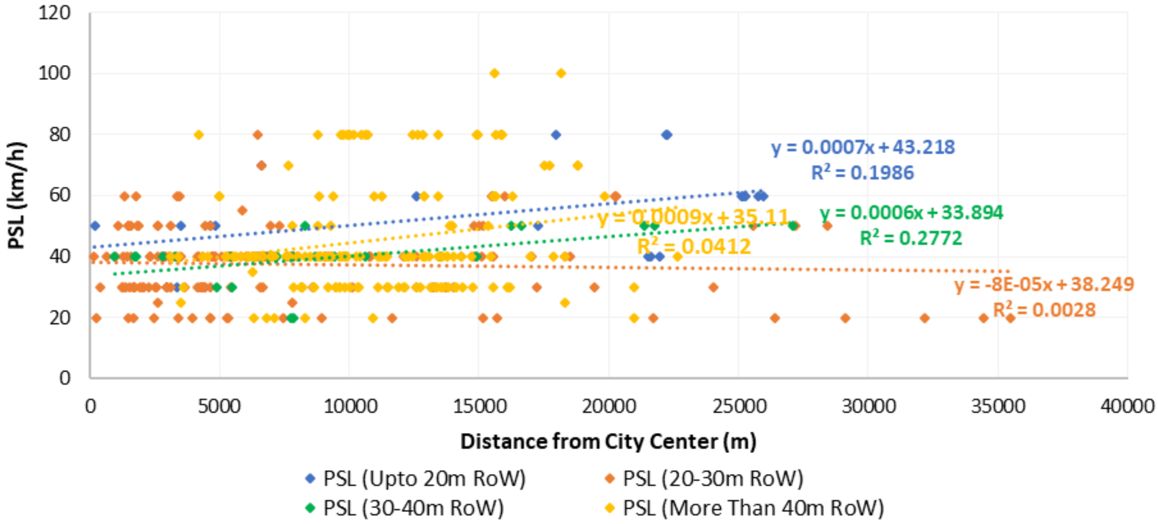


Figure 50: RoW-wise impact on PSLs in core and outer region
Source: Primary Survey, Author Generated

It is observed that PSLs increase with wider RoW, highlighting a tendency towards higher speed limits on broader thoroughfares. When analyzing speed limits (PSLs) in different parts of the city core, middle, and outer regions, a notable pattern emerges. Even with similar right-of-way (RoW) categories, speed limits tend to gradually increase as one moves away from the city center. This suggests that speed limit calibration is tailored to the urban context, considering factors like traffic density and road conditions. Interestingly, in areas with a specific RoW of 20-30 meters, there is no variation in speed limits across the core, middle, and outer regions of the city. Speed limits remain consistent throughout this range of road widths in the surveyed cities.

5.1.5 Transition Zones

Transition zones, critical points where speed limits change, are generally safe across most cities, except for specific roads in Bhopal and Lucknow. These identified unsafe transition zones have very short distances for drivers to slow down, rendering them unsafe. This underscores the importance of targeted interventions to enhance road safety measures and mitigate potential dangers associated with speed limit changes in such transition zones.

Further analysis of the data reveals that while many transition zones have good safety records, the presence of hazardous spots in these locations underscores the need for specific interventions. These identified risk areas emphasize the importance of comprehensive measures to prevent accidents and improve overall road safety.

5.2 Recommendations

Considering the analysis conducted based on the aforementioned parameters, recommendations are provided for enhancing safety and mobility in urban areas, where road user safety remains a major concern alongside efficient mobility management.

- Effective management of speed limit transitions is paramount for promoting road safety and optimizing traffic efficiency. When transitioning between different speed limits, a gradual approach with a transition range of ±20 km/h for higher speed limit changes and ±10 km/h for lower speed limit transitions is recommended. This gradual transition assists drivers in smoothly adapting to changing speed regulations without causing abrupt disruptions to traffic flow or driver behavior, thereby contributing to overall traffic flow in smooth conditions as sudden changes in speed impact other vehicle speeds and may lead to accidents.

- Strategic placement of repetitive speed limit (PSL) signboards within transition zones is recommended to reinforce driver awareness and compliance. These signboards serve as consistent reminders to drivers about changing speed limits, encouraging safer driving practices, and reducing the likelihood of speeding-related incidents.
- Placement of PSL signboards after transition zones or at major junctions is also recommended to reaffirm speed limit changes, providing drivers with necessary reminders and ensuring sustained adherence to adjusted speed regulations, thereby improving safety and mobility on urban roads.

In support of the first recommendation, i.e., mitigating risks associated with sudden changes in speed limits within transition zones, the implementation of transition distances is advised. This approach allows drivers adequate time to comfortably adjust their speed, minimizing the potential for sudden braking or acceleration, which can contribute to traffic congestion and safety hazards. Furthermore, the design of transition zones should prioritize driver safety, incorporating appropriate road markings, signage placement, and visibility enhancements. These elements optimize driver awareness and responsiveness to changing speed limits, fostering safer driving behaviors within urban road environments. Transition distances play a critical role in facilitating safe speed adjustments for drivers. Based on a comfortable deceleration rate of -0.5 m/s2, recommended transition distances for various speed limit adjustments on urban roads are as follows:

Table 10: Recommended Transition distances for different changes in PSLs

Speed (km/h)	**80**	**70**	**60**	**50**	**40**	**30**	**20**
80	0	145	270	376	463	530	578
70		0	125	231	318	386	434
60			0	106	193	260	308
50				0	87	154	202
40					0	67	116
30						0	48
20							0

These calculated transition distances ensure that drivers have sufficient space and time to adjust their speed safely and comfortably within specified speed limit transition zones. These transition distances are applicable only on straight roads, clear sight distances are also considered in case of horizontal alignment or any other geometric features available on the roads.

The graph illustrates the initial speeds of vehicles, the change in PSL, and the transition distances. With the help of any initial PSL and final PSL (Initial PSL-Change in PSL), their mutual distance can be found easily. This will aid in placing the PSL boards in the transition zones at proper locations, enhancing safety and mobility.

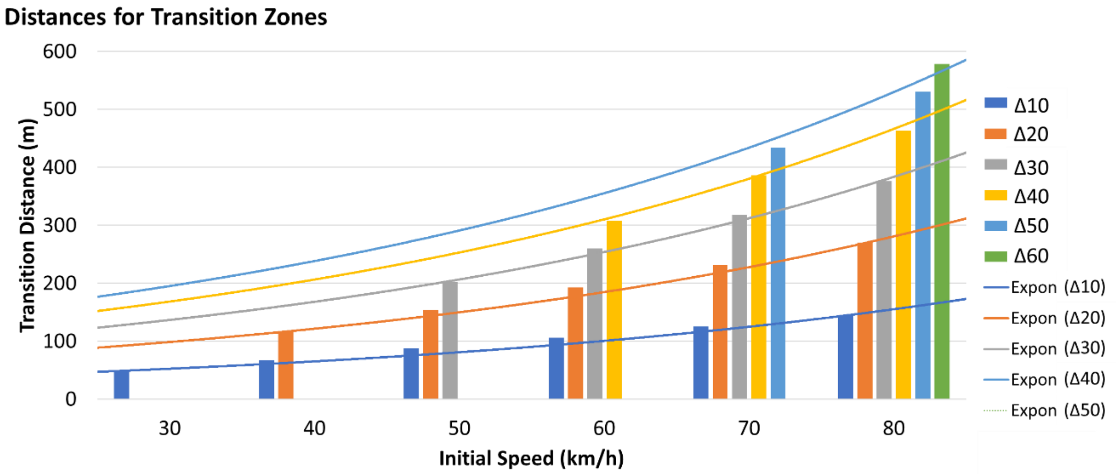


Figure 51: Transition distances for different PSL changes
Source: Author Generated

By integrating these recommended strategies into urban road design and management practices, authorities can create safer and more user-friendly road environments. This approach contributes to enhanced road safety, improved driver compliance with speed regulations, and sustained efficiency of urban traffic flow, ultimately benefiting all road users and promoting a safer and more efficient urban transportation system.

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ANNEXURES

Annexure 1: Survey format for PSL Inventory

Survey Format for data collection of PSL inventory by primary survey for the research.

योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal

Inventory for Speed Limit

Department of Transport Planning
(Transport Planning and Logistics Management)

Name of Surveyor- Date- Time- S.No.
City Location

Name of Road	Location		Landmark	Posted Speed Limit	Location of PSL*	Signage Type**	Carriageway		Reason for PSL	Median	Road Characteristics	Abutting Land use	Remarks
	Latitide	Longitude					Width(m)	Lanes					

* M- median, S- Shoulder, F- footpath, other specify
** Digital/ Fix/ Overhead Marking/ Pavement Marking
For Remark : Encroachment, Existence of roadway hazards, etc.

Annexure 2:Road stretches classification based on travel time differences as per ideal speed and PSLs

Stretch	Time (min.) As per PSL	Time Diff (min.)	Ratio	Road Type
Kanpur Road	38	-5	-0.132	T1
Mohan Road	38	-2	-0.053	
Jagnair Road	27	-1	-0.037	
Tondon Road	34	-1	-0.029	
Kolar Road	34	-1	-0.029	
Bah Road	31	0	0.000	
Faizabad Road	26	0	0.000	
Karond Road	28	1	0.036	
Vidisha Road	24	2	0.083	
Kahadia Road	25	3	0.120	
Airport Road	26	4	0.154	T2
Raibareilly Road	32	6	0.188	
Varanasi Road	30	6	0.200	
Raisen Road	38	8	0.211	
Ujjain Road	23	5	0.217	
Sitapur Road	31	7	0.226	
Bharatpur Road	26	6	0.231	
AB Road	32	8	0.250	
Firozabad Road	37	10	0.270	
Mumbai-Agra Expressway (Agra)	27	9	0.333	T3
Hoahangabad Road	36	12	0.333	
Sehore Road	39	13	0.333	
Bhadbhada Road	42	14	0.333	
Depalpur Road	27	9	0.333	
Mathura Road	38	13	0.342	
Dhar Road	33	13	0.394	
Hathras Road	41	18	0.439	
Mumbai-Agra Expressway (Indore)	33	15	0.455	
Nemawar Road	32	16	0.500	
Pipiliyahana Road	24	12	0.500	
Khandwa Road	50	26	0.520	

Legends

Roads in Agra	Roads in Lucknow
Roads in Bhopal	Roads in Indore

Annexure 3:PSL Inventory table for all four cities

Bhopal

S.No.	Location	PSL	Hierarchy	Reason	Median	Landuse	Lanes	Placement
1	(77.45778077, 23.21178647)	30	Sub-arterial	Congestion	Yes	PSP	2	Shoulder
2	(77.45499769 23.21127928)	20	Sub-arterial	Junction	Yes	Com	2	Median
3	(77.45598651 23.21140828)	30	Sub-arterial	Junction	Yes	Com	2	Median
4	(77.45060103 23.21119442)	20	Sub-arterial	Junction	Yes	Com	2	Median
5	(77.45151820 23.21114401)	30	Sub-arterial	Junction	Yes	Com	2	Median
6	(77.44720047 23.21110296)	20	Sub-arterial	Puncture	Yes	Com	2	Median
7	(77.44780700, 23.21115671)	30	Sub-arterial	Junction	Yes	Com	2	Median
8	(77.51427357, 23.29311209)	40	Ring Road	Congestion	Yes	PSP	2	Shoulder
9	(77.43063193, 23.29923396)	40	Ring Road	Junction	Yes	Res	2	Shoulder
10	(77.46750760, 23.21492004)	20	Sub-arterial	Junction	Yes	Vac	2	Median
11	(77.48760134, 23.25036936)	40	Sub-arterial	Clear	Yes	Com	2	Median
12	(77.46568877, 23.21427153)	20	Sub-arterial	Bottleneck	Yes	Vac	2	Median
13	(77.46193747, 23.21316580)	20	Sub-arterial	Puncture	Yes	Vac	2	Median
14	(77.45863703, 23.21214320)	30	Sub-arterial	Junction	Yes	PSP	2	Median
15	(77.45880252, 23.21211353)	20	Sub-arterial	Congestion	Yes	PSP	2	Shoulder
16	(77.38727332, 23.25982472)	60	Sub-arterial	Clear	Yes	Vac	2	Shoulder
17	(77.39249668, 23.07564236)	40	Arterial	Clear	No	Vac	2	Shoulder
18	(77.32282538, 23.31325670)	30	Arterial	Junction	Yes	Com	2	Shoulder
19	(77.48712724, 23.14342710)	40	Ring Road	Junction	Yes	Com	2	Median
20	(77.36560677, 23.27318163)	30	Arterial	Bottleneck	Yes	Com	2	Shoulder
21	(77.31694483, 23.31810332)	40	Arterial	Curve	Yes	Vac	3	Shoulder
22	(77.37017948, 23.26155704)	60	Sub-arterial	Clear	Yes	Com	2	Shoulder
23	(77.36844946, 23.27036721)	50	Sub-arterial	Clear	Yes	Vac	2	Shoulder
24	(77.38482646, 23.21353097)	30	Sub-arterial	Curve	Yes	Vac	2	Median
25	(77.38778904, 23.22662611)	30	Sub-arterial	Clear	Yes	Com	2	Shoulder
26	(77.39402742, 23.21390841)	30	Sub-arterial	Junction	Yes	Com	2	Median
27	(77.39366614, 23.21358017)	30	Sub-arterial	Junction	Yes	Com	2	Median
28	(77.40786314, 23.22111020)	30	Sub-arterial	Clear	Yes	Res	2	Median
29	(77.39549105, 23.21554550)	30	Sub-arterial	Congestion	Yes	PSP	2	Median
30	(77.39262158, 23.07595920)	40	Arterial	Clear	No	Vac	2	Shoulder
31	(77.40950355, 23.22082539)	30	Sub-arterial	Puncture	Yes	Res	2	Median
32	(77.38404838, 23.22326507)	30	Sub-arterial	Clear	Yes	Com	2	Shoulder
33	(77.36951801, 23.27222090)	50	Sub-arterial	Clear	Yes	Vac	2	Shoulder
34	(77.35227487, 23.29024614)	40	Arterial	Curve	Yes	Vac	3	Median
35	(77.35275588, 23.28814447)	30	Arterial	Curve	Yes	Com	2	Median
36	(77.35220080, 23.29659383)	40	Arterial	Curve	Yes	Vac	3	Median
37	(77.35245216, 23.29032473)	30	Arterial	Curve	Yes	Vac	2	Median
38	(77.34112187, 23.29907986)	30	Arterial	Clear	Yes	Vac	2	Median
39	(77.34353430, 23.29675072)	30	Arterial	Junction	Yes	Com	3	Median
40	(77.32116245, 23.31253046)	40	Ring Road	Junction	Yes	Vac	3	Shoulder
41	(77.32595289, 23.31144828)	40	Arterial	Puncture	Yes	PSP	3	Shoulder
42	(77.40144791, 23.23655350)	40	Sub-arterial	Congestion	Yes	Com	2	Shoulder
43	(77.39049697, 23.26176344)	40	Arterial	Clear	Yes	Com	2	Median
44	(77.36958901, 23.27512570)	30	Arterial	Curve	Yes	Com	3	Shoulder

45	(77.38592417, 23.26231150)	40	Arterial	Clear	Yes	Com	2	Median
46	(77.36507215, 23.27776679)	40	Arterial	Clear	Yes	Vac	3	Shoulder
47	(77.36941604 23.27529081)	40	Arterial	Curve	Yes	Com	3	Shoulder
48	(77.35272975 23.28832542)	40	Arterial	Curve	Yes	Com	3	Median
49	(77.36308127, 23.27902458)	40	Arterial	Curve	Yes	Com	3	Shoulder
50	(77.43794276, 23.22193541)	20	Arterial	Bottleneck	Yes	Com	2	Shoulder
51	(77.44090451, 23.21668056)	20	Arterial	Bottleneck	No	PSP	2	Shoulder
52	(77.42369933, 23.23102084)	60	Sub-arterial	Clear	Yes	Vac	3	Median
53	(77.43475941, 23.22844848)	20	Arterial	Bottleneck	Yes	Com	2	Shoulder
54	(77.40201618, 23.22628034)	40	Sub-arterial	Clear	Yes	Com	3	Shoulder
55	(77.42345568, 23.23105169)	60	Sub-arterial	Clear	Yes	Vac	3	Median
56	(77.40179877, 23.23214263)	40	Sub-arterial	Clear	Yes	Vac	3	Shoulder
57	(77.40208031, 23.22877100)	40	Sub-arterial	Clear	Yes	Vac	3	Median
58	(77.45790953, 23.21188375)	20	Sub-arterial	Junction	Yes	PSP	2	Median

Lucknow

S.No.	Location	PSL	Hierarchy	Reason	Median	Landuse	Lanes	Placement
1	(80.7891676, 26.6502897)	50	Arterial	Curve	Yes	Vac	2	Median
2	(80.9898399, 26.8599641)	40	Sub-arterial	Curve	Yes	Res	2	Median
3	(80.9960000, 26.8669013)	40	Sub-arterial	Curve	Yes	Vac	2	Median
4	(80.8555442, 26.8353516)	40	Sub-arterial	Clear	Yes	Res	2	Shoulder
5	(80.8748108, 26.8234636)	40	Sub-arterial	Junction	Yes	PSP	2	Shoulder
6	(80.8732835, 26.8240250)	40	Sub-arterial	Clear	Yes	PSP	2	Shoulder
7	(80.8849767, 26.8130059)	30	Sub-arterial	Clear	Yes	Res	2	Shoulder
8	(80.8839393, 26.8137820)	30	Sub-arterial	Clear	Yes	Res	2	Shoulder
9	(80.8848697, 26.8125802)	30	Sub-arterial	Clear	Yes	Res	2	Shoulder
10	(80.8845933, 26.8129395)	25	Sub-arterial	Puncture	Yes	Res	2	Shoulder
11	(80.8862339, 26.8113575)	40	Sub-arterial	Puncture	Yes	Res	2	Shoulder
12	(80.8859877, 26.81126344)	30	Sub-arterial	Puncture	Yes	Res	2	Shoulder
13	(80.8967353, 26.8035887)	25	Arterial	Junction	Yes	Com	2	Shoulder
14	(80.8904041, 26.8057098)	40	Sub-arterial	Clear	Yes	Res	2	Median
15	(80.9704932, 26.8173100)	50	Arterial	Clear	No	Vac	2	Shoulder
16	(80.9643902, 26.8255509)	50	Arterial	Clear	No	Vac	2	Shoulder
17	(80.9838809, 26.8092854)	40	Arterial	Bottleneck	No	Vac	2	Shoulder
18	(80.9712009, 26.8155964)	50	Arterial	Clear	No	Vac	2	Shoulder
19	(80.9778412, 26.7744721)	60	Ring Road	Clear	Yes	Com	2	Median
20	(80.9868601, 26.8086827)	40	Arterial	Bottleneck	No	Vac	2	Shoulder
21	(80.8224627, 26.833360)	50	Arterial	Curve	Yes	Com	2	Shoulder
22	(80.8077522, 26.8775922)	40	Arterial	Bottleneck	Yes	Vac	2	Shoulder
23	(80.7604669, 26.8021848)	40	Arterial	Curve	No	Com	2	Shoulder
24	(81.0580137, 26.8891550)	40	Arterial	Market	Yes	Com	2	Median
25	(80.9265084, 26.9652164)	60	Arterial	Clear	Yes	Vac	2	Median
26	(81.0710627, 26.8926423)	40	Arterial	Market	Yes	Com	2	Median
27	(81.0596860, 26.8898441)	40	Arterial	Curve	Yes	Vac	2	Median
28	(81.0725163, 26.8929464)	40	Arterial	Market	Yes	Com	2	Median
29	(81.0846015, 26.8957859)	60	Arterial	Clear	Yes	Com	2	Median
30	(80.9713594, 26.7096371)	50	Arterial	Clear	Yes	Vac	2	Shoulder

31	(80.9508950, 26.7461781)	40	Arterial	Clear	Yes	Com	2	Shoulder
32	(80.9637317, 26.7210989)	50	Arterial	Clear	Yes	Vac	2	Shoulder
33	(80.9479587, 26.7589401)	40	Arterial	Market	Yes	Com	2	Shoulder
34	(80.9464793, 26.7660957)	40	Arterial	Market	Yes	Com	2	Shoulder
35	(80.9595997, 26.7276481)	40	Arterial	Market	Yes	Com	2	Shoulder
36	(80.9516039, 26.7413875)	40	Arterial	Clear	Yes	Com	2	Shoulder
37	(80.9783527, 26.6940982)	40	Arterial	Market	Yes	Com	2	Shoulder
38	(80.9628653, 26.7223078)	50	Arterial	Clear	Yes	Vac	2	Shoulder
39	(80.9882617, 26.6661472)	50	Arterial	Clear	Yes	Vac	2	Shoulder
40	(80.9869202, 26.6693432)	50	Arterial	Clear	Yes	Vac	2	Shoulder
41	(80.8081646, 26.6652637)	50	Arterial	Clear	Yes	Res	2	Median
42	(80.8563800, 26.7368186)	50	Arterial	Market	Yes	Com	2	Median
43	(80.7992488, 26.6533267)	50	Arterial	Curve	Yes	Vac	2	Median
44	(80.7992985, 26.6541667)	50	Arterial	Clear	Yes	Vac	2	Shoulder
45	(80.9611967, 26.7710803)	40	Ring Road	Puncture	Yes	Vac	2	Median
46	(80.9647168, 26.7713623)	40	Ring Road	Clear	Yes	Vac	2	Median
47	(80.9592494, 26.7710880)	20	Ring Road	Clear	Yes	Res	2	Shoulder
48	(80.9596113, 26.7711021)	60	Ring Road	Clear	Yes	Vac	2	Shoulder
49	(80.9842613, 26.7797765)	40	Ring Road	Puncture	Yes	Com	2	Shoulder
50	(80.9559695, 26.7709789)	80	Ring Road	Clear	Yes	PSP	2	Median
51	(80.9967740, 26.7923860)	60	Ring Road	Clear	Yes	Vac	2	Shoulder
52	(80.9968537, 26.7923625)	80	Ring Road	Clear	Yes	Com	2	Median
53	(80.9950278, 26.7902588)	50	Ring Road	Clear	Yes	Vac	2	Shoulder
54	(80.9963157, 26.7914905)	60	Ring Road	Curve	Yes	Com	2	Shoulder
55	(80.9492474, 26.7697810)	40	Ring Road	Puncture	Yes	Vac	2	Median
56	(80.936502, 26.8561939)	30	Sub-arterial	Curve	Yes	Res	2	Shoulder
57	(80.9360863, 26.8553191)	30	Sub-arterial	Junction	Yes	PSP	2	Shoulder
58	(80.9372268, 26.8604662)	30	Sub-arterial	Curve	Yes	PSP	2	Shoulder
59	(80.9374034, 26.8574495)	30	Sub-arterial	Curve	Yes	Res	2	Shoulder
60	(80.9392071, 26.8643919)	30	Sub-arterial	Clear	Yes	Vac	2	Shoulder
61	(80.9384641, 26.8625282)	30	Sub-arterial	Clear	Yes	Res	2	Shoulder
62	(80.9406230, 26.8695398)	30	Sub-arterial	Puncture	No	Com	2	Shoulder
63	(80.9402636, 26.8684555)	30	Sub-arterial	Puncture	No	Res	2	Shoulder
64	(80.9410977, 26.8717099)	30	Sub-arterial	Junction	Yes	Com	2	Shoulder
65	(80.9955717, 26.8748175)	40	Ring Road	Puncture	Yes	Res	2	Shoulder
66	(80.9505719, 26.9103610)	50	Ring Road	Clear	Yes	Res	2	Median
67	(81.0191907, 26.8738865)	40	Arterial	Puncture	Yes	Com	2	Shoulder
68	(81.0189920, 26.8740567)	40	Arterial	Market	Yes	Com	2	Median
69	(81.0222153, 26.8743340)	40	Arterial	Market	Yes	Com	2	Median
70	(81.0457047, 26.8838883)	40	Arterial	Market	Yes	Com	2	Median
71	(81.0387576, 26.8807402)	30	Arterial	Market	Yes	Com	2	Shoulder
72	(80.9391750, 26.7804567)	40	Sub-arterial	Clear	Yes	Res	2	Shoulder
73	(81.0521205, 26.8868515)	40	Arterial	Clear	Yes	Vac	2	Median
74	(80.9667668, 26.8512974)	40	Sub-arterial	Junction	Yes	PSP	3	Shoulder
75	(80.9666810, 26.8512357)	25	Sub-arterial	Junction	Yes	PSP	3	Shoulder
76	(80.9682938, 26.8525303)	40	Sub-arterial	Clear	Yes	PSP	3	Median
77	(80.8643137, 26.8738246)	25	Ring Road	Junction	Yes	Com	3	Shoulder
78	(81.0830212, 26.8835210)	60	Ring Road	Clear	Yes	Vac	3	Shoulder

79	(81.0836736, 26.8815332)	60	Ring Road	Clear	Yes	Vac	3	Shoulder
80	(81.0752625, 26.9061672)	80	Ring Road	Clear	Yes	Vac	3	Median
81	(81.0711555, 26.9198601)	80	Ring Road	Clear	Yes	Vac	3	Median
82	(81.0839051, 26.8764984)	60	Ring Road	Clear	Yes	Vac	3	Shoulder
83	(81.0769992, 26.8939743)	60	Arterial	Clear	Yes	Com	3	Median
84	(81.0764145, 26.8938338)	40	Arterial	Puncture	Yes	Com	3	Median
85	(81.0941229, 26.7699249)	40	Arterial	Curve	Yes	Com	3	Shoulder
86	(81.0675916, 26.8141542)	80	Ring Road	Clear	Yes	Vac	3	OVER
87	(81.0768665, 26.8512440)	80	Ring Road	Clear	Yes	Vac	3	OVER
88	(81.0760436, 26.8516633)	80	Ring Road	Clear	Yes	Vac	3	OVER
89	(81.0848881, 26.8774765)	60	Ring Road	Clear	Yes	Vac	3	Shoulder
90	(81.0851982, 26.8758664)	60	Ring Road	Clear	Yes	Vac	3	Shoulder
91	(80.9448267, 26.7715797)	40	Arterial	Junction	RES	Vac	3	Shoulder
92	(80.9391305, 26.9061185)	50	Arterial	Clear	Yes	Vac	3	Shoulder
93	(81.0045692, 26.8732847)	20	Arterial	Puncture	Yes	Com	3	Shoulder
94	(80.9731287, 26.8564374)	40	Sub-arterial	Puncture	Yes	Com	4	Shoulder
95	(80.9537819, 26.8425171)	40	Sub-arterial	Junction	Yes	Vac	4	Median
96	(80.9604256, 26.8466838)	40	Sub-arterial	Clear	Yes	Com	4	Median
97	(80.9728919, 26.8561943)	25	Sub-arterial	Junction	Yes	Com	4	Shoulder
98	(80.9112962, 26.8718130)	40	Sub-arterial	Curve	No	PSP	4	Shoulder
99	(80.9142421, 26.8706085)	40	Sub-arterial	Curve	No	PSP	4	Shoulder
100	(80.9960339, 26.87206135)	40	Sub-arterial	Clear	Yes	Com	5	Median
101	(80.9960092, 26.8717744)	20	Arterial	Junction	Yes	Com	5	Median

Indore

S.No.	Location	PSL	Hierarchy	Reason	Median	Landuse	Lanes	Placement
1	(75.8638235, 22.70892835)	30	Sub-Arterial	Curve	No	Res	4	Shoulder
2	(75.8644553, 22.7087713)	30	Sub-Arterial	Curve	No	Res	4	Shoulder
3	(75.8936036, 22.7444179)	40	Arterial	Clear	Yes	Com	3	Shoulder
4	(75.8980615, 22.75893598)	40	Arterial	Clear	Yes	Com	3	Shoulder
5	(75.8991552, 22.76235331)	40	Arterial	Clear	Yes	Com	3	Shoulder
6	(75.9002702, 22.76602343)	40	Arterial	Clear	Yes	Com	3	Shoulder
7	(75.9009578, 22.76839521)	40	Arterial	Bottleneck	Yes	Vac	3	Shoulder
8	(75.90105728, 22.7687017)	40	Arterial	Clear	Yes	Vac	3	Shoulder
9	(75.89326311, 22.7444650)	40	Arterial	Clear	Yes	Com	3	Shoulder
10	(75.89142301, 22.7385406)	40	Arterial	Clear	Yes	Com	3	Shoulder
11	(75.89113464, 22.7376208)	40	Arterial	Clear	Yes	Com	3	Shoulder
12	(75.89058723, 22.7357992)	40	Arterial	Clear	Yes	Com	3	Shoulder
13	(75.8152422, 22.63041405)	60	Ring Road	Clear	Yes	Vac	3	Shoulder
14	(75.8310356, 22.63368431)	100	Ring Road	Clear	Yes	Vac	3	Shoulder
15	(75.85584280, 22.6388382)	80	Ring Road	Curve	Yes	Vac	3	Shoulder
16	(75.8580503, 22.63860061)	100	Ring Road	Clear	Yes	Vac	3	Shoulder
17	(75.8983919, 22.64239034)	60	Ring Road	Puncture	Yes	Res	3	Shoulder
18	(75.9037437, 22.64826788)	40	Ring Road	Curve	Yes	Vac	3	Shoulder
19	(75.9242826, 22.69252080)	40	Ring Road	Clear	Yes	Res	3	Shoulder
20	(75.8615816, 22.68124454)	40	Ring Road	Clear	Yes	Vac	3	Shoulder
21	(75.8701982, 22.6825712)	40	Ring Road	Clear	Yes	Vac	3	Shoulder

22	(75.8718511, 22.68452840)	40	Ring Road	Clear	Yes	Vac	3	Median
23	(75.8741912, 22.68560881)	40	Ring Road	Junction	Yes	Com	3	Median
24	(75.8886533, 22.68983825)	40	Ring Road	Puncture	Yes	Res	3	Shoulder
25	(75.90221808, 22.6953680)	40	Ring Road	Clear	Yes	Vac	3	Shoulder
26	(75.90559729, 22.6978099)	40	Ring Road	Clear	Yes	Res	3	Shoulder
27	(75.90693728, 22.7002904)	40	Ring Road	Curve	Yes	Res	3	Median
28	(75.90577898, 22.7123938)	80	Ring Road	Clear	Yes	Com	3	Median
29	(75.90580811, 22.7135576)	40	Ring Road	Clear	Yes	Res	3	Shoulder
30	(75.90552185, 22.7246036)	40	Ring Road	Clear	Yes	Res	3	Median
31	(75.9054943, 22.72469855)	40	Ring Road	Clear	Yes	Res	3	Median
32	(75.9021763, 22.73737980)	40	Ring Road	Clear	Yes	Res	3	Shoulder
33	(75.9007270, 22.76860065)	40	Arterial	Clear	Yes	Com	3	Shoulder
34	(75.9005274, 22.76802723)	40	Arterial	Clear	Yes	Com	3	Shoulder
35	(75.9003017, 22.76736279)	40	Arterial	Clear	Yes	Com	3	Shoulder
36	(75.8984804, 22.76123620)	40	Arterial	Puncture	Yes	Com	3	Shoulder
37	(75.89814207 22.76014300)	40	Arterial	Clear	Yes	Com	3	Shoulder
38	(75.8969671, 22.75646339)	40	Arterial	Clear	Yes	Com	3	Shoulder
39	(75.8957135, 22.75223235)	40	Arterial	Clear	Yes	Com	3	Shoulder
40	(75.8602971, 22.68586753)	40	Arterial	Clear	Yes	Com	3	Shoulder
41	(75.83660065, 22.7863627)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
42	(75.8317197, 22.78325910)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
43	(75.8300312, 22.7819024)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
44	(75.8269760, 22.77941447)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
45	(75.8226119, 22.77523772)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
46	(75.8196876, 22.77250685)	30	Sub-Arterial	Junction	Yes	Vac	2	Median
47	(75.8153932, 22.76846629)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
48	(75.8124051, 22.76492954)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
49	(75.8096038, 22.76109182)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
50	(75.8027924, 22.75211847)	30	Sub-Arterial	Junction	Yes	Vac	2	Shoulder
51	(75.8012841, 22.74703934)	80	Sub-Arterial	Clear	Yes	Res	2	
52	(75.9323897, 22.72238182)	40	Ring Road	Clear	Yes	Vac	2	Shoulder
53	(75.9259953, 22.70111027)	20	Sub-Arterial	Puncture	Yes	Com	2	Shoulder
54	(75.9234993, 22.70200993)	20	Sub-Arterial	Puncture	Yes	Vac	2	Shoulder
55	(75.9223707, 22.70212484)	20	Sub-Arterial	Puncture	Yes	Res	2	Shoulder
56	(75.9163920, 22.70343284)	40	Sub-Arterial	Clear	Yes	Com	2	Shoulder
57	(75.9095114, 22.70530580)	20	Sub-Arterial	Junction	Yes	Vac	2	Shoulder
58	(75.9074894, 22.70578700)	55	Sub-Arterial	Junction	Yes	Res	2	Shoulder
59	(75.8905749, 22.60877663)	30	Arterial	Congestion	No	Res	2	Shoulder
60	(75.8923487, 22.60472897)	30	Arterial	Congestion	No	Res	2	Shoulder
61	(75.9057119, 22.55793484)	50	Arterial	Clear	No	Vac	2	Shoulder
62	(75.7952204, 22.69872435)	20	Arterial	Puncture	Yes	Vac	2	Shoulder
63	(75.7886765, 22.69676040)	20	Arterial	Curve	Yes	Res	2	Shoulder
64	(75.7857058, 22.69652208)	20	Arterial	Curve	Yes	Res	2	Shoulder
65	(75.7745287, 22.69121988)	50	Arterial	Clear	Yes	Vac	2	Shoulder
66	(75.7716425, 22.69040276)	50	Arterial	Clear	Yes	Vac	2	Shoulder
67	(75.8359389, 22.72180413)	30	Arterial	Junction	Yes	Com	2	Median
68	(75.8311658, 22.72312075)	30	Arterial	Clear	Yes	Vac	2	Median

69	(75.7966371, 22.73491314)	30	Arterial	Bottleneck	Yes	Vac	2	Shoulder
70	(75.7933567, 22.73685351)	40	Arterial	Congestion	Yes	Res	2	Shoulder
71	(75.7649237, 22.77241115)	30	Arterial	Puncture	No	Com	2	Shoulder
72	(75.7800786, 22.74118253)	30	Arterial	Curve	Yes	Vac	2	Shoulder
73	(75.8968163, 22.75468846)	40	Arterial	Clear	Yes	Com	2	Shoulder
74	(75.9031619, 22.77621429)	40	Arterial	Clear	Yes	Com	2	Median
75	(75.9032419, 22.77652999)	40	Arterial	Clear	Yes	Com	2	Median
76	(75.875996, 22.75930107)	30	Sub-Arterial	Junction	Yes	Res	2	Median
77	(75.8767808, 22.75712458)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
78	(75.8800866, 22.75436718)	30	Sub-Arterial	Junction	Yes	Res	2	Median
79	(75.8811597, 22.75407253)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
80	(75.8830039, 22.75379788)	30	Sub-Arterial	Bottleneck	Yes	Res	2	Median
81	(75.8866381, 22.75290000)	40	Sub-Arterial	Clear	Yes	PSP	2	Shoulder
82	(75.8893972, 22.75228073)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
83	(75.8934102, 22.75140297)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
84	(75.8865593, 22.71068282)	20	Sub-Arterial	Congestion	Yes	PSP	2	Shoulder
85	(75.8843998, 22.71099287)	20	Sub-Arterial	Junction	Yes	PSP	2	Shoulder
86	(75.8844496, 22.71116422)	20	Sub-Arterial	Puncture	Yes	Res	2	Shoulder
87	(75.8896110, 22.70982581)	20	Sub-Arterial	Puncture	Yes	Vac	2	Shoulder
88	(75.8970866, 22.70804972)	40	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
89	(75.8054233, 22.62699489)	30	Arterial	Junction	Yes	Com	2	Median
90	(75.7974046, 22.61337667)	40	Arterial	Clear	No	Vac	2	Shoulder
91	(75.8052072, 22.62665272)	20	Arterial	Junction	Yes	Com	2	Median
92	(75.8148908, 22.63023517)	20	Ring Road	Puncture	Yes	Vac	2	Shoulder
93	(75.8452730, 22.63701540)	20	Ring Road	Puncture	Yes	Vac	2	Shoulder
94	(75.8904192, 22.63898418)	30	Ring Road	Curve	Yes	Vac	2	Shoulder
95	(75.8979811, 22.64207648)	20	Ring Road	Congestion	Yes	Res	2	Shoulder
96	(75.9117795, 22.65963108)	60	Ring Road	Clear	Yes	Vac	2	Shoulder
97	(75.8577320, 22.68343466)	30	Arterial	Junction	Yes	Com	2	Shoulder
98	(75.8662881, 22.69135305)	40	Arterial	Clear	Yes	Com	2	Shoulder
99	(75.8741566, 22.69601436)	40	Arterial	Clear	Yes	Vac	2	Shoulder
100	(75.8768484, 22.69742651)	40	Arterial	Clear	Yes	Com	2	Shoulder
101	(75.8964224, 22.75468192)	20	Arterial	Junction	Yes	Com	2	Shoulder
102	(75.8888858, 22.73011165)	40	Arterial	Clear	Yes	Com	2	Shoulder
103	(75.7964725, 22.73698547)	30	Sub-Arterial	Puncture	Yes	PSP	2	Median
104	(75.7983558, 22.74060265)	30	Sub-Arterial	Clear		Vac	2	Median
105	(75.79938067, 22.7423868)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
106	(75.8007792, 22.74464698)	30	Sub-Arterial	Junction	Yes	Vac	2	Median
107	(75.8025647, 22.75045811)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
108	(75.8078923, 22.75869653)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
109	(75.8101574, 22.76146992)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
110	(75.8107118, 22.76236165)	30	Sub-Arterial	Puncture	Yes	Com	2	Median
111	(75.8134605, 22.76582962)	80	Sub-Arterial	Clear	Yes	Com	2	Shoulder
112	(75.8156652, 22.76861339)	30	Sub-Arterial	Puncture	Yes	Com	2	Median
113	(75.8158107, 22.76870241)	80	Sub-Arterial	Clear	Yes	Com	2	Shoulder
114	(75.8224120, 22.77487390)	80	Sub-Arterial	Clear	Yes	Vac	2	Median
115	(75.8250705, 22.77735117)	80	Sub-Arterial	Clear	Yes	Vac	2	Median

116	(75.8280044, 22.78000083)	30	Sub-Arterial	Puncture	Yes	Vac	2	Median
117	(75.8325411, 22.78354958)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
118	(75.8349576, 22.78511634)	60	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
119	(75.8398881, 22.78805447)	80	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
120	(75.8409551, 22.7887296)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Shoulder
121	(75.8940596, 22.7514641)	30	Sub-Arterial	Junction	Yes	Res	2	Median
122	(75.8877980, 22.7528291)	30	Sub-Arterial	Bottleneck	Yes	Res	2	Median
123	(75.8873399, 22.7529248)	30	Sub-Arterial	Junction	Yes	Res	2	Median
124	(75.8826083, 22.7539824)	30	Sub-Arterial	Bottleneck	Yes	Res	2	Median
125	(75.8812018, 22.7542956)	30	Sub-Arterial	Bottleneck	Yes	Res	2	Median
126	(75.8773381, 22.7567388)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
127	(75.8679521, 22.7665557)	40	Sub-Arterial	Clear	Yes	Vac	2	Shoulder
128	(75.8661666, 22.7680899)	40	Sub-Arterial	Curve	Yes	Res	2	Shoulder
129	(75.8566350, 22.7801225)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
130	(75.8488411, 22.7897676)	30	Sub-Arterial	Curve	Yes	Vac	2	Median
131	(75.8489726, 22.78951330)	30	Sub-Arterial	Junction	Yes	Vac	2	Shoulder
132	(75.8717509, 22.76380591)	30	Sub-Arterial	Curve	Yes	Com	2	Median
133	(75.8734864, 22.76240884)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
134	(75.8745028, 22.76150497)	40	Sub-Arterial	Clear	Yes	Res	2	Shoulder
135	(75.8844472, 22.71950670)	40	Arterial	Clear	Yes	Com	2	Shoulder
136	(75.8831594, 22.71202484)	40	Arterial	Clear	Yes	Com	2	Shoulder
137	(75.8787927, 22.70599109)	40	Arterial	Clear	Yes	Com	2	Shoulder
138	(75.8763787, 22.70361086)	20	Arterial	Junction	Yes	Com	2	Shoulder
139	(75.8773606, 22.69814426)	20	Arterial	Junction	Yes	Com	2	Shoulder
140	(75.87062229, 22.6944404)	40	Arterial	Clear	Yes	PSP	2	Shoulder
141	(75.8680460, 22.69301988)	40	Arterial	Clear	Yes	Com	2	Shoulder
142	(75.8641226, 22.68973850)	40	Arterial	Clear	Yes	Com	2	Shoulder
143	(75.8471086, 22.79683204)	50	Arterial	Clear	Yes	Vac	2	Shoulder
144	(75.8473160, 22.78767130)	50	Arterial	Clear	Yes	Vac	2	Shoulder
145	(75.8478958, 22.77489422)	40	Arterial	Clear	Yes	Com	2	Median
146	(75.8484747, 22.75662827)	30	Arterial	Clear	Yes	Res	2	Median
147	(75.8487009, 22.75594520)	30	Arterial	Curve	Yes	Com	2	Median
148	(75.8486309, 22.75603679)	30	Arterial	Curve	Yes	Com	2	Shoulder
149	(75.8484742, 22.75526251)	30	Arterial	Curve	Yes	Com	2	Shoulder
150	(75.847967, 22.77523628)	40	Arterial	Clear	Yes	Com	2	Median
151	(75.8479828, 22.77558458)	40	Arterial	Clear	Yes	Com	2	Median
152	(75.8480455, 22.77796158)	40	Arterial	Clear	Yes	Com	2	Median
153	(75.8452377, 22.78997793)	30	Sub-Arterial	Bottleneck	Yes	Vac	2	Median
154	(75.8412430, 22.78909296)	30	Sub-Arterial	Junction	Yes	Vac	2	Median

Agra

S.No.	Location	PSL	Hierarchy	Reason	Median	Landuse	Lanes	Placement
1	(78.00933962 27.17020050)	20	Arterial	Junction	Yes	Com	2	Shoulder
2	(77.93813713, 27.21785261)	20	Arterial	Curve	Yes	PSP	3	Median
3	(78.00491382 27.18009069)	30	Sub-Arterial	Curve	Yes	Com	2	Shoulder
4	(78.01689127, 27.17955268)	30	Sub-Arterial	Junction	Yes	PSP	2	Median

5	(78.01639548, 27.17999888)	30	Sub-Arterial	Congestion	Yes	PSP	2	Shoulder
6	(78.0303241, 27.19020397)	30	Sub-Arterial	Curve	NO	Com	2	Shoulder
7	(78.00921801, 27.16956761)	30	Arterial	Junction	Yes	Vac	2	Shoulder
8	(77.96145310, 27.18865966)	30	Sub-Arterial	Junction	Yes	Com	2	Shoulder
9	(78.00625346, 27.21025681)	30	Arterial	Congestion	Yes	Com	2	Shoulder
10	(78.00075593, 27.19203956)	30	Sub-Arterial	Junction	Yes	Com	2	Shoulder
11	(78.04564567, 27.25126402)	30	Arterial	Puncture	NO	Res	2	Shoulder
12	(78.00890096, 27.16813957)	30	Arterial	Congestion	Yes	Com	2	Shoulder
13	(77.96237093, 27.18850856	30	Sub-Arterial	Junction	Yes	Com	2	Shoulder
14	(78.00169500, 27.19629406)	30	Sub-Arterial	Junction	Yes	Com	2	Shoulder
15	(78.00102673, 27.19285008)	30	Sub-Arterial	Junction	Yes	PSP	2	Shoulder
16	(78.02632078, 27.19269530)	30	Sub-Arterial	Bottleneck	NO	Vac	2	Shoulder
17	(78.04935310, 27.15772752)	30	Arterial	Puncture	Yes	Com	2	Shoulder
18	(78.03216459, 27.20615567)	35	Arterial	Puncture	Yes	Vac	2	Shoulder
19	(78.05405364, 27.15781199)	40	Arterial	Junction	Yes	Com	2	Shoulder
20	(78.06082943,27.15885345)	40	Arterial	Junction	Yes	Com	2	Shoulder
21	(78.0617120, 27.15861277)	40	Arterial	Junction	Yes	Com	2	Shoulder
22	(78.06222152, 27.15871578)	40	Arterial	Junction	Yes	PSP	2	Shoulder
23	(78.03895073, 27.16233084)	40	Arterial	Junction	Yes	PSP	2	Shoulder
24	(78.06280632, 27.15886469)	40	Sub-Arterial	Junction	NO	PSP	2	Shoulder
25	(78.00355883,27.20617554)	40	Sub-Arterial	Junction	Yes	Com	2	Shoulder
26	(77.90199967,27.22600749)	40	Arterial	Puncture	Yes	Vac	3	Shoulder
27	(77.86507433, 27.23509533)	40	Arterial	Curve	Yes	Vac	3	Shoulder
28	(78.03351726,27.16116549)	40	Arterial	Junction	Yes	Com	3	Shoulder
29	(78.03276930, 27.16123118)	40	Arterial	Junction	Yes	Com	3	Shoulder
30	(77.93793702, 27.21772477)	40	Arterial	Clear	Yes	PSP	2	Shoulder
31	(77.99564180, 27.21091437)	40	Arterial	Puncture	Yes	Com	3	Shoulder
32	(77.92857312, 27.22087124)	40	Arterial	Clear	Yes	Com	3	Shoulder
33	(78.0717503, 27.1511778)	40	Arterial	Junction	Yes	Com	3	Shoulder
34	(78.07100888, 27.15206772)	40	Arterial	Junction	Yes	Com	2	Shoulder
35	(78.00424505 27.20943659)	40	Sub-Arterial	Clear	Yes	Com	2	Median
36	(78.05280740, 27.15792575)	40	Arterial	Junction	Yes	Com	2	Shoulder
37	(78.00467461, 27.20392538)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder
38	(78.0014241, 27.19542366)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder
39	(78.00116230, 27.19419561)	50	Sub-Arterial	Clear	Yes	PSP	2	Shoulder
40	(78.00093636, 27.19072188)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder
41	(78.00136334, 27.19421948)	50	Sub-Arterial	Clear	Yes	PSP	2	Shoulder
42	(78.00250988, 27.19774420)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder
43	(78.00484912, 27.20382937)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder

44	(78.00399937, 27.2080601)	50	Sub-Arterial	Clear	Yes	Com	2	Shoulder
45	(78.00905469, 27.1688089)	50	Arterial	Clear	Yes	Com	2	Shoulder
46	(77.86839565, 27.2351739)	70	Arterial	Clear	Yes	Vac	3	Median
47	(77.99432867 27.21094454)	70	Arterial	Clear	Yes	Com	3	Median
48	(77.94116975 27.21750259)	80	Arterial	Clear	Yes	Com	3	Median

Annexure 4: Thesis Sheets

Sheet 01:

Sheet 02:

LITERATURE REVIEW

Research Papers

S.No.	Name of the Document	Author & Year	Findings	Learning Outcomes
1	Impact of Speed Limits and Road Characteristics on Free-Flow Speed in Urban Areas	Ary P. Silvano and Karl L. Bang (2018)	PSL **50 to 40** km/h **lowers** the mean speed by **1.57 km/h** (4%) & accidents by **11%**. PSL **50 to 60** km/h **raises** the mean speed by **2.59 km/h** & accidents by **14%**	The **free flow speed** is **less impacted** by the **Speed Limit** only But **road characteristics impact**.
2	Sustainability Assessment of Speed Regulation of Urban Traffic	Baohua MAO, Haibo CHEN, Shanliang CHEN (2002)	Altering Speed Limit directly impacts **journey time, emission, and energy consumption.** **Additional emissions** if speeds are lowered from **25km/h** increase very rapidly, ranging from **40% to 400%** while **energy consumption** increases by **57.5%.**	**Higher limits** may be **better** in terms of **energy consumption, delay & travel time**
3	Free flow speed estimation A probabilistic, latent approach. Impact of speed limit changes and road characteristics	Silvano, Ary P.; Koutsopoulos, Haris N.; Farah, Haneen (2020)	**Shorter time headways** result in drivers perceiving their state as constrained by the **vehicle in front.**	**Speed choice** is influenced by the presence of the **vehicle ahead** of drivers.
4	Why do drivers exceed speed limits	George Yannis & Georgia Louca & (2012)	**A belief that others break speed limits** influences significantly the **driver's attitude** toward exceeding speed limits.	The **perception** is that **other drivers** often **exceed speed limits**.
5	Impacts of Lowered speed limits in urban areas	Archer J., Fotheringham N., Symmons M. (2008)	**Cost Benefit Analysis** Although it **impact mobility** (individual level) but bring more **reduction in accidents**	Cost- **Delay** and **more travel time** Benefit- **Accident rate reduces**
6	Why is necessary to reduce speed limits in urban areas to 30km/hr?	Hernan Gonzalo , Marta Rojo Arce, Nadia Aponte, -Acebo (2021)	To **avoid an accident**, the Stopping Sight Distance must always be less than the Sight Distance. The **fatality risk** at **50 km/h** is more than **twice higher** than the risk **at 40 km/h** and more than **five times higher** than the risk at **30 km/h.**	Necessary for the safety of pedestrian and cycle users & Accident Reduction **Sight Distance > SSD**
7	Impact of Speed Limits and Information System on Speed Choice from Safety purpose	Ary P. Silvano (2013)	PSL directly influences the driver's speed choice. Drivers are constrained by the vehicle ahead and the relative speed of vehicles.	**PSL** directly influences the **driver's speed choice**

IRC Codes & Guidelines

- Placement of Speed limit signs boards at a uniform and consistent manner.
- Additional signs may also be installed at suitable intervals where necessary.
- After the junction, the speed limit board should be at 25 m from the intersection.

Source: IRC Code: 067-2012

Urban road PSL Placing

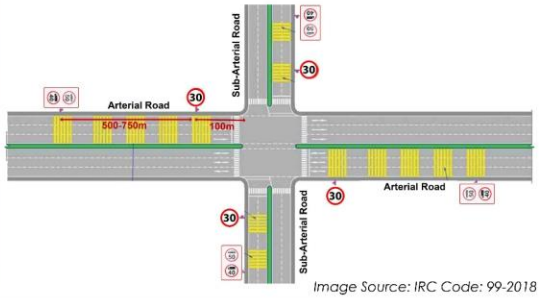


Image Source: IRC Code: 99-2018

- Reduce vehicular speeds to 30 kmph from a distance of 100 m from intersections with roads of the same hierarchy.
- In the Highway, the transition zones are 500-750m from the junction
- Reduce vehicular speed to 50 kmph 250 m before the rail-road intersection

(Source: IRC Code: 99-2018)

Urban expressway PSL Placing

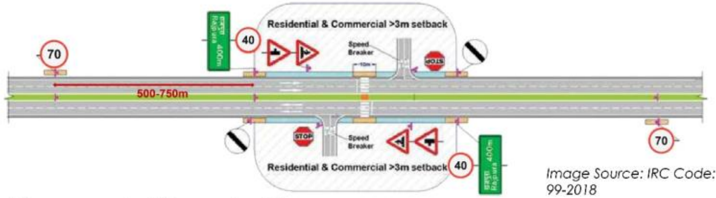


Image Source: IRC Code: 99-2018

Placement of Repeater Signage

Speed Limit (km/h)	Consecutive sign on alternate side of Carriageway (m)	Consecutive sign on same side of Carriageway(m)	Terminal Sign &First Repeater (m)
Below 40	200	300	200
50	250	400	200
60	350	500	250
80	450	700	350

Source: IRC Code: 067-2018)

02	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 03:

METHODOLOGY

Background

Research Framework
- Background & Need
- Aim & Objectives
- Scope & Limitations
- Expected Outcomes

Literature Review
- Speed Limit & its setting
- Parameters
- Cost & Benefits
- Codes & Guidelines

Data Collection Process | **Data Collected**

Stage	Data Collection Process	Data Collected
Stage I	Site Selection (Cities based on Accident ranking)	**Hierarchy-wise PSL** *(Primary Survey)* • PSL Location, Direction, Signage type, Reason for PSL ahead. • Continuity and their Mutual Relatedness.
Stage II	Road Selection (Higher Hierarchy roads)	**Road Inventory w.r.t. PSL** *(Primary Survey)* • Carriageway, No. of Lanes, Geometry, Median availability. • Abutting Landuse and Road Characteristics.
Stage III	Data Identification (Primary and Secondary sources)	**Accident Data** *(Secondary Sources)* • No. of accidents & fatalities for the selected sites. • Data related to accident reason and details of accidents due to road features
Stage IV	Data Collection (PSL & Road Inventory, Speed Data)	**Speed Data** *(Secondary Sources)* • Traffic flow data: vehicle Speed and travel time. • Speed limit data (linked to corresponding road segments).

Analysis Methodology

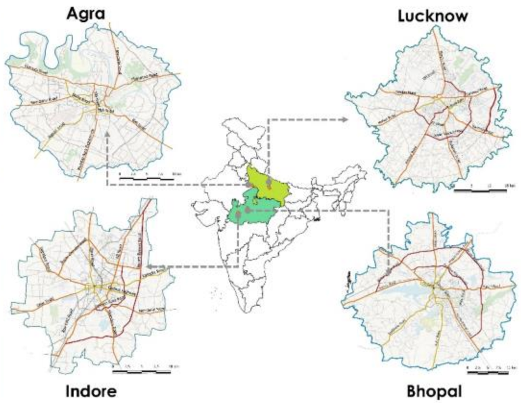
Examine existing speed limits on different urban roads *(Objective I)*
- **Descriptive statistics** Speed limit distribution across different road hierarchy, geometry, and landuse.
- **Spatial Analysis** Map speed limits to visualize geographic patterns.
- Identify inconsistencies or variations in speed limits in urban area.
- Identification of reason for PSL ahead and abutting landuse

Factors influencing Speed Limits *(Objective II)*
- **Spatial Factors** Distance from City Center, Intersection and impact of Landuse pattern
- **Geometric Factors** Impact Of RoW and Transition Distances in Transition zones
- Correlation between Speed Limit and these factors

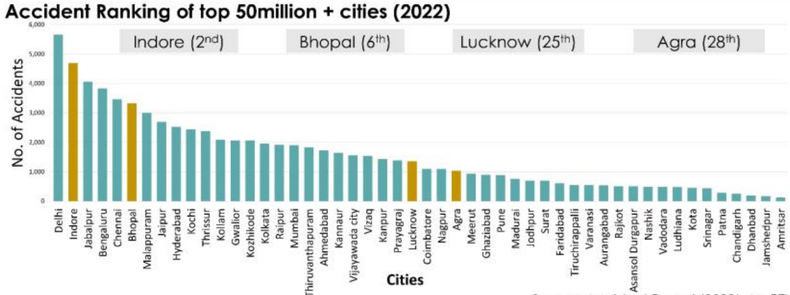
Speed Limit Impacts on Travel Time *(Objective III)*
- Travel Time Contour (Ideal speed condition & with PSL)
- Comparison of Travel Time under both conditions
- Identification of stretches with more travel time difference due to PSLs

SITE SELECTION

- Cities are selected based on Accidents (Safety Perception)
- **Four** Cities are selected as site for comparison
- Arterial, Sub-Arterial, and Ring Roads are surveyed
- The road network in all cities is primarily of **radial pattern**.
- Agra has the least area whereas Lucknow has the maximum area among them.



Accident Ranking of top 50million + cities (2022)



Source: Accident Report (2022)- MoRTH

S.No.	City	Area (Sq.km)	Population (2011)	Road Length (km)	Surveyed Road Length (km)
1	Agra	121	1585704	610.16	109.2
2	Lucknow	631	2902920	1468.77	213.2
3	Bhopal	463	1886100	894.64	225.8
4	Indore	530	2167447	585.13	177.3

Source: DPR, Census 2011, OSM

03	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 04:

ANALYSIS- PSLs DISTRIBUTION ACROSS CITIES

Research Ques. 1- What are the variations in speed limits on urban roads?

Agra

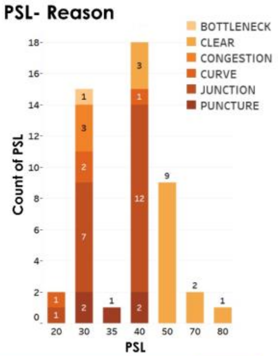
In Agra, very few PSL boards are available on most of the roads (Mathura Road & MG Road)

City Core has comparatively more PSL boards than the outer region.

Total Surveyed Road: **109.2** km
(**18%** of Total Road) | No. of PSL: **68**

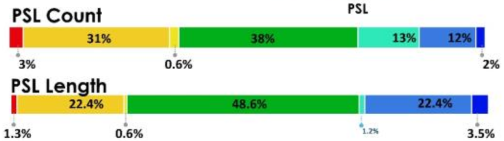
Arterial Road: **66** % (**3** PSL /10 km)

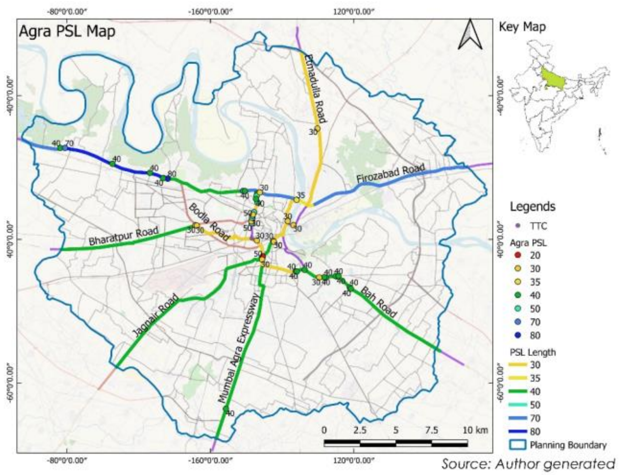
Sub-arterial Road: **34** % (**3** PSL /10 km)



Average Spacing

- For continuity in **40 & 50km/h**, Avg. distance is **500-1000m.**
- PSL 50 → 50 → 30km/h; **150-200m → 50m** → Junction.
- On Highway-PSL (**70, 80km/h**), the distance is above **2 km.**





Source: Author generated

Lucknow

In Lucknow, PSL boards are equally distributed in the core, middle, and outer of the city.

Lower PSL is majorly due to junction, puncture, and horizontal curves.

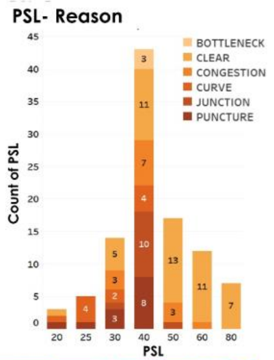
Higher PSL values are in the clear zone to aware the drivers about Maximum permissible limits.

Total Surveyed Road: **213.2** km
(**14.5%** of Total Road) | No. of PSL: **152**

Arterial Road: **61.6** % (**3** PSL /10 km)

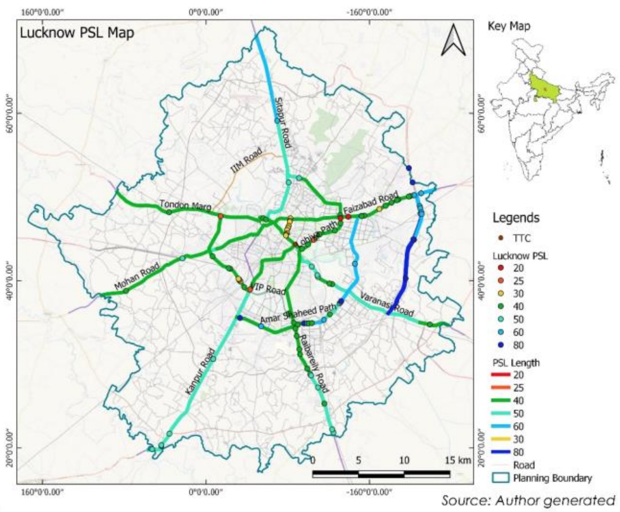
Sub-arterial Road: **34** % (**6** PSL /10 km)

Ring Road: **29** % **4** PSL /10 km



Average Spacing

- For PSL **30km/h**, Avg. distance is **200-500m.**
- PSL 40 → 40km/h; **500-1000m** , Avg. Distance; **3km.**
- For Higher PSL (**50, 60km/h**), the distance is above **4 km.**



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04	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 05:

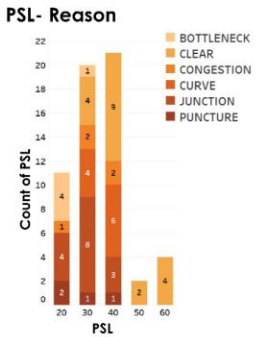
ANALYSIS- PSLs DISTRIBUTION ACROSS CITIES

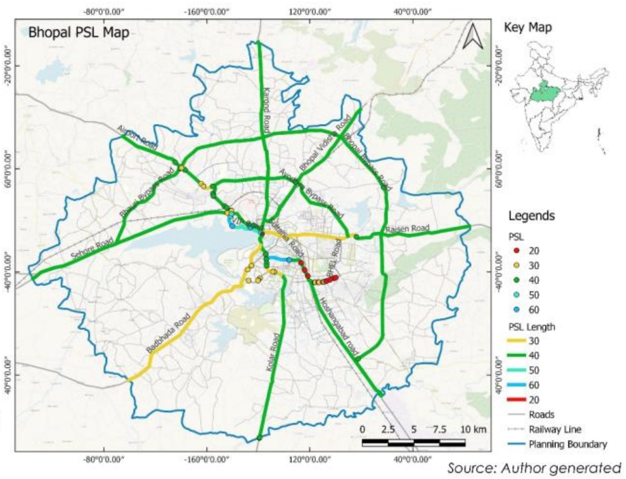
Bhopal

Most of PSLs are found on Airport Road, VIP Road, and New Market Road while others don't.

PSL of 40 km/h is observed on most of the road and AIIMS road has a proper PSL board availability at each junction.

Total Surveyed Road: **225.8** km (**25.2%** of Total Road) | No. of PSL: **79**	Arterial Road: **40.3** %	(**2** PSL /10 km)
	Sub Arterial Road: **29.5** %	(**3** PSL /10 km)
	Ring Road: **30.2** %	(**1** PSL /10 km)

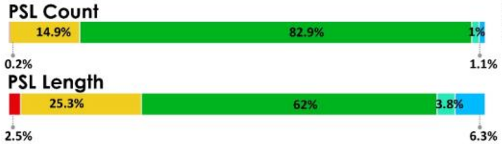




Source: Author generated

Average Spacing

- PSL 40 → 40km/h; **200 - 500m**
- PSL 30 → 20km/h; **200-250m → 50m → Junction**
- For Higher PSL (**50, 60km/h**), the distance is above **2 km**



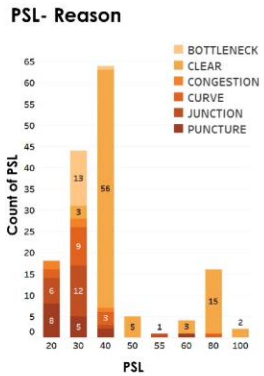
Indore

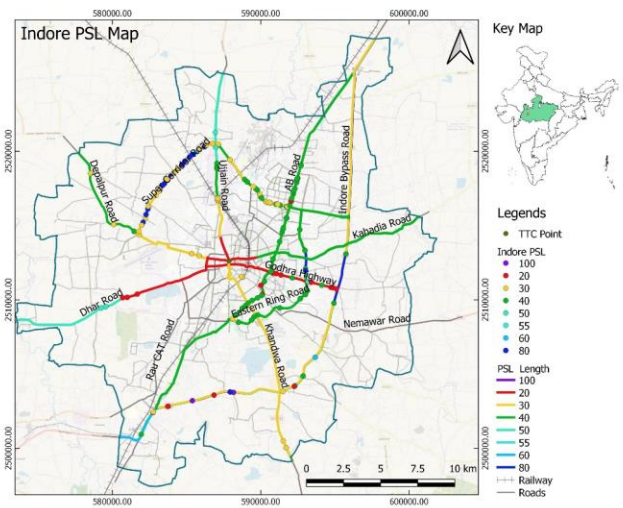
In Indore, PSL boards are uniformly distributed on most roads like AB Road and Super Corridor.

Repetitive Speed limit boards have been placed for considerations of safety and mobility.

PSLs of 30 & 40 are mostly found in most of roads in densified areas.

Total Surveyed Road: **177.3** km (**30.3%** of Total Road) | No. of PSL: **192**	Arterial Road: **51.4** %	(**7** PSL /10 km)
	Sub Arterial Road: **22.6** %	(**5** PSL /10 km)
	Ring Road: **26** %	(**3** PSL /10 km)

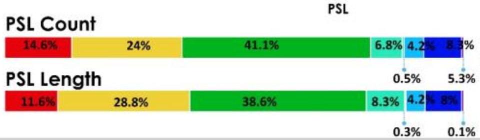




Source: Author generated

Average Spacing

- For PSL **20 & 30km/h**, Avg. distance is **300-350m**
- For Higher PSL (**50, 60, 80 ,100**), the distance is above **2 km**
- PSL 40 → 40km/h & 80 →80km/h; Avg. distance is **500m**



05	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 06:

ANALYSIS- FACTORS INFLUENCING PSLs

Research Ques.2- Does PSL differ in core, middle and outer regions in Urban Areas?

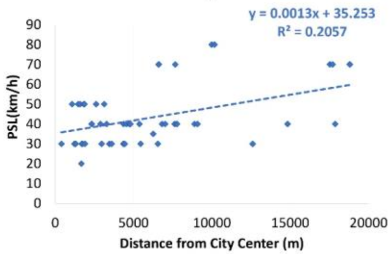
Assumption

It is assumed that city core regions have generally lower PSL and increase while moving away from CBD

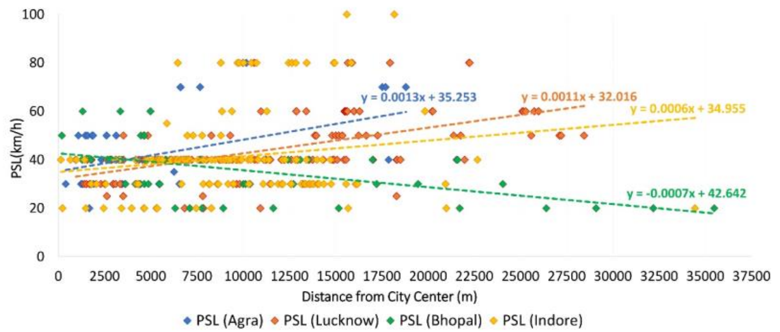
Process Involved

- Identification of City Center Area
- Locate the PSL in the city (On Higher Hierarchy roads)
- Distance from City Center to PSL (Along Identified Roads)
- Relate All PSL's to Distance from City Center

PSL vs Distance from City Center



PSL vs Distance from City Center



Findings

- It is observed that generally **PSL and its distance** from the City Center have a **positive relation.**
- In Agra, Lucknow, and Indore, PSL values are increased when moving away from the city center, While in Bhopal, the reverse is observed.
- **Indore** has the **highest PSL** (15 km from the city center) and **Bhopal** has a **lower PSL** of 20 km/h in the outer region due to construction work on the road.

Research Ques.3- What is the impact of Intersection on different PSLs?

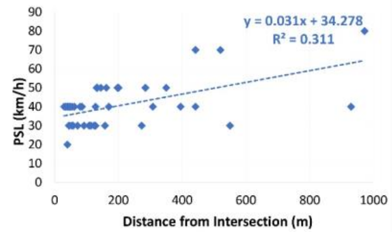
Assumption

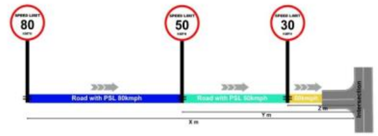
It is assumed that PSL decreases as the Distance Between PSL and Intersection decreases and vice versa.

Process Involved

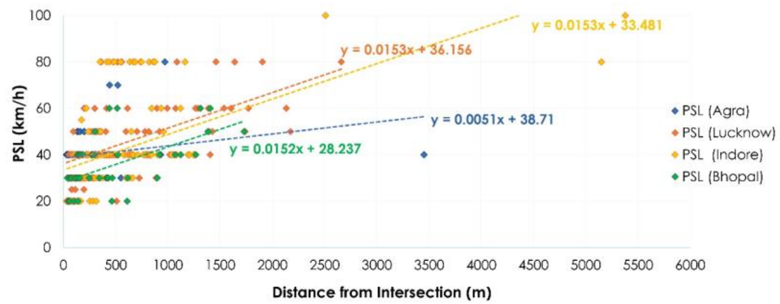
- Identification of Intersection (Along Identified Roads)
- Locate the PSL in the city (On Higher Hierarchy roads)
- Distance from each PSL to upstream Intersections
- Relate All PSL's to Distance from Identified Intersections

PSL vs Distance from Intersection





PSL vs Distance from Intersection

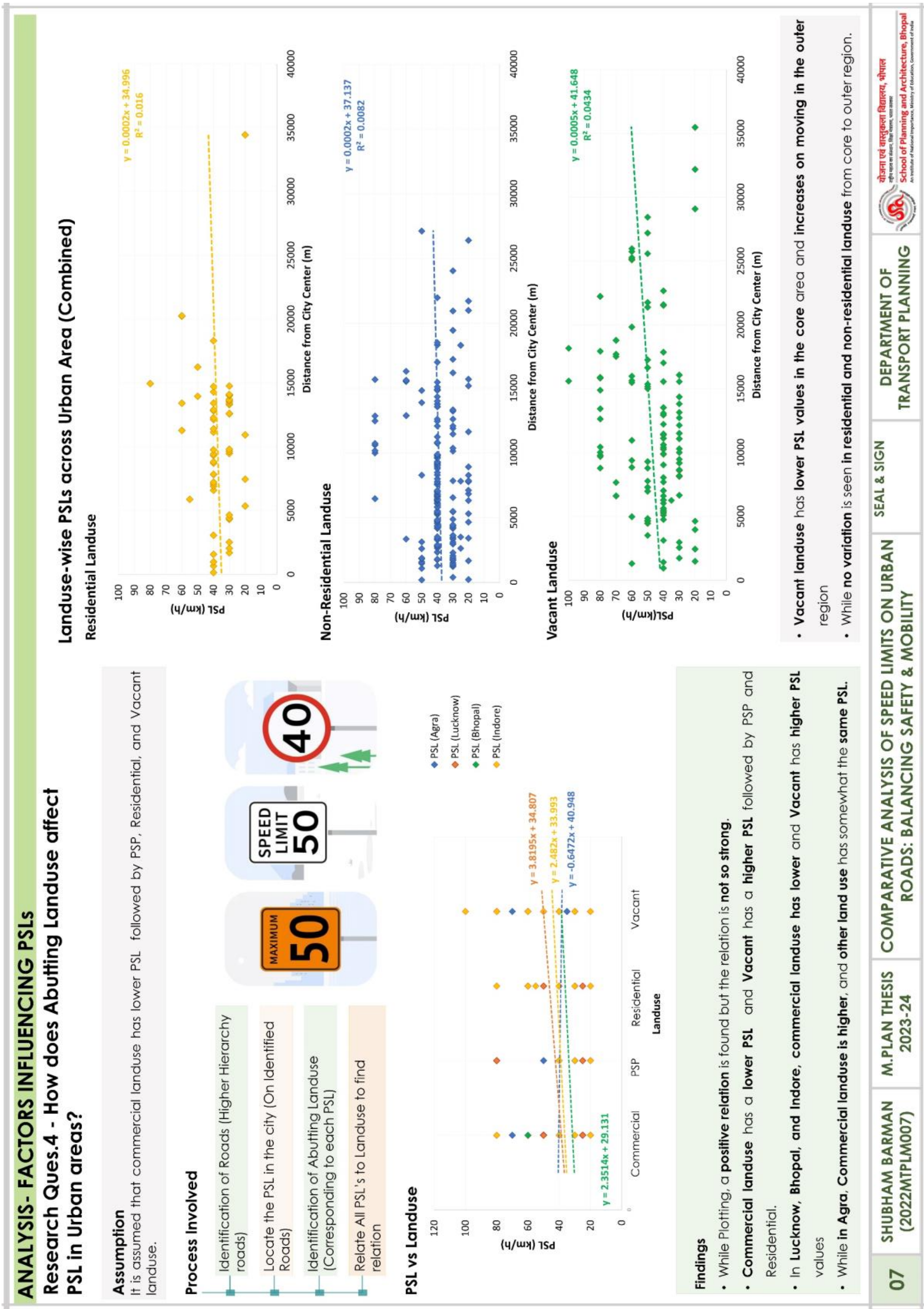


Findings

- While Plotting PSL and Distance from Intersection, **Lucknow, Bhopal, and Indore show similar relations**.
- While in **Agra** as compared to others, there is **less difference in PSL** as the distance from the intersection Increases
- **Min. distance** observed is **30m** (for PSL 20) in **Lucknow** whereas **Max. distance** observed is **5.4km** (for PSL 100) in **Indore**.

06	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 07:


ANALYSIS- FACTORS INFLUENCING PSLs
Research Ques.4 - How does Abutting Landuse affect PSL in Urban areas?
Assumption
It is assumed that commercial landuse has lower PSL followed by PSP, Residential, and Vacant landuse.
Process Involved
Identification of Roads (Higher Hierarchy roads)
Locate the PSL in the city (On Identified Roads)
Identification of Abutting Landuse (Corresponding to each PSL)
Relate All PSL's to Landuse to find relation
MAXIMUM 50
SPEED LIMIT 50
40
PSL vs Landuse
PSL (km/h)
Commercial
PSP
Residential
Vacant
Landuse
PSL (Agra)
PSL (Lucknow)
PSL (Bhopal)
PSL (Indore)
y = 3.8195x + 34.807
y = 2.482x + 33.993
y = -0.6472x + 40.948
y = 2.3514x + 29.131
Findings
• While Plotting, a positive relation is found but the relation is not so strong.
• Commercial landuse has a lower PSL and Vacant has a higher PSL followed by PSP and Residential.
• In Lucknow, Bhopal, and Indore, commercial landuse has lower and Vacant has higher PSL values
• While in Agra, Commercial landuse is higher, and other land use has somewhat the same PSL.
Landuse-wise PSLs across Urban Area (Combined)
Residential Landuse
PSL (km/h)
y = 0.0002x + 34.996
R² = 0.016
Distance from City Center (m)
Non-Residential Landuse
PSL (km/h)
y = 0.0002x + 37.137
R² = 0.0082
Distance from City Center (m)
Vacant Landuse
PSL(km/h)
y = 0.0005x + 41.648
R² = 0.0434
Distance from City Center (m)
• Vacant landuse has lower PSL values in the core area and increases on moving in the outer region
• While no variation is seen in residential and non-residential landuse from core to outer region.
07
SHUBHAM BARMAN (2022MTPLM007)
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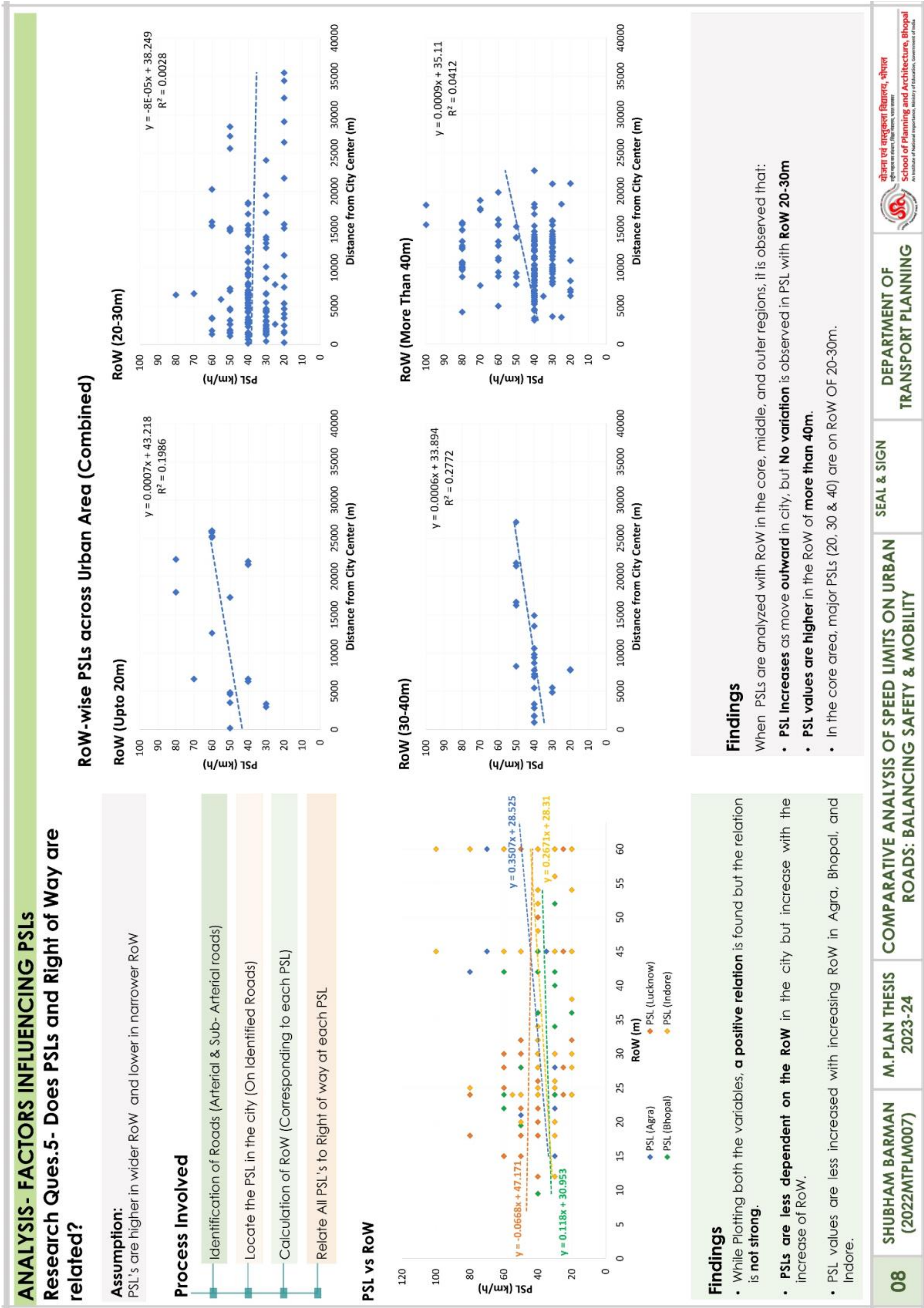
योजना एवं वास्तुकला विद्यालय, भोपाल
School of Planning and Architecture, Bhopal

Sheet 08:


ANALYSIS- FACTORS INFLUENCING PSLs
Research Ques.5- Does PSLs and Right of Way are related?
Assumption:
PSL's are higher in wider RoW and lower in narrower RoW
Process Involved
Identification of Roads (Arterial & Sub- Arterial roads)
Locate the PSL in the city (On Identified Roads)
Calculation of RoW (Corresponding to each PSL)
Relate All PSL's to Right of way at each PSL
PSL vs RoW
PSL (km/h)
RoW (m)
y = -0.0668x + 47.171
y = 0.118x + 30.953
y = 0.3507x + 28.525
y = 0.2671x + 28.31
PSL (Agra)
PSL (Lucknow)
PSL (Bhopal)
PSL (Indore)
Findings
• While Plotting both the variables, a positive relation is found but the relation is not strong.
• PSLs are less dependent on the RoW in the city but increase with the increase of RoW.
• PSL values are less increased with increasing RoW in Agra, Bhopal, and Indore.
RoW-wise PSLs across Urban Area (Combined)
RoW (Upto 20m)
y = 0.0007x + 43.218
R² = 0.1986
RoW (20-30m)
y = -8E-05x + 38.249
R² = 0.0028
RoW (30-40m)
y = 0.0006x + 33.894
R² = 0.2772
RoW (More Than 40m)
y = 0.0009x + 35.11
R² = 0.0412
PSL (km/h)
Distance from City Center (m)
Findings
When PSLs are analyzed with RoW in the core, middle, and outer regions, it is observed that:
• PSL Increases as move outward in city, but No variation is observed in PSL with RoW 20-30m
• PSL values are higher in the RoW of more than 40m.
• In the core area, major PSLs (20, 30 & 40) are on RoW OF 20-30m.
08
SHUBHAM BARMAN (2022MTPLM007)
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योजना एवं वास्तुकला विद्यालय, भोपाल
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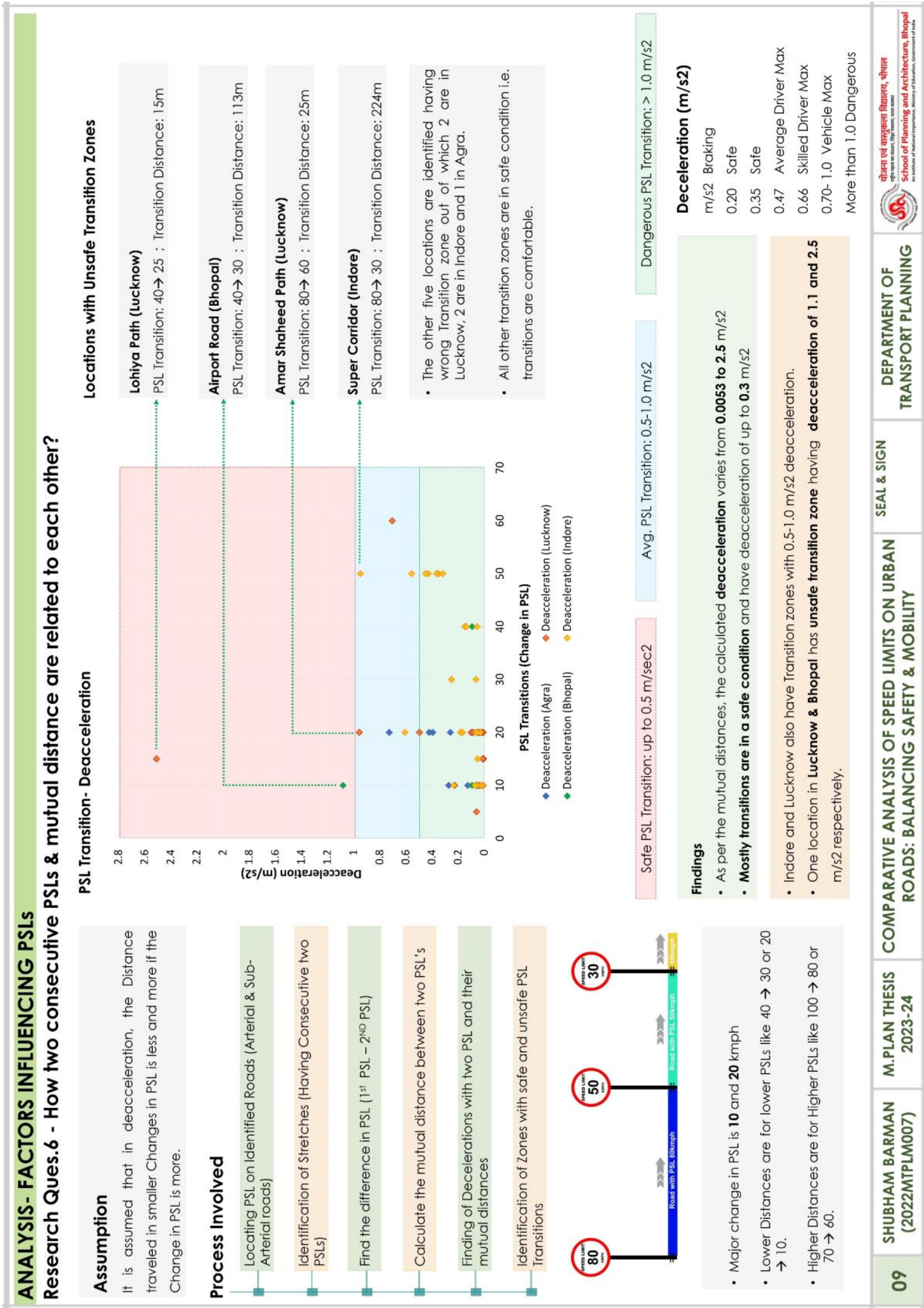
Sheet 09:


ANALYSIS- FACTORS INFLUENCING PSLs
Research Ques.6 - How two consecutive PSLs & mutual distance are related to each other?
Assumption
It is assumed that in deacceleration, the Distance traveled in smaller Changes in PSL is less and more if the Change in PSL is more.
Process Involved
Locating PSL on Identified Roads (Arterial & Sub-Arterial roads)
Identification of Stretches (Having Consecutive two PSLs)
Find the difference in PSL (1st PSL – 2ND PSL)
Calculate the mutual distance between two PSL's
Finding of Decelerations with two PSL and their mutual distances
Identification of Zones with safe and unsafe PSL Transitions
80
50
30
Major change in PSL is 10 and 20 kmph
Lower Distances are for lower PSLs like 40 → 30 or 20 → 10.
Higher Distances are for Higher PSLs like 100 → 80 or 70 → 60.
PSL Transition- Deacceleration
Deacceleration (m/s2)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
PSL Transitions (Change in PSL)
Deacceleration (Agra)
Deacceleration (Lucknow)
Deacceleration (Bhopal)
Deacceleration (Indore)
Locations with Unsafe Transition Zones
Lohiya Path (Lucknow)
PSL Transition: 40→ 25 ; Transition Distance: 15m
Airport Road (Bhopal)
PSL Transition: 40→ 30 ; Transition Distance: 113m
Amar Shaheed Path (Lucknow)
PSL Transition: 80→ 60 ; Transition Distance: 25m
Super Corridor (Indore)
PSL Transition: 80→ 30 ; Transition Distance: 224m
The other five locations are identified having wrong Transition zone out of which 2 are in Lucknow, 2 are in Indore and 1 in Agra.
All other transition zones are in safe condition i.e. transitions are comfortable.
Safe PSL Transition: up to 0.5 m/sec2
Avg. PSL Transition: 0.5-1.0 m/s2
Dangerous PSL Transition: > 1.0 m/s2
Findings
As per the mutual distances, the calculated deacceleration varies from 0.0053 to 2.5 m/s2
Mostly transitions are in a safe condition and have deacceleration of up to 0.3 m/s2
Indore and Lucknow also have Transition zones with 0.5-1.0 m/s2 deacceleration.
One location in Lucknow & Bhopal has unsafe transition zone having deacceleration of 1.1 and 2.5 m/s2 respectively.
Deceleration (m/s2)
m/s2 Braking
0.20 Safe
0.35 Safe
0.47 Average Driver Max
0.66 Skilled Driver Max
0.70- 1.0 Vehicle Max
More than 1.0 Dangerous
09
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Sheet 10:

ANALYSIS- IMPACT OF PSLs ON TRAVEL TIME & DELAY

Research Ques.7 - What impact do speed limits have on Travel Time and delay?

The influence of various speed limits on travel time and delays is analyzed, with investigation the underlying causes of delays.

This is done to understand whether PSLs are placed as per the actual on ground ideal speed (Near to Free flow speed) of vehicles

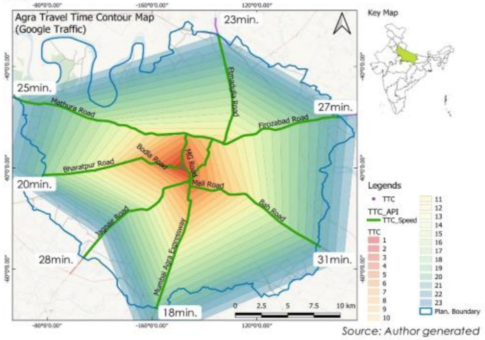
Process Involved

- Identification of Roads (For all four cities)
- Calculation of travel time (Ideal condition & as per PSL)
- Travel time difference for all cities (Ideal speed & as per PSL)
- Arranging cities with min. to max time difference (Ratio of Travel time (PSL) and Travel Time difference)
- Range distribution -(0.132 - 0.120)- Near to PSL (No Difference)
  (0.154 - 0.270)- Up to difference of 10 min.
  (0.333 – 0.520)- More than 10 min
- Identification of three types of Roads (In all four cities)

- Travel Time Contour (TTC) has been made under two conditions:
  - TTC under ideal speed condition
  - TTC as per posted speed limits
- All four cities's main arterial roads are analysed to find the travel time difference in both conditions.
- Delay reasons are also identified for each stretch.

Travel Time Contour under Ideal Speed Condition

Agra



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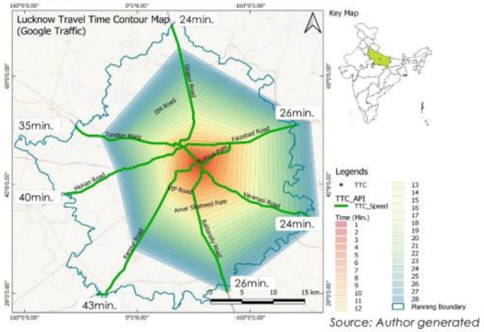
Lucknow



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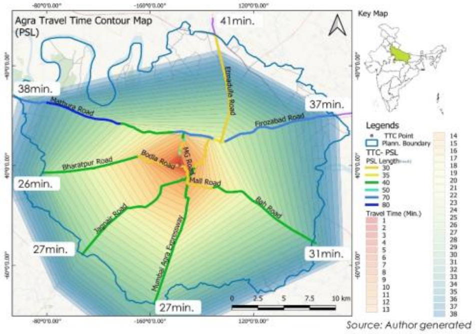
Travel Time Contour with PSL



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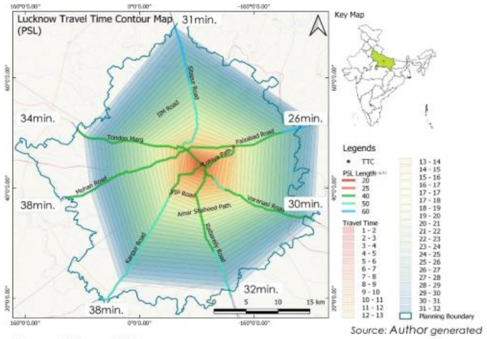


Source: Author generated

Travel Time Difference

Road Name (Agra)	Time (min.) As per Ideal Speed	Time (min.) As per PSL	Time Diff (min.)	Reason
Mumbai-Agra Expressway	18	27	9	Commercial Zone in Core Area
Bah Road	31	31	0	-
Jagnair Road	28	27	-1	Less Traffic
Bharatpur Road	20	26	6	Comm. Zone in Core Area
Mathura Road	25	38	13	Junction & High Traffic
Faizabad Road	27	37	10	Junction & High Traffic
Hathras Road	23	41	18	Parking & High Traffic

Travel Time Difference

Road Name (Lucknow)	Time (min.) As per Ideal Speed	Time (min.) As per PSL	Time Diff (min.)	Reason
Kanpur Road	43	38	-5	High Traffic in Core Area
Raebareilly Road	26	32	6	Less Puncture
Varanasi Road	24	30	6	Less Puncture & Res. Density
Tondon Road	35	34	-1	-
Mohan Road	40	38	-2	Less & Undivided Cariageway
Sitapur Road	24	31	7	No Res. Density along Road
Faizabad Road	26	26	0	-

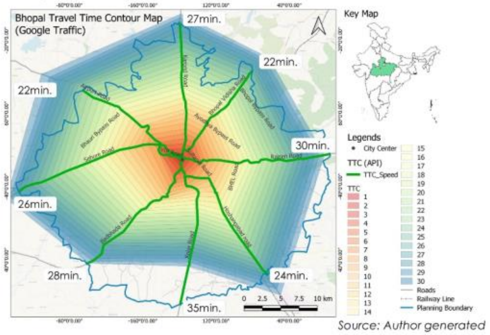
10	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 11:

ANALYSIS- IMPACT OF PSLs ON TRAVEL TIME & DELAY

Travel Time Contour under Ideal Speed Condition

Bhopal



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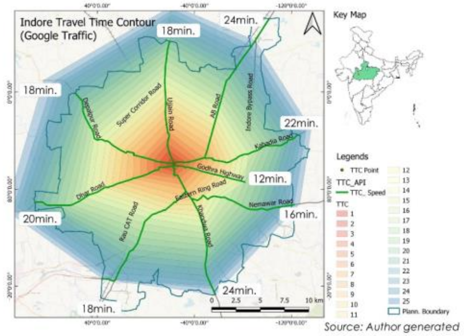
Indore



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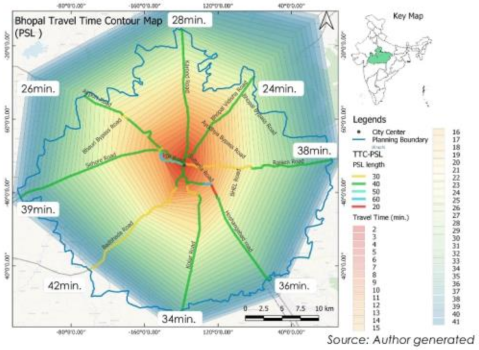
Travel Time Contour with PSL



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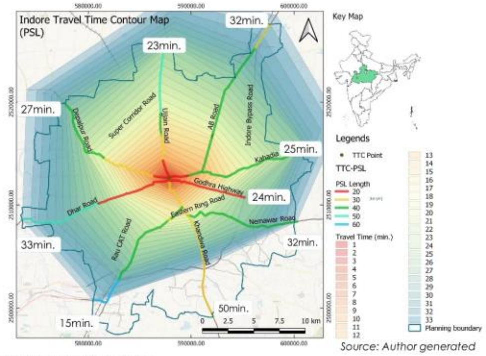


Source: Author generated

Travel Time Difference

Road Name (Bhopal)	Time (min.) As per Ideal Speed	Time (min.) As per PSL	Time Diff (min.)	Reason
Hoshangabad Road	24	36	12	High Traffic
Raisen Road	30	38	8	High Traffic
Karond Road	27	28	1	-
Vidisha Road	22	24	2	Railway Crossing
Sehore Road	26	39	13	Junctions & Traffic
Airport Road	22	26	4	Curves and Junction
Bhadbhada Road	28	42	14	No Speed Limit Board
Kolar Road	35	34	-1	-

Travel Time Difference

Road Name (Indore)	Time (min.) As per Ideal speed	Time (min.) As per PSL	Time Diff (min.)	Reason
Mumbai Agra NH	18	33	15	Junction & High Traffic
Nemawar Road	16	32	16	Horizontal Curve & Punctures
Pipliyahana Road	12	24	12	High Traffic
Dhar Road	20	33	13	High Traffic in Core Area
Ujjain Road	18	23	5	Less & Undivided Cariageway
Depalpur Road	18	27	9	Less & Undivided Cariageway
Kahadia Road	22	25	3	Less & Undivided Cariageway
AB Road	24	32	8	Junction & High Traffic
Khandwa Road	24	50	26	2-way Carriageway

Identification of Stretches (With more time difference)

Type I Road	Travel Time (TT) with PSL = TT with Ideal Speed
Type II Road	TT (PSL) > TT (Ideal Speed) up to 10min.
Type III Road	TT (PSL) > TT (Ideal Speed) more than 10min.

Roads with time difference (As per Ideal Speed & PSL)

City	I Type Roads	II Type Roads	III Type Roads
Agra	2	2	3
Lucknow	4	3	0
Bhopal	3	2	3
Indore	1	2	6

Findings

- **In Indore** most of the **roads have ideal speed more than the posted speed.**
- In **Lucknow** major roads have **PSL as per ideal speed**.
- **Bhopal and Agra are in-between conditions**, fewer roads have large differences in ideal speed and PSL.
- Lucknow also has stretches where the higher PSL boards are placed than ideal speeds of respective stretch.
- One road of Agra & Lucknow, equal travel time is observed with ideal speed and PSL

11	SHUBHAM BARMAN (2022MTPLM007)	M.PLAN THESIS 2023-24	COMPARATIVE ANALYSIS OF SPEED LIMITS ON URBAN ROADS: BALANCING SAFETY & MOBILITY	SEAL & SIGN	DEPARTMENT OF TRANSPORT PLANNING	योजना एवं वास्तुकला विद्यालय, भोपाल School of Planning and Architecture, Bhopal

Sheet 12:

OVERALL FINDINGS

PSL Distribution

6 PSL/ 10km	7 PSL/ 10km	3 PSL/ 10km	10 PSL/ 10km
Agra	Lucknow	Bhopal	Indore

Indore has the maximum no. of PSLs while Bhopal has the least (3PSL Board/10km)

Indore and Lucknow have PSL board proportional to their running length whereas Agra and Bhopal don't.

Higher PSL %age (more than PSL 40)

27%	43.4%	2.8%	21%
Agra	Lucknow	Bhopal	Indore

Lucknow has mostly higher PSL (running length) on roads while Bhopal has the least.

In Bhopal, mostly roads have PSL of 40 km/h except VIP Road and Link Road -1

Impact of Landuse

No variation of PSL in Residential & Non-residential landuse in the core, middle, and outer regions of the city.

In Case of Vacant Landuse, PSL increases as moves outward to the city

Impact of Right of Way

PSL increases with increase in RoW

With the same RoW, an increment in PSLs is seen while moving away from city center

No variation of PSL in RoW of 20-30m in the core, middle, and outer regions of the city.

Transition Zones

All transition zones are safe except for one location in Bhopal and Lucknow which are highly unsafe and dangerous.

RECOMMENDATIONS

PSL Placement

During Transition, Higher PSL should be changed to ± 20 and for lower PSL, it should be ± 10.

- For safety purposes, Repetitive PSL signboards should be placed.
- There should not be a sudden change in PSLs from higher to lower, rather PSL should decrease gradually.

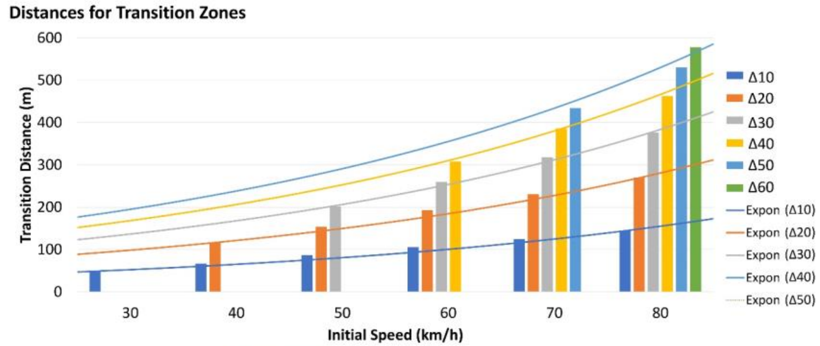
- For reaffirmation to drivers, the PSL board should be placed after the transition zone or junction.
- PSL transition zones should be designed keeping in mind the safety of drivers.

Transition Distances

Based on comfortable deacceleration of **-0.5 m/sec2**, transition distances are recommended for various PSLs on Urban Roads:

Speed (km/h)	80	70	60	50	40	30	20
80	0	145	270	376	463	530	578
70		0	125	231	318	386	434
60			0	106	193	260	308
50				0	87	154	202
40					0	67	116
30						0	48
20							0

These transitions distances are for straight roads.
In case of horizontal alignment or any other geometric features, clear sight distance should also be considered.



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