



VEHICULAR SPEEDING IN UTTAR PRADESH

Statewide Assessment and Recommendations

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List of Abbreviations

API	Application Programming Interface
CMVR	Central Motor Vehicles Rules
GRSP	Global Road Safety Partnership
GRSF	Global Road Safety Facility
IRC	Indian Roads Congress
LMVs	Light Motor Vehicles
MDR	Major District Roads
MoRTH	Ministry of Road Transport and Highways
MVAA	Motor Vehicles (Amendment) Act, 2019
NH	National Highways
ODR	Other District Roads
SH	State Highways
SLF	SaveLIFE Foundation
UP	Uttar Pradesh
VRU	Vulnerable Road Users
WHO	World Health Organisation



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FOREWORD

In 2022, speeding caused 71% of the total road crash deaths in India. Inarguably, excess speed on Indian roads is a major challenge, and a concerted effort by all stakeholders is needed to address the issue. Scientific speed management guidelines are the need of the hour, and critical to implementing evidence-backed speed-limits.

The Government of Uttar Pradesh aims to tackle road safety challenges comprehensively across the State. Given the high number of road crashes and fatalities in the State, we are committed to tackling this issue with immediate attention and unwavering dedication. We have launched numerous road safety interventions across the state.

Recently, in October 2023, Uttar Pradesh became the first state in India to notify a scheme for forensic investigation of crashes under Section 135 of the Motor Vehicles Act, 1988, which empowers states to make a scheme for crash investigation. The scheme for crash investigation is a method by which a holistic reconstruction of the crash is carried out to identify multiple reasons for the cause of crashes. Through the forensic crash investigation scheme, the State Government can get a detailed analysis of the causes of crashes, and make informed decisions on suitable road safety interventions.

This study by the SaveLIFE Foundation, done in collaboration with the Indian Institute of Technology, Kanpur is an appreciable step towards achieving standardised guidelines in the state. This report discusses the trends in speeding across five districts of Uttar Pradesh, namely, Kanpur City, Agra, Bareilly, Gorakhpur, and Prayagraj, through an on-ground speed survey. It also considers factors such as differences in spatial features, temporal variation, and locations such as crash prone spots and school zones.

I applaud the SaveLIFE Foundation and IIT Kanpur for the rigour and empirical approach of this report which will serve as a resource for policymakers, enforcement agencies, and stakeholders to implement effective speed management practices.

In the endeavour to augment road safety in Uttar Pradesh, let us commit to adopting efficient speed management practices that foster collaboration and prompt action so that we can save lives across the State.

Signed by,

(K.P. Singh)
Khempal Singh
Special Secretary
Date: 24-10-2024 12:13:40

Executive Summary

Road crash fatalities are a major public health concern, globally and in India. Over 1.19 million road crash fatalities occur across the globe, of which over 1,50,000 occur in India. Uttar Pradesh witnesses the highest number of road crash fatalities in the country, accounting for 22,595 fatalities in 2022, over 13% of the total road crash fatalities. Vulnerable road users such as pedestrians, cyclists and motorised two-wheelers accounted for the majority of road crash fatalities, comprising over 10,000 of the total fatalities in Uttar Pradesh. Among high-fatality roads, national highways emerged on top, comprising 8,479 fatalities, 38% of the total fatalities in the state. This was followed by other roads including major district roads, which contributed to 7,711 (34%) of the fatalities, and state highways, which contributed to 6,405 (28% of the total) of the fatalities in 2022.

A significant portion of fatalities in India are attributed to driver error, particularly speeding. Speeding in Uttar Pradesh alone contributed to 9,297 fatalities in 2022, 41% of the total in the state. Speeding on national highways alone killed over 3,700 people, which contributed to over one-third of the total speeding fatalities. To address this issue, strict enforcement measures are necessary. Presently, enforcement is primarily carried out manually, is constrained by limited manpower and takes place in limited time frames rather than round-the-clock. This is especially evident on highways, where enforcement is usually conducted by the state police as well as the transport department. Uttar Pradesh does not have a designated state highway police. Due to limited manpower, the level of enforcement across highways remains low. The enhancement of manpower and the adoption of technology for enforcement is therefore, necessary.

There are numerous national and state rules and guidelines in place to curb speeding in Uttar Pradesh. The state has also notified district-wise speed limit notifications, and has reported to the Ministry of Road Transport and Highways (MoRTH) that it has implemented the guidelines for electronic monitoring and enforcement. Yet, on-ground, speeding remains the major killer.

SaveLIFE Foundation (SLF) partnered with the Indian Institute of Technology, Kanpur to gauge an understanding of the situation of speeding in Uttar Pradesh, analyse the gaps in speed curbing measures and enforcement, and make suitable and actionable recommendations tailored along the findings.

This study aims to:

- Assess the prevalence of speeding for different vehicle types (Light Motor Vehicles (LMVs), motorised two-wheelers, autos/tempos, trucks and buses) on major road functional classes (expressways, national highways, state highways, and other district roads).
- Identify the speeding patterns across vehicle classes and road functional classes.
- Identify factors affecting speeding behaviour such as the spatial features of roads, divided vs. undivided lanes, blackspots, number of lanes, and temporal variation.
- Identify the effectiveness of analysing the 85th percentile speed to infer speeding behaviour and compare the speeds to the notified or posted speed limits.
- Prepare a set of targeted recommendations to curb speeding and speed-related crashes in Uttar Pradesh.

For the purpose of our study, we have defined speeding in accordance with the Speed Management Manual (GRSP 2023), speeding encompasses driving above the speed limit. The vehicle categories chosen in this study have different vehicle dynamics due to varying engine sizes and rigid body dynamics. Consequently, speed limit notifications also typically prescribe different speed limits for these vehicle types. Similarly, the selected functional class of roads also have different speed limits, geometric design and built environment characteristics that can induce varied driving behaviour. Given the large geographical area of Uttar Pradesh and a vast underlying road network, the speeding analysis has been conducted by sampling specific districts, corridors and sites where spot speeds have been collected and analysed.

Exploratory analysis of speed Application Programming Interfaces (APIs) has also been undertaken to understand the potential opportunities and challenges of scaling the speed data collection process in the future.

In order to identify sites for speed surveys from across Uttar Pradesh, five districts have been identified that have high crash occurrences and which span the geographical spread of the state - Kanpur Nagar from the Centre, Agra from the West, Bareilly from the North, Gorakhpur from the East, and Prayagraj from the South. These districts were also among the top ten districts for road crash fatalities in Uttar Pradesh in 2022. Within each district, major corridors of interest have been shortlisted by reviewing the list of the blackspots identified from crashes between 2019 and 2021, and the average free flow speeds estimated using a third-party speed API from TomTom. TomTom is a global company that primarily produces mapping and navigation software and devices. Through TomTom, we obtained estimates of the average free flow speeds across stretches in Uttar Pradesh. We have selected stretches with relatively higher free-flow speeds for our study[1]. For each district, three corridors of different functional classes have been selected. For a given corridor, 5-6 sites have been selected based on built environment characteristics (e.g., number of lanes, dividers, roadside features, traffic calming features) and historical crash occurrences.

After the site selection process, each corridor was surveyed from early morning hours (~5 AM) up to late afternoon/early evening time period (~4 PM) covering at least 600 observations consisting of representations of different vehicle classes. The subsequent analysis explores the speeding prevalence in the data samples for the impact of spatio-temporal attributes on speeding proportions for a given functional class and vehicle type.

The results show that speeding was especially prevalent amongst two-wheelers, LMVs, and buses.

[1] *https://developer.tomtom.com/traffic-api/documentation/product-information/introduction*

On an average, about 65% of the two-wheelers were speeding across various functional classes of roads, with 76% of the two-wheelers speeding on national highways. Almost half of the observed LMVs, and over a third of the buses were speeding across functional classes of roads. Interestingly, 73% of the observed buses were speeding on expressways.

In a district-wise analysis, Kanpur Nagar witnessed high speeding among two-wheelers and buses, particularly on the state highway (SH-46), with over two-third of both two-wheelers and buses speeding. Agra witnessed most speeding on the national highway (i.e. NH-19) with over 90% of the two-wheelers, and over three fourth of the buses and LMVs speeding. Gorakhpur witnessed extremely high instances of two-wheeler speeding, with over three-fourth of the two-wheelers speeding across the three corridors, i.e. NH-27, SH-1, and Fatima-Bypass Road. Interestingly, SH-1 also witnessed speeding by 97% of the observed LMVs and 67% of the observed trucks. Trucks had relatively lower instances of speeding, except on the SH-1. On the national highway location (NH-30) in Bareilly, over 85% of the two-wheelers and over half of the LMVs were speeding. Prayagraj's Allahabad-Bypass expressway witnessed high speeding among LMVs (60%). These results show that speeding remains a grave concern on-ground.

Certain issues with the speed management systems were also revealed through our analysis. For instance, the posted speed limits varied in some of the stretches i.e. the same stretch had different posted speed limits. There was significant speeding amongst two-wheelers and LMVs near school zones on national and state highways. In addition, the proportion of vehicles exceeding the speed limit at locations that were not blackspots was higher than the proportion of vehicles exceeding the speed limit at blackspot locations. This revealed that speed curbing measures should not be restricted to blackspots. The final chapter of the study consists of detailed recommendations based on the issues revealed through the observation study.

Given the large geographical coverage of the state, future studies can explore more long-term data collection methods (e.g., 24-96 hours) that are consistent across all sites. Standardised surveying times with large sample sizes will allow for both temporal and spatial influences in speeding patterns to be parsed out using more comprehensive statistical analysis techniques while accounting for differences in sampling uncertainties. A similar data collection effort can also be specifically targeted towards determining the effectiveness of traffic calming measures which can aid future road safety interventions. Finally, information about speed patterns should be integrated with larger safety studies quantifying the linkages between speed and crash occurrences.

Chapter 1: Speeding Scenario in India & Uttar Pradesh

1.1 Background

Road crashes remain a significant global public health concern, causing 1.19 million fatalities annually (World Health Organisation 2023). India holds the unfortunate distinction of leading the world in reported road crash fatalities, with 1.68 lakh fatalities in 2022 (MoRTH Road Accidents in India, 2023). Speeding emerged as the leading cause, contributing to 72.3% of crashes, 72.8% of injuries, and 71.2% of fatalities in the same year. Notably, over 75% of fatalities on national highways were attributed to speeding.

Uttar Pradesh, with 22,595 fatalities in 2022, witnessed a staggering 41% of fatalities (9,297) caused by speeding, making it the leading cause of road crash fatalities in the state. On national highways alone, speeding was responsible for 44% (3,707) of the 8,479 total fatalities on highways.

The World Health Organisation states that while most vulnerable road users can survive if hit by a vehicle travelling 30 km/h, the majority are killed if hit by a vehicle travelling at 50 km/h (GRSP, 2023).

Despite existing regulations within the Motor Vehicles Act,1988 and the guidelines for speed management in India, the persistently high number of speeding-related fatalities in Uttar Pradesh calls for a closer examination of on-ground realities.

1.2 Current Speed Guidelines Nationally & in Uttar Pradesh

Speed legislation in India, under Section 112 of The Motor Vehicles Act, 1988, mentions that no motor vehicle can travel above the maximum or below minimum speed limits fixed for the vehicle. Under this section, the State Governments may prescribe such speed limits[2]. The 2018 Speed Limit Notification by the Ministry of Road Transport and Highways (MoRTH) establishes countrywide speed limits.

[2] *(2) The State Government or any authority authorised in this behalf by the State Government may, if satisfied that it is necessary to restrict the speed of motor vehicles in the interest of public safety or convenience or because of the nature of any road or bridge, by notification in the Official Gazette, and by causing appropriate traffic signs to be placed or erected under section 116 at suitable places, fix such maximum speed limits or minimum speed limits as it thinks fit for motor vehicles or any specified class or description of motor vehicles or for motor vehicles to which a trailer is attached, either generally or in a particular area or on a particular road or roads"*

Section 183 of MVAA further penalises excessive speeding, with fines and penalties for violations. In addition, the Central Motor Vehicles Rules, 1989 (CMVR) mandates speed governors for transport vehicles manufactured post-2015. These speed governors limit speeds to 80km/h.

The guidelines for electronic monitoring and enforcement, released on August 11, 2021, include 17 cities in Uttar Pradesh. Recent reports confirm Uttar Pradesh's adoption of electronic enforcement, employing devices such as speed cameras, and Automatic Number Plate Recognition (ANPR) technology.

In Uttar Pradesh, regional transport authorities and law enforcement agencies, under the UP Motor Vehicle Rules, 1998, wield the power to designate main roads, restrict vehicle speeds, and issue speed limit notifications. Currently, speed limits are determined by the Uttar Pradesh Transport Department and Traffic Police Directorate, with specific road stretches and district-wise notifications in place.

1.3 Classification and Speeds of Non-Urban Highways

The figure 1.1. contains information from IRC:73: Geometric Design Standards for Rural (Non-Urban) Highways. IRC:73 categorises rural (non-urban) highways into five categories:

- National Highways: the main highways running through the length and breadth of the country connecting major ports, foreign highways, State capitals, and large industrial and tourist centres.
- State Highways: the arterial routes of a State linking district headquarters and important cities within the State and connecting them with National Highways or highways of the neighbouring States.
- Major District Roads: important roads within a district serving areas of production and markets, and connecting these with each other or with the main highways.

[3] https://law.resource.org/pub/in/bis/irc/irc.gov.in.073.1990.pdf

- Other District Roads: roads serving rural areas of production and providing them with outlets to market centres, taluka/tehsil headquarters, block development headquarters, or other main roads.
- Village Roads: roads connecting villages or groups of villages with each other and to the nearest road of a higher category.

Figure 1.1. Variation in design speeds as a function of different road classes and terrains for non-urban roads (image source: IRC: 73:1980)

S. No.	Road classification	Design Speed, Km/hr							
		Plain Terrain		Rolling Terrain		Mountainous Terrain		Steep Terrain	
		Ruling Design Speed	Minimum Design Speed	Ruling Design Speed	Minimum Design Speed	Ruling Design Speed	Minimum Design Speed	Ruling Design Speed	Minimum Design Speed
1	National and State Highways	100	80	80	65	50	40	40	30
2	Major District Roads	80	65	65	50	40	30	30	20
3	Other District Roads	65	50	50	40	30	25	25	20
4	Village Roads	50	40	40	35	25	20	25	20

1.4 Classification and Speeds for Urban Roads

Table 1.1. Represents the guidelines in IRC:86. IRC:86 governs the design and speed standards for urban roads and streets in India, providing guidelines for six distinct classes of urban roads:

- Urban Expressway: Urban arterial highway for high-speed regional passenger and goods traffic. They are fully access controlled, having divided carriageways, generally with grade separators at intersections and service roads on both sides.
- Arterial Road: Arterial roads facilitate mobility across the city and connect to long-distance destinations within/outside the city, while providing safe NMT facilities.
- Sub Arterial Road: These are larger collector streets meant for movement through neighbourhoods and to connect to arterial roads.

- Operating Speed: IRC recognises Operating Speed, defined as the “85th percentile speed of cars at low volumes (8 sec headway).” Correlation between Operating Speed and Design Speed is essential to prevent speeding violations.
- Running Speed: It is the average speed over a route and is considered ineffective for designing urban roads due to its limited insight into specific road geometry impacts on speeds.

Table 1.2 & 1.3: List of Guidelines & Speed Notifications perused

Legislation	Sections	Description
Motor Vehicles Act, 1988	112, 116, 183	Limits of Speed, Power to erect traffic signs, Driving at excessive speed, etc
	198A, 136A	Failure to comply with standards for road design, Digital/ E-Enforcement
Central Motor Vehicles Rules, 1989	Rule 167, 118	Electronic monitoring and Enforcement, Speed Governors
UP Motor Vehicle Rules, 1998	Rule 177, 178	Designate main roads, Erect traffic signs
Indian Roads Congress	86, 99-2018, 73-2022	Geometric Design Standards for Urban Roads, Traffic Calming Measures, Geometric Design Standards for Non-Urban Roads

Location	Notification No.	Date
Kanpur Nagar	343	1st July, 2020
Agra	672	19th June, 2020
Bareilly	228/20	4th June, 2020
Gorakhpur	135	20th July, 2020
Prayagraj	342	18th June, 2020
Agra-Lucknow Expressway	376	24th September, 2020
Yamuna Expressway	604	24th September, 2020
Uttar Pradesh Traffic Police	DT-812-2019/2741	30th December, 2019
MoRTH	S.O. 1522(E)	6th April, 2018

1.5 Review of Literature

The literature review aims to comprehensively document global and Indian studies on speeding, focusing on the impact of speed management measures and contributing to the existing body of knowledge. The assessment of speed limits' effectiveness and the role of speeding studies in influencing policy changes are crucial elements of this review. Silvano and Bang (2015) conducted a study assessing changes in posted speed limits in Sweden and their impact on free-flow speeds. Their findings indicated a small but significant reduction in free-flow speed and speed variance, leading to a notable 10% decrease in severe injury road crashes.

Debates surround the effectiveness of speed limits, particularly in relation to the 85th percentile speed. Rawson (2015) suggests aligning the maximum posted speed closely with the 85th percentile value in Texas (United States), while studies by Bellini et al. (2020) in Italy and Azwari & Hamza (2021) in Malaysia demonstrate instances where the 85th percentile speed exceeded posted speed limits, posing challenges for policymakers focused on speeding reduction.

A case study in Thailand (World Bank 2019) showed that simple changes in speed management lead to the overall improvement of road safety for all road users. The analysis showed that by reducing the speed limits, the iRAP star ratings, an internationally recognised method of gauging the safety level of roads, increased. For instance, on a 2.3 km stretch of Hathai Rat Road, located in the Min Buri district of Bangkok, the original iRAP Star Rating findings for pedestrians was 1-star rating along the entire length when the speed limit is 80 km/h. When the speed limit is reduced to 50 km/h, the distribution shifts, with 33% of the road achieving a 3-star rating, 58% rated at 2 stars, and 8% at 1 star. At 40 km/h, the distribution changed further: 33% of the road length received a 4-star rating, 58% received a 3 star rating, and 8% remained at 1 star. For motorcyclists, when travelling at 80 km/h, only 4% of the road length was rated at 3 stars, with 88% at 2 stars, and 8% at 1 star. However, at a speed of 40 km/h, the majority of the road length, 92%, achieved a 5-star rating, with 4% at 4 stars, and the remaining 4% at 1 star. Therefore, reduction in speed limit is an effective measure in curbing speeding.

Other studies have shown that enforcement is a critical measure in improving driver perception and may lead to a change in driver behaviour. For example, a probabilistic model based on information collected from 988 drivers in Indiana, United States of America, indicated that the speed at which drivers perceive they will be ticketed for exceeding the speed limit significantly influences their perception of a safe driving speed, highlighting the significant impact of enforcement measures on drivers' perceptions of safety (Mannering, 2009).

Globally, studies conducted by the United States Federal Highway Administration emphasise the importance of comprehensive data collection techniques. These methods include radar guns, laser guns, stopwatches, and considerations of average traffic speeds, road features, school zones, and posted speed limits. Similar survey techniques have been applied in India, such as the radar gun-based study by United Way Mumbai and IIT Bombay, assessing speeding patterns in Mumbai's blackspots.

Indian studies have explored speeding behaviour near toll booths (Bari et al., 2021), on rural highways (Pala and Saha, 2016), and in metropolitan regions (Khaddar et al., 2023), providing valuable insights into diverse contexts within the country.

Box 1: Success Story: Bogotá, Columbia

In Bogotá, Colombia, the implementation of the Programa de Gestión de la Velocidad (PGV), a speed management program, brought positive outcomes. Identifying that 75% of road crash fatalities occurred on arterial roads, the PGV launched an initiative targeting 10 high-casualty corridors. With the installation of speed cameras and a reduction in the speed limit from 60 km/h to 50 km/h, fatal crashes per week decreased compared to the previous three years. In 2019, the programme saved nearly 50 lives, marking a 21% reduction in road crash fatalities compared to the average between 2015-18. The speed cameras also contributed to increased compliance, with lower excess speeds (International Transport Forum 2020).

The Global Road Safety Partnership has recently released a report titled "Speed Management - A Road Safety Manual for Decision Makers and Practitioners" outlining key strategies for effective speed management. The manual underscores the importance of considering various factors while setting speed limits:

- Consideration of Road Users: The type and mix of all road users, with special attention to vulnerable road users
- Assessment of Road Infrastructure: Evaluation of the safety quality of infrastructure
- Vehicle Fleet Safety: Considering the crashworthiness and crash avoidance capabilities of vehicle fleets

The manual advocates for a comprehensive approach to speed management, combining manual speed enforcement, speed cameras, overt and covert deployment, along with a communication programme supporting and explaining enforcement activities.This approach is highlighted as highly effective and cost-efficient.

Additionally, the manual emphasises the importance of studying the road and its environment to assess speed-related injury risks. Based on this assessment, understanding the risk profile of road users becomes crucial.

Incorporating in-vehicle technologies, such as speed limiters, intelligent speed adaptation technology, and autonomous braking, is highlighted as effective measures to curb speeding. These technologies play a significant role in enhancing road safety by addressing speeding-related risks.

A matter of great concern is the speeding behaviour of two-wheelers. A study by Monash University in Victoria, Australia stated that a high number of motorists at all speed levels did not believe it to be dangerous to travel 30 km/h above the posted speed limits (Fildes et. al. 1991).

Another study in India stated that among 340 riders surveyed, 117 (34.4%) admitted that they disobey speed limits mandated for them while driving on roads late at night or in early hours of the morning (Thombre et. al. 2020). two-wheelers are especially vulnerable, as the maximum deaths in Uttar Pradesh were among two-wheeler users (6,959) in 2022.

1.6 West Bengal Speed Management Study

In April 2023, the Indian Institute of Technology-Kharagpur (IIT-KGP) submitted a paper titled "Enhancing Road Safety in West Bengal: Policy Interventions for Speed Management" to the Government of West Bengal (Maitra et al., 2023). This comprehensive document focuses on the current state of speeding, particularly in Kolkata, the capital of West Bengal. The study assesses the existing challenges on the ground and advocates for the implementation of an effective Speed Management Program. Noteworthy recommendations include:

- Road Safety Lead Agencies: The agencies responsible for overall planning and monitoring of speed limit recommendations, road signages, and traffic calming measures.
- Road Audits: Audits conducted to recommend appropriate speed limits, aligned with traffic signs, road markings, delineators, and traffic calming measures following IRC guidelines.
- Audits of Existing Speed Management Measures: Audits to ensure the effectiveness and relevance of current speed management strategies.
- Adoption of iRAD/e-DAR: State-wide implementation for recording road crash data.
- Crash Data Analysis: Identification of critical locations with respect to speeding, facilitating targeted interventions.
- Speed Monitoring & Technology: Implementation of Vehicle Location Tracking Devices, speed governors, and the development of protocols for Intelligent Transportation Systems.

- Capacity Building: Training programs for District Road Safety Councils, police personnel, civic volunteers, road development authority personnel, and emergency vehicle drivers.
- Education & Awareness Campaigns: Strategically conducted, focusing on at-risk groups such as truck drivers, two-wheeler users, and bus drivers. Quarterly campaigns recommended.
- Pilot Speed Management Programme: Implementation across eight selected stretches, in consultation with relevant departments like the West Bengal Public Works Department.

The present study seeks to build upon the IIT-Kh study by evaluating the on-ground situation in Uttar Pradesh and providing state-specific, evidence-based recommendations. Furthermore, it aspires to serve as a template for similar studies across India, influencing stakeholders to implement effective interventions that reduce crashes and fatalities caused by speeding.

The outcomes of this study hold significant relevance for the national discourse on speed management, providing valuable insights to suggest speed limits for National Highways and Expressways. By addressing the challenges faced in Uttar Pradesh, the recommendations aim to contribute to the broader goal of addressing such challenges and enhancing road safety on a national scale.

1.7 The Importance Enforcement

1.7.1 The Importance of Manual Enforcement

Manual enforcement is the major measure for speed enforcement across India. According to GRSP (2023), there are various kinds of manual enforcement models. These can be broadly categorised as stationary and mobile speed enforcement. In a stationery enforcement model, the enforcement official uses a laser speed detection device. These speed detection devices target each individual speeding vehicles and measure the speeds.

In this model, either the operating officer of the laser device in low traffic volume areas will stop the offending driver, or police further down the road will undertake the stop and take enforcement action. In mobile enforcement models, The visible presence of police officers conducting manual speed enforcement can serve as a deterrent to speeding behavior. In this model, a marked or unmarked patrol car is equipped with a mobile radar that allows an enforcement officer driving on a road to detect the speed of surrounding vehicles or vehicles approaching the patrol car from the rear. Mobile mode radar is ideally suited to rural or urban roads with lower traffic volumes.

There are many advantages to manual enforcement (GRSP 2023). Through manual speed enforcement, the police can conduct road enforcement drives to manage speeding as well as other road traffic violations such as drinking and driving, non-usage of safety devices, distracted driving, or non-carrying of essential documentation. Through manual enforcement, police personnel have the ability to immediately stop unsafe behaviour, provide immediate feedback to offending drivers, and taking immediate enforcement action against offending drivers. A study by Soole et. al (2008) demonstrated that non-camera based methods, such as on-road traffic patrols, received stronger support and was associated with greater self-reported compliance to speed limits than camera-based methods. Thus, visible manual enforcement enhances public perception of law enforcement agencies and their commitment to road safety.

1.7.2 The Importance of Electronic Enforcement

Electronic enforcement stands as a crucial measure in combating speeding, addressing the limitations of traditional enforcement methods where policing resources are dwarfed by the magnitude of speeding violations (Zaal 1994). Rothengatter (1991) underscores the transformative impact of automated speed enforcement, enhancing the likelihood of detecting speeding violations, influencing driver behaviour, and ensuring fairness and objectivity in enforcement.

Another study based in Barcelona showed that speed cameras prevented an estimated 364 collisions and 507 injuries in two years (Pérez et. al. 2007). Studies by Shin et al. (2009) in the Arizona (United States), Hoye (2015) in Norway, and Li et al. (2020) in the United Kingdom, have consistently demonstrated a reduction in crashes attributable to automated speed enforcement cameras. It is imperative to effectively implement Section 136A of the MVA(as Amended in 2019), specifically across Uttar Pradesh's million-plus population cities, in accordance with Rule 167 of the CMVR. This strategic deployment of electronic enforcement is integral to the comprehensive efforts aimed at reducing speeding-related incidents and enhancing road safety in the state. Studies in India, discuss the various traffic enforcement methods that can be clubbed with manual enforcement for augmenting safety w.r.t. curbing speeding. A study by Roopa et. al. (2018) tested out a traffic enforcement device, which was an Android-based camera phone and tablet equipped with the latest mobile data network capabilities serve as a practical technological tool for law enforcement officers. It allowed them to efficiently issue citations or verify compliance with traffic laws, offering a cost-effective and swift operational solution tailored to current needs. Such methods are currently being utilised in Hyderabad, where video evidence is being added along with penalties, including videos recorded by police personnel (Times of India 2023).

The (GRSP) emphasises the increasing relevance of electronic enforcement in low and middle income countries and considers it as "one of the most effective, evidence-based, low-cost opportunities to reduce speeds and save lives and injuries is the introduction of speed cameras combined with the promotion of enforcement activity" (Job et. al. 2020). The GRSP mentions that eleven issues may come up while identifying the most effective automated speed enforcement measures. These are:

- Political acceptance of electronic enforcement measures
- Legislation and policy decisions around speed enforcement
- Funding mechanisms for electronic enforcement

- Site selection for installation of speed cameras
- Camera maintenance and calibration
- Appropriate identification of vehicles through images generated by speed cameras
- Linking vehicle to registered owner and contacting the registered owner when an infringement is issued
- Issuing penalties for speeding to violating vehicles
- System by which penalties can be contested
- Management of repeat offenders
- Monitoring and evaluation to show road safety improvements

Numerous equipment have been introduced for speed detection such as Fixed cameras, Mobile cameras, Point to Point Speed Control, Red Light/speed cameras, to name a few (GRSP and GRSF 2020). Further, the Interestingly, certain studies have suggested that covert speed enforcement might be more effective than overtly visible speed enforcement cameras in Australia (Diamantopoulou and Cameron 2002; Afghari et al. 2018). Whereas, Shaaban et al. (2023), based on their analyses conducted in Qatar, claim that in specific areas like intersections or roads near schools, the deployment of visible fixed speed cameras is essential for effective enforcement. They claim that in such locations, using a visible fixed speed camera, paired with a warning sign, proves more effective than a hidden speed camera.

1.8 Deterrence Theory

According to the GRSP, “penalties and the ways they are applied through traffic law enforcement regimes to improve road safety are based on deterrence theory principles. This theory proposes that individuals are deterred from offending if they perceive that there is a high risk of being caught if they break the law and that they also fear the perceived consequences of the offence - the level of fear is said to be influenced by the individual’s perceptions about the certainty, severity and swiftness of punishment.”

According to Zaal (1994), the perceived risk of apprehension is a major factor in determining the level of speeding behaviour. A low risk of apprehension could encourage speeding, because offending vehicle users are under the perception that they will not be penalised for their offence (Ostvik & Elvik, 1990). The certainty of punishment is built with strong enforcement. When offending vehicles are committing a road traffic violation, they must be caught and penalised. With strong enforcement, vehicle users will be cautious as to not get a penalty, thus deterring unsafe driving practices.

The severity of punishment also makes a difference to speeding behaviour. With the 2019 Amendment to the Motor Vehicles Act, 1988, the penalties for speeding have been rationalised to meet the current rates of inflation. Prior to the Amendment, the fine amounts for speeding were the same as the rates notified in 1988, which were very low for the current economy. With the rationalised fines, the penalty for speeding is much more severe than it was prior to the 2019 Amendment.

Finally, the swiftness at which an offending vehicle receives a penalty also makes a sizable difference to the speeding behaviour. According to the GRSP (2021), "penalties applied close in time to when the illegal behaviour is performed are expected to be more likely to produce stronger learning of not repeating the behaviour. "

A combination of manual and electronic enforcement can effectively detect and reduce speeding behaviour (GRSP 2023). It also has a positive benefit-cost ratio, according to the GRSP. As manual enforcement is the predominant method of enforcement in multiple countries (GRSP 2023), it is important to develop an efficient and uniform protocol for such enforcement models. Uniform checkposts should be deployed on high-speed roads to curb speeding behaviour. In a recent road crash case, a police personnel was injured by a speeding vehicle that rammed through checkposts (The Times of India, 2023).

Chapter 2: Methodology

2.1 Identification of Speed Limits

To establish benchmarks for speeding, we reference the Uttar Pradesh Government's speed limit notifications for various districts. These notifications encompass the following:

- District-specific road notifications (last updated in 2020)
- Expressway notifications from corresponding operators (last updated in 2020)
- A consolidated list of traffic police speed limits (last updated in 2019)

2.2 Speed Data Collection Methods

A variety of data collection methods are used in road safety research and practice to measure vehicular speeds. Some of them are as follows:

Speed Survey Recording Tools: The Global Road Safety Facility (GRSF) created two Excel sheet-based speed survey tools to help users record and analyse data at locations.

- One tool records readings from speed measurement devices, and included metrics such as vehicle type and speeds. The mean, standard deviation, 85th percentile speed and the proportion of vehicles exceeding the posted speed limit is then calculated. This version of the speed survey tool can be used when a speed measurement device, such as a radar or laser, is available.
- The other tool is used even when speed measuring equipment is not available. The assessment is undertaken using a stopwatch to measure the time it take a vehicle to travel between two points.

Point-Based Traffic Detectors: Including radar, laser-based sensing, manual, and automated camera-based estimation. Laser and radar-based methods, used in portable speed guns and automated speed violation detection systems, offer high precision (Del Serrone et al., 2023).



Camera-Based Detection: Involving calibration techniques translating pixels into real-world coordinates. Advancements in image-based vehicle detection and tracking enhance computer vision-based systems, benchmarked against ground truth from other methods (Llorca et al. 2021).



Embedded Sensors: Including loop detectors within pavement for speed estimation.



Probe Vehicle-Based Data Collection: Utilising data from sensors within vehicles or smartphones to estimate traffic speeds. Quality depends on the number of probe vehicles and is augmented by mobile applications and mobility platforms aggregating geospatial data.

2.3 Collecting Data at Scale using APIs

Probe vehicle data (typically obtained via location-based services) is processed and shared by some mapping and navigation technology companies through APIs for real-time or typical speed profile assessment. Speed APIs provide estimates of current and/or free flow speed estimates for a given location (defined by its latitude and longitude). A speed API is defined as a cloud-based service which takes location information as input and provides current/historical speed estimates as output. The speeds estimates are typically based on data processing of crowdsourced probe vehicle trajectories.

Two speed API services, provided by TomTom and HERE, were explored as a potential data source as part of this work. These APIs offer expected speed estimates for a given location and time, denoted as “current_speed” in TomTom and “speed”/”uncapped_speed” in HERE. “Uncapped_speed” doesn’t exceed legal speed limits. However, legal speed limits aren’t provided by the APIs. The syntax, input, and output information are provided in Appendix F.

Based on some preliminary testing of the two APIs, the TomTom API was chosen for assessing average free flow speed conditions . However, these estimates represent average speed for the overall traffic stream and don't differentiate between speed profiles of different vehicle classes. Consequently, the free flow speed information data from TomTom was primarily considered as an input to the corridor selection process to target roads with high average speeds of the traffic streams. After the on-site speed data collection was completed, a comparison between TomTom free-flow speed estimates with the prevailing speed conditions was undertaken. Therefore, for our study, we have majorly used the APIs to identify locations and stretches. Our analysis is based on the observational survey conducted on-ground, involving primary data collection.

2.4 Manual Surveys

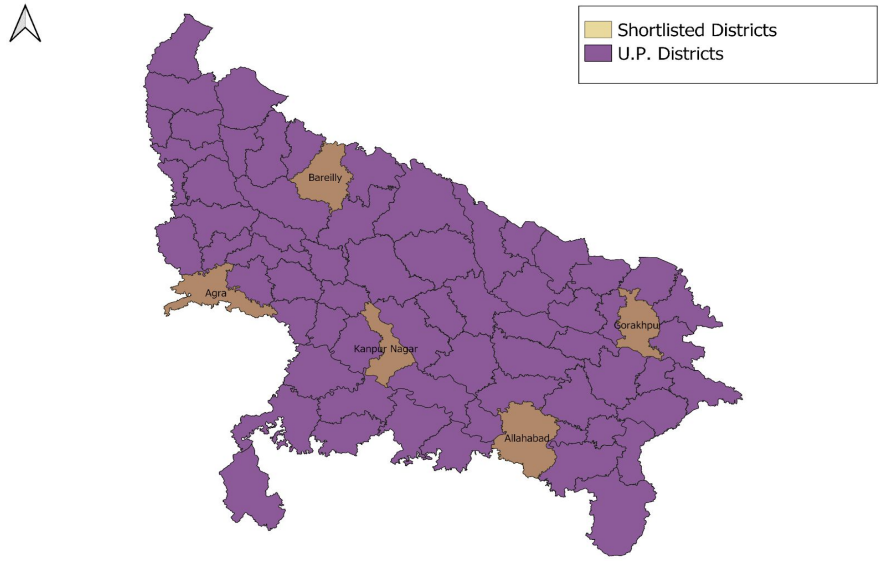
Manual speed surveys were conducted using speed guns to account for the variability in speed limits based on vehicle classes. This method offered precise ground-truth speed estimates for different vehicle classes at various corridors and sites. While limited by sample size, the manual approach provided flexibility in selecting locations for spot speed surveys. The radar gun utilised in the spot speed survey had a resolution of 1 km/h with an accuracy of 3%.

2.5 District, corridor and site selection methodology

a. District selection methodology

Considering Uttar Pradesh's vast size, districts for spot speed surveys were chosen to ensure geographical variation. The selected districts—Kanpur Nagar (centre), Agra (west), Gorakhpur (east), Bareilly (north), and Prayagraj (south)—are distributed across different parts of Uttar Pradesh, as illustrated in Figure 2.1.

Figure 2.1: Shortlisted districts for spot speed surveys



These districts were selected not only to ensure geographical diversity but also due to their high incidence of road crash fatalities. In 2021, Kanpur Nagar, Agra, and Prayagraj reported the highest number of fatalities in Uttar Pradesh, while Bareilly and Gorakhpur reported the highest road crash deaths in the northern and eastern parts of the state, respectively. Moreover, these districts ranked prominently at the national level in terms of road crash fatalities. As the site selection occurred in May 2023, the data for 2022 was not available at that time. Subsequent to our site selection, the road crash fatalities in Kanpur Nagar, Gorakhpur, Bareilly, and Prayagraj increased in 2022. The table below presents the road crash data for the years 2021 and 2022 for the five selected districts:

Table 2.2. Road crash data for selected districts

District	Fatalities (2021)	Fatalities (2022)	Crash Severity (2022)*	District Ranking in State^
Kanpur Nagar	598	640	44.9	1
Agra	549	548	53.2	4
Prayagraj	535	603	44	2
Bareilly	433	487	46.4	9
Gorakhpur	411	512	42.7	6

** Fatalities per 100 crashes*

^ In terms of total number of fatalities in 2022

b. Corridor Selection Methodology

Two sets of data sources were considered for the identification of corridors for speed surveys:

- List of blackspots (2019-2021): Identifying locations with a high incidence of crashes within each shortlisted district.
- OpenStreetMap (OSM) Data: Utilising motorway, trunk, and primary roads data from OSM, randomly sampled for free flow speeds using TomTom's API.

Criteria for Corridor Selection:

- Number of blackspots identified (2019-2021) on expressways, national highways, state highways, and major/other district roads.
- High average free-flow speed from TomTom data, indicating conditions conducive to speeding.

c. Site selection Methodology

Given the variations in road lengths, the corridors were further sampled for 5-6 locations spanning around 20 km for speed surveys. Google Street View[4] and MapMyIndia's Mappls[5] services were used to survey attributes like intersections, signage, traffic calming measures, crossing points, etc.

Table 2.3. Attributes Considered for Site Selection:

Intersection, off-ramps, on-ramps	Potential crossing points, midblock crosswalks	Rest areas
Signages (speed limits, warnings)	Potential conflict points with vulnerable road users (schools, markets)	Curves
Traffic calming measures (speed bumps, rumble strips)	Divided vs. undivided and breaks in the median	Blackspots
Flat stretches of road		

[4] *Google Street View is a feature available in Google Maps and Google Earth, offering interactive panoramic views from various locations on numerous streets globally: https://www.google.com/maps/@28.6205226,77.2483171,13z?entry=ttu*

[5] *The Mappls App provides users with step-by-step voice-guided directions to their desired destination, accompanied by live traffic updates and estimated time of arrival (ETA). A distinctive feature of Mappls is its digital address and location identity system known as Mappls ID. Mappls utilises comprehensive maps sourced from MapmyIndia, a leading mapping company in India. Additionally, the app offers detailed maps spanning approximately 200 countries worldwide. https://www.mapmyindia.com/*

After a virtual survey of points of interest, 5-6 points were identified within a 20-25 km corridor, reasonably separated (at least 500 metres) based on specified criteria. The number of points within a corridor were determined by available resources for each day's survey.

Table 2.4. Corridors Considered for Each District:

District	Agra			Bareilly		
Corridor	Yamuna Expressway	NH19	SH62	NH30	SH37	Pilibhit Bypass Road
Length	26 kms	20.2 kms	11.2 kms	13.2 km	22.5 km	14.9 km
Average TomTom freeflow speed	80 km/h	64.8 km/h	42.4 km/h	75 km/h	59.8 km/h	46.6 km/h

District	Gorakhpur			Kanpur Nagar		
Corridor	NH27	SH1	Sports College Road and Fatima Hospital Bypass Road - Jail Bypass Road	Lucknow-Agra Expressway	NH34	SH46
Length	11.9 km	11.4 km	8.1 km	7.6 kms	26 kms	19.2 kms
Average TomTom freeflow speed	64.6 km/h	58.4 km/h	32.2 km/h	102.2 km/h	38.4 km/h	49.9 km/h

District	Prayagraj		
Corridor	Allahabad Bypass Expressway	NH35	SH7
Length	19 km	15.3 km	13.6 km
Average TomTom freeflow speed	70.4 km/h	49.8 km/h	51.8 km/h

Appendices A-E list the details of the sites and corridors surveyed in this study.

d. Limitations:

Interpreting circulars poses a challenge as they do not provide a singular set of speed limits for the entire roadway in a stretch. Instead, they offer broad descriptions of locations, potentially resulting in speed limits being fragmented across a highway. To address this, we assessed each notification and spatially interpolated trends to determine the speed limits at specific sites.

An additional limitation is the absence of a speed limit notification for the Agra-Lucknow Expressway stretch passing through Kanpur Nagar. In this case, we referenced the notification for the Kannauj stretch, an adjacent district. For stretches without any notification, the Ministry of Road Transport and Highways' speed limit notification from April 6, 2018, was consulted.

Chapter 3: Overall Speeding Trends

Speeding, identified as a leading cause of road crashes, is a complex issue influenced by a multitude of factors. This chapter delves into a comprehensive comparative analysis derived from the observational study findings, establishing a nuanced understanding of the correlation between speeding and crashes. The study explores the impact of various factors on speeds across different vehicle classes. Notably, the study uncovers that speeding tendencies are higher in less densely populated areas. Intriguingly, contrary to common assumptions, segments near blackspots don't consistently exhibit the highest incidence of speeding.

The analysis discerns that, on average, speeds across vehicle and road functional classes are elevated in non-blackspot locations compared to blackspot locations. This chapter meticulously examines trends associated with temporal variation, road types (divided vs undivided), number of lanes, intersections vs non-intersections, and the presence of blackspots. Additionally, it scrutinises the influence of features such as pavement conditions, warning signs, and traffic calming measures on speeding behaviours. This holistic exploration contributes to a comprehensive understanding of the intricate relationship between speeding and crashes, paving the way for targeted interventions and effective speed management strategies.

3.1 Distinguishable trends across corridors:

- Sections with limited roadside activity exhibit higher instances of speeding across functional classes. In other words, a larger proportion of vehicles were exceeding the speed limit across functional classes on sections with limited roadside activity.
- Sites near intersections/interchanges had a lower proportion of vehicles exceeding the speed limit than straight stretches.
- Sections with more lanes within a functional class had a higher tendencies to speed larger proportion of vehicles crossing the speed limit than sections with less lanes within a functional class.
- Blackspots in this study tended to have less speeding than other locations on the same stretch.

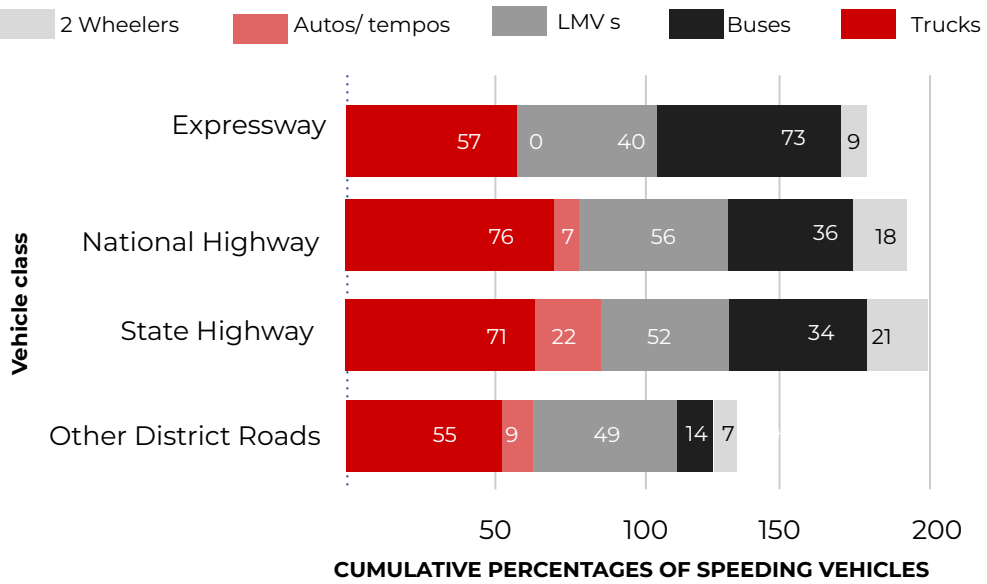
3.2 Overall trends of speeding:

The data reveals that a majority of two-wheelers exceeded speed limits across functional classes, indicating that two-wheeler speeding is a significant issue. The average percentage of speeding vehicles was 35.3%, with two-wheelers leading at 64.8%. Buses, interestingly, tend to speed more than trucks across road types, with 73% of buses observed speeding on expressways.

Table 3.1: Overall speeding trends across road types and vehicle classes

Vehicle Class	Percentage of vehicles speeding				
Vehicle Class	Expressway	National Highway	State Highway	Other District Roads	Average
Two-wheelers	57	76	71	55	64.8
Autos/ Tempos	0	7	22	9	9.5
LMVs	40	56	52	49	49.2
Buses	73	36	34	14	39.2
Trucks	9	18	21	7	13.8
Average	35.8	38.6	40	26.8	35.3

Figure 3.1: Proportion of speeding vehicles amongst vehicle classes



The observed trends are consistent with some other studies on speeding behaviour and road safety analysis in Indian conditions. Balasubramaniam and Sivasankaran (2021) analysed speeding-related crashes in Tamil Nadu and observed higher instances of speeding in crashes for highway segments (when compared to other local roads). The authors argue that the better quality of road infrastructure, absence of control devices, and inadequate enforcement may be potential contributing factors for speeding on highways. Khadder et al. (2023) observed the speeding frequency to typically increase for arterial segments (potentially related to higher gaps between intersections).

The lower incidence of speeding amongst trucks as compared to buses can be attributed to one or more of the following reasons amongst other probabilities:

- The loads of trucks may be higher than those of buses. Thus, the speed of trucks may be restricted by their loads.
- There may be instances of speeding among inter-city and intra-city buses to meet the scheduled arrival times.
- According to a study by Balakrishnan and Sivanandan (2015), interstate buses were fastest and MTC or intra-city buses were the slowest. As our study considers high-speed inter-state corridors such as expressways, national highways, and state highways, it is possible that the high speeds amongst observed buses was indicative that the majority of the buses observed were inter-state buses. In the study, interstate buses also had higher speeds than the trucks observed, indicating high speeds among these type of buses throughout.

3.3 Temporal variation of speeding

The temporal trends show that the speeds across vehicle classes and road functional classes do not have significant variation. They indicate that speeding was marginally higher across vehicle classes during the night time (i.e. before 7:00AM) than during the day time (i.e. after 7:00 AM).The speeding was relatively higher amongst two-wheelers before 7:00 AM (i.e. average of 72% at night time vs. 63.5% at daytime).

The speeding patterns in the early morning hours may be attributed to the following:

- Less traffic congestion during early morning hours
- Less road-side activity early morning
- Non-peak hours for work or school traffic

Table 3.2a: Temporal variation of speeding in Uttar Pradesh-Night time

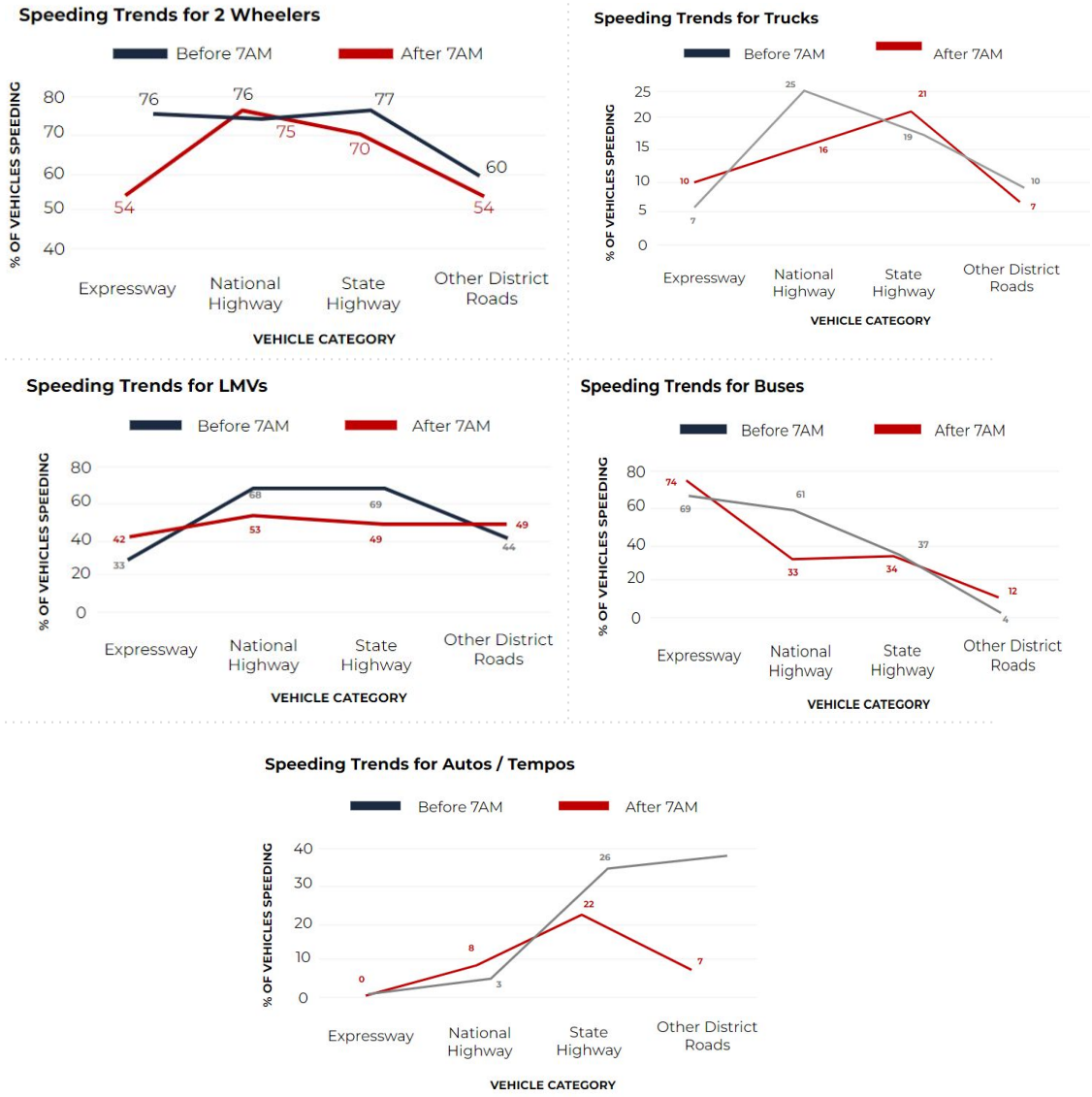
Vehicle Class	Percentage of vehicles speeding (%)				
	Expressway	National Highway	State Highway	Other District Roads	Average
Two wheelers	76	75	77	60	72
Autos/ Tempos	0	3	26	29	14.5
LMVs	33	68	69	44	53.5
Buses	69	61	37	4	42.75
Trucks	7	25	19	10	15.25
Average	37	46.4	45.6	29.4	39.6

Table 3.2b: Temporal variation of speeding in Uttar Pradesh- Day time

Vehicle Class	Percentage of vehicles speeding (%)				
	Expressway	National Highway	State Highway	Other District Roads	Average across vehicle class
Two wheelers	54	76	70	54	63.5
Autos/ Tempos	0	8	22	7	9.25
LMVs	42	53	49	49	48.25
Buses	74	33	34	12	38.25
Trucks	10	16	21	7	13.5
Average across road class	36	37.2	39.2	25.8	34.55

A marginally higher proportion of buses were speeding on expressways during the day time (i.e. 74%) as compared to the night time (i.e. 69%), which may be subject to sampling variation, but also indicative of consistent speeding patterns across time. However, on an average, a significantly larger proportion of two-wheelers were speeding on expressways during the night time (i.e. 76% in the night time vs. 54% in the daytime)

Figure 3.2: Comparison of proportions of speeding vehicles across vehicle class



The observed temporal trends in speeding align with multiple traffic flow studies in the Indian context, utilising early morning speed estimates for free flow speed analysis (Balakrishnan and Sivanandan, 2015; Pal and Roy, 2016; Chathoth and Asaithambi, 2018). Studies analysing bus travel times in specific Indian cities have also noted higher speeds in the early morning hours (Kumar et al., 2021; Jain et al., 2022).

3.4 Spatial features (sparse vs dense roadside activity)

Roadside activity, such as pedestrian movement, parked vehicles, and commercial activity near shops and marketplaces plays a role in influencing traffic speed. Sparse roadside activity correlates with a considerably higher proportion of speeding across vehicle classes and roads. For instance, for other district roads, 88% of LMVs were speeding on sparse stretches, while only 28% were speeding on stretches with considerable or dense roadside activity. This discrepancy may be attributed to sparse roadside activity in less populated stretches, where mixed-use activity is less prominent. Notably, there was a small difference in speeding percentages among two-wheelers on sparsely populated (78%) and densely populated (71%) stretches of national highways.

Table 3.3a: Spatial features - limited road side activity

Vehicle Class	Percentage of vehicles speeding		
	National Highway	State Highway	Other District Roads
Two wheelers	78	75	79
LMVs	66	56	88
Buses	41	38	30
Trucks	20	22	24

Figure 3.1. Examples of sparse roadside features



Table 3.3b: Spatial features - dense roadside activity

Vehicle Class	Percentage of vehicles speeding		
	National Highway	State Highway	Other District Roads
Two-wheelers	71	64	43
LMVs	20	42	28
Buses	17	26	2
Trucks	8	18	1

Figure 3.2. Examples of dense roadside features



Multiple studies in road safety literature have reported open landscapes to be associated with higher speeding through both driver simulation and naturalistic driving studies (Antonson et al., 2014; Yu et al., 2019). In their analysis of operating speeds on rural highways in India, Pal and Saha (2016) argue that increase in roadside features (also referred to as roadside friction by the authors) results in reduction of speeds.

3.5 Intersections and interchanges :

The proportion of vehicles speeding on intersections tended to be less than the proportion of vehicles speeding on non-intersections. However, the exception could be seen in the proportion of two-wheelers speeding on national highways. In our analysis, we have not selected any staggered intersections or Y-intersections as locations. We have also categorised intersections and interchanges together as both are points within the network where vehicle streams from different roads merge or diverge and can generate potential points of conflict.

Figure 3.3. Examples of intersections and interchanges



Table 3.4a: Non-Intersections/ Non-Interchanges

Vehicle Class	Percentage of vehicles speeding		
	Expressway	National Highway	State Highway
Two-wheelers	61	75	72
Autos/Tempos	0	2	15
LMVs	40	59	52
Buses	75	39	37
Trucks	9	19	25

Table 3.4b: Intersections/Interchanges

Vehicle Class	Percentage of vehicles speeding		
	Expressway	National Highway	State Highway
Two-wheelers	47	78	69
Autos/Tempos	0	9	23
LMVs	39	46	47
Buses	62	27	20
Trucks	10	16	6

Balasubramaniam and Sivasankaran (2021) observed a higher incidence of speeding-related crashes at uncontrolled intersections in their study. Researchers have also identified intersections as dilemma zones for decision-making for minor approach road users (Pawar and Patil, 2017). Similarly, multiple studies indicate that the proximity of ramps influence vehicular speeds on expressways (van Beinum et al., 2018; Bari et al., 2021).

3.6 Analysis of speeds based on number of lanes

Speeding was observed to be greater on stretches with an increase in the number of lanes on highways. This could be attributed to the increase in road space and also to the fact that roads with higher number of lanes tended to be divided roads, vs roads with lower number of lanes, which tended to be undivided roads. An increase in the number of lanes, especially during non-congested regimes, may also provide more opportunities to speed. The drop in speeds for expressways occurs due to the 4 lanes corresponding to locations near ramps.

Figure 3.4. Examples of variation in number of lanes



Table 3.5: Lane-wise analysis

Vehicle Class	No. of Lanes	Expressway	NH	SH	ODRs
Two wheelers	One	NA	72	65	51
	Two	NA	72	74	58
	Three	61	95	NA	NA
	Four	47	NA	NA	NA
LMVs	One	NA	56	43	49
	Two	NA	50	58	49
	Three	40	72	NA	NA
	Four	39	NA	NA	NA
Buses	One	NA	NA	24	11
	Two	NA	30	42	11
	Three	75	76	NA	NA
	Four	62	NA	NA	NA
Trucks	One	NA	NA	7	14
	Two	NA	15	7	24
	Three	9	38	NA	NA
	Four	10	NA	NA	NA

*NA- Not applicable

Some studies have found positive association with higher number of lanes and an increase in speeding events (Liu et al., 2020; Khadder et al., 2023).

3.7 Analysis of Speed: Black Spot vs. Non-Black Spot:

To understand whether any distinct speeding trends were observed around blackspot zones, we compared sites surveyed near blackspots with non-blackspot sites from the same corridors (4 NHs, 2 SHs). LMVs and Buses on national highways had a higher incidence of speeding at non-blackspots than at blackspots which can indicate that while focus on blackspots rectification by the authorities may have led to traffic calming, subsequent scale up or replication to entire stretches is warranted to ensure universal reduction in speeding.

Table 3.6. Proportion (in %) of vehicles speeding on blackspots vs non-blackspots.

Vehicle Class	Category	Expressway	National Highway
Two-wheelers	Blackspot	84	77
	Non-Blackspot	84	86
LMVs	Blackspot	39	45
	Non-Blackspot	49	79
Buses	Blackspot	13	32
	Non-Blackspot	27	68
Trucks	Blackspot	10	10
	Non-Blackspot	20	50

3.8 Analysis of school zones :

For our study, the following school zones were included:

1. Kanpur Nagar: Site 3, NH-34-Undivided road near a school and petrol pump
2. Bareilly: Site 5, SH-37- School zone, parked trucks and stalls nearby
3. Prayagraj: Site 3, NH-35, Near a school and parked vehicles
4. Bareilly: Site 2, Pilibhit Bypass Road, School with a slow down warning

In 4 locations across districts, in which schools were present, a number of speeding two-wheelers are observed on national and state highways. This indicates an urgent need to introduce measures to make school zones safer across the state, especially those along highways.

Table 3.7. Proportion (in %) of vehicles speeding above the posted speed limits in proximity of 4 school zones.

Vehicle Class	National Highway	State Highway	Other District Roads
Two-wheelers	75.8	63.9	4.4
Autos/Tempos	15.4	0	0
LMVs	27.3	14.7	0
Buses	3.2	13	3.7
Trucks	2.3	7.1	0

Table 3.8. Proportion of vehicles on each school zone travelling at speeds above 25 km/h

	School Zone on			
Vehicle Category	**NH-34**	**NH-35**	**SH-37**	**Pilibhit Bypass Road**
2-wheeler	98.4%	100.0%	100.0%	86.7%
Autos/ Tempos	100.0%	12.5%	100.0%	33.3%
LMV	100.0%	100.0%	100.0%	84.6%
Bus	100.0%	100.0%	100.0%	81.5%
Trucks	100.0%	96.4%	100.0%	68.2%

Figure 3.5. Examples of sites near schools in Bareilly (left: Pilibhit Bypass road; right: SH-37)





Chapter 4: Speeding Realities: Practical Implications

4.1 Overall Trend of 85th Percentile Data:

The 85th percentile speed limit is rooted in the idea that it represents the speed at or below which 85% of vehicles travel on a particular road segment. It is often used as a basis for setting speed limits, with the assumption that most drivers naturally choose a safe and reasonable speed. However, when a considerable proportion of observed vehicles are found to be exceeding the 85th percentile speed, it raises questions about the effectiveness of this concept in certain contexts and it may indicate a discrepancy between the presumed safe speed and the actual speeds chosen by drivers. This could lead to increased risks of accidents, reduced reaction times, and more severe consequences in the event of a crash.

The 85th percentile speed of the 10,580 observed vehicle was calculated as per the vehicle class. It was found that the 85th percentile speed for two-wheelers was 68 km/h, which is above the speed limit for two-wheelers on all roads observed in the study except expressways. However, it is evident that a considerable number of two-wheelers drive at speeds above the speed limits on national highways, state highways and other district roads, that range from 40-60 km/h. About 15% of the total LMVs and 14% of the total buses were travelling above the 85th percentile speed.

Table 4.1: Comparison of observations with the 85th percentile speed limit

Vehicle Category	Proportion of vehicles travelling above the 85th percentile speed	Total no. of Observations	Observations with speeds above the 85th percentile	85th percentile speeds (km/h)	Maximum observed speed (km/h)	Minimum observed speed (km/h)	Speed limit range (km/h)
Two wheelers	13.52%	4025	544	68	111	10	40-80
Autos/ Tempos	13.73%	590	81	42	72	10	40-60
LMV	14.89%	2733	407	94	146	11	40-100
Bus	14.48%	1333	193	70	104	12	40-80
Trucks	12.80%	1899	243	56	120	10	40-80

The practice of utilising 85th percentile in setting speed limits was established in the 1940s in the United States of America as part of early explorations in establishing safe speed limits derived from prevailing driving behaviour (Taylor and Hwang, 2020). However, this criterion is not consistent with current research endeavours which seek to link travel speed distributions with crash risk (both frequency and risk) as a function of vehicle category, geometric design, built environment characteristics and driver behaviour (Forbes et al., 2012). WHO Guidelines for speed management also argue that the use of 85th percentile speeds is inconsistent with the safe systems approach to speed management, but rather can be viewed as a measure to evaluate whether the existing road design and enforcement measures facilitate alignment between the posted speed limits and driving speeds.

Table 4.2. represents the 85th percentile speeds across vehicle classes and functional classes of roads for 10,580 observations.The analysis of 10,580 observed vehicles revealed that the 85th percentile speed, a measure indicating the speed below which 85% of vehicles operate, exceeded the maximum speed limits within each functional class. Notably, two-wheelers, representing highly vulnerable road users, consistently surpassed the speed limits across all functional classes. Similar trends were observed for LMVs on all functional classes except other district roads, as well as for buses on expressways and national highways. In contrast, autos/tempos and trucks, with speed limits comparable to buses, demonstrated 85th percentiles within the observed speed limit ranges.

Table 4.2: Vehicle-Class wise 85th percentile speeds

Vehicle Type	Corridor Type	No. of Observations	85th percentile (km/h)	Minimum limit (km/h)	Maximum limit (km/h)
Two wheelers	Expressway	180	88.15	60	80
Two wheelers	NH	1596	68	40	60
Two wheelers	ODR	630	56	40	50
Two wheelers	SH	1619	67	40	50

Autos/ Tempos	NH	251	40	40	60
Autos/ Tempos	ODR	88	40	40	50
Autos/ Tempos	SH	251	44	40	50
Bus	Expressway	214	89	60	80
Bus	NH	493	64	50	60
Bus	ODR	176	45	40	60
Bus	SH	450	58	40	60
LMV	Expressway	761	117	100	100
LMV	NH	959	83	50	70
LMV	ODR	297	56	40	70
LMV	SH	716	73	40	70
Trucks	Expressway	265	63.4	60	80
Trucks	NH	798	56	50	60
Trucks	ODR	256	42.75	40	60
Trucks	SH	580	56	40	60

Studies on the impact of speed limit adjustments yielded varied results. While some noted increased crash occurrences with raised speed limits, others found no statistical significance in certain regions. A study by Gayah et al. (2018) suggested that setting speed limits slightly below the 85th percentile speed led to considerable reductions in crash frequency, emphasising the importance of nuanced speed limit adjustments. Doecke et al. (2018) analysed crash data in Australia, revealing a higher percentage of fatal crashes with increased posted speed limits.

Further studies indicated the statistical significance of operating speed variances in crash occurrences. In the Indian context, Nalo et al. (2020) found a positive association between speed dispersion (difference between the 15th and 85th speed percentiles) and crash frequency on two-lane rural highway curves. Acknowledging the heterogeneity in vehicle classes, future research should delve into understanding the impact of speed variation on safety in the Indian context.

4.2 Speeding across Different Road Classes

The table 4.3 below shows the proportion of vehicles driving above the speed limits. For context, the speed limits of all vehicles are given below across vehicular and functional classes in table 4.3:

Table 4.3: Posted speed limit ranges across vehicle and functional classes

Vehicle Type	Corridor Type	Minimum limit (km/h)	Maximum limit (km/h)
Two-wheelers	Expressway	60	80
Two-wheelers	NH	40	60
Two-wheelers	ODR	40	50
Two-wheelers	SH	40	50
Autos/Tempos	NH	40	60
Autos/Tempos	ODR	40	50
Autos/Tempos	SH	40	50
Bus	Expressway	60	80
Bus	NH	50	60
Bus	ODR	40	60
Bus	SH	40	60
LMV	Expressway	100	100
LMV	NH	50	70
LMV	ODR	40	70
LMV	SH	40	70
Trucks	Expressway	60	80
Trucks	NH	50	60
Trucks	ODR	40	60
Trucks	SH	40	60

Table 4.4: Identifying variations in observations exceeding the speed limit on NHs

Vehicle Class	Percentage of vehicles speeding				
	Expressway	National Highway	State Highway	Major District Roads	Average across vehicle class
Two wheelers	76	75	77	60	72
Autos/ Tempos	0	3	26	29	14.5
LMVs	33	68	69	44	53.5
Buses	69	61	37	4	42.75
Trucks	7	25	19	10	15.25
Average across road classes	37	46.4	45.6	29.4	39.6

In general, the following observations can be made regarding the speed distributions of different vehicle classes:

- More than half of LMVs surveyed along national highways travel in excess of 60 km/h, while 20% of them also travel in excess of 80 km/h, which is higher than the speed limits proposed for LMVs.
- 30% of two-wheelers and 22% of buses travel between 60 km/h and 80 km/h, which represents speeds in excess of the limits reported for two-wheelers in most settings.
- About 73% of trucks on national highways travel at speeds between 40 km/h and 60 km/h, once again suggesting that trucks tend to travel slower than buses (59% of which yielded speeds between 60 km/h and 80 km/h).
- 89% of auto/tempos travel at speeds less than 40 km/h, which is expected given their limited engine sizes.

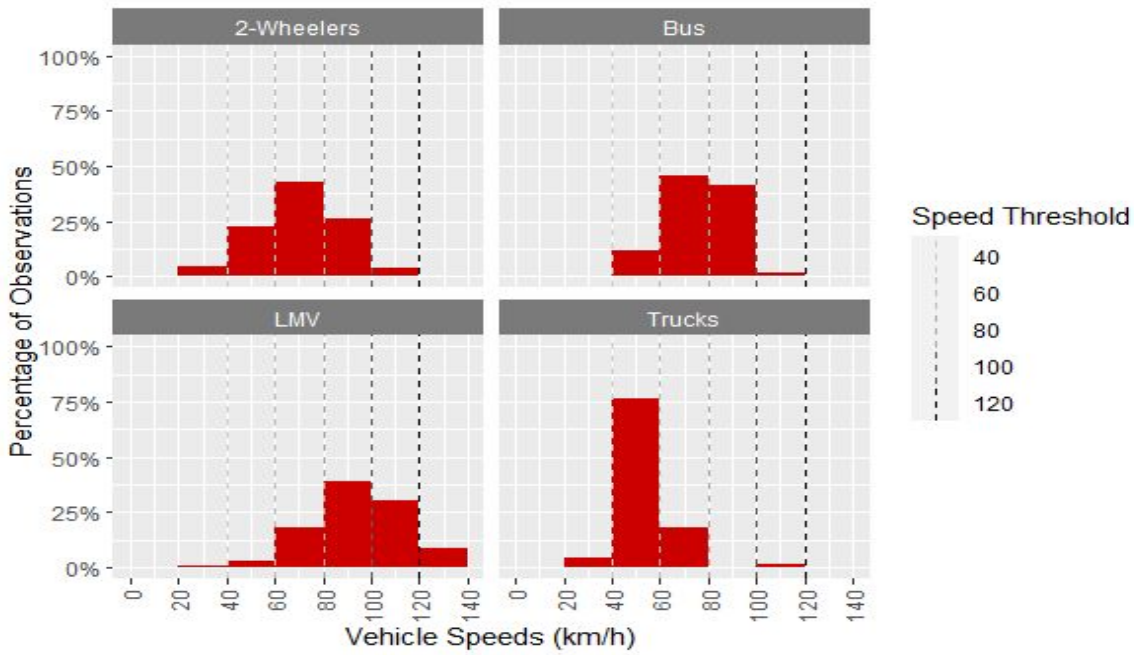
As observed previously, buses and two-wheelers have the highest speeding proportions even in excess of 10 km/h of the speed limit. The extent of drop-off varied for each vehicle class on expressways. For instance, out of the 73% of the speeding buses, 45% were speeding by more than 10 km/h. The maximum recorded speed was 146 km/h for LMVs which is about 1.5 times the posted speed limit. As high as 46% of two-wheelers were travelling at speeds 10 km/h above the speed limit. Despite the speed limits of two-wheelers on expressways already being as high as 60-80 km/h, 17% of the two-wheelers were travelling at speeds 20 km/h over the speed limits.

Table 4.5: Identifying variations in observations exceeding the speed limit

Corridor Type	Type of Vehicle	Number of Observations	Percentage of vehicles speeding (%)				
			Exceeding Speeding	Speed Limit + 5	Speed Limit + 10	Speed Limit +15	Speed Limit + 20
Expressway	Two Wheelers	180	57%	53%	35%	29%	17%
	Bus	214	73%	64%	45%	33%	24%
	LMV	761	40%	31%	27%	19%	10%
	Trucks	265	9%	5%	2%	2%	2%
National Highway	Two Wheelers	1596	76%	60%	46%	34%	22%
National Highway	Autos/ Tempos	251	7%	2%	1%	1%	0%
National Highway	Bus	493	36%	23%	14%	9%	4%
National Highway	LMV	959	56%	47%	34%	24%	17%
National Highway	Trucks	798	18%	9%	2%	1%	0%
State Highway	Two Wheelers	1619	71%	54%	41%	31%	19%
State Highway	Autos/ Tempos	251	22%	8%	4%	2%	2%
State Highway	Bus	450	34%	21%	13%	10%	5%
Other District Road	Trucks	256	7%	3%	1%	1%	1%

Other District Road	Autos/Tempos	88	9%	2%	0%	0%	0%
Other District Road	Bus	176	11%	2%	1%	1%	0%
Other District Road	LMV	297	49%	30%	24%	16%	6%
Other District Road	Trucks	256	7%	3%	1%	1%	1%

Figure 4.1. Graphical representation of variations in observations exceeding the speed limit on expressways



Given the difference in speed limits for different corridors and vehicle classes, the speed characteristics can also be recapitulated by summarising the percentage of vehicles exceeding a given speed threshold, as shown in Table 4.5.

Table 4.6: Identifying variations in observations exceeding the speed thresholds on expressway

Vehicle Class	Percentage of vehicles speeding (%)				
	Exceeding 40 km/h	Exceeding 60 km/h	Exceeding 80 km/h	Exceeding 100 km/h	Exceeding 120 km/h
Two wheelers	96	73	30	4	0
LMVs	100	97	79	40	10
Buses	100	88	43	1	0
Trucks	96	19	2	1	0

4.3 Comparison of spot speeds and APIs

The Indian Highway Capacity Manual (Indo-HCM) defines free flow speed as the “maximum speed achievable by a given vehicle type in ideal traffic conditions”. We compared TomTom's free flow speed estimates, intended for diverse vehicle types in the Global North, with observed speeds of Light Motor Vehicles (LMVs), the category with the highest average speeds in our dataset. TomTom's estimate exceeded posted speed limits for LMVs in 55% of the sites.

- Expressways: 50% of sites showed free flow speeds above limits.
- National Highways: 67% of sites exceeded limits.
- Other District Roads: No sites exceeded LMV limits.

Correlation between observed LMV speeds and TomTom's estimate was 0.77. While TomTom's API may identify free flow conditions, its lack of speed information for different vehicle classes limits its ability to understand heterogeneous traffic speeding. Additionally, the service’s quality may vary across urban and rural areas due to crowdsourced data.

4.4 Minimum Speed Limits

The issue with high speed roads across India, including Uttar Pradesh, is that there is a high difference in speeds. Ideally, the speeds of all vehicles travelling on the road should be the same. If there is a difference in speed, then at the very least, the difference should be minimal. Therefore, minimum speed limits are typically essential on high-speed corridors like Expressways and National Highways to ensure that slower-moving vehicles don't impede traffic flow or create hazards for other drivers. However, from our study, there are large speed ranges amongst vehicle and functional classes. For instance, consider the truck speed on the SH-46, which has a truck speed limit of 60km/h. While the median truck speed was 46 km/h, the minimum speed was as low as 20 km/h and the maximum speed was 70 km/h. Similarly, on the Agra-Lucknow Expressway, the same site witnessed speeds ranging from 50 km/h to 121 km/h amongst LMV users. With such large speed differentials, the risk of rear-end crashes considerably increases. To ensure streamlined flow of traffic, a minimum speed limit could be introduced specifically on high-speed roads.

4.5 Issues with Speed Limit Identification

Determining speeding necessitates clear identification of speed limits for various vehicle classes. The Challenges with speed notification include:

1. Contradictory Notifications: Multiple conflicting state notifications complicated speed limit assessment. For example, the Lucknow-Agra Expressway section lacked coverage in state notifications, requiring comparison with neighbouring districts.
2. On-Ground Notifications: Inconsistent on-ground signage for vehicle class-specific speed limits was observed. Virtual inspections revealed variable signage frequency across corridors, with surveyors noting contradictory indicators, adding complexity to speed limit determination.

Figure 4.2: Instance of contradictory speed limit signage towards site S1 of SH46



Chapter 5: Districts in Focus

KANPUR NAGAR

Speeding was most prevalent amongst two-wheelers and buses. Figure 5.1. indicates that a considerable number of two-wheelers (68%) and buses (67%) were speeding on SH-46 in Kanpur Nagar. Further, nearly two third of the two-wheelers (71%) and over half of the buses (53%) were speeding on NH-34. Over half of the LMVs on the Agra-Lucknow Expressway were speeding. This indicates that there is a need to enhance enforcement targeted towards two-wheelers and buses.

Figure 5.1: Proportion of vehicles speeding in Kanpur Nagar

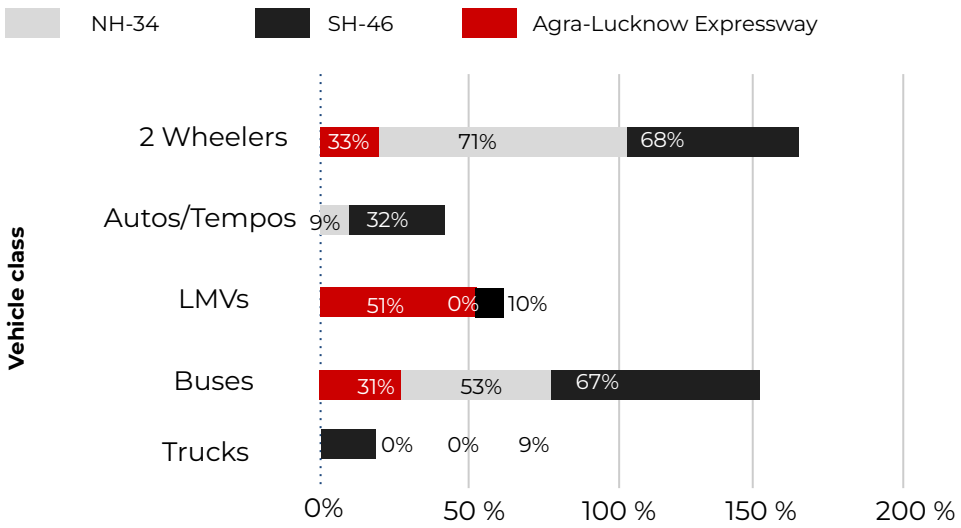
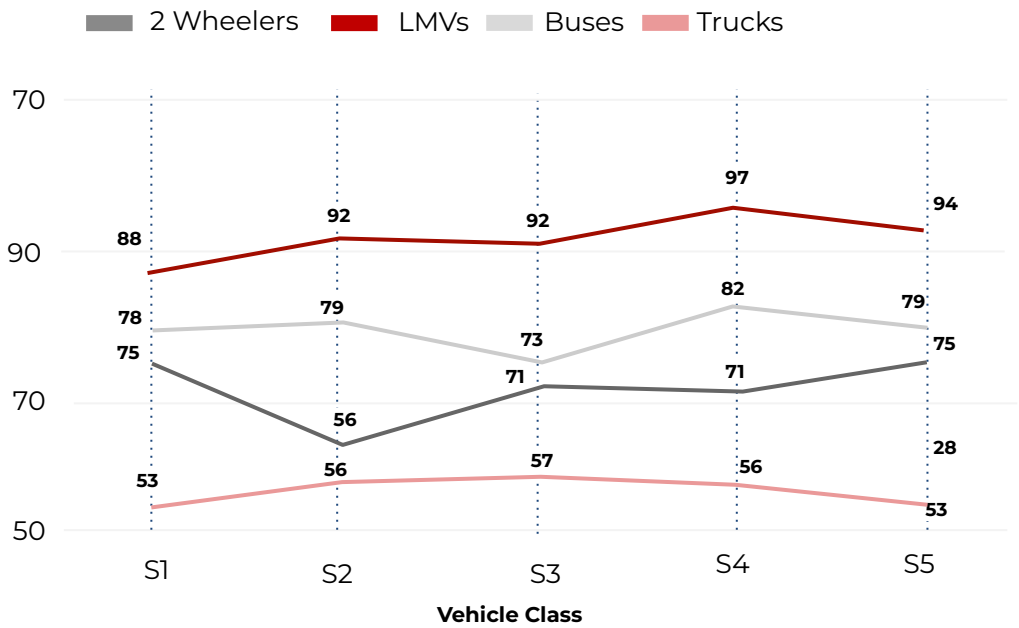


Figure 5.2. represents the average speeds for each vehicle class on each site of the Agra-Lucknow Expressway. The details of each site for the Agra-Lucknow Expressway is given in Annexure 1. The following instances represent the differences in the average speeds for a given vehicle category across classes:

- The average speeds for buses at S3 are lower than the average speed observed at S4. It is possible that this may be an influence of the interchange present between the two sites, in case some of the buses in the S3 are seeking to exit via the off ramp.

- Overall speed distribution of trucks was relatively lower than other vehicle classes.
- Owing to the small sample size of two-wheelers at each site, the variation in average speed patterns could not be differentiated using 95% confidence intervals. However, the overall distribution was observed to be lower at S2 relative to S1, S3 and S5 using the KS test. The out of the KS test in this case is reflective of the speeds at S2 were lower than those observed at other sites for various percentiles.
- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance.

Figure 5.2 : Speeds across sites on the Agra-Lucknow Expressway



The reduced speeds in S4 and S5 can possibly be attributed to the fact that these locations were in more densely populated areas in market places, as well as the surveys being conducted early in the morning, especially for S5 (4:50 - 9 AM).

- While autos/tempos demonstrated the slowest average speeds (expected given their limited engine sizes), their speeds were again lower in urban areas (S4, S5) relative to the rural parts of NH34.
- In the case of buses and trucks, while the average speeds associated with S5 were the lowest relative to other sites, there was also a small decrease in the average speeds at S2 (near the flyover) relative to S1. However, in comparison to the passenger vehicles, the variation in average speeds for buses and trucks were not statistically significant between S4 and sites S1, S2 and S3.
- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance.

Figure 5.3 : Speeds across sites on the NH-34

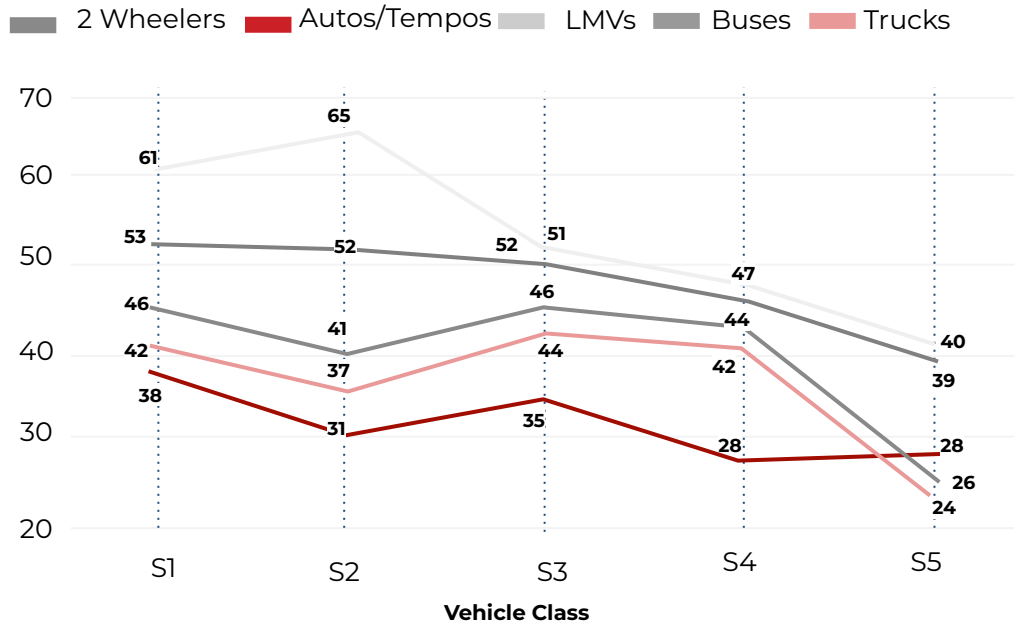
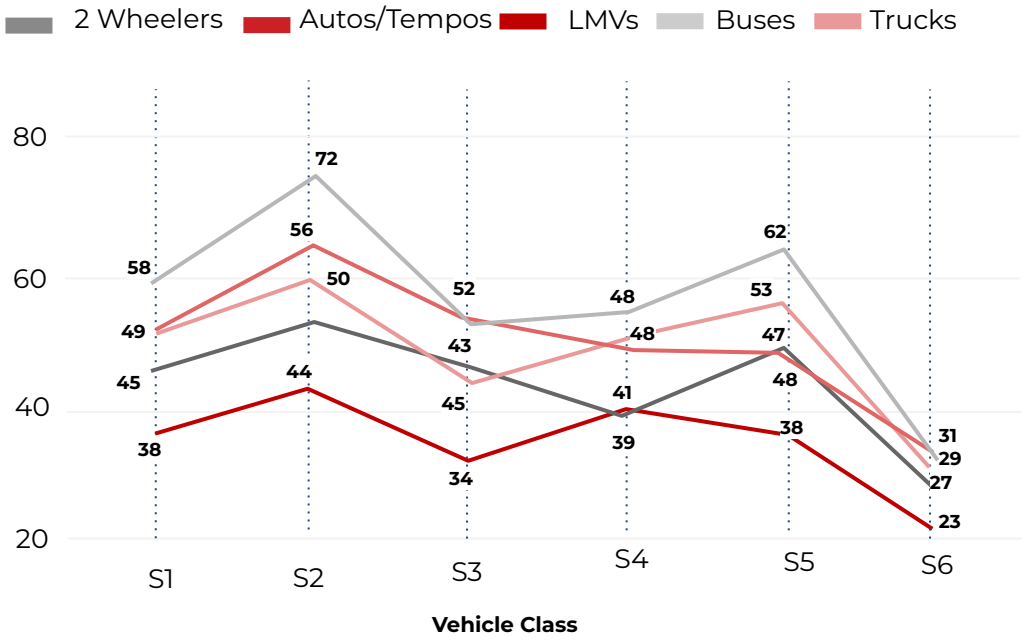


Figure 5.4 represents the average speeds for each vehicle class on SH-46. The details of each site for SH-46 is given in Annexure 1. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Across all vehicle classes, the observed average speeds were highest for S2, while they are lowest in S6. It is important to note that S2 was surveyed between 7 and 8 AM in a sparsely populated region while S6 was surveyed in the afternoon (12 to 3:15 PM) in a densely populated environment.
- The average speeds observed at S2 were greater than all other sites for all classes.
- While the average speeds for LMVs and two-wheelers at the other flat stretch (S5) were not statistically different from the average speeds at S1/S3/S4 at 95% confidence interval. However, the KS test for LMVs suggests that the speed distribution (at different percentiles) was greater at S5 relative to S1/S3/S4.
- Among the sparsely populated regions with an intersection (at S1 and S4), only trucks were observed to have a lower average speed at S4 with some statistical significance.
- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance.

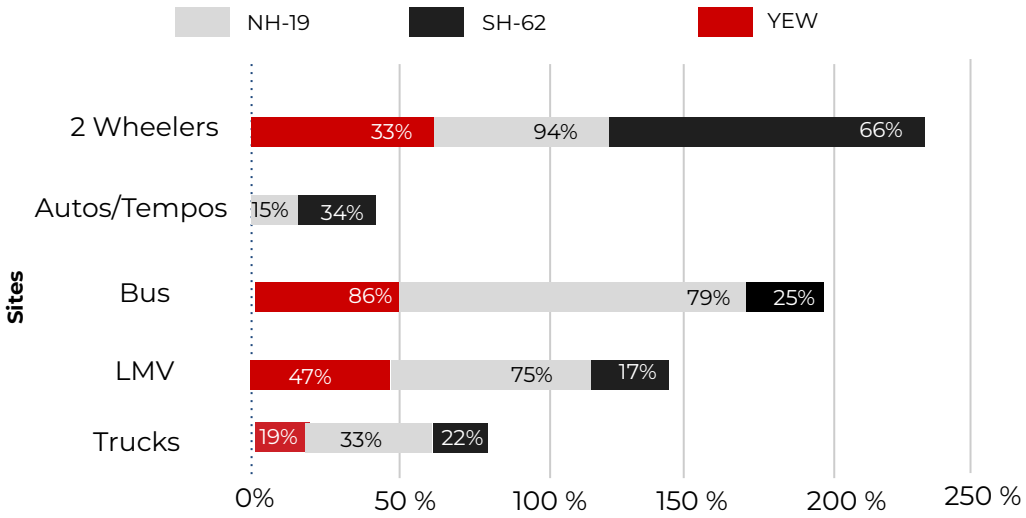
Figure 5.4 : Speeds across sites on the SH-46



AGRA

Figure 5.5. indicates that a considerable number of two-wheelers were speeding on the Yamuna Expressway (73%) and the SH-62 (66%). A considerable number of buses (86%) were speeding on the Yamuna Expressway. The National Highway (NH-19) witnessed prevalent speeding amongst two-wheelers (94%), buses (79%) and LMVs (75%). This indicates that NH-19 needs some drastic changes in terms of speed management.

Figure 5.5 : Proportion of vehicles speeding in Agra



The Yamuna Expressway (YEW) has a dynamic speed limit and adjusts the limits every year during the winters to reduce road crashes witnessed due to winter conditions. For instance, in the winter of 2023, the speed limits were revised to 75 km/h for light motor vehicles and 60 km/h for heavy motor vehicles.

Table 5.1 Average speeds across different sites for each vehicle category on YEW

	Average speeds at different sites (in km/h)				
Vehicle Class	**S1**	**S2**	**S3**	**S4**	**S5**
Two-wheelers	81	76	72	72	66
Autos/Tempos	N/A	N/A	N/A	N/A	N/A
LMVs	99	100	99	96	97
Buses	76	78	75	74	75
Trucks	58	52	56	58	58

Table 5.1 represents the average speeds for each vehicle class on the Yamuna Expressway. The details of each site for the Yamuna Expressway has been provided in Annexure 2. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- In the case of LMVs (which comprise over 50% of the observations), no statistical difference in the mean speed was observed across sites as per the t-test. The KS test revealed some differences in the speed distribution of LMVs at S3 vs S2 and S4 vs S2. In these cases, the KS test outcome wasn't due to an overall shift in the distribution, but rather a reflection of the difference in the spread of the distributions. lower in S2 relative to S4 and S3.

- The average speeds as well as the overall distribution for buses cannot be identified to be statistically different at 95% confidence interval.

- In comparison, the average speeds for trucks is observed to lower at S2 (after the off ramp), when compared to other sites. A longer duration study is required to assess the phenomenon more carefully, but the proximity of the toll road could be influential there too.

- There appears to be a drop in the average speed of motorised two-wheelers from site S1 to S5, which were traversed sequentially during the course of the day. However, owing to the small sample size of two-wheelers at each site, the variation in average speed patterns (as well as in the overall distribution) using 95% confidence intervals is only distinguishable for S1 vs S4 and S1 vs S5. S5 in particular also observes a change in the shoulder presence which may impact two-wheeler driving behaviour.

- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance.

Table 5.2 Average speeds across different sites for each vehicle category on NH19 within Agra district

	Average speeds at different sites (in km/h)				
Vehicle Class	**S1**	**S2**	**S3**	**S4**	**S5**
Two-wheelers	53	64	66	64	62
Autos/Tempos	32	38	38	35	34
LMVs	75	67	70	70	67
Buses	47	62	72	58	57
Trucks	41	49	50	47	51

Table 5.2 represents the average speeds for each vehicle class on the NH-19. The details of each site for the NH-19 has been provided in Annexure 1. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- In the case of two-wheelers, the average speed was lowest at S1 when compared to other sites at 95% confidence interval. There were no statistically significant differences in the speed distributions among the other sites.

- While autos/tempos demonstrated the slowest average speeds, some statistical difference in the speed distribution was observed between S3 vs S1 and S3 vs S5.
- In the case of buses, the highest average speeds were observed at S3 followed by S2, S4/S5 and S1. It is possible that S3 being a part of a large section of elevated passageway with minimal roadside features allows buses to travel fastest. In comparison, the average speeds were lowest at S1 where a bus stop is located. The average speeds for trucks were also lowest at S1.
- In the case of LMVs, the average speed was highest at S1, while the speed distribution among the other sides were indistinguishable. While a more in-depth study of lane distribution over a longer duration is required, it is possible that a combination of early morning hours and travelling in inner lanes may have led to LMVs not getting affected by the built environment of S1, when compared to other vehicle categories.
- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance

Table 5.3 Average speeds across different sites for each vehicle category on SH62 within Agra district

	Average speeds at different sites (in km/h)				
Vehicle Class	**S1**	**S2**	**S3**	**S4**	**S5**
Two-wheelers	35	43	48	52	58
Autos/Tempos	27	37	38	38	44
LMVs	36	43	49	54	64
Buses	26	35	44	49	51
Trucks	25	32	35	43	48

Table 5.3 represents the average speeds for each vehicle class on the SH-62. The details of each site for the SH-62 have been provided in Annexure 1. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- For two-wheelers, LMVs, trucks, and buses, the average speeds increase as one transitions from site S1 to S5.
- While all pairwise differences are statistically significant for 95% confidence intervals for two-wheelers and LMVs, the average speeds for buses are indistinguishable for S4 and S5 given the available sample size.
- Similarly, for trucks, the average speeds observed at S2 and S3 cannot be differentiated at 95% confidence intervals.
- Auto/tempo speeds were also lowest on average for site S1, and highest for S5.
- The average speeds of buses and trucks did not reveal any statistically significant variation when considering the entire sample of observations collected at SH-62.

A possible factor associated with low average speeds at S1 across all sites could be the presence of a slight curve/bend at the location as well as the early morning rains. In comparison, S5 is located further away from the city with limited roadside features, and is along a straight road.

GORAKHPUR

Gorakhpur witnessed high instances of speeding among two-wheelers across functional classes of road, with 89% of the two-wheelers speeding on NH-27, 93% speeding on SH-1 and 77% speeding on the Fatima-Bypass Road. Further, almost all the LMVs (97%) and over four fifths (85%) of the buses were speeding on SH-1. Over two-third of the trucks were speeding on SH-1 and almost half of the trucks were speeding on NH-27. This indicates that all the roads surveyed in Gorakhpur need improved speed management systems.

Figure 5.6. Proportion of vehicles speeding in Gorakhpur

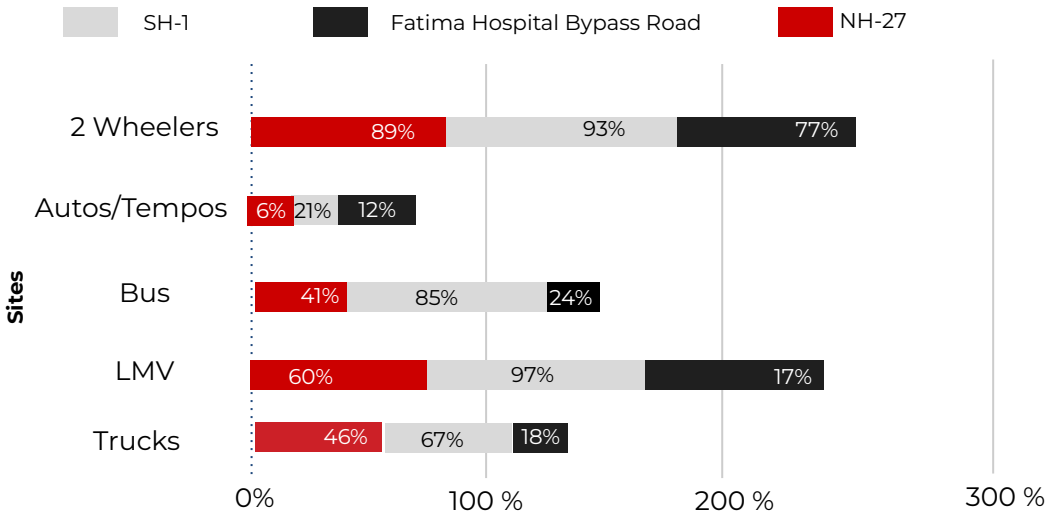


Figure 5.7 represents the average speeds for each vehicle class of NH-27. The details of each site for the NH-27 has been provided in Annexure 3. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Sites S3 to S5 were observed to have higher average speeds when compared to S1 and S2 for two-wheelers, buses, trucks and LMVs with statistical significance. Thus, even after controlling for vehicle-specific trends, the variation in built environment characteristics and possible time-of-day effects could explain the difference in speeds.
- Early morning surveys (S4 and S5) were consistently observed to have higher average speeds across all vehicle classes (excluding autos/tempos).
- Finally, when combining the data across all sites, we note that average speeds of trucks was lower than that of buses with statistical significance.

Figure 5.7. Speeds across sites on the NH-27

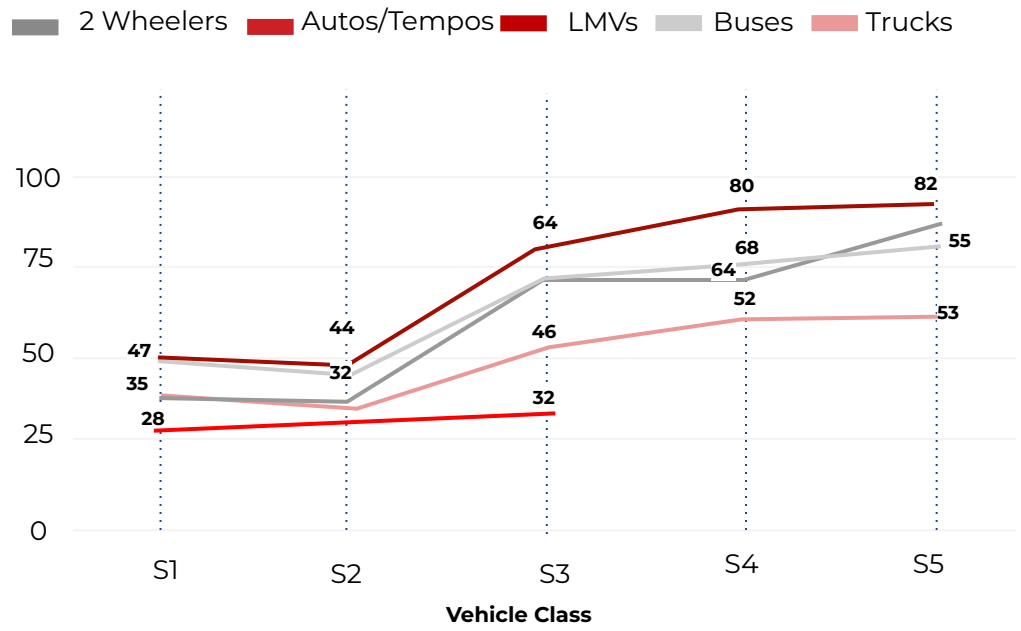


Figure 5.8. Speeds across sites on the SH-1

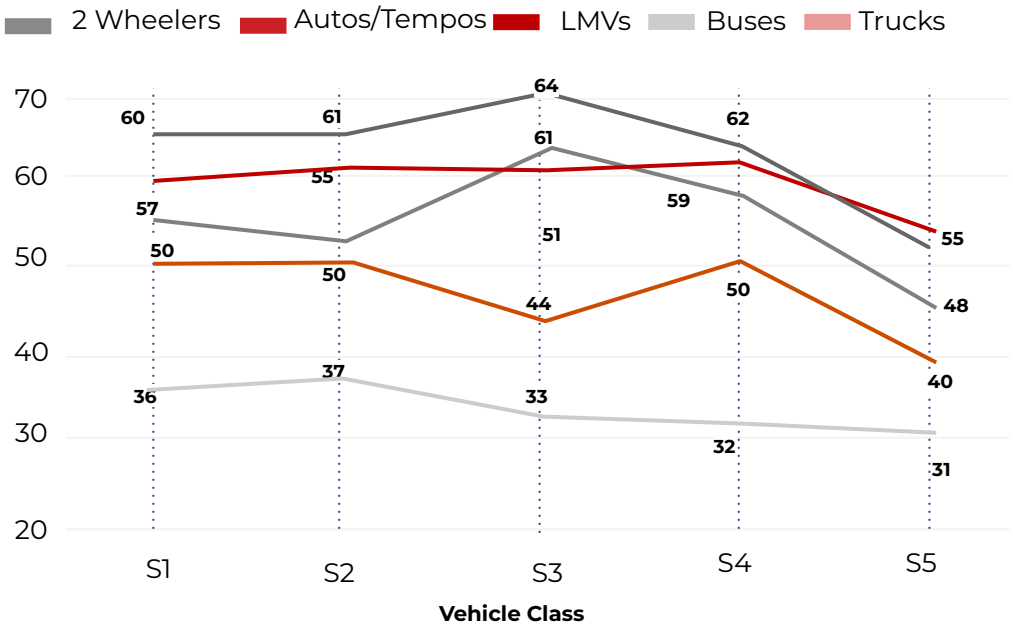


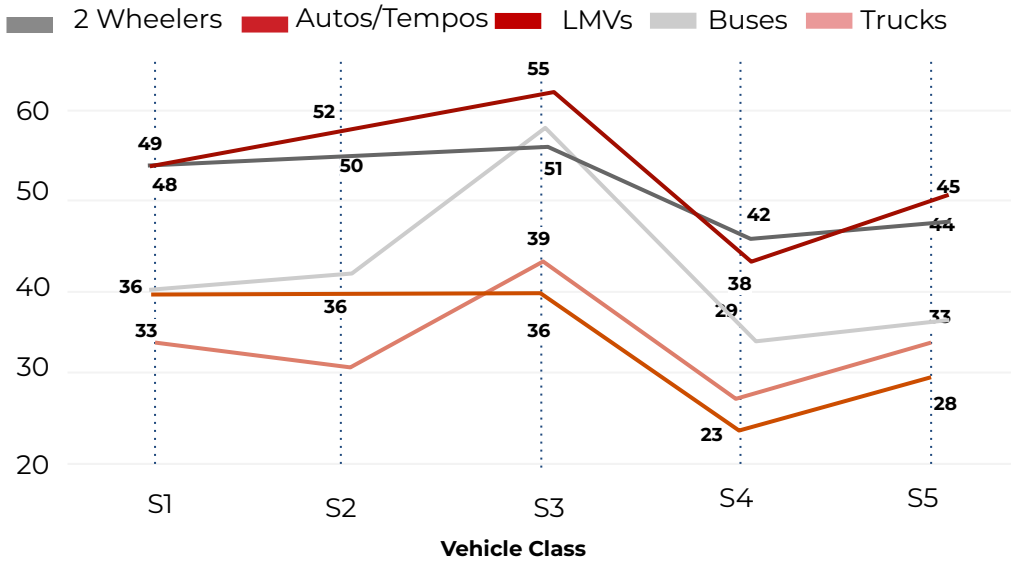
Figure 5.8 represents the average speeds for each vehicle class on SH-1. The details of each site for the SH-1 have been provided in Annexure 3. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Across all vehicle classes, except autos/tempos, the average speeds at site S5 were the lowest with statistical significance, which supports the hypothesis that the presence of the interchange led to lower observed speeds.
- No significant temporal patterns were observed with the distribution of average speeds not distinguishable with high significance along this corridor.
- While the sample mean for LMVs and buses were observed to be highest at S3, the no statistical significant differences were identified with sites other than S5, except between S1 and S3 for buses.
- As observed in other settings, buses had higher speeds than trucks.

Figure 5.9. represents the average speeds for each vehicle class on the Fatima-Bypass road. The details of each site for the Fatima-Bypass road have been provided in Annexure 3. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Across two-wheelers, LMVs and even autos/tempos, there was a statistically significant decrease witnessed in average speeds between the divided (S1-S3) and undivided road segments (S4-S5) in the corresponding pairwise t-tests. A similar trend is qualitatively observed for the buses and is statistically significant for some of the pairwise cases as well (e.g., S2 vs S4).
- No distinct temporal patterns were observed with the distribution of average speeds not distinguishable with high significance along this corridor.
- Two-wheelers had higher speeds on average when compared to trucks.
- Buses had higher speeds than trucks.

Figure 5.9. Speeds across sites on the Fatima-Bypass Road



BAREILLY

The NH-30 stretch in Bareilly witnessed the highest incidence of speeding among two-wheelers (86%), and LMVs (51%). Over two-thirds of the two-wheelers were also speeding on the SH-37. Speeding was low on the Pilibhit Bypass road, which could be attributed to the less number of lanes i.e. the road had either 1 lane or 2 lanes in each location.

Figure 5.10. Proportion of vehicles speeding in Bareilly

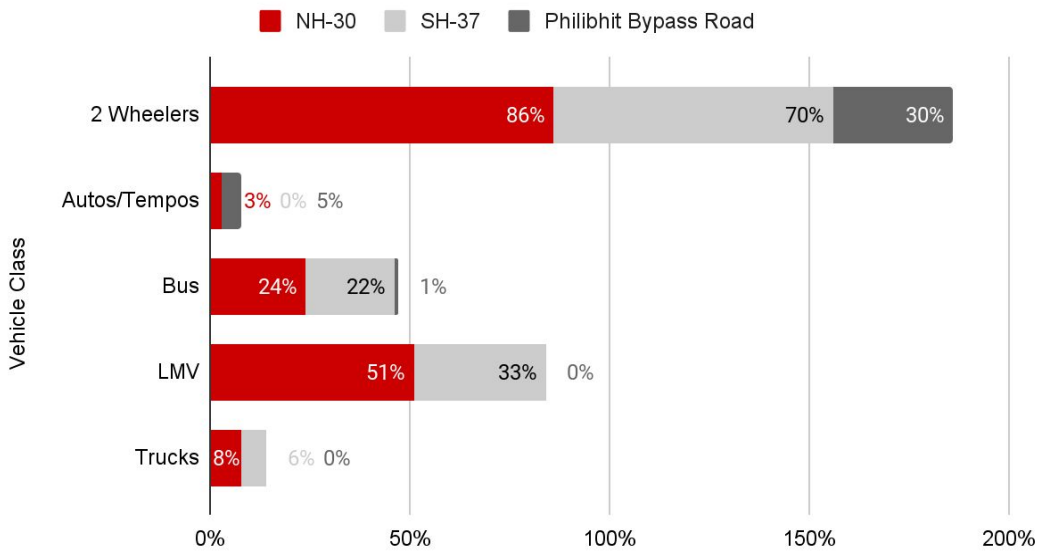


Figure 5.11. Average speeds across different sites for each vehicle category on NH-30 within Bareilly district

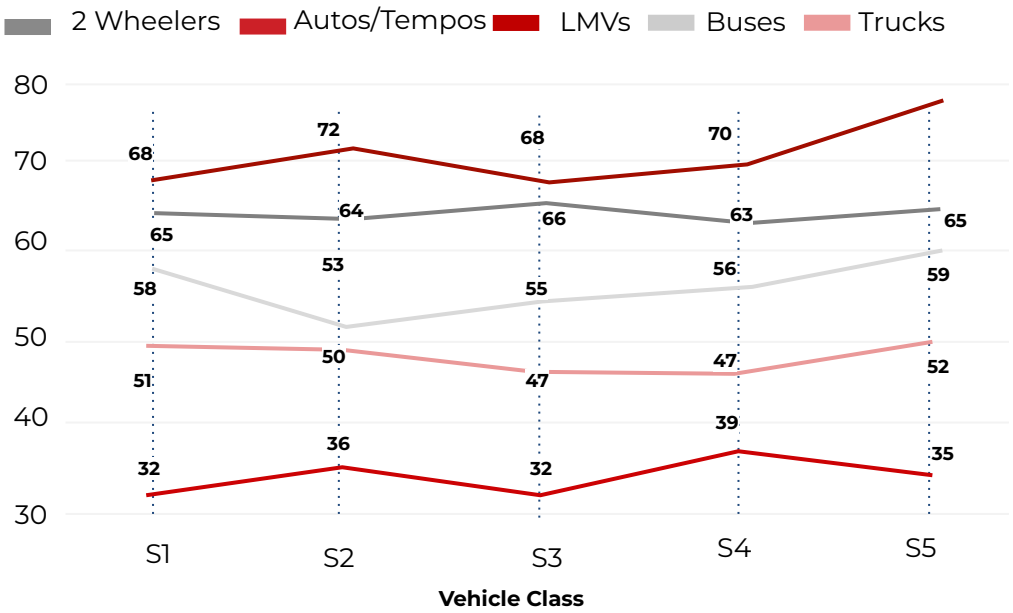


Figure 5.11. represents the average speeds for each vehicle class on NH-30. The details of each site for NH-30 have been provided in Annexure 4. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- The early morning surveys at S5 observed the highest average speeds for LMVs and trucks, but were not statistically different from other sites for other mode types.
- There is a difference in the speeds of trucks at the intersection sites versus the non-intersection sites.
- The average speeds for two-wheelers were higher than buses.
- The average speeds for buses were higher than trucks.

Figure 5.12. represents the average speeds for each vehicle class. The details of each site for SH-37 has been provided in Annexure 4. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- The low average speeds at S1 was consistently observed across all vehicle classes, possibly linked to the neighbouring market being active early in the morning.

- Aside from S1, S5, which also observed roadside activity in the vicinity of the survey site, also witnessed low average speeds for two-wheelers and LMVs, relative to some of other sites with limited roadside features (e.g., S2, S3 and S4).
- As observed in other settings, buses had higher speeds than trucks.

Figure 5.12. Average speeds observed at each site on SH-37

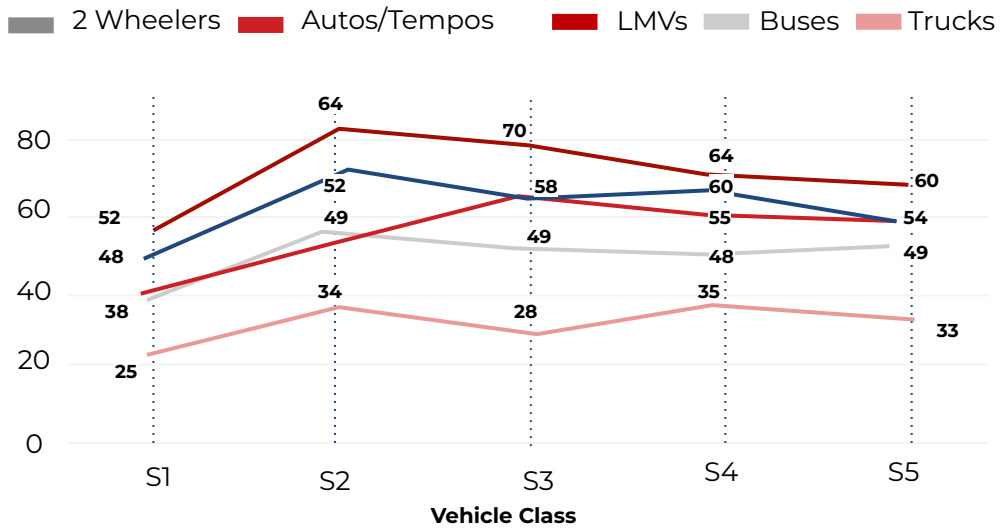
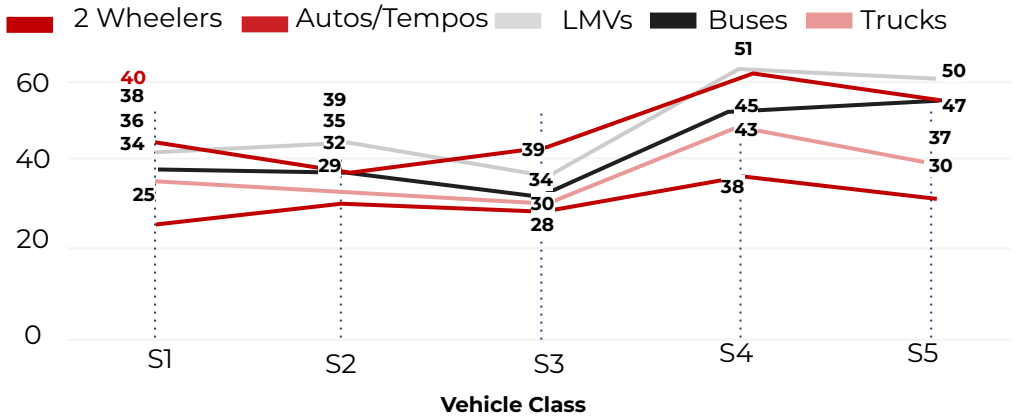


Figure 5.13 represents the average speeds for each vehicle class on the Pilibhit Bypass Road. The details of each site for the Pilibhit Bypass Road is given in Annexure-4. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Aside from auto/tempos, all other modes exhibit higher average speeds along sites S4 and S5, which could be due to a combination of built environment and temporal factors.
- Two-wheelers had higher speeds on average when compared to trucks.
- The average speeds of buses and trucks could not be distinguished on this corridor.

Figure 5.13. Average speeds observed along Pilibhit Bypass Road in Bareilly



PRAYAGRAJ

two-wheelers were speeding extensively on the NH-35 (86%) and the SH-7 (60%). Further, a considerable proportion of LMVs (68%) were speeding on the SH-7. Almost two third (60%) of the LMVs were speeding on the Allahabad-Bypass Expressway. Speeding is prevalent in Prayagraj despite the fact that all three stretches have only two lanes.

Figure 5.14. Proportion of Vehicles Speeding in Prayagraj

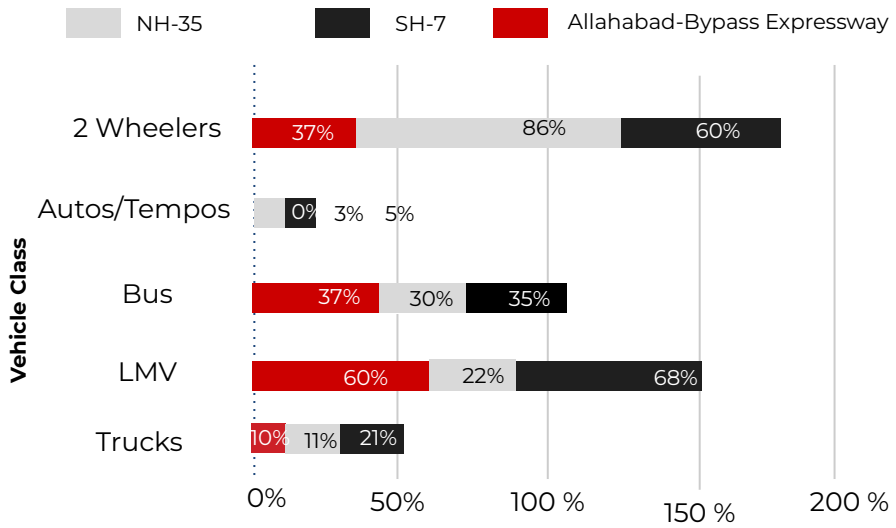


Figure 5.15. represents the average speeds for each vehicle class on the Allahabad-Bypass Expressway. The details of each site for the Allahabad-Bypass Expressway is given in Annexure 5. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- The early morning surveys at S5 observed the highest average speeds for LMVs, buses and two-wheelers.
- Relative to S5, the average speeds at S3 and S4, where roads merge/diverge, is lower for buses and two-wheelers with 95% confidence. The effect is less pronounced for LMVs.
- The average speeds for two-wheelers and buses were not distinguishable with statistical significance.
- The average speeds for buses were higher than trucks.

Figure 5.15. Average speeds across different sites for each vehicle category on Allahabad Bypass Expressway within Prayagraj district

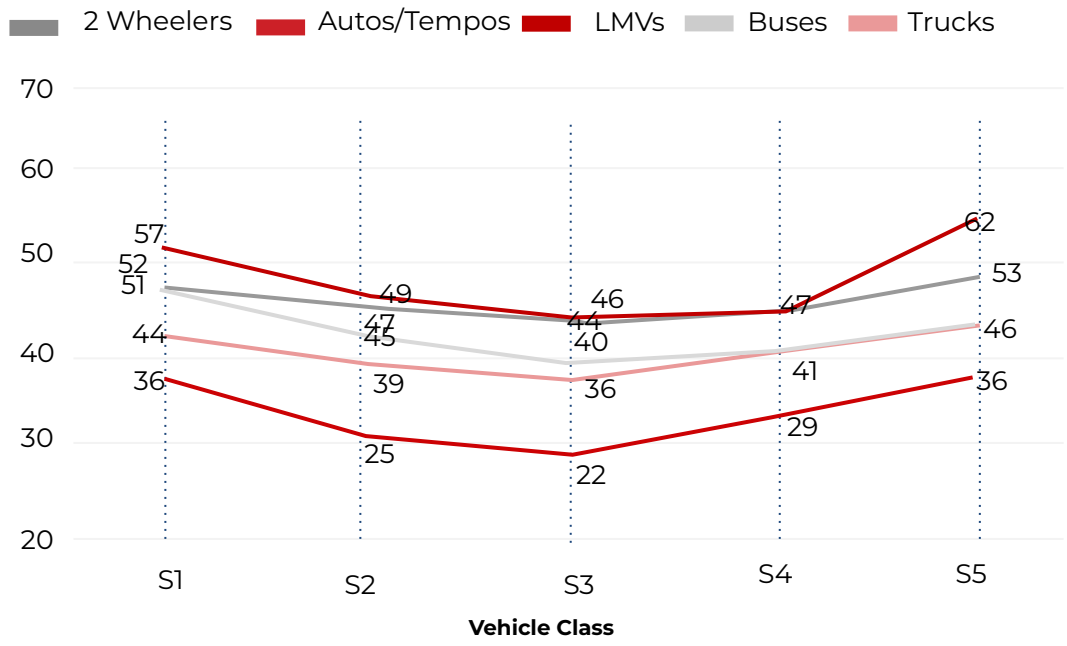


Figure 5.16 represents the average speeds for each vehicle class on the NH-35. The details of each site for the NH-35 have been provided in Annexure 5. The following instances represented statistically significant differences in the average speeds for a given vehicle category across classes:

- Across LMVs, two-wheelers and trucks, at sites S1 and S5 higher average speeds were observed as compared to sites S2-S4, which have more roadside features (shops, parked vehicles, etc.).
- A similar trend was also observed for buses and autos/tempos, but some of the pairwise differences are difficult to statistically evaluate with significance due to the small sample sizes at individual locations.
- In two-wheelers higher average speeds were observed relative to buses along this corridor.
- Buses observe higher average speeds relative trucks along this corridor.

Figure 5.16. Average speeds across different sites for each vehicle category (on NH-35 within Prayagraj district)

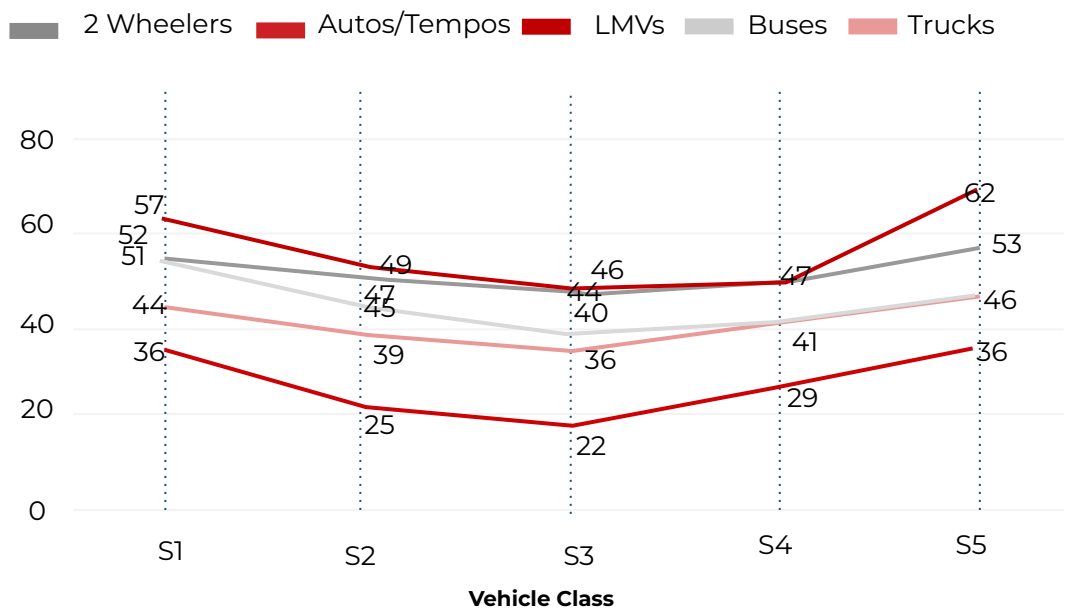
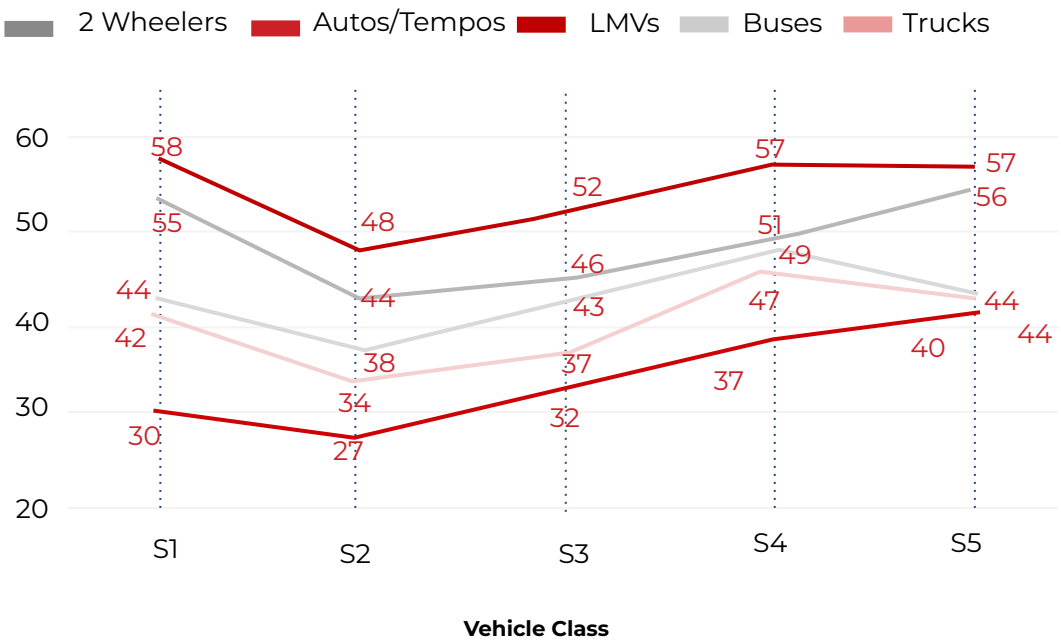


Figure 5.17 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along NH-35:

- 86% of two-wheelers (244 out of 284) exceeded the speed limit with a maximum observed speed of 73 km/h
- 30% of buses (27 out of 90) exceeded the speed limit with a maximum observed speed of 42 km/h

- 22% of LMVs (31 out of 138) exceeded the speed limit with a maximum observed speed of 88 km/h
- 51% of trucks (67 out of 132) exceeded the speed limit with a maximum observed speed of 59 km/h
- 3% of the autos/tempos (1 out of 37) exceeded the speed limit with a maximum speed limit of 42 km/h.

Figure 5.17. Average speeds across different sites for each vehicle category on SH-7 within Prayagraj district



Chapter 6: Recommendations

The findings from the observational study underscore several challenges in implementing effective speed management practices in Uttar Pradesh. Key issues include the lack of standardised speed limits across districts, variations between posted and officially notified limits, and pervasive instances of excessive speeding. Notably, over half of observed two-wheelers consistently exceeded speed limits on all surveyed roads, posing a heightened risk given their vulnerability in road crashes. Further concerns arise from vehicles travelling above posted speed limits, indicating a disparity between driving behaviour and existing speed management strategies.

The speeding behaviour of buses, essential for public transportation, adds another layer of risk to road safety. Notable incidents, such as a crash on Uttar Pradesh's Agra-Lucknow Expressway in October 2022 resulting in 4 fatalities and 42 injuries, highlight the urgency of addressing this issue (NDTV 2022).

This chapter presents comprehensive recommendations for enhancing speed management and improving road safety across the country. To enhance road safety at the national level, several key learnings can be derived from this report. Firstly, there is a need for speed limits commensurating with sectional characteristics of the road. Secondly, there is a pressing need for the standardisation of speed limits across different road types and vehicle classes to provide clarity for drivers and to facilitate consistent enforcement practices nationwide. Further, harmonising traffic enforcement policies, including the widespread use of electronic enforcement systems, is crucial to ensure a uniform and effective approach across all states. The integration of intelligent transportation systems (ITS) on a national scale can enhance real-time monitoring and enforcement capabilities. Allocating resources for research and development initiatives will foster the adoption of innovative speed management technologies.

In the context of Uttar Pradesh, the table below discusses the recommendations for improving speed management and curbing speeding across the state.

Each recommendation has been made, along with action points for implementation by the state government. It also includes information on the tentative agencies responsible for implementing the recommendations.

Recommendation: Establishing safe speed limits

Rationale:

1. The study found that the speeding pattern and the speeding limit had specific gaps such as:
    a. The current notified and posted speed limits on various roads in Uttar Pradesh appear to lack a comprehensive consideration of the safe speeds suitable for road users. The existing speed regulations do not adequately factor in the diverse conditions that prevail on different roads, such as road geometry, built up characteristics, and road user characteristics.
    b. Most of the speed limit notifications issued by the authorities do not have the highway number or road number stated. It only includes the list of places through which the stretch passes. In such cases, it becomes difficult to identify speed limits as a road user. Hence, it is recommended to include specific highway numbers while notifying the speed limits.
    c. In a few cases, speed limit notifications for the roads within a district are not documented at all. For instance, a small stretch of Lucknow-Agra Expressway passes through the Kanpur Nagar district, but the state notifications do not document the corresponding speed limits.
    d. Speed limits were not standardised across districts for the same stretch of road. For example, the Agra-Lucknow Expressway passes through Unnao and Kannauj, two adjacent districts. Yet, the speed limits for two-wheelers and HMVs differed for both districts (60 km/h for Unnao and 80 km/h for Kannauj).

Recommendation: Establishing safe speed limits
2. On National Highways and State Highways, there was no difference in speeding patterns between the intersections and non-intersections. a. The same proportion of two-wheelers were speeding at intersections as well as non-intersections. This indicates that there were minimal variations in speeds of two-wheelers at intersections and non-intersections. Only a slightly lower proportion (47%) of LMVs were speeding on state highways at intersections compared to non- intersections (52%) 3. Local bodies such as RTOs are most aware of the safety features on-ground. To implement safe speed limits, it is essential that the inputs of these local bodies are incorporated while determining speed limits.
Agency Responsible: State Transport Department, National Highways Authority of India, Ministry of Road Transport and Highways
Proposed Actions: 1. It is recommended that speed limits be commensurate with respect to sectional characteristics of the road as opposed to establishing a single speed limit for a specific category or hierarchy of the road. Speed limits across sections of the road should also be commensurate with the safety infrastructure. The following safe speed limits (World Health Organisation, 2023) may be enforced at different sections to ensure the safety of road users.

Type of Road/Road Section	Safe System Speed
Road sections with possible crashes between cars and vulnerable road users	Max. 30km/h
Road sections with intersections with possible side-on crashes between cars	Max. 50km/h
Road sections with possible frontal (head-on)crashes between cars	Max. 70km/h
Road sections with no likelihood of side-on or frontal crashes between cars	Max. 100km/h

Table. Safe Speeds for Different Road Sections

S.No	Safe Speed	Type of Road Section	Reference Locations
1	30 km/h	Sections with the possibility of conflict between vehicles and unprotected road users such as pedestrians and cyclists	Built-up areas School and Hospital Zones
2	50 km/h	Sections with the possibility of side impact collisions between vehicles	At grade intersections
3	70 km/h	Sections with the possibility of head-on collision between vehicles	Undivided Carriageway, Curves, Hills
4	100 km/h	Sections with no likelihood of head-on or side impact collision between vehicles	Access controlled Highways and Expressways

- Involve Regional Transport Offices (RTOs) and Traffic Police in determining speed limits, with local governments having the authority to make adjustments.
- Consider interventions including design interventions to gradually lower the vehicle speeds when vehicles are approaching an intersection, interchange, school zones or other crash-vulnerable areas.
- As described in the rationale, a single stretch may have multiple speed limits across districts. The Traffic Police and RTOs should thus be thorough with the speed limits across all sections of the road. It is important that the speed limits are effectively enforced, which is possible only of enforcement agencies are aware of the different speed limits
- Electronic enforcement devices should be calibrated in accordance with the varying speed limit across stretches.

Recommendation: Enhanced Enforcement for curbing speeding

Rationale:

1. The severity of speeding was high across vehicle classes:
    a. 17% of the two-wheelers travelling at speeds 20 km/h over the speed limit on expressways, 22% of the two-wheelers travelling at speeds 20 km/h over the speed limit on national highways, and 19% of the two-wheelers travelling at speeds up to and over 20 km/h over the speed limit on state roads.
    b. 24% of the buses were travelling at speeds up to and over 20 km/h over the speed limit on expressways
    c. 17% of the LMVs were travelling at speeds up to 20 km/h over the speed limit on National Highways.

Agency Responsible: State Traffic Police, District Police

1. Enhanced enforcement models should be deployed on-ground. This should be a combination of manual and electronic enforcement. While electronic enforcement alone can issue penalties, it is important to stop speeding vehicles so that they do not pose a risk for the rest of the road users. Hence, manual intervention is necessary to stop speeding vehicles.
2. Develop a strict mechanism of penalising drivers caught for speeding under Section 183 of the MVAA, including government as well as private bus drivers.

Recommendation: Installation of Appropriate Speed Limit Signage
Rationale: 1. The speed limit signage was not posted for all vehicle classes at certain locations included in the study. For example, S2 of the Agra-Lucknow Expressway stretch mentions a speed limit of 100km/h in general, without specifying the vehicle class. Also, the notification states that the speed limit for buses and trucks is 80 km/h. Further, on location 5 of NH-19, there was a speed limit of 50 km/h across vehicle classes, whereas the notified speed limit specified that 50km/h was the limit only for buses and trucks. 2. There were instances of contradictory speed limit signages, specifically at site S1 of SH-46, the image of which has been added in chapter 4 (Figure 4.2).
Agency Responsible: State Transport Department, National Highways Authority of India
1. Speed limits for all vehicle classes should be present on road signages. 2. There should be no two different posted speed limits on the same stretch. 3. Ensure that design and installation of speed limit signages shall be in accordance with the IRC 67:2022 guidelines, and the minimum frequency of speed limit signages on expressways and National Highways are as per MoRTH guidelines published on 20 July 2023 for existing and new stretches.

Recommendation: Prioritise Electronic Enforcement for speeding Two-Wheelers.
Rationale: • Two-wheelers users are the most vulnerable in the event of a road crash. However, it is also observed that this vehicle class is also the one speeding the most across all vehicle classes. Over 74 thousand two-wheeler users lost their lives in 2022 countrywide i.e. 44% of total road crash fatalities in 2022. In Uttar Pradesh alone, 6959 two-wheeler users died in road crashes in 2022.

- Despite the higher risk of road crashes, two-wheelers also formed the largest category of vehicles speeding in Uttar Pradesh. As per the study, 76 percent and 71 per cent of the Two-wheelers were recorded to be speeding above the specified speed limits on National Highways and State Highways, respectively. In the case of Expressways, 35% of Two-wheelers were speeding above the speed limit by 10 km/ph.
- Currently, while Section 183 of the Motor Vehicles (Amendment) Act, 2019 delineates the penalties for offending LMVs and HMVs, it does not explicitly include the penalty for two-wheelers.

Agency Responsible: Uttar Pradesh Traffic Police and Transport Department

Proposed Actions:

1. Section 183 should also include penalties for motorised two-wheelers.
2. Prioritisation of SH for E-enforcements by the state govt (at least for two-wheelers)
    a. NHAI should strengthen E-enforcement to check for speeding especially of two-wheelers on National Highways.
    b. The State Departments should focus on electronic enforcement techniques that capture speeding violations. These E-enforcement techniques should proactively counter instances of two-wheeler speeding on state roads. Devices should be deployed in such a manner that they ensure an accuracy of at least 90% while capturing two-wheelers speeding. It needs to be noted that the current two-wheelers number plates are not standardised, and solely relying on Automated Number Plate Recognition (ANPR) may not be possible. Therefore, there should also be a manual audit of violations captured by electronic enforcement devices, by analysing the pictures of violating vehicles.

Recommendation: Enforcement for curbing bus speeding

Rationale:

1. Buses speeding is a major concern for the following reasons:
    a. Size and Mass: Buses are considerably larger and heavier than regular vehicles. This means that when a bus is involved in a collision at high speed, it can cause more severe damage and result in more serious injuries and fatalities.
    b. Passenger Capacity: As an essential source of public transport, buses generally carry many passengers.
    c. Limited Manoeuvrability: Buses typically have limited manoeuvrability, especially at high speeds. They may struggle to change lanes or avoid obstacles quickly, making it harder to mitigate the impact of speeding-related incidents.
    d. Stopping Distance: Buses require a longer distance to come to a complete stop due to their size and weight. Speeding reduces the driver's ability to stop quickly, leading to a higher risk of rear-end collisions or the inability to stop in emergencies.
    e. Impact Severity: When a bus is speeding and collides with another vehicle or a pedestrian, the severity of the impact can be much greater than that of a smaller sized vehicle, potentially leading to more severe injuries and fatalities.
2. On Expressways, 73% of the buses were found to be speeding and 45% were speeding by 10 km/ph over the speed limit. Over 30% of the buses were speeding on National and State Highways including 20% plus speeding by 10 km/ph.
3. Heavy vehicles over-speeding is also indicative of their speed governors not working and the same may be a violation of the speed governor rules under the Central Motor Vehicles Rules, 1989.

Agency Responsible: UPSRTC, Transport Department
Proposed Actions: Bus speeding and Speed Governors: 1. Monitoring of bus speeding by Traffic Police, UPSRTC and RTOs through random check posts. Technology may also be used to improve monitoring of the speed of buses. 2. Ensuring the proper functioning of speed governors on buses. 3. Strengthening of E-enforcement techniques for buses, with special focus on capturing the number plates accurately. 4. Developing Driver refresher training to make heavy vehicle drivers aware about the existing speed limits and practise anticipatory driving. 5. Special enforcement drives should be conducted for targeting speeding among inter-state buses.

Recommendation: Speed Enforcement to not be limited to black spot locations
Rationale: ● For two-wheelers, speeding was found to be consistent at blackspot locations (84%) and non blackspot locations (86%) on National Highways. ● For LMVs, speeding was marginally higher for Expressways i.e 49% at non blackspots and 39% at black spots. A similar trend was observed for other vehicles as well. ● In the case of national highways, the speeding for LMVs, buses and trucks was higher at non blackspot locations as compared to blackspot locations. For example, only 10% of the trucks were found to be speeding at blackspot locations compared to 50% speeding at non blackspot locations.
Agency Responsible: UP Transport Department, National Highways Authority of India (for National Highways)

Proposed Actions:

1. Focus on speed calming measures in non-black spot regions along with black spot regions. This practice is consistent with the holistic road safety management framework adopted by several countries (Mooren et al. 2011; Elvik and Nævestad 2023), also referred to as the Safe System Approach.
2. Visual awareness mechanism to be employed in the ways of signages and information boards regarding approaching black spots to warn road users.
3. The assessment of black spot regions should not be limited to a 500 metre stretch but rather a larger road area including non black spot regions that may be a contributing factor towards the black spot location.
4. Adherence to IRC 131: 2022 for black spot identification, notification and interventions.
5. An analysis of crashes for each district/corridor should be undertaken to identify systemic characteristics of sites that may induce speeding-related crashes.

Recommendation: Employing Design Interventions for Speed Calming

Rationale:

- All vehicle classes showed a considerable reduction in speeding at road stretches with road side activities compared to roads with limited roadside activity. Only in the case of two-wheelers on national highways this reduction was marginal.
- In case of school zones covered in the survey, two-wheelers showed the highest incidence of speeding on National Highways (75.8%) followed by LMVs (27.3%) and Auto/ Tempos (15.4%). For School zones on State highways 63.9% two-wheelers were found to be speeding followed by LMVs (14.7%) and buses (13%). Given that all these vehicle classes are also predominantly used to ferry school students, authorities should focus on making school zones speeding free. Moreover, as students also commute to school on foot or by using NMT, they are exposed to speeding motorised traffic. Therefore, school zones should be designed in a manner that minimises the exposure of pedestrians and NMT users to motorised traffic.

- Posted speed limits should indicate a speed limit of 25 km/h for school zones. As per the Central Motor Vehicles Rules, 1989, vehicles should drive at a speed of 25 km/h or under on school zones. From our analysis, the stretches near school zones had the same posted speed limits as the notified speed limits for the stretch. As per the C

Agency Responsible: Local government and Police Department

Proposed Actions:

Design Interventions:

1. Tailor measures specific to road types, such as:
    a. Transverse bar markings (rumble strips) of required thickness, mandatory/regulatory signages (as per IRC: 67–2022),
    b. Work message 'SPEED LIMIT' and direction information 'SLOW' (as per IRC: 35–2015) on national highway and various speed calming measures such as speed humps or uneven road surface or stone set pavement (as per IRC: 99–2018) on minor roads connecting to them.
    c. Implement design interventions at intersections such as transverse bar markings (rumble strips), speed tables, road narrowing, and blinkers to reduce speeding.
2. Strict Adherence to IRC codes for designing minor roads, speed humps and traffic calming measures.

School Zones and Roadside Features:

- Install clear speed signages in school zones. For urban roads, school zones have a speed limit of 25 km/h (IRC 99:2018).
- In the case of highways, there should be consistent signage warning passers by of a school zone at least 5 kilometres ahead of it.

- The frequency and details of speed limit signages (such as documenting vehicle-specific speed limits) should follow the established guidelines.
- Provide adequate traffic calming measures in school zones to facilitate better compliance to the reduced speed limits.
- Ensure that highway gates do not open directly onto highways. Any schools near highways should ideally open only on service roads. In case there are schools opening directly to the highways, there should be infrastructure in place to reroute the opening of the school onto a service lane.
- Impose time limits for parking near highways, or provide designated parking spaces on the service lanes.
- School zones should be designed in such a manner so as to minimise the exposure of pedestrians and NMT users to motorised traffic.

Additional Actionable Points:

1. GIS-based integration of speed limits with Google Maps and other technology-based platforms to make information accessible.
2. Standardisation of number plates and speed detection technology in future that can capture two-wheeler speeding.
3. Using design considerations, data and technology to decide realistic speed limits that are both safe and acceptable by road users.
4. The evaluation of the effectiveness of the interventions should be conducted using before-after studies and user perceptions surveys. This will allow establishing the extent to which speeding is curb, the impact on crash reduction and whether road users are following traffic rules.
5. Consideration of risk associated with each speeding vehicle class is also required while deciding on interventions to curb speeding.

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Centre for Advancement of Road Traffic
Safety (CARTS), SaveLIFE Foundation

6, Ground Floor, Bhagwan Das Road,
Mandi House, New Delhi, 110001
Telephone: 011-41091911
Email: info@savelifefoundation.org

www.savelifefoundation.org
savelifefoundation
@savelifeindia

ANNEXURE 1 :
Districts in Focus - Kanpur Nagar Spot Speed Analysis

1. Agra-Lucknow Expressway

Table. A1.1 Summary of site characteristics surveyed along the Agra-Lucknow Expressway

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	3	Yes	Yes	Yes	No	No	No	No
S2	3	Yes	Yes	Yes	No	No	Yes	No
S3	4	Yes	Yes	No	No	Yes	Yes	Yes
S4	3	Yes	Yes	No	No	No	No	No
S5	3	Yes	Yes	No	No	No	No	No

A total of 619 observations were obtained, with over 50% samples corresponding to light motor vehicles. Table A1.2 summarises the samples collected across different road users on the Agra-Lucknow Expressway.

Table. A1.2 Number of observations collected for specific sites on the Agra-Lucknow Expressway

Sites	Number of Observations (Grand Total: 619)					
	LMVs	Two wheelers	Autos/Tempos	Buses	Trucks	Total
S1	55	7	0	20	26	108
S2	70	18	0	18	19	125
S3	53	25	0	14	21	113
S4	66	11	0	17	34	128
S5	88	9	0	10	38	145
Total	332	70	0	79	138	**619**

1.1 Comparison across Sites

Table A1.3 shows the average speeds estimated by combining samples across all vehicle classes at each site depicting the variation in the average speed observed at a given location.

Two types of statistical tests were conducted (at level of significance of 0.05) to compare the trends observed between any two sites and to assess whether the 5 sites chosen on the stretch had significant variation in speed:

- The *t-test* tests whether the population mean of the speeds observed at site A is equal to that of the popular mean of speeds at site B or not. This test relies on the distribution of the sub-populations to be normally distributed.
- The *Kolmogorov-Smirnov (KS) test* evaluates whether the overall distributions of the two sites A and B are equal or not. Statistically significant differences in the mean speeds of two sites (or two vehicle classes) can also be captured by the KS test. However, in some instances, it may be possible for the means of two distributions to be comparable but demonstrate differences in their variances, low values or high values. Such scenarios can also be captured by the KS test. Furthermore, unlike the *t-test*, the *KS test* is a non-parametric test.

We conducted a pairwise evaluation of sites surveyed within the Agra-Lucknow Expressway stretch within Kanpur Nagar (e.g., S1 vs S2, S1 vs S5, S3 vs S4). While the average speeds in the sample show some differences in Table A1.3, when accounting for the sampling variation, the differences are not statistically significant when conducting the t-test at 95% confidence interval. In comparison, the overall distribution of sites 1 and 5 are statistically different as per the KS test with 95% confidence. Thus, while interpreting the sample averages, it is important to recognize that these values are based on finite sample sizes which may change as more samples are collected. For more robust comparisons, the underlying variation in the averages also needs to be undertaken.

Table. A1.3 Average speeds observed at each site on the Agra-Lucknow Expressway

Sites	Average speed for the sampled observations at each site (km/h)
S1	**77**
S2	**80**
S3	**79**
S4	**82**
S5	**81**

Based on the state's speed limit notifications, the speeding statistics for different vehicle classes are provided in the table below. The speeding trends indicate that the percentage of speeding is highest for buses, followed by two-wheelers and LMVs.

Table. A1.4 Speeding statistics for the Agra-Lucknow Expressway

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two wheelers	70	23	33%	100
Autos/ Tempos	N/A	N/A	N/A	N/A
Bus	79	40	51%	96
LMV	332	103	31%	134
Trucks	138	0	0%	76

2. National Highway-34

The site characteristics, including the posted speed limit description, for the five sites surveyed along NH-34 are provided in Table A1.5. The sites largely represent undivided, single-lane road segments with a few locations with some roadside activity.

Table. A1.5 Summary of site characteristics surveyed along the NH-34

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	1	No	Yes	No	No	No	No	No
S2	1	No	Yes	No	Yes	No	No	No
S3	1	No	Yes	No	No	No	No	No
S4	2	Yes	No	No	No	No	No	No
S5	1	No	No	Yes	No	No	No	No

A total of 660 observations were obtained, with the highest representation of samples corresponding to two-wheelers, followed by LMVs, HMVs and autos/tempos. Table A1.6 summarises the site-specific distribution of observations across different road users on NH-34.

Table. A1.6 Number of observations collected for specific sites in NH-34

Sites	Number of Observations (Grand Total: 660)					
	LMVs	Two wheelers	Autos/ Tempos	Buses	Trucks	Total
S1	17	60	11	13	13	114
S2	28	73	12	16	19	148
S3	20	62	18	15	16	131
S4	16	73	5	20	14	128
S5	23	84	18	2	12	139
Total	104	352	64	66	74	**660**

2.1 Comparison across Sites

Table A1.7 shows the average speeds estimated by combining samples observed across all vehicle classes at each site. Additional checks such as computing the 95% confidence interval depicting the statistical variation in the average speed expected at a given location were also conducted. The overall variation suggests that the average speeds were lower at sites observed during the early morning hours (S4,S5) compared to those observed later in the day.

Table. A1.7 Average speeds observed at each site on NH-34

Sites	Average speed for the sampled observations at each site (km/h)
S1	**51**
S2	**50**
S3	**48**
S4	**45**
S5	**37**

2.2 Speeding trends for each vehicle category

Based on the state's speed limit notifications, the speeding statistics for different vehicle classes have been provided in table A1.8. The results indicate the highest proportion of speeding for two-wheelers, followed by LMVs, both in excess of 50%.

- 71% of two-wheelers (251 out of 352) exceeded the speed limit with a maximum observed speed of 89 km/h.
- None of the buses exceeded the speed limit with a maximum observed speed of 57 km/h.
- 53% of LMVs (55 out of 104) exceeded the speed limit with a maximum observed speed of 89 km/h.
- None of the trucks exceeded the speed limit with a maximum observed speed of 60 km/h.
- 9% of the autos/tempos (6 out of 64) exceeded the speed limit with a maximum observed speed of 72 km/h.

Table. A1.8 Speeding statistics for NH-34

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two wheelers	352	251	71%	89
Autos/ Tempos	64	6	9%	72
Bus	66	0	0%	57
LMV	104	55	53%	89
Trucks	74	0	0%	60

3. State Highway-46

The site characteristics for the six sites surveyed along SH-46 are provided in Table A.3 (appendix A). The sites consist of single-lane roads that are primarily without medians. Some of the sites have some roadside activity, while one of them is also an intersection.

Table. A1.9 Summary of site characteristics surveyed along SH-46

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	1	No	Yes	Yes	No	No	No	No
S2	1	No	Yes	No	No	No	Yes	No
S3	1	No	No	No	No	No	No	No
S4	1	No	No	No	No	Yes	Yes	Yes
S5	1	No	Yes	No	No	No	No	No
S6	1	Yes	No	No	No	No	No	No

A total of 656 observations were obtained, with the highest representation of samples corresponding to two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A1.10 summarises the site-specific distribution of observations across different road users on SH-46.

Table. A1.10 Number of observations collected for specific sites in SH-46

Sites	Number of Observations (Grand Total: 660)					
	LMVs	Two wheelers	Autos/ Tempos	Buses	Trucks	Total
S1	19	58	9	12	29	127
S2	19	40	9	13	22	103
S3	10	36	17	10	13	86
S4	19	48	12	11	16	106
S5	15	47	9	11	17	99
S6	14	56	10	17	38	135
Total	96	285	66	74	135	**656**

3.1 Comparison across Sites

Table A1.11 shows the average speeds estimated by combining samples across all vehicle classes at each site depicting the variation in the average speed observed at a given location. The overall variation suggests that the average speeds were lowest in the dense urban environment with a divided road observed at S6, while they were highest in the flat stretches with sparse built environment features (S2, S5).

Table. A1.11 Average speeds observed at each site on SH-46

Sites	Average speed for the sampled observations at each site (km/h)
S1	49
S2	59
S3	46
S4	47
S5	52

ANNEXURE 2 :
Districts in Focus - Agra Spot Speed Analysis

1. Yamuna Expressway

Along the Yamuna Expressway that intersected with the Agra district, a total of five sites were surveyed. The site characteristics, including the posted speed limit description has been provided in Table A2.1. In terms of distinguishable built environment characteristics, site S4 is located just after an off-ramp on the Yamuna Expressway. The Yamuna Expressway has a dynamic speed limit and every winter speeds are adjusted to reduce winter road crashes. For instance, in 2023, the speed limits were revised to 75 km/h for light motor vehicles and 60 km/h for heavy motor vehicles during the winter.

Table. A2.1 Summary of site characteristics surveyed along the Yamuna Expressway

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	3	Yes	Yes	Yes	No	No	No	No
S2	3	Yes	Yes	No	No	No	No	No
S3	3	Yes	Yes	No	No	No	Yes	No
S4	4	Yes	Yes	No	No	Yes	No	Yes
S5	3	Yes	Yes	No	No	No	No	No

A total of 801 observations were obtained, with over 50% samples corresponding to light motor vehicles. Table A2.2 summarises the samples collected across different road users on the Yamuna Expressway.

Table. A2.2 Number of observations collected for specific sites on the Yamuna Expressway

Sites	Number of Observations (Grand Total: 801)					
	LMVs	Two wheelers	Autos/Tempos	Buses	Trucks	Total
S1	69	22	0	34	12	137
S2	79	13	0	18	27	137
S3	75	24	0	21	24	144
S4	72	24	0	20	31	147
S5	134	27	0	42	33	236
Total	429	110	0	135	127	**801**

1.1. Comparison across sites

Table A2.3 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting general trends in the average speed expected at a given location. It is important to note here that variations in vehicle class proportions and time-of-day can impact these sample averages.

Table. A2.3 Average speeds observed at each site on the Yamuna Expressway

Sites	Average speed for the sampled observations at each site (km/h)
S1	87
S2	85
S3	84
S4	81
S5	84

1.2. Speeding trends for each vehicle category

Table A2.4 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along the Yamuna Expressway:

- 73% of two wheelers (80 out of 110) exceeded the speed limit with a maximum observed speed of 111 km/h.

- 86% of buses (116 out of 135) exceeded the speed limit with a maximum observed speed of 104 km/h.
- 47% of LMVs (202 out of 429) exceeded the speed limit with a maximum observed speed of 146 km/h.
- 19% of trucks (24 out of 127) exceeded the speed limit with a maximum observed speed of 120 km/h.
- None of the autos/tempos exceeded the speed limit.

Table. A2.4 Speeding statistics for the Yamuna Expressway

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	110	80	73%	111
Autos/Tempos	N/A	N/A	N/A	N/A
Buses	135	116	86%	104
LMV	429	202	47%	146
Trucks	127	24	19%	120

2. National Highway-19

Table A2.5. lists the sites covered along NH-19 within Agra district. The sites are a part of divided, multi-lane roads, with S3 situated in proximity to some roadside shops.

Table. A2.5 Summary of site characteristics surveyed along NH-19

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	Yes	No	No	No	No
S2	3	Yes	Yes	No	No	No	No	No
S3	3	Yes	No	No	No	No	No	No
S4	3	Yes	Yes	No	No	No	No	No
S5	3	Yes	Yes	No	No	No	Yes	No

A total of 682 observations were obtained with the highest representation of samples corresponding to LMVs, followed by two-wheelers, HMVs and autos/tempos. Table A2.6 summarises the site-specific distribution of observations across different road users on NH-19.

Table. A2.6 Number of observations collected for specific sites in NH-19

Sites	Number of Observations (Grand Total: 682)					
	LMVs	**Two wheelers**	**Autos/Tempos**	**Buses**	**Trucks**	**Total**
S1	52	35	8	13	17	125
S2	35	38	9	19	23	124
S3	44	37	10	14	16	121
S4	60	52	11	18	20	161
S5	44	49	16	20	22	151
Total	235	211	54	84	98	**682**

2.1. Comparison across Sites

Table A2.7 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed at a given location. The overall variation suggests that the average speeds were highest at S3 and S4 compared to other locations. However, given that the representation of different vehicle classes also differs from site to site, it is difficult to interpret the trend.

Table. A2.7 Average speeds observed at each site on NH-19

Sites	Average speed for the sampled observations at each site (km/h)
S1	59
S2	60
S3	64
S4	62
S5	58

2.2. Speeding trends for each vehicle category

Based on the state's speed limit notifications, the speeding statistics for different vehicle classes have been provided in Table A2.8. High speeding percentages, in excess of 75%, have been observed for two-wheelers, buses and LMVs.

- Table A2.8 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along NH-19:
- 94% of two-wheelers (198 out of 211) exceeded the speed limit with a maximum observed speed of 90 km/h
- 79% of buses (66 out of 84) exceeded the speed limit with a maximum observed speed of 86 km/h
- 75% of LMVs (176 out of 235) exceeded the speed limit with a maximum observed speed of 108 km/h
- 33% of trucks (32 out of 98) exceeded the speed limit with a maximum observed speed of 90 km/h
- 15% of the autos/tempos (8 out of 54) exceeded the speed limit with a maximum observed speed of 48 km/h

Table. A2.8 Speeding statistics for NH-19

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	211	198	94%	90
Autos/Tempos	54	8	15%	48
Buses	84	66	79%	86
LMV	235	176	75%	108
Trucks	98	32	33%	90

3. State Highway-62

Table A2.9 lists the five sites surveyed along SH-62 in Agra district. Some salient built environment features include bends, divided and undivided roads. Furthermore, as one progresses from S1 to S5, the corridor progresses away from the city centre. It is also important to note that it had also rained early in the morning of the survey.

Table. A2.9 Summary of site characteristics surveyed along SH-62

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	1	No	Yes	No	No	No	No	No
S2	2	Yes	No	No	No	No	No	No
S3	3	Yes	Yes	No	No	No	No	No
S4	1	No	Yes	No	No	No	No	No
S5	1	No	Yes	No	No	No	No	No

A total of 825 observations were obtained, with the highest representation of samples corresponding to two-wheelers, followed by LMVs, HMVs and autos/tempos.

Table. A2.10 summarises the site-specific distribution of observations across different road users

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two wheelers	Autos/Tempos	Buses	Trucks	Total
S1	46	109	17	16	2	190
S2	35	87	15	20	6	163
S3	29	62	13	24	7	135
S4	28	55	10	18	20	131
S5	44	89	19	31	23	206
Total	182	402	74	109	58	**825**

3.1. Comparison across Sites

Table A2.11 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed of the surveyed samples at a given location. The overall variation suggests that as one progresses from S1 to S5, the average speed increases. The differences could be due to the effect of early morning rain (sites S1 to S5 were surveyed in sequence) or transitioning from city environments to two-lane roads in the periphery of the city.

Table. A2.11 Average speeds observed at each site on SH-62

Sites	Average speed for the sampled observations at each site (km/h)
S1	34
S2	41
S3	46
S4	49
S5	56

3.2. Speeding trends for each vehicle category

Based on the state's speed limit notifications, the speeding statistics for different vehicle classes are provided in Table A2.12:

- 66% of two-wheelers (265 out of 402) exceeded the speed limit with a maximum observed speed of 88 km/h
- 25% of buses (27 out of 109) exceeded the speed limit with a maximum observed speed of 66 km/h
- 17% of LMVs (31 out of 182) exceeded the speed limit with a maximum observed speed of 86 km/h
- 22% of trucks (13 out of 58) exceeded the speed limit with a maximum observed speed of 65 km/h
- 34% of the autos/tempos (25 out of 74) exceeded the speed limit with a maximum observed speed of 67 km/h

Table. A2.12 Speeding statistics for SH-62

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	402	265	66%	88
Autos/Tempos	74	25	34%	67
Buses	109	27	25%	66
LMV	182	31	17%	86
Trucks	58	13	22%	65

ANNEXURE 3 :
Districts in Focus - Gorakhpur Spot Speed Analysis

1. National Highway-27

Along the NH-27 that intersected with the Gorakhpur district, a total of five sites were surveyed. The site characteristics, including the posted speed limit description has been provided in Table C.1 (Annexure C). In terms of distinguishable built environment characteristics, sites S1 and S2 are located in denser urban environments. In comparison, the selected corridor transitions to a bypass road for sites S3, S4 and S5. A summary of the site characteristics has been provided in Table A3.1.

Table. A3.1 Summary of site characteristics surveyed along NH-27

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	No	No	No	Yes	No	Yes
S2	2	Yes	No	No	Yes	Yes	No	Yes
S3	2	Yes	Yes	No	No	No	No	No
S4	3	Yes	Yes	No	No	No	No	No
S5	2	Yes	Yes	Yes	No	Yes	No	No

A total of 687 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A3.2 summarises the samples collected across different road users on the NH-27.

Table. A3.2 Number of observations collected for specific sites in NH-27

Sites	Number of Observations (Grand Total: 801)					
	LMVs	Two-wheelers	Autos/Tempos	Buses	Trucks	Total
S1	31	66	15	17	17	146
S2	34	67	17	16	17	151
S3	37	46	1	12	34	130
S4	36	42	0	5	37	120
S5	47	49	0	6	38	140
Total	185	270	33	56	143	**687**

1.1. Comparison across sites

Table A3.3 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed of the sampled road users at a given location. The differences in the average speeds between S1/S2 and S3/S4/S5 could be due to a combination of multiple factors: time of day (S1 and S2 were surveyed in the afternoon), built environment (more roadside features at S1 and S2) and vehicle mix (very few autos/tempos captured in S3-S5).

Table. A3.3 Average speeds observed at each site on NH-27

Sites	Average speed for the sampled observations at each site (km/h)
S1	42
S2	41
S3	61
S4	66
S5	70

1.2. Speeding trends for each vehicle category

Table A3.4 provides a summary of the speeding instances for each vehicle category on NH-27, using the posted speed limits for each vehicle category, as indicated in Table C.1. The following speeding trends were observed along the NH-27:

- 89% of two-wheelers (241 out of 270) exceeded the speed limit (40 km/h) with a maximum observed speed of 89 km/h.
- 41% of buses (23 out of 56) exceeded the speed limit (50 km/h) with a maximum observed speed of 87 km/h.
- 60% of LMVs (110 out of 185) exceeded the speed limit (60 km/h) with a maximum observed speed of 99 km/h.

- 46% of the trucks (65 out of 143) exceeded the speed limit (50 km/h), with a maximum speed of 72 km/h.
- 6% of the autos/tempos exceeded the prescribed speed limit (60 km/h) with a maximum observed speed of 45 km/h.

Table. A3.4 Speeding statistics for NH-27

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	270	241	89%	89
Autos/Tempos	33	2	6%	45
Bus	56	23	41%	87
LMV	185	110	60%	99
Trucks	143	65	46%	72

2. State Highway-1

The site characteristics surveyed along State Highway 1 (SH-1), including the posted speed limit description, has been provided in Table C.2 (Annexure C). In terms of distinguishable built environment characteristics, the sites comprise both dense and sparse build environments within the vicinity of the segments. Site S4 was identified as a blackspot, while S4 and S5 also represent approaches to unsignalised intersection and an interchange, respectively. Table A3.5 provides a summary of site characteristics.

Table. A3.5 Summary of site characteristics surveyed along SH-1

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	Yes	No	No	No	No
S2	2	Yes	No	No	No	No	No	Yes
S3	2	No	Yes	No	No	No	No	No
S4	2	Yes	Yes	No	Yes	No	No	No
S5	2	Yes	No	No	No	No	No	No

A total of 692 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A3.6 summarises the samples collected across different road users on SH1-.

Table. A3.6 Number of observations collected for specific sites in SH-1

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two-wheelers	Autos/Tempos	Buses	Trucks	Total
S1	24	68	10	17	16	135
S2	36	72	8	11	11	138
S3	38	54	9	8	11	120
S4	25	63	7	12	13	120
S5	26	72	5	31	45	179
Total	149	329	39	79	96	**692**

2.1. Comparison across Sites

Table A3.7 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed observed at a given location. A drop off in the average speed is observed at site S5, which is an approach leading to a major interchange, which can potentially cause yielding and lane-changing manoeuvres. However, the distribution of vehicles sampled at each location may also influence the speed distributions.

Table. A3.7 Average speeds observed at each site on SH-1

Sites	Average speed for the sampled observations at each site (km/h)
S1	55
S2	56
S3	57
S4	56
S5	49

2.2. Speeding trends for each vehicle category

Table A3.8 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along SH1:

- 93% of two-wheelers (305 out of 329) exceeded the speed limit with a maximum observed speed of 99 km/h.
- 85% of buses (67 out of 79) exceeded the speed limit with a maximum observed speed of 89 km/h.
- 97% of LMVs (145 out of 149) exceeded the speed limit with a maximum observed speed of 99 km/h.
- 21% of Autos/Tempos (8 out of 39) exceeded the speed limit with a maximum observed speed of 45 km/h.
- None of the trucks or autos/tempos exceeded the speed limit.

Table. A3.8 Speeding statistics for SH-1

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	329	305	93%	99
Autos/Tempos	39	8	21%	45
Buses	79	67	85%	89
LMV	149	145	97%	99
Trucks	96	64	67%	70

3. Sports College Road - Fatima-Bypass Road - Jail Bypass Road

The site characteristics surveyed along the Sports College Road - Fatima Hospital Bypass Road - JailBypass Road, a local corridor within Gorakhpur, has been provided in Table C.3 (Annexure C). In terms of distinguishable built environment characteristics, the sites comprise both divided and undivided roads in dense and sparse built environments. Table A3.9 provides a summary of the site characteristics.

Table. A3.9 Summary of site characteristics surveyed along the local road in Gorakhpur

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	No	Yes	No	No	No	No
S2	2	Yes	Yes	No	No	No	No	No
S3	2	Yes	Yes	No	No	No	No	No
S4	1	No	No	No	No	No	No	No
S5	1	No	No	No	No	No	No	No

A total of 748 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by LMVs, HMVs and autos/tempos. Table A3.10 summarises the samples collected across different road users on the local corridor.

Table. A3.10 Number of observations collected for local corridor in Gorakhpur

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two -wheelers	Autos/Tempos	Buses	Trucks	Total
S1	29	68	5	24	29	155
S2	34	77	10	29	29	179
S3	39	59	12	3	10	123
S4	58	68	12	11	19	168
S5	32	58	11	9	13	123
Total	192	330	50	76	100	**748**

3.1. Comparison across Sites

Table A3.11 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed observed at a given location. There was an observed drop in the average speed is observed at the undivided roads at S4 and S5, relative to the divided roads at S1-S3. However, the distribution of vehicles sampled at each location may also influence the speed distributions, as observed with the small HMV samples at S3.

Table. A3.11 Average speeds observed along Fatima-Bypass road in Gorakhpur

Sites	Average speed for the sampled observations at each site (km/h)
S1	43
S2	44
S3	50
S4	37
S5	41

3.2. Speeding trends for each vehicle category

Table A3.12 provides a summary of the speeding statistics for each vehicle class. As observed from the result, a significant proportion of two-wheelers and LMVs were speeding on the Fatima-Bypass road.

Table. A3.12 Speeding statistics for local corridor in Gorakhpur

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	330	255	77%	90
Autos/Tempos	50	6	12%	50
Bus	76	18	24%	60
LMV	192	145	76%	68
Trucks	100	18	18%	67

ANNEXURE 4 :
Districts in Focus - Bareilly Spot Speed Analysis

1. National Highway 30

Along the NH-30 that intersected with the Bareilly district, a total of five sites were surveyed. The site characteristics, including the posted speed limit description has been provided in Table D.1 (Annexure D). In terms of distinguishable built environment characteristics, these sites consist of sparse roadside features, with a couple of sites that are close to intersections (S3 and S4). A summary of the site characteristics has been provided in Table A4.1.

Table. A4.1 Summary of site characteristics surveyed along NH-30

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	No	No	No	No	No
S2	2	Yes	Yes	No	Yes	No	No	No
S3	2	Yes	Yes	No	No	Yes	No	No
S4	3	Yes	Yes	No	No	Yes	No	No
S5	2	Yes	Yes	Yes	No	No	No	No

A total of 666 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A4.2 summarises the samples collected across different road users on the NH-30.

Table. A4.2 Number of observations collected for specific sites in NH-30

Sites	Number of Observations (Grand Total: 801)					
	LMVs	Two-wheelers	Autos/Tempos	Buses	Trucks	Total
S1	28	49	2	18	28	125
S2	29	48	6	30	42	155
S3	20	40	7	15	45	127
S4	32	45	11	19	30	137
S5	29	24	7	16	46	122
Total	138	206	33	98	191	666

1.1. Comparison across sites

Table A4.3 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the statistical variation in the average speed expected at a given location. The differences in the average speeds between S1/S2 and S3/S4/S5 could be due to a combination of multiple factors: time of day (S1 and S2 were surveyed in the afternoon), built environment (more roadside features at S1 and S2) and vehicle mix (very few autos/tempos captured in S3-S5).

Table. A4.3 Average speeds observed at each site on NH-30

Sites	Average speed for the sampled observations at each site (km/h)
S1	61
S2	58
S3	56
S4	58
S5	61

1.2. Speeding trends for each vehicle category

Table A4.4. provides a summary of the speeding instances for each vehicle category on NH-30, using the posted speed limits for each vehicle category, as indicated in Table D.1. The following speeding trends were observed along the NH-30:

- 86% of two-wheelers (178 out of 206) exceeded the speed limit (50 km/h) with a maximum observed speed of 100 km/h.
- 24% of buses (23 out of 98) exceeded the speed limit (60 km/h) with a maximum observed speed of 76 km/h.
- 51% of LMVs (70 out of 138) exceeded the speed limit (70 km/h) with a maximum observed speed of 110 km/h.
- 8% of the trucks (16 out of 191) exceeded the speed limit (60 km/h), with a maximum speed of 78 km/h.
- 3% of the autos/tempos (1 out of 33) exceeded the speed limit (50 km/h), with a maximum speed of 67 km/h.

Table. A4.4 Speeding statistics for NH-30

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
two-wheelers	206	178	86%	100
Autos/Tempos	33	1	3%	67
Bus	98	23	24%	76
LMV	138	70	51%	110
Trucks	191	16	8%	78

2. State Highway-37

The site characteristics surveyed along SH-37, including the posted speed limit description, has been provided in Table D.2 (Annexure D). In terms of distinguishable built environment characteristics, the sites comprise both dense and sparse build environments along a two-lane, divided road. Multiple sites along this stretch were designated as blackspots (S1-S4), although the details of the crash occurrences at these were unavailable. Table A4.5 provides a summary of the site characteristics.

Table. A4.5 Summary of site characteristics surveyed along SH-37

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	No	Yes	Yes	Yes	Yes	No
S2	2	Yes	Yes	No	Yes	No	No	No
S3	2	Yes	Yes	No	Yes	Yes	Yes	No
S4	2	Yes	Yes	No	Yes	Yes	No	No
S5	2	Yes	No	No	No	No	No	No

A total of 824 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A4.6. summarises the samples collected across different road users on the SH3-7.

Table. A4.6 Number of observations collected for specific sites in SH-37

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two -wheelers	Autos/Tempos	Buses	Trucks	Total
S1	26	48	7	13	38	132
S2	36	50	4	15	43	148
S3	38	76	4	22	43	183
S4	60	67	7	23	48	205
S5	34	61	10	23	28	156
Total	194	302	32	96	200	**824**

2.1. Comparison across Sites

Table A4.7. shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed observed at a given location. Without considering the variation in the proportion of vehicle classes at these locations, it appears that site S1 has the slowest average speed, despite the early morning survey. Upon further analysis of the roadside features, it was observed that the intersecting roads lead to a wholesale fruit and vegetable market, which also opens early in the morning. The trends of S2 to S5 reflect a gradual drop-off in the average speeds as the day progresses. However, it is important to analyse these variations for each vehicle class separately.

Table. A4.7 Average speeds observed at each site on SH-37

Sites	Average speed for the sampled observations at each site (km/h)
S1	44
S2	60
S3	58
S4	57
S5	53

2.2. Speeding trends for each vehicle category

As the speed limits for SH-37 were not identifiable within the state notifications, the central notifications were assumed (and documented in Table D.2). These speed limits are defined for certain road design characteristics (e.g., divided four-lane roads, other roads within municipal limits), and not specific state highways. Consequently, in this instance, the speed limits assumed for this corridor for multiple sites are higher than the speed limits identified for NH27 within the state notifications.

Table A4.8 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along SH-37:

- 70% of two-wheelers (211 out of 302) exceeded the speed limit with a maximum observed speed of 90 km/h.
- 22% of buses (21 out of 96) exceeded the speed limit with a maximum observed speed of 76 km/h.
- 33% of LMVs (64 out of 194) exceeded the speed limit with a maximum observed speed of 99 km/h.
- 6% of trucks (11 out of 200) exceeded the speed limit with a maximum observed speed of 68 km/h.
- None of the autos/tempos exceeded the speed limit.

Table. A4.8 Speeding statistics for SH-37

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	302	211	70%	90
Autos/Tempos	32	0	0%	43
Bus	96	21	22%	76
LMV	194	64	33%	99
Trucks	200	11	6%	68

3. Local Road within District: Pilibhit Bypass Road

The site characteristics surveyed along the Pilibhit Bypass Road, including the posted speed limit description is provided in Table D.3 (Annexure D). In terms of distinguishable built environment characteristics, the sites comprise of both divided and undivided roads in dense and sparse built environments. Table A4.9. provides a summary of site characteristics.

Table. A4.9 Summary of site characteristics surveyed along local road in Bareilly

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	1	No	Yes	No	No	No	Yes	No
S2	1	No	No	No	No	No	No	No
S3	2	Yes	No	No	No	No	No	Yes
S4	2	Yes	Yes	Yes	No	No	No	No
S5	2	Yes	No	No	No	No	No	No

A total of 699 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by LMVs, HMVs and autos/tempos. Table A4.10 summarises the samples collected across different road users on the local corridor.

Table. A4.10 Number of observations collected for Pilibhit Bypass Road in Bareilly

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two-wheelers	Autos/Tempos	Buses	Trucks	Total
S1	29	68	9	25	36	167
S2	26	45	6	27	22	126
S3	17	51	11	26	30	135
S4	10	87	5	11	21	134
S5	23	49	7	11	47	137
Total	105	300	38	100	156	**699**

3.1. Comparison across Sites

Table A4.11. shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the statistical variation in the average speed expected at a given location. A higher average speed is observed at sites S4 and S5 relative to S1 to S3, which is expected given that the former sites have two lanes each with a divider, while S1 and S2 are undivided, single lane roads and S3 is placed along an approach of a signalized intersection. In addition, S4 and S5 were surveyed in the morning which may further yield higher speeds.

Table. A4.11 Average speeds observed along local corridor in Bareilly

Sites	Average speed for the sampled observations at each site (km/h)
S1	37
S2	35
S3	34
S4	49
S5	43

3.2. Speeding trends for each vehicle category

Table A4.12 provides a summary of the speeding statistics for each vehicle class. The following are the key observations regarding speeding on this corridor:

- Two-wheelers had the highest percentage of speeding (30%) with a highest speed of 78 km/h, relative to a posted speed limit of 50 km/h.
- 5% of autos/tempos travelled in excess of the speed limit of 50 km/h, with a highest speed of 54 km/h.
- While only one bus observation exceeded the prescribed speed limit of 60 km/h, neither trucks nor LMVs were observed to exceed the speed limits of 60 km/h and 70 km/h respectively.

Table. A4.12 speeding statistics for local corridor in Bareilly

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-Wheelers	300	89	30%	78
Autos/Tempos	38	2	5%	54
Bus	100	1	1%	65
LMV	105	0	0%	67
Trucks	156	0	0%	58

ANNEXURE 5 :
Districts in Focus-Prayagraj Spot Speed Analysis

1. Allahabad Bypass Expressway

Along the Allahabad Bypass Expressway that intersected with the Prayagraj district, a total of five sites were surveyed. The site characteristics, including the posted speed limit description is provided in Table E.1 (Annexure E). The sites have similar built environment characteristics with a merging area (S3), turning area (S1) and roadside openings for local traffic to enter (S5).

Table. A5.1 Summary of site characteristics surveyed along the Allahabad Bypass Expressway

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	No	No	No	No	No
S2	2	Yes	Yes	No	No	No	No	No
S3	2	Yes	Yes	No	No	Yes	No	No
S4	2	Yes	Yes	Yes	No	No	No	No
S5	2	Yes	Yes	Yes	No	No	Yes	No

A total of 721 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A5.2 summarises the samples collected across different road users on the Allahabad Bypass Expressway.

Table. A5.2 Number of observations collected for specific sites on the Allahabad Bypass Expressway

Sites	Number of Observations (Grand Total: 801)					
	LMVs	Two-wheelers	Autos/Tempos	Buses	Trucks	Total
S1	36	74	1	8	16	135
S2	32	32	4	32	32	132
S3	32	58	9	19	31	149
S4	28	61	10	29	42	170
S5	31	48	6	11	39	135
Total	159	273	30	99	160	**721**

1.1. Comparison across sites

Table A5.3 shows the average speeds estimated by combining samples observed across all vehicle classes at each site depicting the variation in the average speed observed at a given location. Sites S1 and S5 have the highest average speeds. Site S5 was surveyed during early morning hours.

Table. A5.3 Average speeds observed at each site on Allahabad Bypass Expressway

Sites	Average speed for the sampled observations at each site (km/h)
S1	58
S2	56
S3	55
S4	56
S5	60

1.2. Speeding trends for each vehicle category

Table A5.4. provides a summary of the speeding instances for each vehicle category on Allahabad Bypass Expressway, using the posted speed limits for each vehicle category, as indicated in Table E.1. The following speeding trends were observed along the Allahabad Bypass Expressway:

- 37% of two-wheelers (102 out of 273) exceeded the speed limit (60 km/h) with a maximum observed speed of 80 km/h
- 37% of buses (37 out of 99) exceeded the speed limit (60 km/h) with a maximum observed speed of 76 km/h
- 60% of LMVs (96 out of 159) exceeded the speed limit (60 km/h) with a maximum observed speed of 114 km/h
- 10% of the trucks (16 out of 160) exceeded the speed limit (60 km/h), with a maximum speed of 90 km/h
- None of the autos/tempos sampled along the corridor exceeded the speed limit.

Table. A4.4 Speeding statistics for the Allahabad Bypass Expressway

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	273	102	37%	80
Autos/Tempos	30	0	0%	52
Buses	99	37	37%	76
LMV	159	96	60%	114
Trucks	160	16	10%	90

2. National Highway 35

The site characteristics surveyed along NH-35, including the posted speed limit description, is provided in Table E.2 (Annexure D). In terms of distinguishable built environment characteristics, the sites comprise of both dense and sparse build environments along a 2 lane, divided road. One site along this stretch was designated as a blackspot (S1), although the details of the crash occurrences at these were unavailable. Table A5.5 provides a summary of site characteristics.

Table. A5.5 Summary of site characteristics surveyed along NH-35

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	Yes	Yes	No	Yes	No
S2	2	Yes	No	Yes	No	Yes	No	Yes
S3	2	Yes	No	No	No	No	No	No
S4	2	Yes	No	No	No	Yes	No	No
S5	2	Yes	Yes	No	No	No	Yes	No

A total of 824 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by HMVs, LMVs and autos/tempos. Table A5.6 summarizes the samples collected across different road users on the NH35.

Table. A5.6 Number of observations collected for specific sites in NH-35

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two -wheelers	Autos/Tempos	Buses	Trucks	Total
S1	25	47	3	9	27	111
S2	25	44	8	9	36	122
S3	25	58	8	17	28	136
S4	32	80	9	27	28	176
S5	31	55	9	28	13	136
Total	138	284	37	90	132	**681**

2.1. Comparison across Sites

Table A5.7 shows the average speeds estimated by combining samples across all vehicle classes at each site depicting the variation in the average speed observed at a given location. The sites with sparser roadside features (S1 and S5) observe higher average speeds relative to the other locations. However, the proportions of HMVs also vary across sites.

Table. A5.7 Average speeds observed at each site on NH-35

Sites	Average speed for the sampled observations at each site (km/h)
S1	50
S2	43
S3	41
S4	44
S5	52

2.2. Speeding trends for each vehicle category

Table A5.8 provides a summary of the speeding statistics for each vehicle class. The following speeding trends were observed along NH-35:

- 86% of two-wheelers (244 out of 284) exceeded the speed limit with a maximum observed speed of 73 km/h.

- 30% of buses (27 out of 90) exceeded the speed limit with a maximum observed speed of 42 km/h.
- 22% of LMVs (31 out of 138) exceeded the speed limit with a maximum observed speed of 88 km/h.
- 11% of trucks (14 out of 132) exceeded the speed limit with a maximum observed speed of 59 km/h.
- 3% of the autos/tempos (1 out of 37) exceeded the speed limit with a maximum speed limit of 42 km/h.

Table. A5.8 Speeding statistics for NH-35

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
2 Wheelers	284	244	86%	73
Autos/Tempos	37	1	3%	42
Bus	90	27	30%	64
LMV	138	31	22%	88
Trucks	132	14	11%	59

3. State Highway-7

The site characteristics surveyed along SH-7, including the posted speed limit description is provided in Table E.3 (Annexure E). The corridor comprises two-lane, divided roads with variations in roadside features and signages (e.g., parked trucks, shops, speed limit signs) in the vicinity of the sites. Table A5.9 provides a summary of site characteristics.

Table. A5.9 Summary of site characteristics surveyed along SH-7 in Prayagraj

Sites	Number of Lanes	Divided	Sparse Built Environment	Early Morning (< 7 AM) Survey	Blackspot	Intersection Approach	Warnings or Signs	Traffic Calming
S1	2	Yes	Yes	Yes	No	No	No	No
S2	2	Yes	No	No	No	No	Yes	No
S3	2	Yes	No	No	No	No	No	No
S4	2	Yes	Yes	No	No	No	No	No
S5	2	Yes	Yes	No	No	No	No	No

A total of 619 observations were obtained, with the sampling corresponding to most observations for two-wheelers, followed by LMVs, HMVs and autos/tempos. Table A5.10 summarizes the samples collected across different road users on the local corridor.

Table. A5.10 Number of observations collected for SH-7 in Prayagraj

Sites	Number of Observations (Grand Total: 682)					
	LMVs	Two wheelers	Autos/Tempos	Buses	Trucks	Total
S1	18	53	11	22	14	118
S2	11	55	9	18	15	108
S3	24	49	6	16	18	113
S4	23	35	8	24	30	120
S5	19	109	6	12	14	160
Total	95	301	40	92	91	**619**

3.1. Comparison across Sites

Table A5.11 shows the average speeds estimated by combining samples across all vehicle classes at each site depicting the variation in the average speed observed at a given location. S2 (with a slight bend and merge) observed lowest average speed followed by S3 (with parked trucks). However, the difference in sampling characteristics (e.g., the large number of two-wheelers sampled at S5), needs to be accounted by comparing site-specific trends for each vehicle class.

Table. A5.11 Average speeds observed along local corridor in Prayagraj

Sites	Average speed for the sampled observations at each site (km/h)
S1	49
S2	41
S3	45
S4	50
S5	53

3.2. Speeding trends for each vehicle category

Table A5.12 provides a summary of the speeding statistics for each vehicle class. The following are the key observations regarding speeding on this corridor:

- 60% of two-wheelers (181 out of 301) exceeded the speed limit with a highest speed of 84 km/h
- 68% of LMVs (65 out of 95) exceeded the speed limit with a highest speed of 76 km/h.
- 35% of buses (32 out of 92) and 21% of trucks (19 out of 91) travelled in excess of the speed limit, with a highest speed of 69 km/h and 68 km/h respectively.
- 5% of autos/tempos (2 out of 40) travelled in excess of the speed limit, with a highest speed of 55 km/h.

Table. A5.12 Speeding statistics for SH-7 in Prayagraj

Type of Vehicle	Total Observations	Speeding Observations	Speeding Percentage	Maximum Observed Speed
Two-wheelers	301	181	60%	84
Autos/Tempos	40	2	5%	55
Buses	92	32	35%	69
LMV	95	65	68%	76
Trucks	91	19	21%	68

Appendices

Appendix A Kanpur Nagar District Locations

Table A.1

Site identified for spot speed assessment on the Lucknow-Agra Expressway

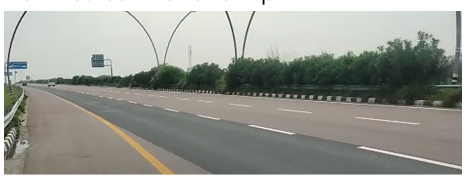
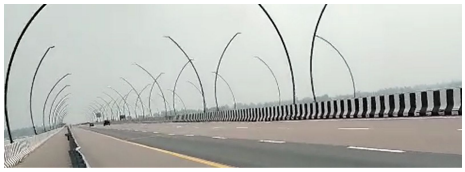
Site	Speed Limit (in km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 100 Two-wheelers: 80 Buses and Trucks: 80 Autos/Tempos: N/A	Kanpur Nagar	Flat stretch; over an underpass 	5:09-6:29 AM	26.897537724686035, 79.9790188923954
S2	LMVs: 100 Two-wheelers: 80 Buses and Trucks: 80 Autos/Tempos: N/A	Kanpur Nagar	Near a speed limit sign 	6:45 - 7:49 AM	26.901127387634105, 80.00591904877732
S3	LMVs: 100 Two-wheelers: 80 Buses and Trucks: 80 Autos/Tempos: N/A	Kanpur Nagar	At an exit ramp after rumble strips 	8:01 - 9:28 AM	26.9065, 80.02115
S4	LMVs: 100 Two-wheelers: 80 Buses and Trucks: 80 Autos/Tempos: N/A	Kanpur Nagar	Downstream of a ramp 	9:46 AM - 11:38 AM	26.912932472405775, 80.03300939094362
S5	LMVs: 100 Two-wheelers: 80 Buses and Trucks: 80 Autos/Tempos: N/A	Kanpur Nagar	Over a bridge 	12:12 - 2:48 PM	26.92487577484474, 80.04606943171663

Table A.2
Site identified for spot speed assessment on NH 34

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	Flat stretch; undivided road with sparse built environment features, and signs to slow down nearby 	2:15-4:15 PM	26.253804649268307, 80.21801513888147
S2	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A blackspot 	12:50 - 2 PM	26.2681349858517, 80.23284933442213
S3	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	An undivided road near a school and petrol pump 	11:15 AM - 12:15 PM	26.353326236071364, 80.30138471872496
S4	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A divided, two lane road with roadside markets 	9:30 AM - 11 AM	26.40077906213187, 80.31415890428612)
S5	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	An undivided, single lane road in a market area 	4:50 - 9 AM	26.449341273426104, 80.33152611803331

Table A.3
Site identified for spot speed assessment on SH-46

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	An undivided road with sparse roadside features) 	4:45-7 AM	26.10438953231364, 80.34300769370554
S2	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A flat stretch near a petrol pump 	7 - 8 AM	26.10504226273597, 80.30058237570464
S3	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A market area, post-rain 	8 AM - 3 PM	26.127194044343906, 80.24623330144023
S4	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A road approaching a wide intersection 	10 AM - 11 AM	26.135291007296708, 80.22091220717026
S5	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	A flat stretch near a petrol pump 	11:15 AM - 12:30 PM	26.140276938520085, 80.1974965911628

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S6	LMVs: 50 Two-wheelers: 40 Buses and Trucks: 60 Autos/Tempos: 40	Kanpur Nagar	Dense built environment and a divided road 	12 - 3:15 PM	26.148010320798807, 80.17241519861275

Appendices

Appendix B Agra District Locations

Table B.1

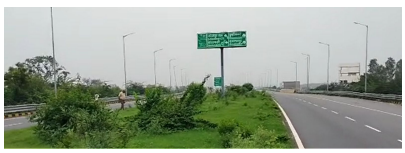
Site identified for spot speed assessment on the Yamuna Expressway

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 100 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: NA	Agra	Flat stretch 	4:45-6:24 AM	27.304591632364694, 77.99628425163075
S2	LMVs: 100 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: NA	Agra	A site near a toll road with a curve indicator 	6:52 - 8:29 AM	27.30005026589984, 78.02885146517507
S3	LMVs: 100 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: NA	Agra	A site with a curve indicator 	9 - 10:43 AM	27.2849403,78.0495925
S4	LMVs: 100 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: NA	Agra	At an interchange, after rumble strips 	11:22 AM - 1:07 PM	27.22841097011028, 78.11691045616989
S5	LMVs: 100 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: NA	Agra	A flat stretch 	3:06 - 4:46 PM	27.144236492038907, 78.1330345375105

Table B.2
Site identified for spot speed assessment on NH-19

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	At the edge of flyover preceded by a merge 	5:04-7:30 AM	27.208906392830272, 78.01093780097953
S2	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	At the edge of the flyover; bus pick up area; curve indications 	7:37 - 9:14 AM	27.2099086, 78.0580506
S3	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Roadside shops on a flat stretch 	9:46 AM - 11:18 AM	27.217345691538004, 78.0824233647352
S4	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	A flat stretch (source: Google Maps) 	12:12 - 2:16 PM	27.231452803728487, 78.16559933642694
S5	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	A lat stretch with a speed limit sign 	2:31 - 3:33 PM	27.23144, 78.20538

Table B.3
Site identified for spot speed assessment on SH-62

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Along a bend 	8:03-9:19 AM	27.1725377,78.027509
S2	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Roadside activity 	9:30 - 10:47 AM	27.158087022615355, 78.05493596122777
S3	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Flat stretch 	8 AM - 3 PM	27.149283130347637, 78.07533106792475
S4	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Flat stretch 	12:09 - 12:59 PM	27.1283267,78.1066045
S5	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Agra	Near an educational institution 	1:46 - 3:05 PM	27.1216356,78.1191105

Appendices

Appendix C Gorakhpur District Locations

Table C.1

Site identified for spot speed assessment on NH-27

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Gorakhpur	Rumble strips near an intersection approach 	3:32-4:42 PM	26.751469259932765, 83.22429589275933
S2	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Gorakhpur	Blackspot with rumble strips; in vicinity of an interchange 	1:16 - 3:19 PM	26.7472341,83.2485796
S3	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Gorakhpur	Sparse road stretch with curve signages and a reduction in number of lanes 	10:32 AM - 12:26 PM	26.728402834400384, 83.26497856334203
S4	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Gorakhpur	Temporary increase in number of lanes 	7:30 - 9:58 AM	26.71902474875 43,83.28652510484478
S5	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Gorakhpur	Near an interchange 	4:31-7:01 AM	26.706938550791406, 83.32730659950614

Table C.2
Site identified for spot speed assessment on SH-1

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Sparse roadside features 	4:40 AM - 6:20 AM	26.650319371570806, 83.567764516084 86
S2	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Psychological markings leading up to a crossing 	6:40-8:22 AM	26.65969070020862, 83.54924781781 13
S3	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Transition from divided to undivided roads 	8:42 - 10:11 AM	26.667694135092088, 83.53319900539401
S4	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	A sparsely populated stretch with a cut the vicinity of blackspot 	11:01 AM - 12:50 PM	26.68425775071297, 83.50225673273872
S5	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Divided road with roadside shops 	2:03 - 4:25 PM	26.69542835057624, 83.48083413598269

Table C.3
Site identified for spot speed assessment on Sports College Road - Fatima Hospital Bypass Road - Jail Bypass Road

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Near a flyover 	5:03-7:59 AM	26.75277, 83.39862
S2	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Sparse built environment, a gentle bend 	8:09 - 9:42 AM	26.764349053209138, 83.39335339900606
S3	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Flat stretch 	9:15 - 10:11 AM	26.76801, 83.39189
S4	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Undivided road with roadside activity 	2:23 - 4:05 PM	26.79858, 83.37922
S5	LMVs: 40 Two-wheelers: 40 Buses and Trucks: 40 Autos/Tempos: 40	Gorakhpur	Undivided road with roadside activity 	12:35 - 2:01 PM	26.80043015958943, 83.37194185667958

Appendices

Appendix D Bareilly District Survey Locations

Table D.1
Site identified for spot speed assessment on NH-30

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Flat stretch with a narrow waterway crossing underneath 	2:30 - 3:42 PM	28.42921685086022, 79.48456744723154
S2	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Blackspot 	3::43 - 4:28 PM	28.41045,79.4971
S3	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	An approaching intersection 	10:32 AM - 12:57 PM	28.3878767,79.498353
S4	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	An approaching intersection 	7:56 - 10:31 AM	28.3541132,79.4960232
S5	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	An approaching intersection 	6:12- 7:14 AM	28.3142378,79.4968606

Table D.2
Site identified for spot speed assessment on SH-37

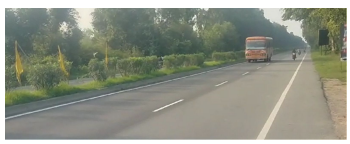
Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Intersection designated as a blackspot 	5:16 - 6:41 AM	28.775592, 79.4870955
S2	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Intersection in the vicinity of blackspot region 	6:42 - 8:17 AM	28.735842913577937, 79.49243039180192
S3	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Blackspot; approaching a t-junction 	8:18 - 10:16 AM	28.717808600066427, 79.48880284381904
S4	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Blackspot 	10:17 AM - 12:30 PM	28.6756687,79.4811337
S5	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	School, parked truck, stalls nearby 	1:50 - 3:31 PM	28.5772381,79.4661858

Table D.3
Site identified for spot speed assessment on Pilibhit Bypass Road

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Near an educational institution 	2:14- 3:42 PM	28.4249133, 79.4695139
S2	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	A slow down warning near a school 	11:49 AM - 1:03 PM	28.4100865, 79.4689886
S3	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Intersection approach with CCTV cameras 	8:49 - 10 AM	28.3731698, 79.4548718
S4	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Flat stretch with a cut and shops/institutions by the roadside 	6:20 - 7:09 AM	28.32719424604946, 79.46442340571735
S5	LMVs: 70 Two-wheelers: 50 Buses and Trucks: 60 Autos/Tempos: 50	Bareilly	Divided road with shops nearby 	7:14 - 7:59 AM	28.317332862558242, 79.47096531832061

Appendices

Appendix E Prayagraj District Survey Locations

Table E.1

Sites identified for spot speed assessment on the Allahabad Bypass Expressway

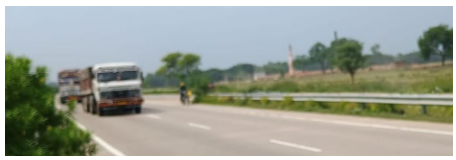
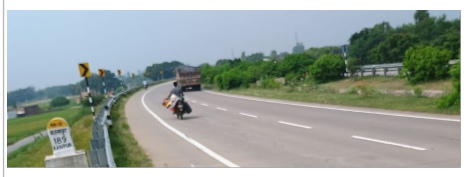
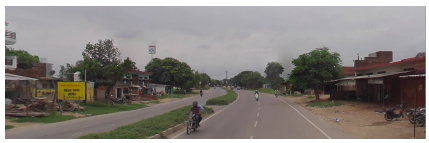
Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 60 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: 60	Prayagraj	Near a cut 	2:14 - 4:04 PM	25.604841157639097, 81.59355155353143
S2	LMVs: 60 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: 60	Prayagraj	Flat stretch 	10:57 AM - 12:44 PM	25.60240410453832, 81.617748383450 77
S3	LMVs: 60 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: 60	Prayagraj	Before a ramp 	8:55 - 10:56 AM	25.59830262438496, 81.63707022711311
S4	LMVs: 60 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: 60	Prayagraj	Cut in road 	6:39 - 8:54 AM	25.576980285413036, 81.68104739920366
S5	LMVs: 60 Two-wheelers: 60 Buses and Trucks: 60 Autos/Tempos: 60	Prayagraj	Curve 	4:50 - 6:38 AM	25.558752207565608, 81.77216335049388

Table E.2
Sites identified for speed assessment on NH-35

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Prayagraj	Flat stretch, in proximity of a blackspot, near an underbridge 	5:16 - 6:33 AM	25.412505881450482, 81.85286181767266
S2	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Prayagraj	Near some enforcement cameras 	6:34 - 7:59 AM	25.390277132128105, 81.86346029752225
S3	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Prayagraj	Near a school, parked vehicles 	7:59 - 10:40 AM	25.377893727619806, 81.87213441811724
S4	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Prayagraj	Near a T-junction 	10:33AM - 12:37 PM	25.3303406433456, 81.90753017255453
S5	LMVs: 60 Two-wheelers: 40 Buses and Trucks: 50 Autos/Tempos: 40	Prayagraj	Flat stretch, unevenroad 	2:38 - 4:12 PM	25.30958136785738, 81.93076994295271

Table E.3
Sites identified for spot speed assessment on SH-7

Site	Speed Limit (km/h)	District	Location Information	Survey Time Period	Coordinates
S1	LMVs: 50 Two-wheelers: 50 Buses and Trucks: 50 Autos/Tempos: 50	Prayagraj	A cut in the road, some roadside shops 	5:06-6:36 AM	25.47274496992346, 81.96709008001582
S2	LMVs: 50 Two-wheelers: 50 Buses and Trucks: 50 Autos/Tempos: 50	Prayagraj	Gentle curve with a street merging 	7:03 - 8:29 AM	25.488765328095887, 81.98923167271067
S3	LMVs: 50 Two-wheelers: 50 Buses and Trucks: 50 Autos/Tempos: 50	Prayagraj	Flat stretch with parked trucks 	8:56 - 10:54 AM	25.49993464897268, 82.01267875524121
S4	LMVs: 50 Two-wheelers: 50 Buses and Trucks: 50 Autos/Tempos: 50	Prayagraj	Flat stretch with some roadside features  (image source: Google Maps)	11:25 AM - 12:37 PM	25.52253122200414, 82.04519011356085
S5	LMVs: 50 Two-wheelers: 50 Buses and Trucks: 50 Autos/Tempos: 50	Prayagraj	Flat stretch with a few roadside features 	2:08 - 3:35 PM	25.539820002998134, 82.07441857626775

Appendices

Appendix F: Summary of API syntax, inputs and outputs

	TomTom Flow Segment API	HERE Flow API
API Syntax	https://api.tomtom.com/traffic/services/4/flowSegmentData/absolute/15/json?key={YOUT_API_KEY}&point={latitude},{longitude}&unit=kmph	https://data.traffic.hereapi.com/v7/flow?in=circle:{latitude},{longitude};r={radius}&locationReferencing=olr&apiKey={YOUR_API_KEY}
Input	lat: Latitude of a point near road segment	lat: Latitude of center of circle
	long: Longitude of a point near road segment	long: Longitude of center of circle
		r: Radius of circle
Output	current_speed: Current speed of the road near the point in kmph	description: Name of the route
		flow_length: length of route (in meters)
		speed: the expected speed (in meters per second) along the roadway; will not exceed the legal speed limit
	FreeFlow_speed: free flow speed of the road near the point in kmph	uncapped_speed: the expected speed (in meters per second) along the roadway; may exceed the legal speed limit
		free_flow_speed: the reference speed (in meters per second) along the roadway when no traffic is present
API Key	https://developer.tomtom.com/how-to-get-tomtom-api-key	https://developer.here.com/tutorials/getting-here-credentials/

Centre for Advancement of Road Traffic
Safety (CARTS), SaveLIFE Foundation

6, Ground Floor, Bhagwan Das Road,
Mandi House, New Delhi, 110001
Telephone: 011-41091911
Email: info@savelifefoundation.org

www.savelifefoundation.org
savelifefoundation
@savelifeindia