Abstract

The goal of the study is to evaluate the Samruddhi Mahamarg Expressway's existing road infrastructure for safety and to identify any potential dangers or hazards. In order to assess the safety performance of expressways, interchanges, and other transportation facilities and pinpoint areas for improvement, the study involves conducting thorough safety audits of those infrastructures.

Through this study, stakeholders may increase the safety of roads for all users by better understanding the safety hazards associated with current road infrastructure and making data-driven decisions. The overall goal of this study is to offer a thorough assessment of the security of the road network, to identify possible risks, and to develop suggestions for enhancing safety for all users.

The ultimate goal of this study is to improve the safety of the road infrastructure for all users. This can be achieved by identifying and addressing safety issues by conducting Questionnaire. At the final stage of the report, recommendations were made.

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1 INTRODUCTION

India has the second largest road network in the world about 63.72 lakh kilometres consisting of NHS. Expressways, State Highways (SHs), major district roads, other district roads and village roads Maharashtra state has 50,151 km road length and ranked first in India.

This road network carries nearly 65% of freight and 85% of passenger traffic.

Also, road traffic is estimated to be growing at an annual rate of 7-10%, while the vehicle population is growing at the rate of 12% per year.

In India, out of the 4.70 lakh road accident/crashes, 1.48 lakh fatalities and 4.71 lakh injuries had resulted as per the data year 2017.

In economic terms, the cost to the nation is an estimated 3% of the Gross Domestic Product (GDP). Major fatalities are in the age group of 18 to 45 years.

The road system and the traffic operations in India are deficient in safety management. One of the reasons for this situation is that there is very little opportunity to learn from past mistakes. The accident records are supposed to provide a clue about deficiencies in the road, vehicle and user systems to explain the causes of accidents and to develop remedial measures. This road safety management system is poor in India, with untrained police officers collecting only incomplete records of fatal accidents and always stating the road user's fault as the cause of the accident. In a road environment where the road design, knowledge of traffic rules, traffic control and policing (enforcement) are responsible for the accident. In a deficient road and traffic environment, causes are related to poor road geometry and poor traffic control aggravated by poor traffic sense.

Hence there is a need for coordinated action by all the key stakeholders to address this serious concern. Road Safety Audit on road is one critical step in this direction.

In this case study, one of the major expressways, the Nagpur-Mumbai Super Communication expressway called Samruddhi Mahamarg will be undertaken for a safety audit.

The Samruddhi Mahamarg is an under Construction 6 lane wide (Expandable to 8-lane) 701 km long access-controlled Expressway in Maharashtra, India.

At present, around 85-90% of the civil construction work is completed on the Samruddhi Mahamarg.

Figure 1: Toll Plaza at Ch. 10+475 (Near Nagpur)

The Section of Samruddhi Mahamarg from chainage km 10+300 (Wayfal Village) to km 106+000[IC-06] (Package II) of 95.7 km long in wardha district will be undertaken for detailed study and safety audit at post-opening stage.

1.1 Road Accidents in India Annual Report India- 2021(Latest):

The Ministry of Road Transport and Highways has published the annual report 'Road accidents in India — 2021'. The report provides information on various facets of road accidents in the country during the calendar year 2021. This report is based on the data/information received from police departments of States/Union Territories collected on a calendar year basis in standardized formats as provided by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) under the Asia Pacific Road Accident Data (APRAD) base project. It consists of ten sections and covers

information relating to road accidents in the context of road length and vehicular population.

As per the report, there were 4, 12,432 unfortunate incidences of road accidents during 2021 which claimed 1, 53,972 lives and caused injuries to 3, 84,448 persons. During the previous year 2020, the country saw an unprecedented decrease in accidents, fatalities and injuries. This was due to the unusual outbreak of the COVID-19 pandemic and the resultant stringent nationwide lockdown particularly during March-April, 2020 followed by gradual unlocking and phasing out of the containment measures. Major indicators related to accidents have performed better in 2021 when compared to 2019. Road accidents decreased by 8.1 per cent and injuries decreased by 14.8 per cent in 2021 compared to 2019. Fatalities, however, on accounts of road accidents increased by 1.9 per cent in 2021 corresponding to the same period in 2019.

India is committed to bringing down fatalities caused by road accidents. As road accidents are multi-causal which requires multi-pronged measures to mitigate the problems through concerted efforts of all agencies of both Central Government and State Governments. The Ministry, along with related organizations and stakeholders has formulated a multi-pronged strategy to address the issue of road safety based on Education, Engineering (both roads and vehicles), Enforcement and Emergency Care.

In this direction, the Ministry of Road Transport & Highways has implemented a scheme, "Grant of Financial Assistance for Administering Road Safely Advocacy and Awards for the Outstanding Work Done in the Field of Road Safety". Advancement of Vehicle Engineering plays a major role in taking efficient Road Safety measures, therefore, the Crash Safety Norm of vehicles has been revised. To strengthen the system of driver licensing and training to improve the competence and capability of drivers, Ministry is setting up model Institutes of Driving Training and Research (IDTR) Centres. Also, The Motor Vehicles (Amendment) Act, 2019, is expected to bring reforms in the various segments such as the enforcement of Road Safety norms and guidelines, bring citizen facilitation, and transparency, and reduction corruption with the help of information technology and removing intermediaries. A central repository, Integrated Road Accident Database (iRAD) system has been developed by Ministry for reporting, management, claim processing and analysis of road accident data to enhance road safety in the Country.

The purpose of this publication is to present an in-depth analysis and overview of road accidents in India. The data and analysis on road accidents contained in this volume will help create awareness, formulate suitable policies, take effective measures and also assist in informed decision-making in the area of road safety. The success of road safety initiatives requires active cooperation and participation of all stakeholders. The ministry hopes that the data on road accidents and the basic analysis contained in this report will be useful to administrators, policymakers, civil society organizations as well as researchers in the analysis of road safety issues leading to appropriate policy interventions to achieve a reduction in road accidents and resultant fatalities.

Today, Maharashtra is known for its excellent transport facilities and road connectivity in India. It is a matter of pride that the state has always been at the forefront of economic development with the highest state GDP. It models this roadway to propel the prosperity of villages and extend it to cities and major metropolises. This profound network of road connectivity, including National Highways, Major State Highways, State Highways, Major District Roads, Other District Roads, Rural Roads, and Urban Roads, is driving the all-inclusive prosperity of Maharashtra. Mumbai is known as an international metropolitan, and Nagpur is the growing sub-capital, the continuous drive to accelerate development in every metropolitan city by constructing highways is in full throttle.

To bring the entire state into the development stream, the state government has missioned to connect Maharashtra's two major metro cities. Hence, the state government plans the Hindu Hrudaysamrat Balasaheb Thackeray Maharashtra Samruddhi Mahamarg project to drive the state's overall development. This arterial expressway project in Maharashtra has been designed to ensure that the maximum distance should be covered seamlessly within the minimum time.

1.2 Seamless Journey through Samruddhi Mahamarg:

- The Expressway Benefitting 24 Districts.
- Balanced Care Between Fast Developments And Sustainable Environment.
- Transforming New Forests Landscape.
- Developing 18 Agriculture Oriented New Townships.

1.3 Key segmental developments:

- **Agriculture & Allied Activities-**The Samruddhi Corridor aims to build an encompassing agro ecosystem for the regional population as agriculture continues to be their primary occupation. With export-ready infrastructure, food processing zones, and food markets, the expressway cum utility belt will boost farmers' income and quality of livelihood.
- **New Townships & Industrial Hubs-**The HBTMSM corridor will ensure equal economic growth opportunities to the remote regions by developing 18 new townships. Several economic nodes catering to industrial hubs, IT parks, manufacturing units, and skill development & training institutes will generate new employment opportunities and migration control.
- **Integrated Logistics & Warehousing Hubs**- Warehousing hubs are planned at strategic locations close to industrial and manufacturing units to facilitate storage and quick logistics. Truck terminals and bus bays at various economic nodes will complement the freight forwarding experience and ease the supply chain for domestic markets. New townships are being developed in the districts of Aurangabad, Buldhana, and Wardha by the State Warehousing Corporation.
- **Tourism Circuits & Hospitality-** The state government has identified a massive scope of promoting tourism and hospitality along the expressway route. Several tourism circuits for eco, pilgrim, and heritage tourism besides wayside amenities are proposed to develop along the route having wildlife resorts, museums, tiger safaris, food plazas, regional and theme-based retail outlets, periodic cultural events, restaurants, etc.

1.4 Socio-Economic Aspect:

Maharashtra is a state in the western region of India and is India's second-most populous state and third-largest state by area.

- Total Area - 307,713 km^2 (118,809 sq. miles)
- Total population - 112,372,972 (2011 census).
- Bordered by –
  i) the Arabian Sea on the West

ii) States of Karnataka, Telangana, Goa, Gujarat, Chhattisgarh, Madhya Pradesh and the Union territory of Dadra and Nagar Haveli.

- No. of Districts - 36 Nos.
- Revenue Divisions- 6nos. viz. Konkan, Pune, Nashik, Aurangabad, Amravati and Nagpur.
- The Nagpur Mumbai Super Communication Expressway (NMSCE) is designated as a Maharashtra Prosperity Corridor being a great growth opportunity.
- The project highway is a green field corridor which starts from Shivmadka Village on the Outer Ring Road of Nagpur and ends in Bhiwandi, Mumbai having an approximate length of 706.6 km.
- The project corridor passes through five divisions namely, Nagpur, Amravati, Marathawada, Nashik and Mumbai in the state of Maharashtra.
- It promises to revive the textile, tourism, education and manufacturing industries at its major nodes.
- It also connects the regional headquarters of the state thereby facilitating administrative activities of the state.
- Connecting the easternmost and the westernmost parts of the state in seven hours, the Expressway is a boon to the transportation industry of the entire country.
- An equal opportunity to grow and develop is the only way for a region to ensure a prosperous demography.
- Cities have concentrated employment opportunities, a skilled workforce, financial independence and the infrastructure to keep the demand-supply cycle intact.
- Most of the needs of the urban areas in terms of food and electricity are sourced from rural areas.
- Urban areas act as the drivers of the economy for the rural regions that surround them, whereas rural areas provide the necessary resources.
- Thus the urban and rural areas in any state have an interdependent relationship with each other.

1.5 Project Particular details:

Table 1: Project Particular Details

Sr. No.	Description	Details
1)	Name of Project:	Construction of Access Controlled Nagpur – Mumbai Super Communication Expressway (Hindu Hrudaysamrat Balasaheb Thakarey Maharashtra Samruddhi Mahamarg)
2)	Developer:	Maharashtra State Road Development Corporation (MSRDC)
3)	Project Length :	701.00km
4)	Project Cost:	55,000.00 Cr.
5)	Lane Details :	6 Lanes (Expandable up to 8 Lanes) – 11.25 mtr. Carriageway (3 lanes of 3.75 mtr. each on either side), 3 mtr. Wide paved shoulder on either side & 2 mtr wide earthen shoulder on either side
6)	Structures Details:	6 Tunnels, 24 IC, 65 Fly over/Viaduct, 400+ VUP, 300+ CPUP

1.6 Design Standards:

Design standards are adopted because of achieving safety, mobility and efficiency in traffic operation conforming to the standards set out in the MoRTH, Manual for expressway and relevant other MoRTH, IRC 99:2013 and International Guidelines.

- The Right-of-Way - 120 m. (inclusive connector/service roads, wherever required.
- The design speed i) for plain terrain - 150 kmph (120 kmph for first 8 km) ii) for rolling terrain - 120 kmph.
- Lane width - 3.75m with three lanes for each direction.
- Depressed median width - 15.0.
- Crossfall/ Camber - 2.0% minimum.

1.7 Key Alignment:

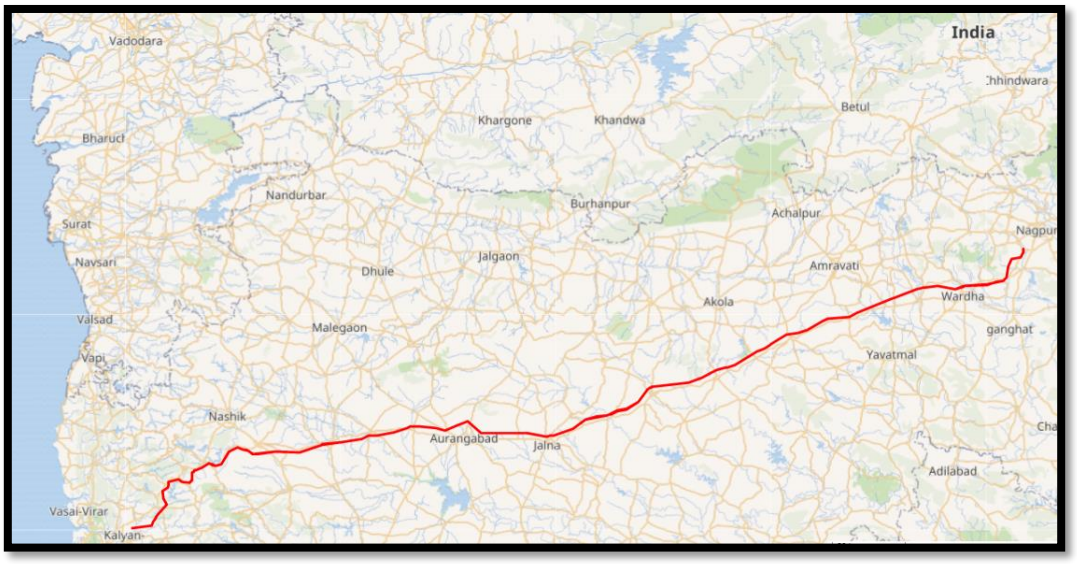

Figure 2: Key alignment of Samruddhi Expressway

1.8 Pre – DPR:

- General Alignment finalization using LIDAR technology (2017).
- Land Acquisition using Hyderabad land acquisition model (2017-2018).
- DPR Preparation (2018).
- Tendering on EPC mode in 16 packages (2019).

1.9 Post – DPR:

- Appointment of Contractors.
- Appointment of Design Consultant, Proof Consultant and Safety consultant by Contractor.
- Preparation of Detailed drawing of Highways and Structures by Contractor.
- Review of Detailed Drawing by Authority Engineer and granting the approval.
- Execution and supervision of daily construction activities and preparation of Daily Progress Report.
- Conducting weekly review meeting with Contractor.

1.10 Alignment Selection:

Three aspects were considered for selection of alignment.

i) Engineering, ii) Environmental and Social, iii) Cost

Following basic principles were observed while finalizing the alignments:

- Avoid Forest and Bor wild life sanctuary areas.
- Avoid passing through areas already under planning / development (eg. Development plan areas of urban canter's, Buti-Bori industrial area, etc.).
- Minimize route through irrigated/ two-season crop area.
- Maximize route through barren land.
- Use existing Right of Way or Government lands wherever available.
- Minimum distance from habitations / gaothan areas to be more than 150m.
- Alignment to have least number of curves and minimum radius to be 2000m.
- Minimize Railway over Bridges (RoB).
- Avoid water bodies Necessarily the start point needs to be located sufficiently close and easily accessible from the city of Nagpur and accordingly located near Shivmadka on the southern arc of the outer ring road of Nagpur city which connects NH7 to NH6.

1.11 Environmental Clearance:

- To undertake any new project or expansion/modernization of any existing infrastructure, industry or project listed in Schedule-I of the EIA Notification, 14 September 2006 and as amended till 1 December 2013, the project authority - shall have to apply to the Ministry of Environment and Forests, Government of India in accordance with the guidelines issued by the Central Government in the Ministry of Environment and Forests from time to time.
- As per EIA Notification 2006 amended thereto, the proposed project (NMSCE Package I) falls under category "B" project of 7(f) Sector. Hence the project will require prior Environmental Clearance from State Level Expert Appraisal Committee (SEAC) and State Level Environmental Impact Assessment Authority (SEIAA), Mumbai, Maharashtra.

1.12 Forest Clearances:

- The project also involves the private land pooling / land procurement, interface with the forest land at some stretches.
- The project road is passing through forest area in several stretches.

- Thus, the project shall require Forest Clearance as per provisions of Forest Conservation Act 1980 from Ministry of Environment and Forest and Climate Change (MOEF&CC).

1.13 Special Features of Project:

1) Equipped with Safety Features (Road markings, Road Signs, Traffic control devices are properly placed).
2) The maximum speed limit of 120 Km/hr.
3) Wildlife Mitigation Measures such as Wildlife Overpass (WOP) and Wildlife Underpass (WUP).
4) Boundary wall to prohibit the movement of vehicles, domestic and wild animals to achieve speed safety.
5) All the Toll plazas are operated by (ITMS) Integrated Toll Management System.
6) 5 Major bridges at Nagpur, Wardha, Nashik, Buldhana, and Thane are proposed to have a theme-based iconic design
7) 19 Nodes to be developed along the route which will include state-of-the-art healthcare facilities, skill development centres, IT parks and educational institutions.
8) Rainwater harvesting was executed in the corridor and integrated along with the proposed arboriculture throughout the corridor.
9) Arboriculture will also be executed as part of the project to study individual trees, shrubs, vines, and other perennial woody plants. (500 Crores)
10) The solar plants planned to be installed to generate 250MW of energy, and the Samruddhi Corridor aims to become a model of an energy-efficient corridor.
11) U-Turns are provided for emergency
12) Merging and Diverging is provided smoothly.
13) Sound barriers are provided.
14) Free nitrogen air at every fuel stations (Which may cost Rs.40/Tyre.

Figure 3: Sound Barriers provided at Samruddhi Expressway

Figure 4: Semi Rigid Crash Barriers Provided to Entire Expressway

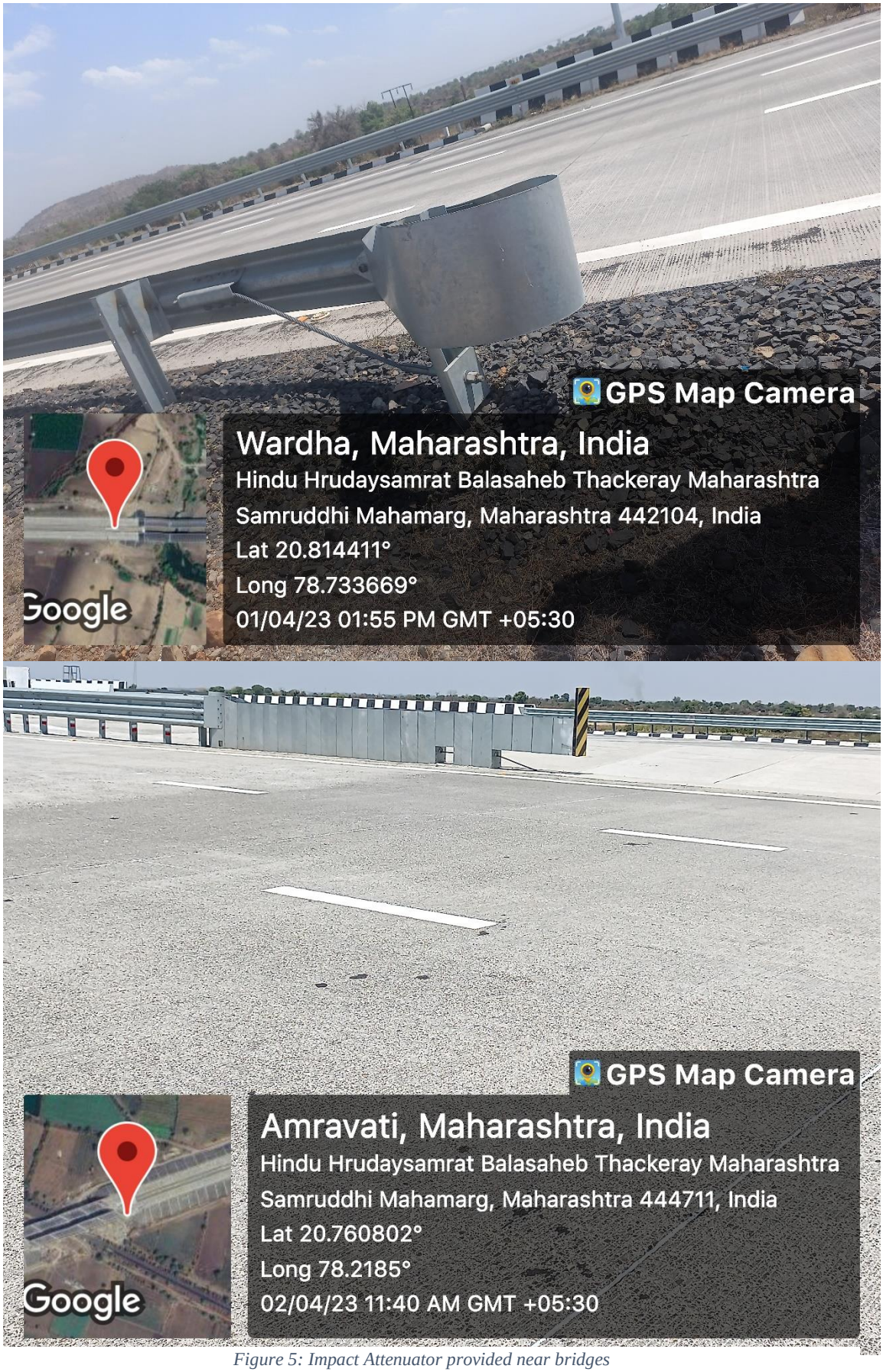

Figure 5: Impact Attenuator provided near bridges

1.14 Toll Plaza:

1) The Toll Plaza to have Hybrid Toll Management System (HTMS) where the toll will be collected via Fastag.
2) The entry of vehicle will be recorded at main toll plaza and entrance toll plaza at Interchange and toll will be collected at exit toll plaza at interchange and main toll plaza.
3) The Toll Plazas are equipped with the following components:
    a. Central Control Room (CCR).
    b. Highway Safety Police (HSP).
    c. Incident Management Responder (IMR).
    d. Quick Response Vehicle (QRV).
    e. Vehicle Tracking System (VTS)

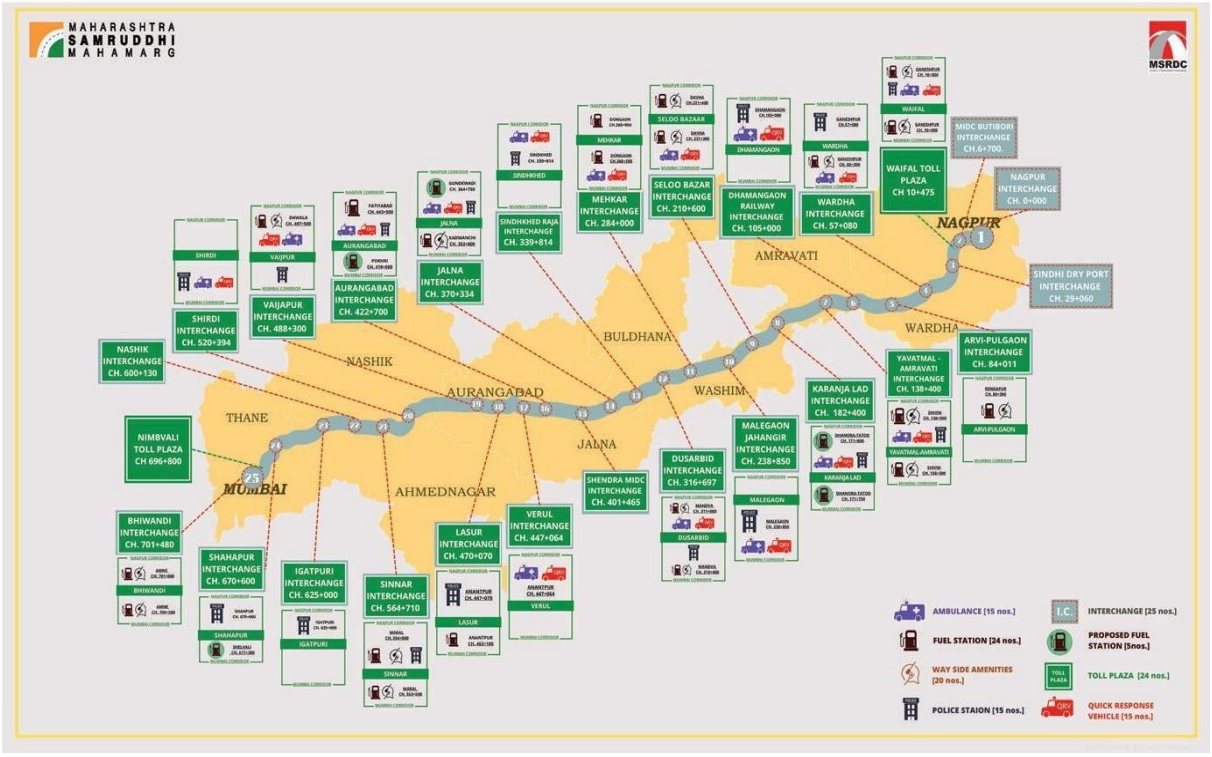

Figure 6 : Toll Plaza at various Locations

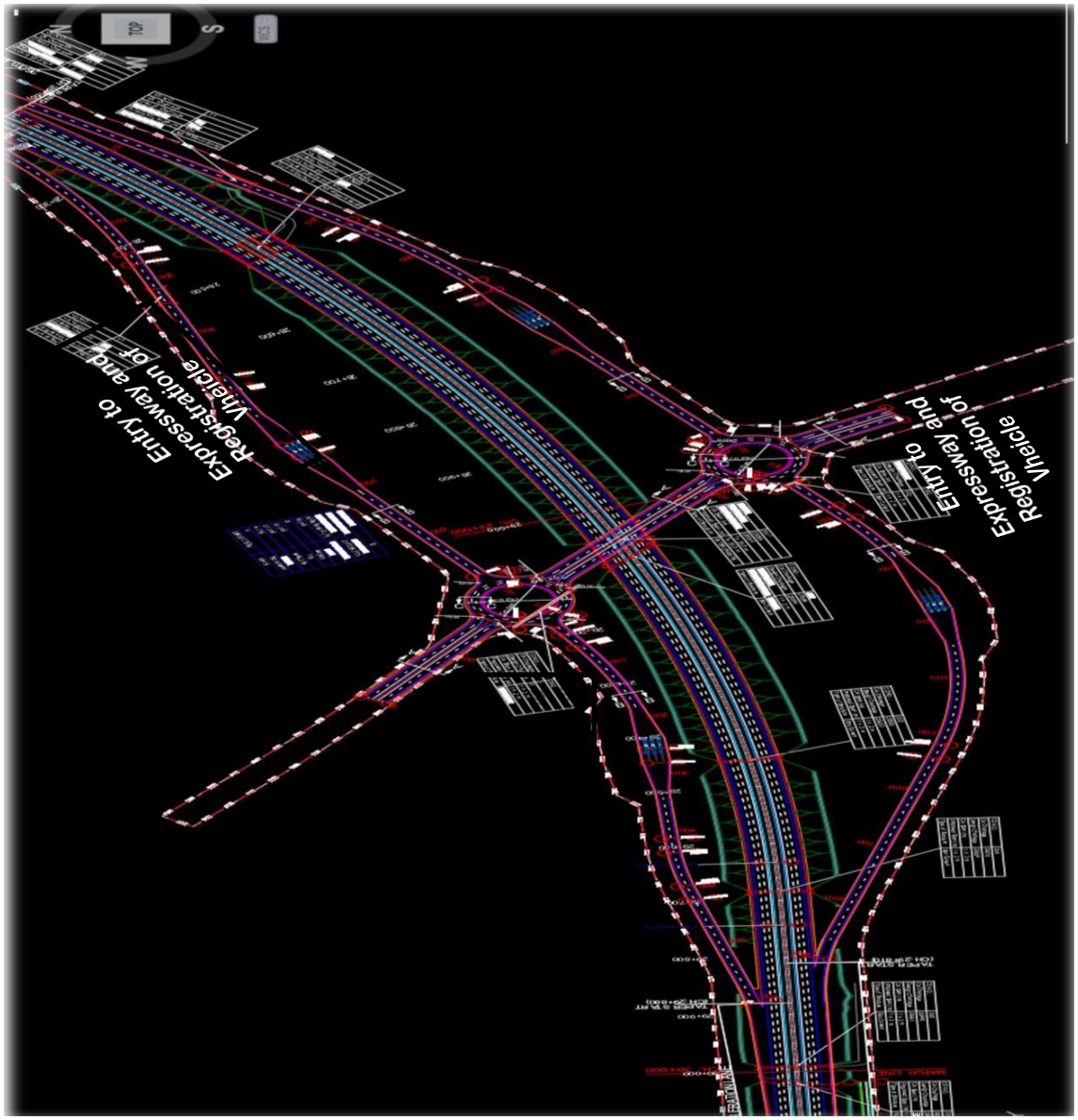

Figure 7: Plan of toll plaza at interchange (Exit)

1.15 Boundary Wall:

- The boundary wall is a key element of the project – Precast and Prestressed Concrete.
- The boundary wall will restrict the movement of wildlife animals and outside commuters which may cause hindrance and ultimately leading to accidents.
- The boundary wall is made of many components such as precast columns and precast panels. The foundation of Column is In-situ.
- The barbed wire fencing is also provided over the top of wall to ensure extra security.

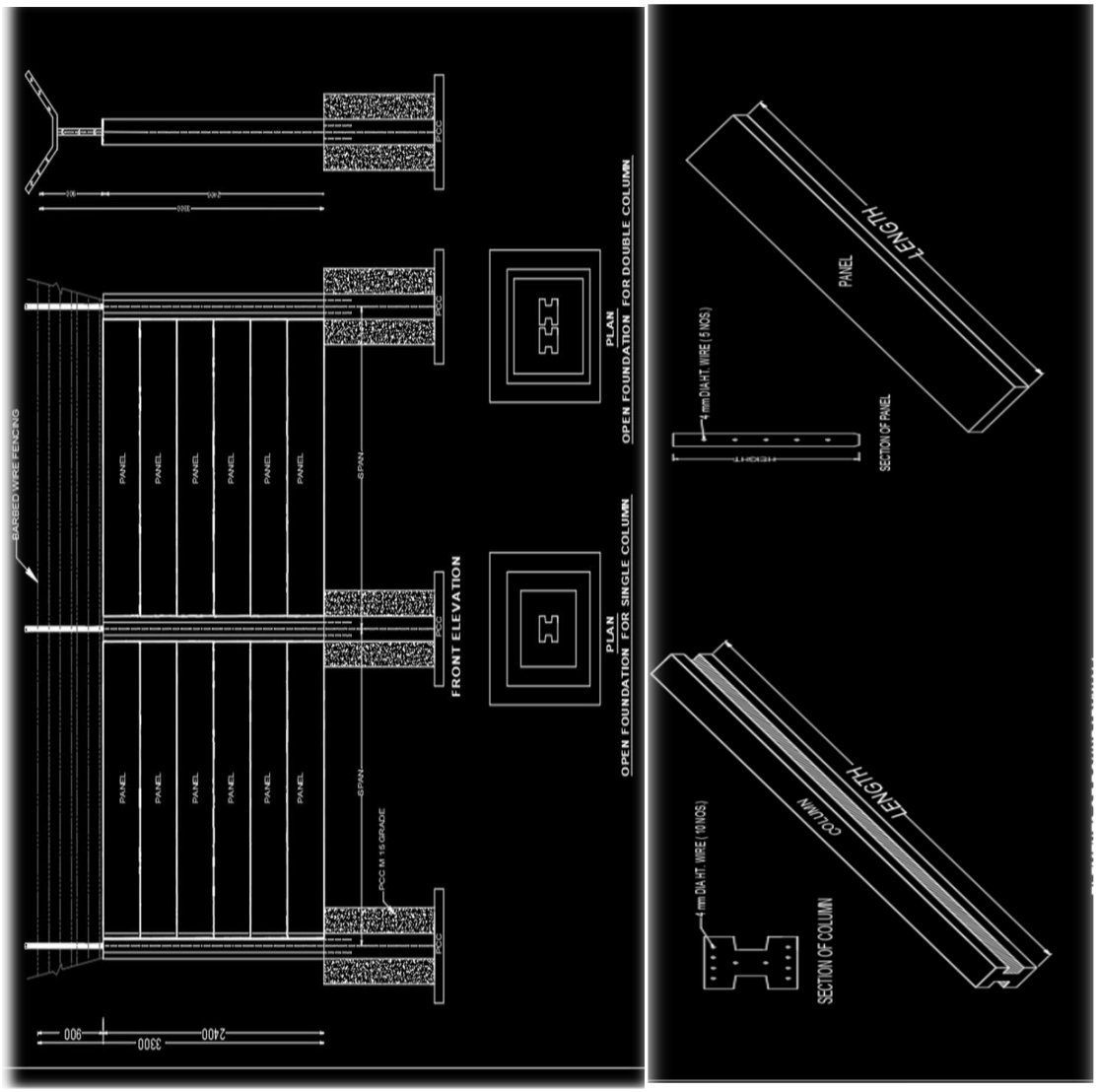

Figure 8: Details of boundary wall

1.16 5D BIM (Building Information Modelling):

1) The BIM, as a whole, refers to the process of all parties involved in the construction and lifecycle management of built assets, working collaboratively and sharing data.
2) The 3D models were prepared of the project in various software and those were integrated on one platform.
3) 5D model stands for :
    a. 1D Line diagrams
    b. 2D Plans, Sections, Elevations etc.
    c. 3D geometric Models
    d. 4D Simulation and Integration of 3D models with Construction management software (MS Project, Primavera etc.).
    e. 5D Quantification of whole projects with respect to assigned attributes.
4) The following software were used for the process:
    a. Revit (For Structures)
    b. Civil 3D (For Highway)
    c. Navisworks (For Integration of structure, highway models and for 4D simulation).

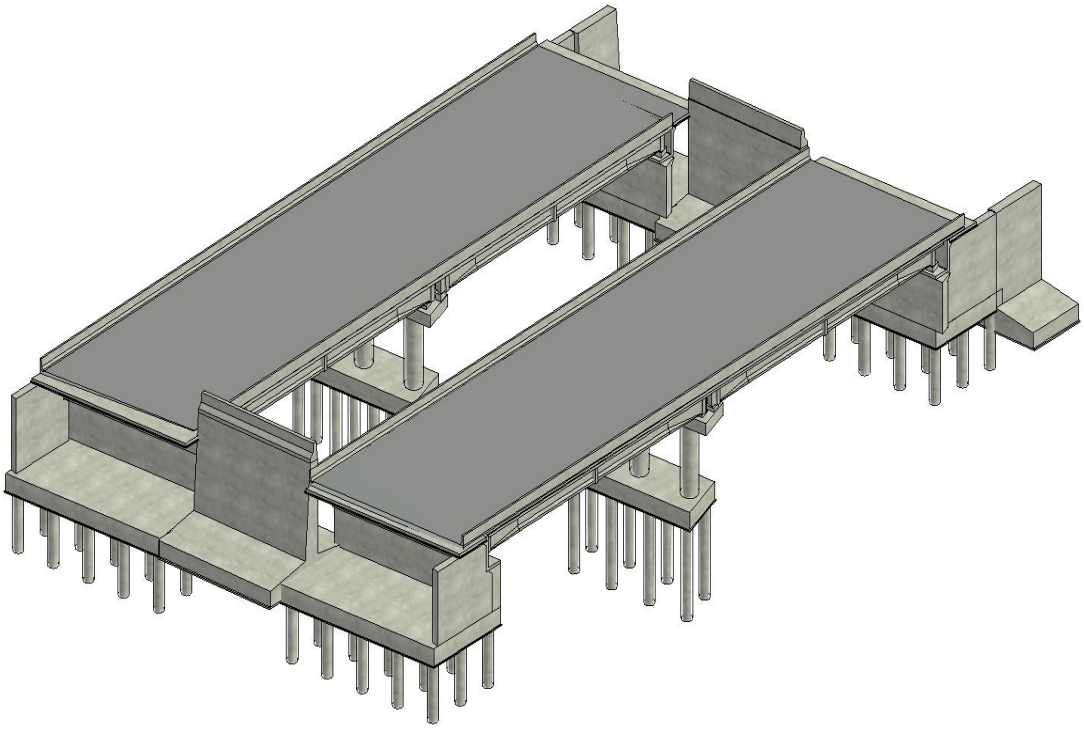

Figure 9:3D Model of structure.

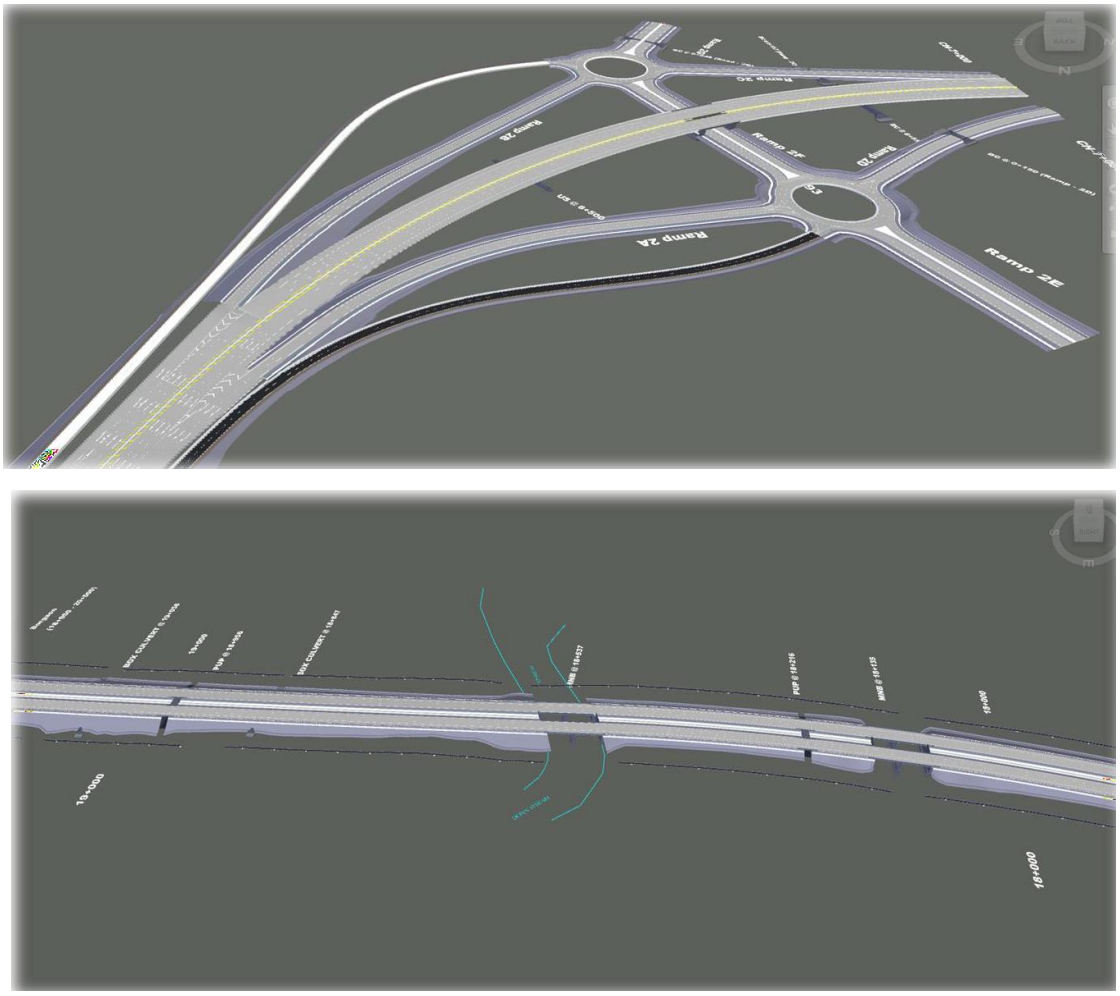

Figure 10: 3D Appended models of Highway and structure

1.17 Future Prospects:

Samruddhi Mahamarg Expressway will be connected by the following upcoming Feeder Highways by MSRDC Department:

1) 141 km Nagpur – Bhandara – Gondia Expressway
2) 152 km Nagpur – Gadchiroli Expressway
3) 760 km Nagpur – Goa Expressway (Shaktipeeth Expressway)
4) 225 km Pune – Aurangabad Expressway
5) 180 km Pune – Nashik Expressway

The above projects will enhance the connectivity and will result into Socio-economic growth of the state of Maharashtra.

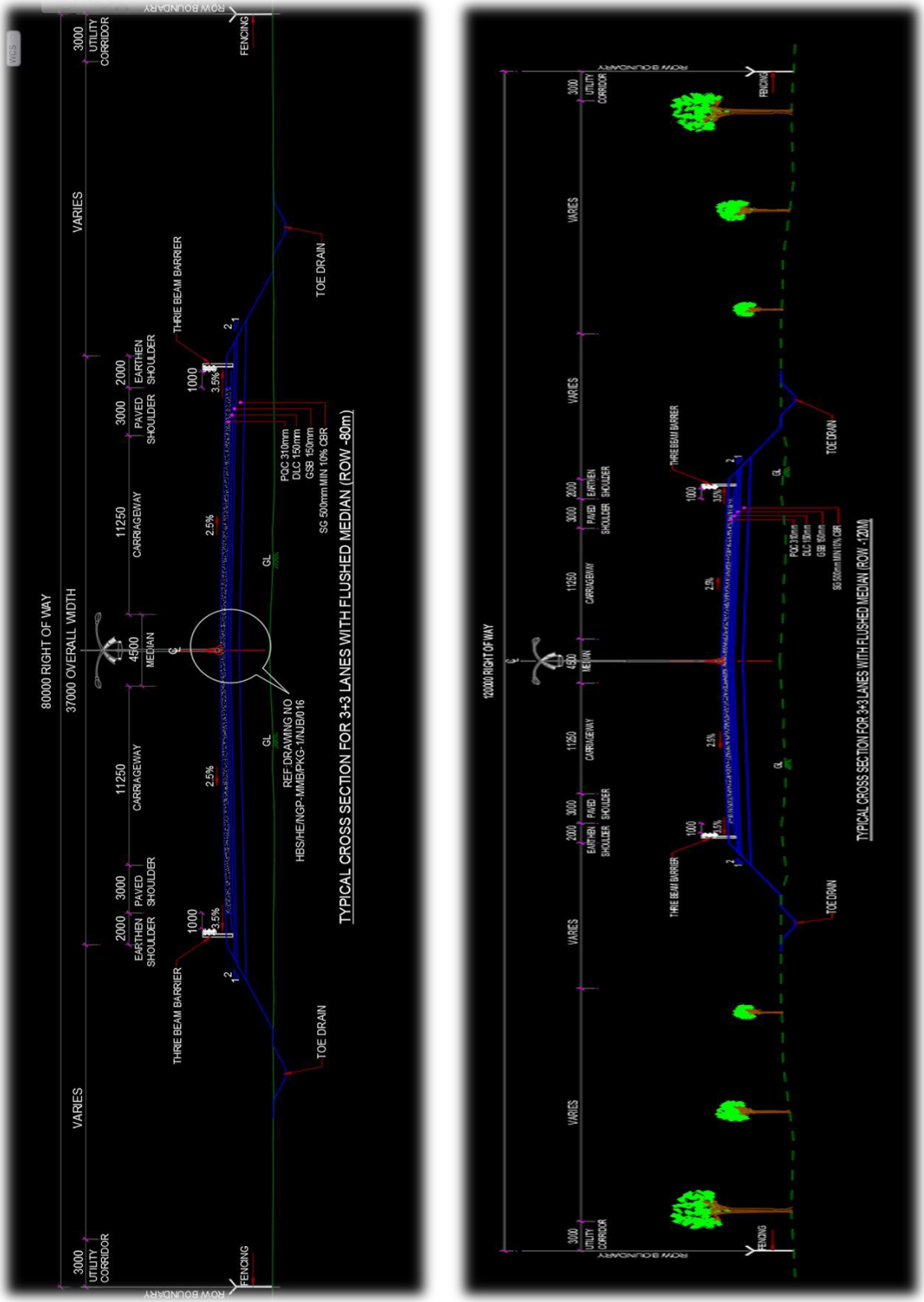

Figure 11: Typical C/s of 3+3 lanes with flushed median

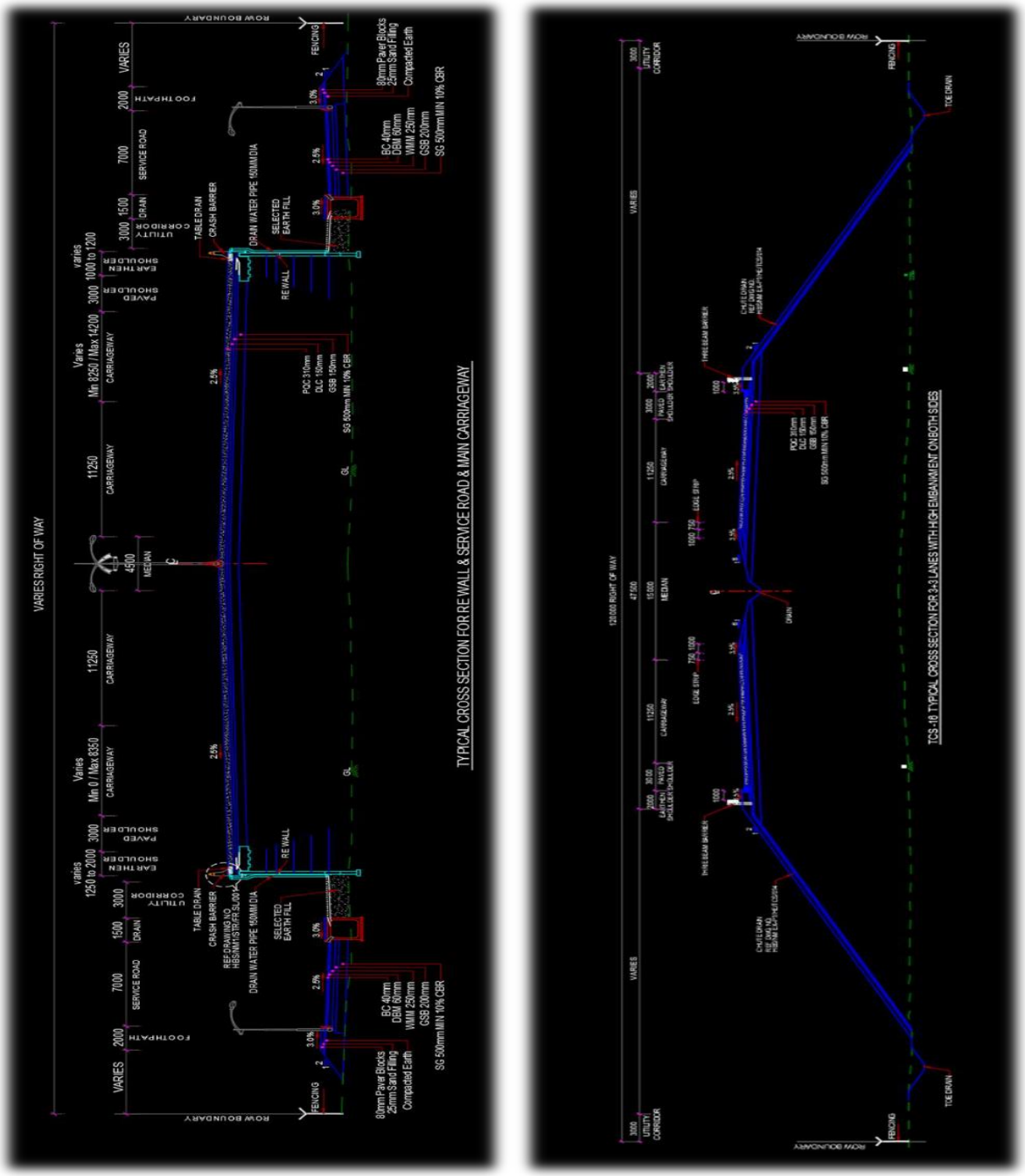

Figure 12: Typical C/s for wall and service road and main carriageway

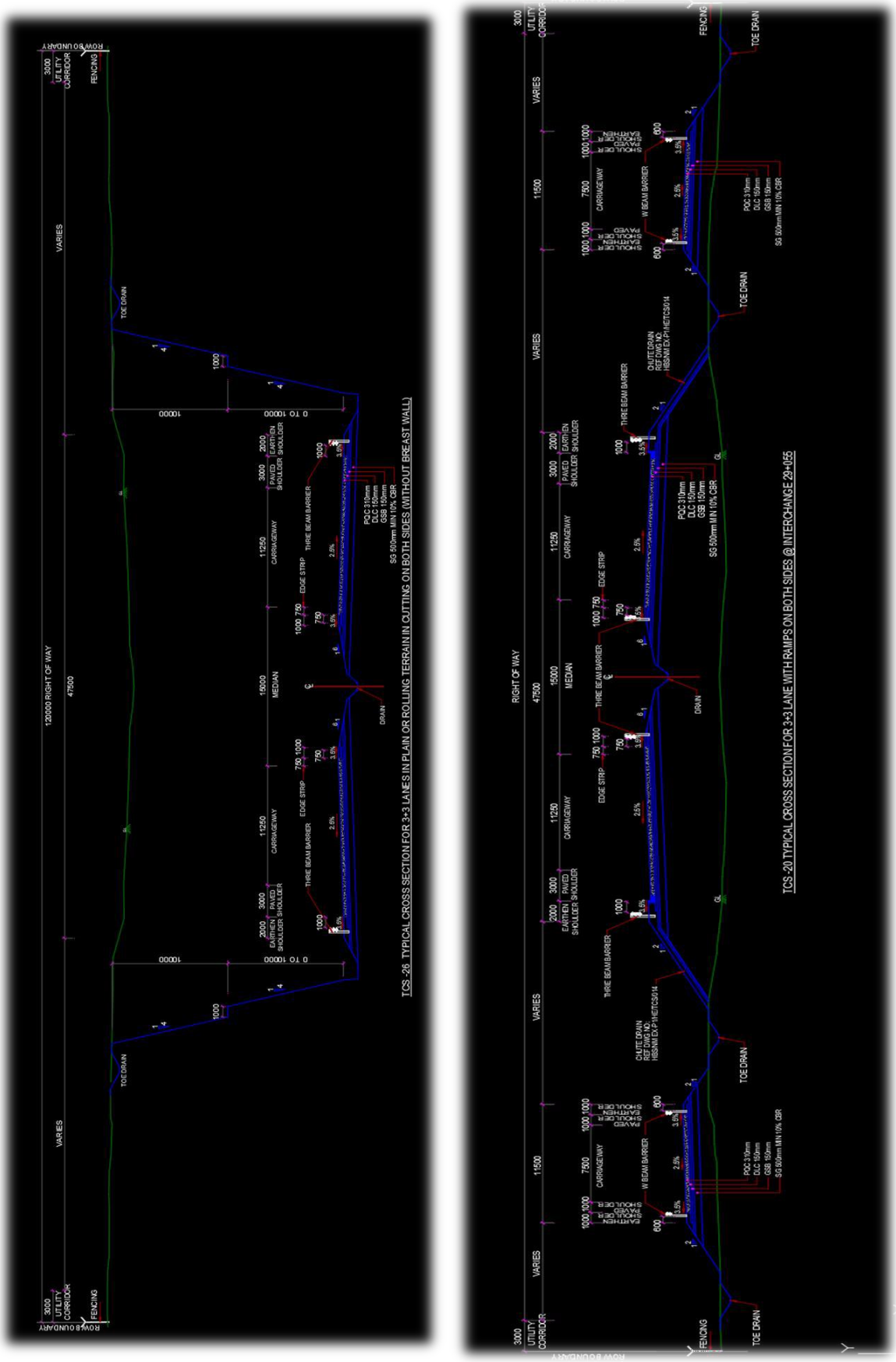

Figure 13: Typical C/s of 3+3 lanes in plain and rolling terrain

2 LITERATURE REVIEW

A road safety audit (RSA) is a systematic and independent review of a road project or an existing road to identify potential road safety issues and provide recommendations for improvements. The purpose of a literature review for RSA is to identify and summarize the existing knowledge and research on RSA, including its benefits, challenges, and best practices.

S SanMithra, N. Naveen, M S Renuka [1] highlighted the issues in safety engineering , along with good and bad maintenance practises for Road safety such as Route signs, Interchange signs, Exit signs, Miscellaneous information signs, and Road markings. The lives Road Users can be saved by self-explanatory and forgiving roads. RSA has been shown to be effective in improving road safety by identifying potential road hazards and providing recommendations for improvements. Several studies have demonstrated that RSA can reduce the number and severity of crashes, injuries, and fatalities on roads. RSA also helps to ensure that road projects meet the required safety standards and regulations, reducing the potential for litigation and liability claims.

Gajanan B Takey et.al [2] have given the Comprehensive Review on Road Safety Audit. RSA can be challenging due to the complexity of road systems and the diverse range of stakeholders involved in road projects. Some of the challenges include limited resources, lack of standardized RSA procedures, and conflicting stakeholder interests. Additionally, the effectiveness of RSA can be limited by the quality of data and the accuracy of crash data analysis.

Abdul Rahoof, Bipin Kumar Singh [3] explained Road safety review is an essential means for giving careful consideration to road safety amid the configuration of road plans. This unequivocal consideration ought to help everybody required in settling on choices with respect to changes to road base to survey the safety ramifications of the numerous decisions that emerge amid the outline procedure, and accordingly build the road safety familiarity with base organizers, fashioners and powers.

A road safety audit is an important process used to evaluate the safety of roads, particularly during the design and planning stages. A literature review on road safety audit would involve examining existing research on this topic to identify trends,

challenges, and opportunities for improving the effectiveness of road safety audits. Here are some key findings from the literature review on road safety audits:

1. Importance of road safety audits: Several studies have emphasized the importance of road safety audits in reducing traffic accidents and fatalities. Road safety audits can identify potential hazards, assess risk, and propose solutions to improve road safety.

2. Types of road safety audits: The literature identifies several types of road safety audits, including desktop audits, site inspections, and post-construction audits. Each type has its strengths and weaknesses, and the choice of audit type depends on the project stage and scope.

3. Factors affecting road safety audits: The effectiveness of road safety audits can be influenced by several factors, such as the qualifications and experience of the auditors, the availability of data, the level of stakeholder involvement, and the legal framework in place.

4. Challenges facing road safety audits: Some of the challenges facing road safety audits include limited funding, lack of awareness among stakeholders, inadequate data, and difficulty in quantifying the benefits of road safety audits.

5. Best practices for road safety audits: The literature suggests several best practices for conducting road safety audits, including using a multidisciplinary team, involving stakeholders, using standardized audit protocols, conducting audits at different stages of the project, and incorporating the results of audits into the design and planning process.

2.1 Effectiveness of RSA in Reducing Road Accidents

Road safety audits are an effective method of reducing accidents and improving road safety. The audit process involves a comprehensive review of existing and planned road infrastructure to identify potential hazards and risks and suggest appropriate countermeasures to improve safety. Here are some of the ways road safety audits can be effective:

1. Identifying Potential Safety Issues: Road safety audits help identify potential safety issues before they become accidents. By evaluating road infrastructure against

established safety standards and guidelines, auditors can identify areas where improvements are needed to reduce the risk of accidents.

2. Prioritizing Safety Improvements: Road safety audits help prioritize safety improvements based on their potential impact on reducing accidents. Auditors can use crash data and other relevant information to identify areas of the road infrastructure where safety improvements are most needed.

3. Enhancing Road User Awareness: Road safety audits can help enhance road user awareness of potential safety issues. By identifying and addressing hazards and risks, road users become more aware of the need to exercise caution and follow traffic rules.

4. Improving Road Infrastructure: Road safety audits help improve road infrastructure to make it safer for all road users. By suggesting appropriate countermeasures, auditors can improve road geometry, traffic control devices, road surface condition, and other aspects of the road infrastructure to reduce the risk of accidents.

Overall, road safety audits are an effective method of reducing accidents and improving road safety. By identifying potential safety issues, prioritizing safety improvements, enhancing road user awareness, and improving road infrastructure, road safety audits help ensure that roads are designed and maintained to maximize safety for all road users.

2.2 Different methods and tools used in road safety audits

Road safety audits are essential procedures used to assess the safety of existing and proposed road infrastructure projects. They help identify potential safety risks and hazards and recommend measures to improve road safety. The following are some of the methods and tools used in road safety audits:

1. Site inspection: The inspection involves an on-site examination of the roadway, infrastructure, and surroundings to identify existing and potential safety issues. This is usually done by a team of experts, including engineers, planners, and safety professionals.

2. Traffic analysis: Traffic analysis is an essential tool used in road safety audits. It involves analyzing traffic flow, volumes, and patterns to identify potential safety issues.

3. Crash analysis: Crash analysis involves studying past crashes on the roadway to identify patterns, causes, and contributing factors to accidents. This information can be used to recommend measures to prevent similar accidents in the future.

4. Safety performance functions: Safety performance functions are mathematical models that predict the number of crashes expected on a roadway based on traffic flow and other variables. These models are used to identify potential safety issues and recommend measures to reduce the likelihood of crashes.

5. Geometric design standards: Geometric design standards are used to assess the alignment, sight distance, and other geometric features of the roadway. The standards are used to identify potential safety issues and recommend measures to improve safety.

6. Simulation tools: Simulation tools are used to evaluate the impact of proposed roadway changes on traffic flow and safety. The tools can predict the impact of changes in traffic volumes, speed limits, and other factors on safety.

7. Expert judgment: Expert judgment is used to evaluate the potential safety risks associated with proposed roadway changes. Experts may use their experience, knowledge of best practices, and other factors to evaluate the safety impact of proposed changes.

Overall, a combination of these methods and tools is used in road safety audits to evaluate the safety of existing and proposed road infrastructure projects and recommend measures to improve safety.

2.3 Summary of Literature Review:

RSA is a vital tool for reducing traffic accidents and fatalities. However, several challenges must be addressed to ensure the effectiveness of RSA, including improving data collection and analysis, increasing stakeholder engagement, and promoting the use of best practices. The literature review highlights the importance of using a multidisciplinary team, involving stakeholders, using standardized audit protocols,

conducting audits at different stages of the project, and incorporating the results of audits into the design and planning process. Overall, this paper provides valuable insights for researchers, policymakers, and practitioners seeking to enhance the effectiveness of RSA.

3 METHODOLOGY:

3.1 The appropriate methodology for conducting a road safety audit:

Here is a basic flow chart for a road safety audit process:

Figure 14: Flow chart of Methodology

- **Site Visit:** The audit process begins with a site visit to physically inspect the road infrastructure, including road geometry, traffic control devices, road surface condition, and adjacent land use.
- **Data Collection:** Data collection involves gathering and analyzing a wide range of data, including traffic volume and speed, crash history, road user behavior, and land use.
- **Risk Assessment:** A quantitative and qualitative method of assessing the potential hazards and risks associated with the road infrastructure is conducted.
- **Identify Potential Safety Issues:** Based on the risk assessment, potential safety issues are identified, such as high-speed areas, sharp curves, poor lighting, and inadequate signage.
- **Prioritize Safety Improvements:** The safety issues identified are then prioritized based on their potential impact on reducing accidents.

- **Develop Countermeasures:** Appropriate countermeasures are developed to address the prioritized safety issues, such as speed reduction measures, intersection improvements, or better lighting.
- **Implement Countermeasures:** The countermeasures are implemented, such as installing new signs, pavement markings, or traffic signals.
- **Monitor and Evaluate:** The effectiveness of the implemented countermeasures is monitored and evaluated to ensure they are achieving the desired safety outcomes.
- **Repeat the Process:** The audit process is repeated regularly to ensure that the road infrastructure continues to meet safety standards and guidelines.

This flow chart provides a basic overview of the road safety audit process. The actual process may vary depending on the scope and complexity of the audit.

3.2 Establish the audit team:

The first step was to establish a team of professionals with relevant expertise and experience in road safety, including engineers, planners, and traffic safety specialists.

For the purpose of gathering information for a road audit safety study on the Hindu Hrudaysamrat Balasaheb Thakare Maharashtra Samruddhi Mahamarg over a 95.7 km stretch. Students from Visvesvaraya National Institute of Technology in Nagpur who were doing their MTech in Transportation Engineering made up the team. The names are as follows: G.B. Takey was the guide for Ayush M. Dudhabaware, Prajwal M. Madghe, Pratik A. Gajallewar, and Vinay C. Rajput.

3.3 Objectives of the Audit:

The application of safety principles, the improvement and upkeep of roads as a means of accident prevention, and making sure that road users would be exposed to the least amount of danger of accidents on existing roads are the main goals of these studies.

These study specific goals are as follows:

- Determining and evaluating potential risks and dangers related to the layout of the road, the movement of the traffic, and the surrounding area.
- Analysing the efficiency of the current traffic control devices, markings, and signage for an expressway.

- Providing suggestions for enhancing the road infrastructure to lower the likelihood of accidents and injuries.
- Increasing public trust in the safety of the road system, which may result in more utilization and financial gains.
- Seeing potential risks and hazards to everyone using the expressway.
- Analysing the road design's safety performance and pinpointing any flaws or potential improvement areas.
- Finding opportunities to include safety features and procedures, such as traffic calming measures, and better lighting.
- Making recommendations to enhance road safety and lessen the chance and severity of incidents.
- Assessing the performance of current traffic safety measures and offering suggestions for enhancements.

3.4 Road safety parameters to be analysed

There are several parameters related to road safety that can be analyzed to understand and improve the safety of a particular road or transportation system. Some of these parameters include:

1. **Speed limits:** Speed limits are crucial in maintaining road safety. Higher speeds result in more severe accidents, as they increase the distance required to stop and reduce the reaction time of drivers. Analysing the current speed limits and identifying areas where speed limits need to be adjusted is important
2. **Accident frequency:** This refers to the number of accidents that occur on a particular road or transportation system within a given time period. By analyzing accident frequency, we can identify areas of the road where accidents are more likely to occur and take measures to reduce the risk.
3. **Accident severity:** This refers to the severity of injuries or damage caused by accidents. By analyzing accident severity, we can identify the types of accidents that are most dangerous and take measures to reduce their occurrence.

4. **Traffic volume:** This refers to the amount of traffic that uses a particular road or transportation system. By analyzing traffic volume, we can identify areas where congestion is most likely to occur, which can increase the risk of accidents.
5. **Road geometry:** This refers to the design of the road, including the number of lanes, curvature, and slope. By analyzing road geometry, we can identify areas where the road design may increase the risk of accidents and take measures to improve safety.
6. **Weather conditions:** This refers to the weather conditions that may impact road safety, such as rain, snow, or fog. By analyzing weather conditions, we can identify areas where weather-related accidents are more likely to occur and take measures to reduce the risk.
7. **Driver behaviour:** This refers to the behaviour of drivers on the road, such as speeding, distracted driving, or driving under the influence of drugs or alcohol. By analyzing driver behaviour, we can identify areas where risky driving behaviour is most common and take measures to improve safety.
8. **Road condition:** This refers to the condition of the road surface, including potholes, cracks, and bumps. By analyzing road condition, we can identify areas where the road surface may increase the risk of accidents and take measures to improve safety.
9. **Road signage and markings:** Proper road signage and markings can help to reduce the risk of accidents by providing drivers with clear and concise information about the road ahead.
10. **Emergency response:** Effective emergency response is essential in the event of a road accident. Analyzing response times and identifying areas where improvements can be made is important in reducing the severity of accidents.
11. **Vehicle maintenance:** Regular maintenance of vehicles can help to ensure that they are in good working order and reduce the risk of accidents caused by mechanical failures.

These are just a few of the parameters that can be analyzed to improve road safety. By identifying and addressing these factors, we can work towards creating safer roads and reducing the number of accidents on our roads.

4 DATA COLLECTION:

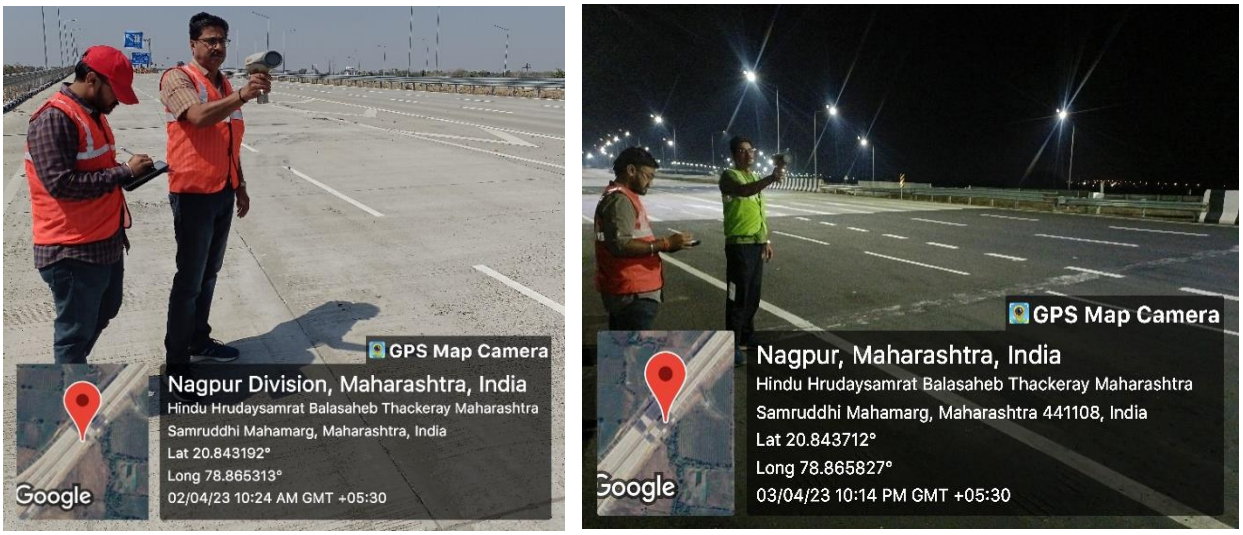

Figure 15: Spot speed data collection at day and night

4.1 Spot Speed Study:

A technique for determining the speed of vehicles in a single area on a road is called a spot speed study. This kind of study is often carried out to gather information on the average speeds of moving vehicles, which may be used to evaluate the effectiveness and safety of the road and guide traffic management decisions.

The general procedures for carrying out a spot speed investigation are as follows:

- **Site Location:** at very interchange spot speed survey at carried out, first at chainage (28+006) second at chainage (42+300), and third at interchange 03 (IC-03), the spot speed study was performed so to get an idea of what speed the vehicles are travelling, more than the site location also consists of a curve as well as an exit point known as IC-02 so as being the exit and curve ahead the speed of

the vehicles should in the given speed limit range. The speed limit that is allocated for the Samruddhi Mahamarg by the MSRDC is as follows: Car: HCV/LCV:

- **Sample Size:** The sample taken for the spot speed study was 200 vehicles at every location taken to determine then the speed of the vehicles.
- **Choose the measurement tool:** Radar guns, LIDAR devices, and speed cameras are some examples of measurement tools that can be used for a spot speed study. A gadget should be chosen based on aspects including accuracy, affordability, and usability, for our studies we used Radar guns.
- **Radar Guns:** Radar guns are handheld or vehicle-mounted devices that use radio waves to measure the speed of a moving vehicle. The device emits a high-frequency radio wave, which is reflected in the device after bouncing off the vehicle. By measuring the time, it takes for the wave to travel to the vehicle and back, the device can calculate the speed of the vehicle. Radar guns can be used to measure the speed of vehicles travelling in both directions, but they are typically most accurate when used to measure the speed of vehicles approaching the device in a straight line. The accuracy of the device can be affected by factors such as the distance between the device and the vehicle, the angle of the vehicle relative to the device, and the presence of other objects in the vicinity of the vehicle. As a result, radar guns are typically calibrated and tested regularly to ensure accuracy.
- **Conduct the measurements:** The measurements are typically taken over a period of time, during which the device is aimed at passing vehicles to measure their speed. At every Location 2 hrs data has been taken and surveyed to determine the spot speed study.

Table 2: Spot speed data

Speed of Vehicles (km/hr)			
	Type of Vehicles		
Sr.no	Car	HCV	LCV
1	127	46	78
2	118	86	81
3	134	73	87
4	85	77	84
5	92	55	86
6	107	47	84
7	104	61	71
8	126	88	88

9	92	50	88
10	110	49	85
11	121	50	68
12	106	64	78
13	88	56	70
14	116	63	77
15	131	46	85
16	92	62	89
17	99	82	83
18	104	70	70
19	88	78	81
20	93	86	76
21	96	48	73
22	127	74	77
23	117	84	66
24	106	61	85
25	91	49	89
26	121	72	90
27	88	75	66
28	105	86	69
29	99	64	90
30	99	88	83
31	120	85	66
32	110	76	75
33	111	55	68
34	132	74	74
35	91	48	70
36	130	88	85
37	122	79	82
38	114	72	68
39	134	73	77
40	119	55	79
41	116	51	75
42	102	59	75
43	120	57	78
44	133	74	83
45	122	48	83
46	122	86	80
47	126	54	81
48	95	62	85
49	118	69	81
50	94	63	78
51	133	76	75
52	131	73	86
53	118	56	65

54	131	86	81
55	116	87	82
56	95	83	73
57	102	72	70
58	106	50	87
59	98	86	73
60	110	56	73
61	114	55	68
62	96	83	66
63	134	74	79
64	99	87	71
65	98	90	90
66	106	66	
67	133	58	
68	134	45	
69	116	49	
70	120	61	
71	131	66	
72	106	71	
73	112	48	
74	121	84	
75	97	50	
76	93	54	
77	129	51	
78	89	58	
79	131	72	
80	118	69	
81	119	71	
82	122	75	
83	107	68	
84	106	57	
85	131	75	
86	89	60	
87	119	50	
88	120	67	
89	124	59	
90	129	81	
91	103	74	
92	131	60	
93	116	63	
94	112	58	
95	122	70	
96	111	50	
97	114	58	
98	109	45	

99	107	72	
100	102	80	
101	126	71	
102	100	75	
103	92	57	
104	89	89	
105	122	68	
106	85	48	
107	111	53	
108	123	59	
109	127	90	
110	90	75	
111	105	64	
112	86	45	
113	99	73	
114	96	46	
115	89	74	
116	134	69	
117	119	67	
118	130	58	
119	88	89	
120	99	61	
121	120	45	
122	87	69	
123	85	77	
124	132	71	
125	110	50	
126	111	45	
127	130	50	
128	131	90	
129	131	61	
130	87	48	
131	123	70	
132	96	67	
133	95	87	
134	134	64	
135	115	66	
136	104	62	
137	114	72	
138	108	58	
139	86	67	
140	123	66	
141	86	88	
142	116	88	
143	106	66	

144	94	63	
145	105	74	
146	126	68	
147	113	70	
148	111	84	
149	103	49	
150	88	70	
151	113	46	
152	122	88	
153	94	62	
154	88	69	
155	103	83	
156	87	54	
157	133	81	
158	92	90	
159	102	87	
160	131	80	
161	93	53	
162	101	76	
163	93	52	
164	88	61	
165	131	84	
166	115	64	
167	97	56	
168	103	59	
169	93	57	
170	96	49	
171	104	68	
172	134	80	
173	134	85	
174	124	67	
175	107	56	
176	95	55	
177	132	53	
178	128	46	
179	90	46	
180	122	49	
181	88	67	
182	107	72	
183	134	45	
184	120	66	
185	123	51	
186	134	57	
187	113	68	
188	131	86	

189	102	82	
190	99	84	
191	94	51	
192	97	78	
193	105	68	
194	115	78	
195	99	82	
196	112	48	
197	114	85	
198	98	90	
199	125	45	
200	85	87	

- Total Count of Cars: 200
- Total Count of HCVs: 200
- Total Count of LCVs: 65
- Count of Cars whose speed is greater than 120 km /hr = 60
- Count of HCVs whose speed is greater than 80 km/hr = 41
- Count of LCVs whose speed is greater than 80 km/hr = 29

4.2 Data Analysis:

Once the measurements are completed, the data has been analysed to calculate key metrics of Vehicles exceeding their maximum speed limit. These metrics can be used to assess the prevailing speed behaviour and identify trends.

- Total Count of Cars: 200
- Total Count of HCVs: 200
- Total Count of LCVs: 65
- Count of Cars whose speed is greater than 120 km /hr = 60
- Count of HCVs whose speed is greater than 80 km/hr = 41
- Count of LCVs whose speed is greater than 80 km/hr = 29

	Cars	HCVs	LCVs
Total Count of vehicles	200	200	65
Exceeding their Max. Speed	60	40	41

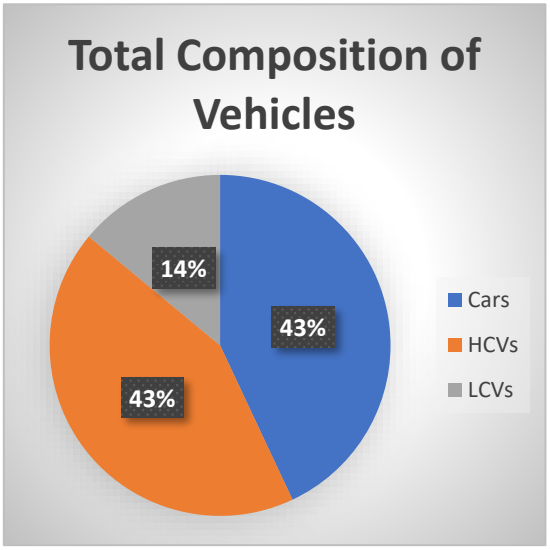

Figure 16: Total Composition of Vehicles

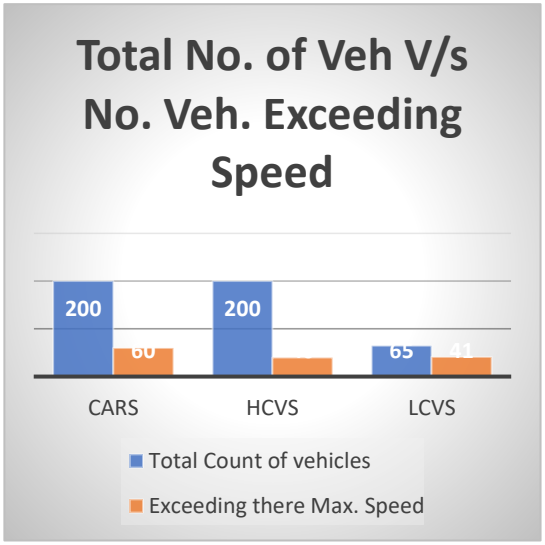

Figure 17: Total No. of Veh. V/S Veh. Exceeding speed

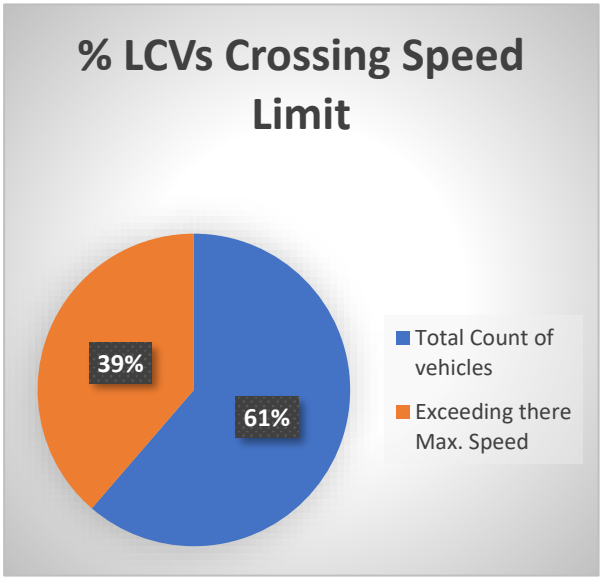

Figure 19: % LCVs Crossing Speed Limit

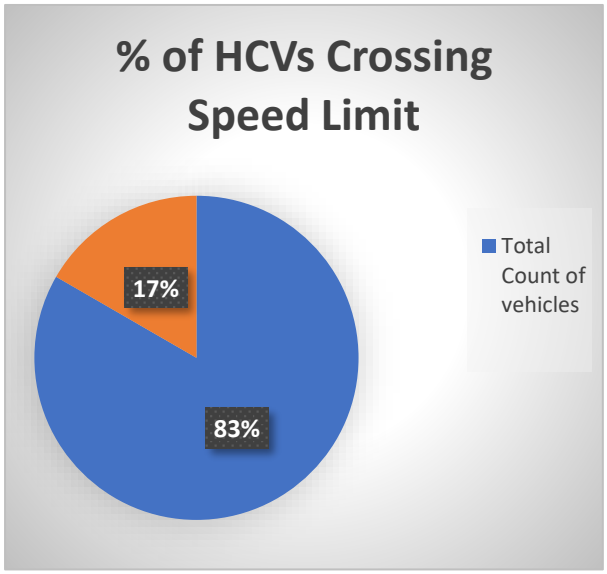

Figure 18: % of HCVs Crossing Speed Limit

4.3 Questionnaire Survey

A survey that uses a standardized set of questions to collect data is known as a questionnaire survey. It is a kind of survey in which participants are requested to provide information on their thoughts, deeds, attitudes, convictions, or experiences on a certain subject or region of interest.

The questionnaire can be utilized in a variety of sectors, including social sciences, marketing, health, and education. It is often delivered via a variety of means, including online, mail, telephone, or in-person. The information gathered from the questionnaire survey can be utilized to guide decision-making by being evaluated to learn more about the perceptions, attitudes, and actions of the respondents.

A questionnaire survey was administered during day and night time for this investigation. The following is a list of the questions asked to drivers and passengers:

- Did the driver feel that the journey was tiresome and monotonous?
- Did they have trouble in their vision at night because of the glare of light from cars coming from the other side?
- Could you see the sign boards clearly?
- Were messages displayed on sign boards clear to read?
- How convenient was their trip?
- Do you they any suggestions to enhance the driving experience?

At the IC-06 toll plaza, a questionnaire survey was also conducted with an RTO officer, and the question asked was as follows:

- What are the main challenges that users of this expressway face?
- What were the accident's primary causes?
- What time of day did the majority of accidents occur?
- How do they uphold the law and order?
- What conditions or knowledge must a road user have in order to operate a vehicle on this expressway?
- What steps can be taken to improve road users' safety?

Figure 20: Questionnaire survey with RTO Officers

4.4 Road Inventory Survey

A road inventory survey is a methodical procedure for gathering comprehensive data regarding the structural and functional elements of a road network. The survey entails a thorough analysis of the road infrastructure, including the quality of the pavement, the drainage system, the signage, and other elements.

The road inventory survey's major goal is to obtain precise information that may be utilized to create maintenance schedules that are effective and to decide on future road construction projects. Depending on the scale and complexity of the road network, the survey can be carried out using a variety of techniques, including manual inspections, mobile mapping systems, or remote sensing technology.

In this study, a road inventory survey is conducted using a manual inspection technique. The following observations were made:

- Examining the pavement surface for any significant deterioration or damage of any kind.
- Verifying that sign boards are clearly visible for a vehicle moving at the permitted speed.
- If adequate drainage is offered.
- Accessibility to various roadside amenities like gas stations, garages, entertainment areas, restrooms, hotels, and restaurants.
- The state of the sign boards.

Figure 21: Examining the pavement surface and road markings

4.4.1 Checklist for Safety Audit of Existing Roads as per IRC: SP: 88-2019

Table 3: Checklist of Safety Audit

Issue	Yes	No	NA	Comments
1. Sight Distances				
Are all sight distances adequate for the speed of traffic using this road?	✓			
Are safe overtaking opportunities provided?	✓			
Are U turn provisions conspicuous and "safe"?	✓			
2. Intersections				
Are all intersections clear and visible?			✓	
Are all traffic signals conspicuous, functioning properly and safely?			✓	
Are roundabouts visible and recognisable from all approaches?			✓	
3. Interchange				

Are sight lines open and free of obstruction at all merges and diverges?	✓			
Are the distances between decision-making points sufficient for safety at the operating speed?	✓			
Is the direction sign for each interchange clear and easily understood at the operating speed?	✓			
4. Cross Sections				
Are lane widths, shoulder widths and bridge widths, "safe" for the traffic volume and mix?	✓			
Are medians and islands of adequate width for the safety of likely users?	✓			
Are the shoulders suitable for use by all vehicles and road users, including pedestrians, cyclists and animals?	✓			
Issue	**Yes**	**No**	**NA**	**Comments**
Is appropriate super elevation and extra width of carriageway provided on curves?	✓			
5. Roadside Hazards				
Are all larger (more than 100mm diameter) sign supports located outside the clear zone if they are not frangible?	✓			
Are all crash barriers correctly and safely installed?	✓			
Are any hazards within the agreed clear zone for this road?		✓		
Are crash barriers used only where necessary?	✓			
Are impact attenuators provided in gore area?	✓			Moreover, impact attenuators ought to be installed on the median side, particularly on

				bridge approaches.
Are all the crash barriers correctly installed?	✓			
6. Drainage				
Is the road well drained?	✓			Dust has clogged the drains on bridges due to lack of routine maintenance.
Are all drains outside the clear zone, covered, or behind suitable barrier?	✓			
Issue	**Yes**	**No**	**NA**	**Comments**
7. Signs, Pavement Markings and Delineation				
Do all signs and pavement markings satisfy the 6C's of good signage and pavement marking practice?	✓			
Are road signs and road markings tested for retro-reflectivity and conforming to relevant IRC standards?	✓			Some sign boards need to be replaced.
Is the road well delineated (warning signs, plastic guide posts, chevron alignment markers) installed as necessary and spaced in accordance with installation guidelines?	✓			
Is there a need for more signs to warn, inform, guide, control or delineate?	✓			• Sign boards indicating the minimum speed restriction

				must be fitted. • Sign board indicating the Speed limit lane-wise must be installed. • The need for more installation of animal crossing sign boards.
Is the speed zone "safe", and clearly signed?			✓	
Issue	**Yes**	**No**	**NA**	**Comments**
Are pavement markings conspicuous and continuous?	✓			
8. Vulnerable Road Users (pedestrians, bicyclists, two wheelers and three wheelers, and animal drawn carts)				
Do all vulnerable road users have connectivity along the road, with suitable lateral clearance to motor traffic?			✓	
Are pedestrians (particularly the young, old and disabled) able to safely walk along the road?			✓	
Is the road free of "squeeze" points where vulnerable road users are exposed to nearby moving traffic?			✓	
Are pedestrians (particularly the young, old and disabled) able to safely cross the road?			✓	

Are dropped kerbs provided at all intersections and mid-block locations where pedestrians are to cross?			✓	
Is the number and placement of the pedestrian facilities adequate and safe for the situation and the pedestrian numbers?			✓	
Are all the formal crossings clearly marked and conspicuous on each approach?			✓	
Are the correct signs and pavement markings installed at each pedestrian facility?			✓	
Is each crossing facility well illuminated at night so that pedestrians can be seen by drivers/riders?			✓	
Do all mid-block traffic signals have pedestrian push buttons?			✓	
Issue	**Yes**	**No**	**NA**	**Comments**
Are pedestrian paths provided through medians to permit pedestrians to cross "at road level" and to assist disabled pedestrians?			✓	
Has adequate provision been made for safe parking and stopping by three-wheelers/cycle rickshaws?			✓	
Does the road allow adequate visibility for an approaching driver to see a pedestrian waiting to cross the road?			✓	
Does the road allow adequate visibility funnel for an approaching driver to see a vehicle waiting to cross the carriageway from side road or storage space of median?			✓	
Are bus stops located where passengers will use them?			✓	

Are bus stops well delineated and lit?			✓	
9. Access to Property and Developments				
Are all accesses to/from adjoining properties "safe"?	✓			
10. Lighting and Night Time Issues				
Are the illumination levels of an appropriate standard, consistent with the needs of the location, pedestrian and other factors?	✓			
Are all signs easy to see and read at night?	✓			The letter size on the sign board displaying the emergency contact information should be bigger.
Issue	**Yes**	**No**	**NA**	**Comments**
Are the critical locations (intersections, pedestrian facilities, bus bays, bus stops, truck lay bye, toll plaza, etc) conspicuous at night?	✓			
Is lighting provided on road sections passing through built up areas, service roads, above and below the grade separator, underpass, etc?	✓			
Is the "through route" well signed, line marked and obvious to road users at night?	✓			Place white studs at the road markings designating the lanes.
Is there a need for more signs to warn, inform, guide, control or delineate?	✓			• Sign boards indicating the minimum speed

				restriction must be fitted. • Sign board indicating the Speed limit lane-wise must be installed. • The need for more installation of animal crossing sign boards.
Issue	**Yes**	**No**	**NA**	**Comments**
Are the lighting columns frangible? If not, are they located outside the clear zone	✓			
Is the road free of visual deceit for road users at night?	✓			
Is all lighting adequate and safe?	✓			
Are the lighting columns frangible? If not, are they outside the clear zone?	✓			
Are there any lighting poles in the median (less than 2m wide) unprotected by crash barriers?		✓		
11. General Road Safety Considerations				
Is the road as safe as practical given the local weather conditions (sunrise, sunset, snow, fog, storms, and wind)?	✓			
Is the road surface free of gravel and sand, and with good skid resistance?	✓			

Here, Yes = likely to be satisfactory for safety

No = there are possible safety issues

NA = not applicable

5 Accident Data Study:

An accident data study is a method used to analyse data related to road traffic accidents. The goal of such a study is to identify patterns and trends in accident data that can be used to inform decisions about road safety policies, education, and infrastructure improvements.

The Accident Data has been collected by MSRDC office, which contains data from December to March from day of inauguration

Total accident that has been recorded till now are 237.

Month On Month Accident Data:

Table 4: Monthly Accident Data

month on month accident data	
December	35
January	63
February	72
March	67
Total	237

Data Trends:

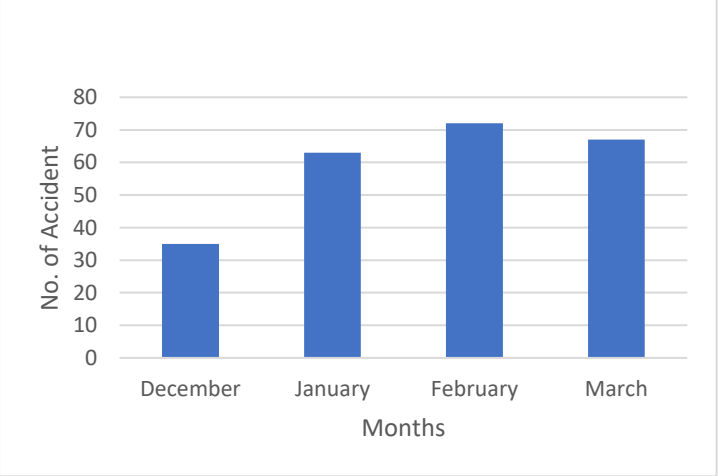

Figure 22: Bar chart of No. of accidents v/s months

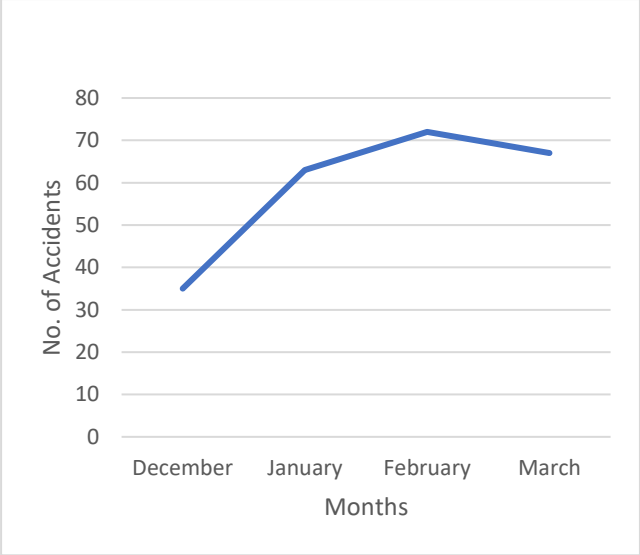

Figure 23: Month on month trend line.

Table 5: Count of accident type

Row Labels	Count of Accident Type
Fire	1
Major	7
Mechanical Failure	105
Minor	104
Out of Fuel	20
Grand Total	237

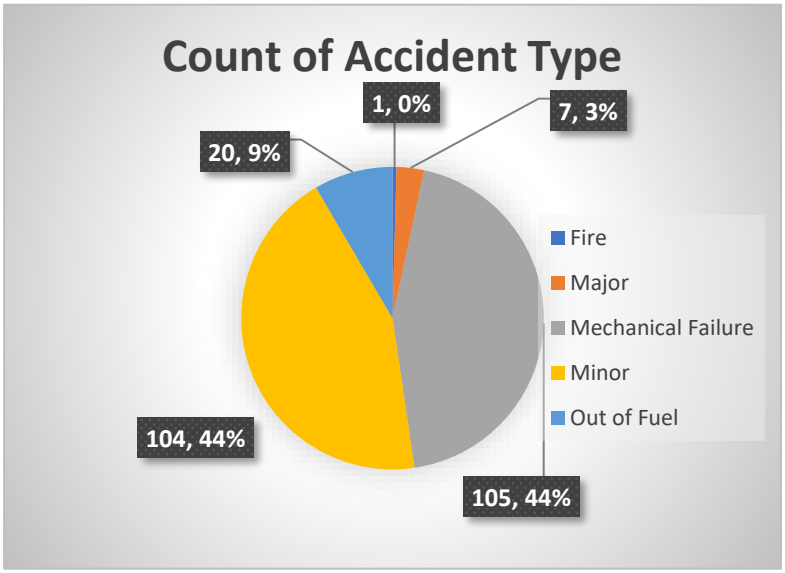

Figure 24: Pie chart for count of accident type

5.1 Accidents caused by animals coming in carriageway:

Road accidents caused by animals are unfortunately quite common, and can result in serious injuries or even fatalities. Some of the most common animals involved in road accidents include deer, moose, elk, and domestic animals like cows and horses.

When an animal suddenly appears on the road, it can be difficult for drivers to avoid a collision, especially if they are driving at high speeds. The impact of the collision can cause significant damage to the vehicle, and in some cases, the animal can be killed or seriously injured as well.

1. **Road accidents:** Animals such as deer, moose, elk, and even domestic animals like cows and horses can cause accidents on the road by running into the path of oncoming vehicles.
2. **Animal attacks:** Wild animals such as bears, cougars, and wolves can attack humans who venture too close to their habitats. Dogs and other domestic animals can also attack people, particularly if they feel threatened or provoked.

5.2 Accidents caused by human error in carriageway:

Unfortunately, accidents brought on by human mistake happen frequently. Human error is the term used to describe mistakes or improper acts carried out by people that can result in mishaps, injuries, or even fatalities. Human error-related mishaps include the following examples:

1. Car accidents caused by distracted driving, speeding, or driving under the influence of drugs or alcohol.
2. Workplace accidents caused by employees failing to follow safety protocols, such as not wearing the required safety equipment or not following proper procedures for handling hazardous materials.
3. Aviation accidents caused by pilot error, such as misinterpreting instructions or making incorrect decisions.

Table 6: No. of accidents caused by human and animals

Cause Of Accident	No. Of Accidents
Human	35
Animal	87
Total	122

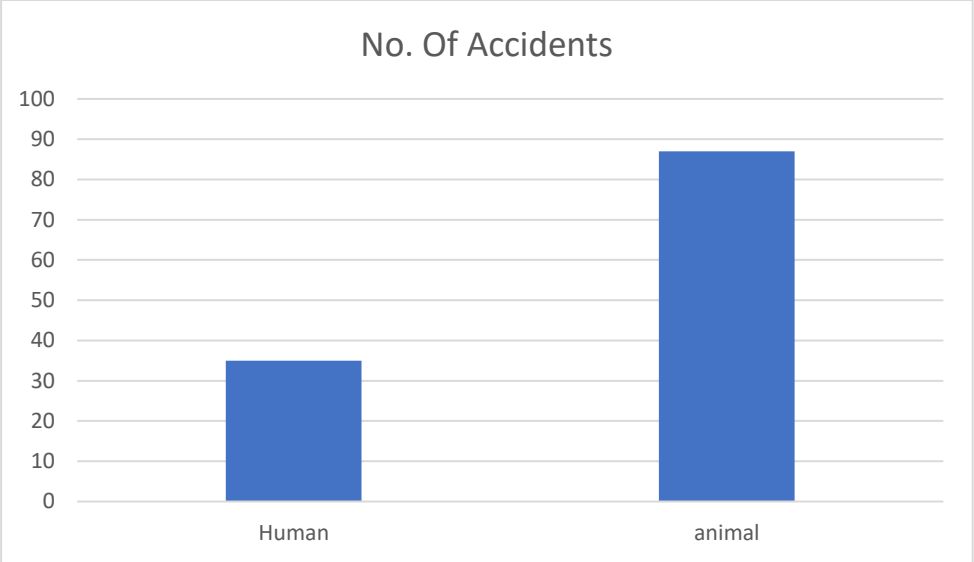

Figure 25: Bar graph of No. of accidents of animal and human

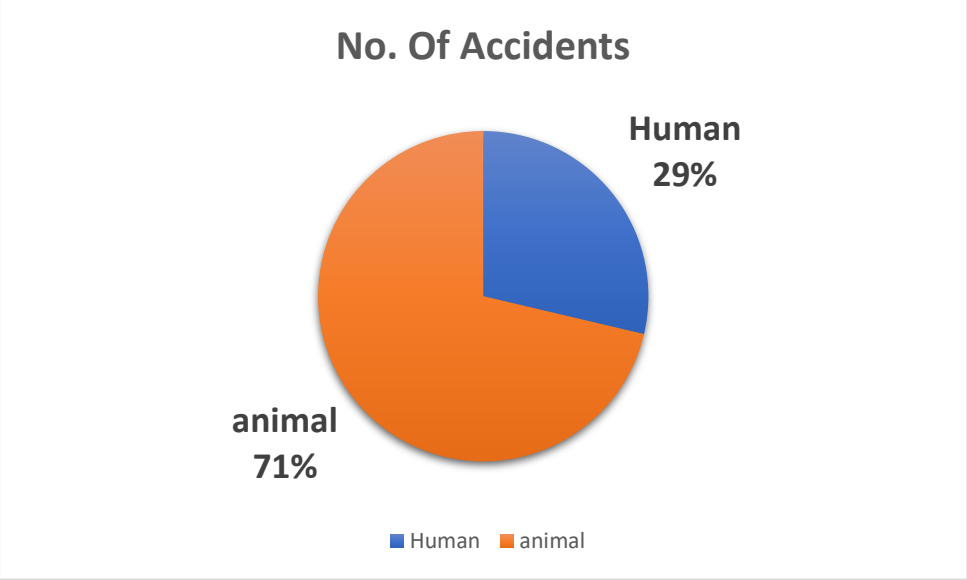

Figure 26: Pie chart of No. of accidents

To determine the accidents probability from which direction vehicles are coming the table shows the bifurcation of direction from which vehicles are moving towards.

Table 7: Count of vehicles in particular direction

Direction	Count of Vehicles
Mumbai	109
Nagpur	128
Grand Total	237

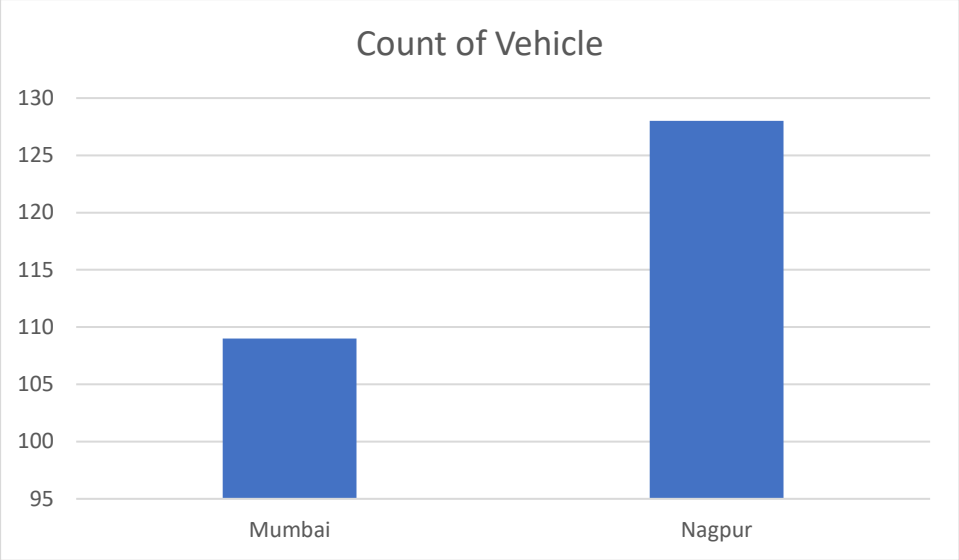

Figure 27: Bar graph of veh. in particular direction

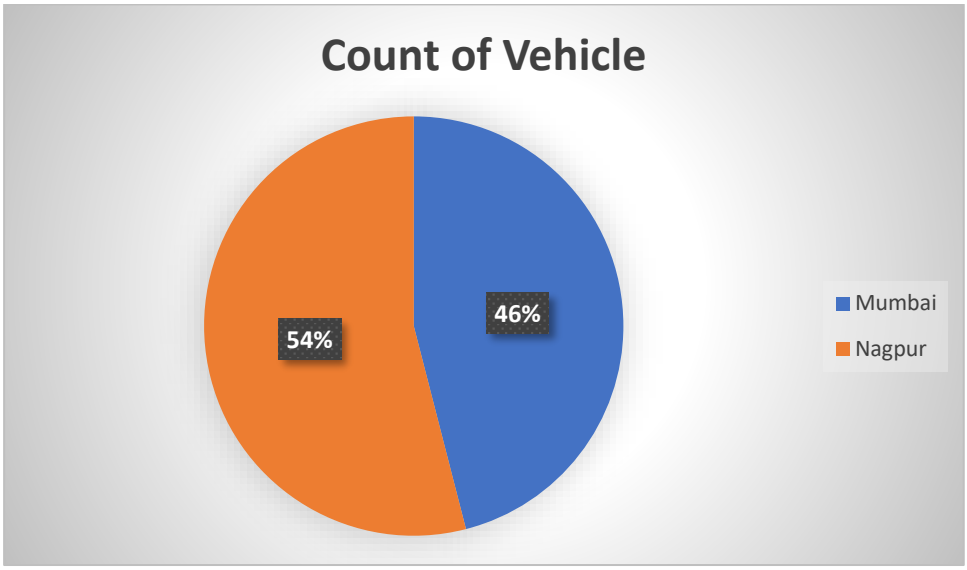

Figure 28: Pie chart of Count of Vehicles in each direction

5.2.1 Lane Discipline:

On a multi-lane road or highway, maintaining lane discipline is the act of driving in the proper lane. It entails observing traffic laws and operating a vehicle in a way that is secure and mindful of other road users.

For a number of reasons, lane discipline is crucial. It primarily contributes to lowering the likelihood of traffic crashes and accidents. Drivers are less likely to collide with other cars or roadside items when they stay in their allotted lane. In addition, maintaining correct lane discipline can aid in enhancing traffic flow and easing congestion on congested highways.

Drivers should always stay in their allotted lane until they need to change lanes to pass another car or get off the highway in order to demonstrate strong lane discipline. Drivers should check their mirrors and blind spots before changing lanes to make sure it is safe to do so. They should also use their turn signals to announce their intentions.

In order to minimize accidents and promote efficient traffic flow, it's also critical to keep a safe following distance from the car in front of you. Finally, vehicles should refrain from swerving across lanes because doing so can be hazardous and disruptive to other motorists.

Overall, maintaining strong lane discipline while driving safely and responsibly is essential. We can all contribute to making the roads safer by abiding by the law of the road and showing consideration for other motorists.

For Lane Discipline Survey we collected sample size of 100 trucks on the current road stretch.

Figure 29: Truck observed violating lane discipline during survey

Data is shown for analysis of lane discipline:

Table 8: Table of analysis of lane discipline

Sr.No	Lane Discipline
1	Not Following
2	Following
3	Not Following
4	Following
5	Following
6	Following
7	Following
8	Not Following
9	Not Following
10	Following
11	Not Following
12	Not Following
13	Following
14	Not Following
15	Not Following
16	Not Following
17	Not Following
18	Not Following
19	Following
20	Not Following
21	Following
22	Following
23	Following
24	Not Following
25	Following
26	Following
27	Not Following
28	Following
29	Following
30	Not Following
31	Following
32	Following
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34	Following
35	Not Following
36	Following
37	Not Following
38	Following
39	Not Following
40	Following
41	Following
42	Not Following
43	Not Following
44	Not Following
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66	Following
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68	Following
69	Following
70	Not Following
71	Not Following
72	Not Following
73	Following
74	Not Following
75	Not Following
76	Not Following
77	Following
78	Following
79	Following
80	Not Following

81	Following
82	Not Following
83	Not Following
84	Following
85	Following
86	Following
87	Not Following
88	Following
89	Following
90	Following

91	Following
92	Not Following
93	Following
94	Following
95	Following
96	Not Following
97	Following
98	Following
99	Following
100	Not Following

Count of Trucks not following the lane discipline: 51 Vehicles

Table 9: Analysis of Lane Discipline

	No. of Trucks
Total Count of Trucks	100
No. of Trucks not Following their Lane	51

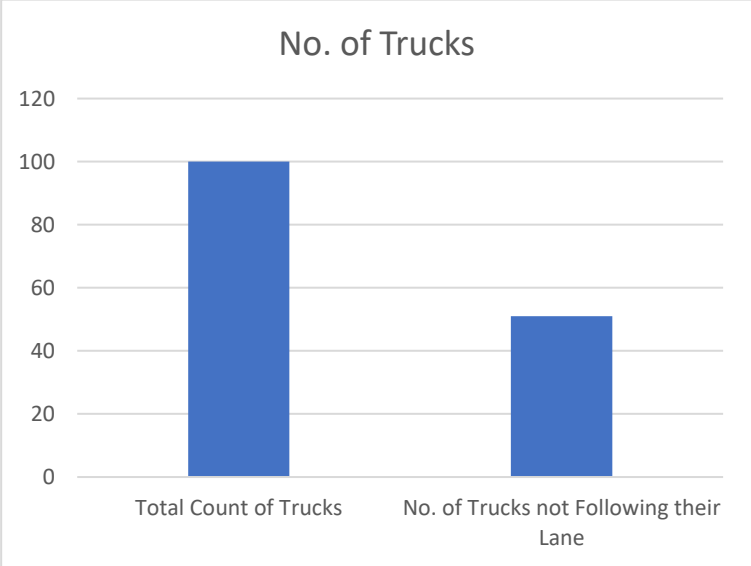

Figure 30: Bar graph of analysis of lane discipline

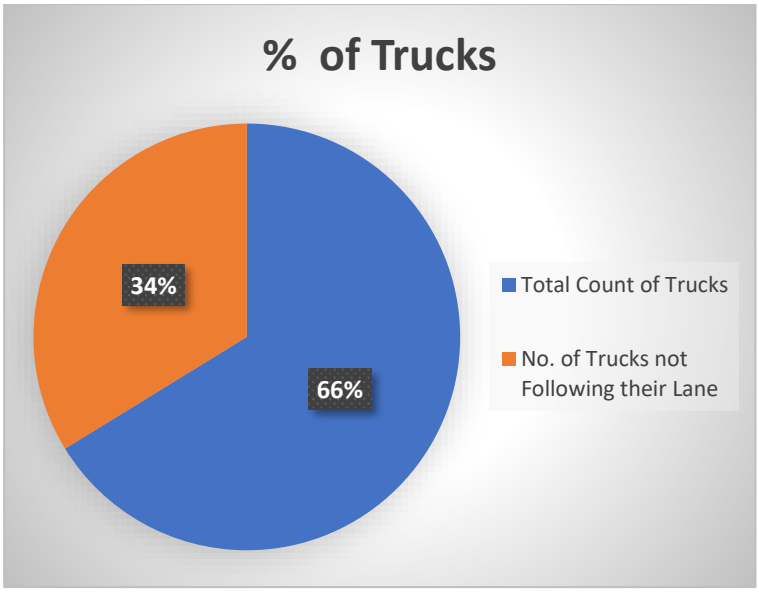

Figure 31: Pie chart of analysis of lane discipline

5.3 With the reference to the TOI article regarding accidents in Nagpur-Mumbai Samruddhi Expressway:

In the first 100 days since its inauguration, the Samruddhi Expressway has witnessed as many as 900 accidents, including many fatal. A study conducted by Regional Transport Office of Maharashtra government revealed that these accidents had claimed 31 lives till March 20, 2023.

The article main focuses on deciding to introduce mandatory counselling of drivers at all eight entry points of the expressway. The counselling session include curbing over-speeding, tyre pressure information, etc. For this, eight counselling centres will be set up on the Nagpur-Shirdi section. There will be 30 minutes to 1 hour counselling sessions for drivers by RTO officials to curtail overspeeding, which has resulted in the highest number of accidents.

The counselling session will begin with a short film on road safety, which will be followed by a question paper solving by the driver and a pledge to not indulge in dangerous driving. The drivers will also be given information about the dangers of under/over-inflated and worn-out tyres.

Several instructions were also given to the MSRDC for installing awareness boards regarding road safety

As per the analysis of accident data of Samruddhi Expressway from December 11, 2022 to March 20, 2023, mechanical breakdowns due to overspeeding of vehicles accounted for over 400 accidents.

Punctures and tyre bursts had led to over 130 and 108 accidents, respectively. Similarly, vehicles running out of fuel contributed to 14% (126) accidents on the portion of the expressway opened for traffic.

The article briefly describe the issue related to Road Accidents in Samruddhi Expressway.

Figure 32: Accident caused due to head-tail collision with breakdown vehicle.

Figure 33: Accident caused due to tyre burst

6 RECOMMENDATIONS

The Hindu Hrudaysamrat Balasaheb Thakare Maharashtra Samruddhi Mahamarg Expressway can be made safer for drivers and more enjoyable for users by implementing the following suggestions and to assist drivers in getting to their destinations in a safe and comfortable manner.

6.1 Guidelines for Drivers

Considering the posted speed restriction. Since expressways are intended for high-speed travel, the limit should reflect this. It's crucial to strike a balance between safety and speed. Making sure that the speed limits on the road are suitable, and that there are enough warning signs and other safety precautions in place. Taking these factors into account, the minimum speed restriction for each type of vehicle should be displayed often on sign boards. Moreover, the Gentry Board and regular markings on the road should be used to show the lane-by-lane speed restriction.

Expressways are high-speed roadways where vehicles travel at fast speeds, making awareness for drivers extremely crucial because even a small error can result in a major accident. Here are some pointers for drivers to be more aware and stay safe on expressways:

- Always be focused and on the lookout when operating a vehicle on a expressway. Avoid activities that could divert your attention from the road, such as using a phone, eating, drinking, or indulging in other activities.
- Maintain Safe Speeds: One of the main factors contributing to accidents on expressways is speeding. Always drive at a safe speed that is within the posted speed limit, and slow down when the weather is poor.
- Keep a Safe Distance: To prevent rear-end crashes, keep a safe distance from the car in front of you. A safe distance is usually the length of two cars or a minimum of three seconds.

Figure 34: Headway sign boards at regular intervals were provided

- Use your mirrors and your turn signals whenever you are changing lanes or making a turn. This will make it easier for other drivers to predict your movements and prevent collisions.
- Always abide by traffic laws and regulations when operating a vehicle on an expressway. This includes using your phone while driving, not driving when intoxicated or under the influence of drugs, and fastening your seatbelt.
- Be Prepared for Emergencies: Always keep a first aid kit, a spare tyre, and any other tools you might need in your car. In the event of a breakdown, pull over as soon and safely to the side of the road as you can.
- Drivers must maintain proper lane discipline based on their speed. While traveling at a speed under 80 kmph, use the leftmost lane. 80 to 120 kmph vehicles must use the centres lane. And the right-most lane must always be used by the overtaking car.

Figure 35: Lane wise speeds provided at Delhi-Dausa-Lalsot section of Delhi-Mumbai Expressway

- Regular maintenance should be performed on the vehicle. Moreover, the tyre must be in good shape, and remould tyres must be avoided. Furthermore, nitrogen gas ought to be used because it doesn't expend unlike regular compress air, and prevents tyre blowouts.

Counselling sessions should be provided at toll booths to raise awareness among drivers. A brief instructional video regarding how to operate the Samruddhi Mahamarg Expressway, what safety precautions should be taken, and what are the consequences of not adhering to the posted speed limit should be displayed at toll booths.

Figure 36: Common counselling sessions for travellers

Figure 39: Counselling session through short informative films

Figure 38: Oath taking sessions before using expressways

Figure 37: Form filling for various parameters before travelling through expressway

6.2 Recommended Infrastructure

The following infrastructure needs to be put in place for the Samruddhi Mahamarg Expressway to carry traffic safely and comfortably:

6.2.1 Rest Areas with Solar Power:

This facility will have rest areas with solar power installed. These rest areas can cut down on carbon emissions while also offering seating, shade, restrooms, food stalls and places to charge Electronic Vehicles.

6.2.2 Speed Cameras:

On expressways, speed camera is a form of traffic enforcement device, which can be used to track vehicle speeds and enforce speed limits. In regions where speeding is known to be an issue, like construction zones or high-accident zones, speed cameras are frequently installed.

Speed cameras can be an efficient tool for enhancing safety on Samrudhi Mahamarg Expressway. As overspeeding was noted, it will discourage drivers from doing so because they risk receiving a challan if they go over the posted speed limit.

Figure 40: Speed Camera

6.2.3 CCTV Cameras

CCTV cameras can be deployed on expressways for a number of reasons, including traffic flow monitoring, incident detection, and enhancing general safety and determining whether or not a vehicle is adhering to lane discipline.

Figure 41: CCTV Cameras at Expressways

6.2.4 Feedback Signs

A smart speed limiting solution is required because to the rising number of road accidents in the Samruddhi Mahamarg Expressway caused by speeding and the limitations of the current speed limit signs. (Reference- Clause 2.7.2, IRC: 99-2018)

The purpose of a Driver Feedback Sign (DFS) is to provide the driver with real-time feedback regarding the speed of the vehicle. It uses radar to gauge the vehicle's speed and shows that speed in real-time on an LED display. These signs may be programmed to flash when drivers go over the posted speed limit.

Driver Feedback Signs provide a highly visible display to the driver day or night, in all kinds of weather. DFS warns drivers when they are going too fast thanks to its improved sign visibility. The goal is to continuously warn vehicles that are travelling above the speed limit and promote this behaviour.

Figure 42: Driver Feedback Signs

6.2.5 Variable Sign Board

Electronic message boards called variable signboards are placed along expressways to advise drivers about traffic, road closures, accidents, weather, and other pertinent information that may have an impact on their travel plans. The highway management system controls these signboards remotely and typically places them at key spots along the expressway.

Variable signboards' main objective is to give drivers access to real-time data so they may make educated judgments regarding their route and speed. For instance, if there is an accident up ahead, a message warning cars to slow down and use caution will be displayed on the signboard. Similar to this, the signboard will recommend alternate routes if there is excessive traffic or road works.

Highway management systems must have variable signboards since they help with traffic flow, congestion reduction, and overall motorway safety. These signboards can also lower the chance of accidents and speed up travel times for vehicles by giving timely information to vehicles. (Refer IRC: SP: 85-2010 Guidelines for Variable Message Signs)

Figure 43: Variable Sign Board

6.2.6 Telephone Booths

Telephone booths should be erected at frequent intervals because they are essential for providing emergency communication and help to travellers, especially in rural or remote regions with poor cell phone service.

Figure 44: Telephone booth near carriageway for emergency

6.2.7 Recreational places

There should be recreation places at every 50 Km to 100 Km stretch on Samrudhi Mahamarg Expressway as these locations can give travellers a break from driving and the chance to get fresh, eat something, or enjoy some downtime. On expressways, there should be the following leisure areas:

- **Rest areas:** Rest areas often offer amenities like restrooms, vending machines, picnic spots, and occasionally playgrounds and are spaced out along expressways.

Figure 45: Example of some picnic areas

- **Service areas:** Similar to rest areas, service areas frequently include extra facilities like petrol pumps, convenience stores, garages and restaurants.

Figure 46: Example for service areas

- **Scenic vistas:** Beautiful viewpoints where travellers can pull over and observe the scenery and take photos. Some scenic vistas are shown below:

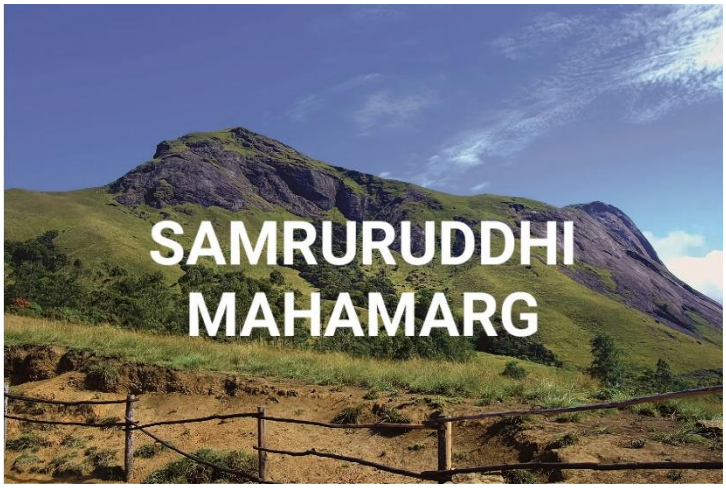

Figure 47: Examples of some Scenic Vistas

- **Parks and natural reserves:** Expressways should pass through or close to parks and nature reserves, giving travellers the chance to go hiking or partake in other outdoor pursuits.

Figure 48: Example of some parks and natural reserve

- **Theme parks and attractions:** Theme parks and other attractions may be close to Samruddhi Mahamarg Expressway, giving travellers a pleasant and exciting opportunity to break up a lengthy commute.

Figure 49: Example of theme park

6.3 Traffic Control Devices

6.3.1 Road Markings (As per- Clause 7.7, IRC: 35-2015)

Raised profile edge lines should be provided near the median. It is a continuous line marking with ribs spaced regularly across the line. The benefit of ribs is that, under wet situations, the vertical edges of the elevated ribs are visibly visible above the water film. The additional benefit of raised ribs is that when a vehicle passes over them, the ribs emit loud vibrations that serve as a warning to drivers.

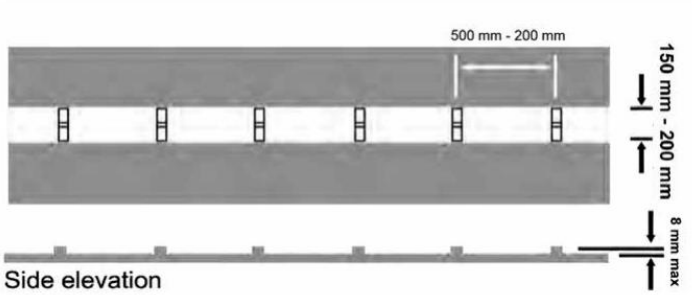

Figure 50: Raised profile edge lines

Generally speaking, there shouldn't be more than 500 mm between any two ribs. However, for expressways, 250 mm should be left between each rib. The raised profile edge's minimum and maximum widths should be 150 mm and 200 mm, respectively, and its height typically ranges from 4 mm to 8 mm; however, it can be up to 11 mm in the case of expressways. To facilitate drainage, a gap of 100 mm to 150 mm should be provided at an interval of around 36 m; otherwise rainwater may get collected on the road surface.

Given the lack of adherence to speed-based lane distribution, we can suggest providing directional speed limit markings on the pavement in accordance with Annexure: A (Refer Section 3 under Para 3.6) IRC 35:2015.

We can set speed limitations for vehicles to comply to in order to enforce lane discipline, as indicated in the below figure.

Figure 51: Lane Wise Speed Markings

6.3.2 Sign Boards

- More signboards warning drivers that there may be an animal crossing ahead are needed. According to observations made during the study, there is a potential for accidents because monkeys have been seen crossing the road close to bridge sections.

Figure 52: Animal Crossing Sign Board

- If a vehicle is moving at the desired speed limit, the Emergency Contact Number indicated sign boards should have a larger font size because they were difficult to see from a distance.

Figure 53: Emergency contact boards were seen small in size

- A gantry sign board should be available to display the lane-by-lane speed limit and the minimum speed limit.

Figure 54: Lane wise speed distribution

- As per IRC: 67-2012, a facility information sign for a petrol station should be provided at chainage of 82+000 km.

Figure 55: Petrol Pump Sign Board

- There should be "No Stopping No Standing" signboards placed close to the bridge. As trucks were found to be parked under the bridge during the survey for shelter, creating a blind spot and raising the risk of an accident.

Figure 56: Trucks were found parked under the overpass during road inventory survey.

Figure 57: No stopping, No standing sign

6.4 Maintenance Work needed on Samruddhi Mahamarg Expressway

To keep expressways safe and effective and to avoid accidents and delays, routine maintenance is necessary. However in general, maintenance of expressways may involve duties like patching up holes and cracks, repaving worn-out areas, replacing damaged guardrails, clearing debris, trimming trees and vegetation, cleaning drains and culverts, inspecting and maintaining signs and light poles, and repairing or replacing damaged bridges or overpasses.

6.4.1 Maintenance of sign boards

- At chainage 32+300 km and 59+800 km Object Hazard Marker is worn out it is needed to be replaced.

Figure 58: Worn out hazard markers were observed during road inventory survey

- In some locations, object hazard markers are not put appropriately; for instance a Left Object Hazard Marker was placed where a Right Object Hazard Marker should have been placed.

Figure 59: Object Hazard Markers were placed wrongly, observed during road inventory survey

6.4.2 Maintenance of bridge drains

- Bridge drains needed to be cleaned since they were clogged with dust. It could result in water logging and vehicle accidents.

Figure 60: Drains were clogged by dust

6.5 Implementation of ITS in Samruddhi Mahamarg Expressway

Expressway safety and efficiency can be greatly improved by intelligent transportation systems (ITS), especially in places with heavy traffic. India's Samrudhi Mahamarg Expressway, a high-speed route between Mumbai and Nagpur, could benefit from the use of ITS.

Here are some ways in which ITS can be implemented in Samrudhi Mahamarg Expressway:

1. Advanced Traffic Management System (ATMS): By giving the control centre real-time traffic statistics, ATMS can assist in regulating traffic on the expressway. This may facilitate quicker incident detection and response, which will shorten response times and increase safety.

2. Variable Message Signs (VMS): VMS can be installed along the expressway to give travellers up-to-the-minute information on weather, roadwork and traffic patterns. By directing traffic to alternative routes, can ease congestion while also enhancing driver safety by alerting them to potential dangers.

3. Intelligent Speed Adaptation (ISA): ISA can be used to regulate expressway traffic speed based on weather and traffic circumstances. ISA systems use GPS and other

technologies to monitor a vehicle's speed and provide feedback to the driver. Ensuring that drivers stay under the acceptable speed limit, can aid in reducing accidents.

4. Incident Detection and Response System (IDRS): IDRS can assist in more rapidly and correctly detecting problems like accidents, road works and breakdowns. This can aid in quicker road clearing times, more effective incident response, and increased safety.

Overall, adding ITS to the Samruddhi Mahamarg Expressway can aid with safety enhancements, traffic flow reductions, and overall expressway performance.

7 Conclusion

The Purpose of the study was to Audit the Deficiencies in road infrastructure which include improper visibility of signage, Risk factors for accidents such as over speeding, driver hypnosis which is caused by monotonous Driving, Poor enforcement of safety regulations in enforcing measures such as the effectiveness of speed limits, Inadequate public awareness campaigns (counselling). The findings of a road safety audit can help stakeholders to identify areas of concern and develop targeted interventions to improve road safety.

The detailed safety audit is carried out though the site inspection in day hours and night time also in accordance with IRC-SP-88-2019. The concern audit findings is summarized and presented in standard format. The layout of these audit reports, including the tabular representation of the audit findings, is also given. Thereafter all changes and recommendations are provided to minimize the risk of accidents in future.

Recommendations for all the findings are then given in separate section of recommendation which includes Guidelines for Drivers, Recommended Infrastructure, implementation of CCTV and Speed Cameras to avoid over speeding. Recreational places are recommended to give travellers a break to avoid monotonous driving.

Overall, the road safety audit project serve as a roadmap for improving road safety in the area under review and should be used as a basis for future policy decisions and infrastructure investments.

8 References:

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सत्यमेव जयते

प्रमाण पत्र
Certificate

प्रमाणित किया जाता है कि

इं. गजानन भगवानराव टाके, (नामांकन संख्या *CRSA/2021-22/04)*

ने भारतीय राजमार्ग अभियंता अकादमी द्वारा आयोजित 2 से 16 अगस्त 2021, 15 दिवसीय "सड़क सुरक्षा लेखा परीक्षक" प्रमाणन पाठ्यक्रम को सफलतापूर्वक पूर्ण किया

Certified that

Er. Gajanan Bhagwanrao Takey, (Enrollment No. CRSA/2021-22/04)

has successfully completed 15 days Certification Course for "Road Safety Auditor"

from 2nd to 16th August, 2021 at IAHE, Noida (India)

organized by Indian Academy of Highway Engineers (IAHE)

डॉ. संजय वाकचौरे / *Dr. Sanjay Wakchaure*
अपर निदेशक / *Additional Director*

संजीव कुमार / *Sanjeev Kumar*
निदेशक / *Director*

Indian Academy of Highway Engineers (IAHE)

15 days Certification Course for

"Road Safety Auditors"

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