iRASTE Nagpur

Detailed Report

APRIL
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Project

iRASTE

INTELLIGENT SOLUTIONS FOR ROAD SAFETY THROUGH TECHNOLOGY AND ENGINEERING

Project Goal: Implementation of a holistic Safe Systems approach, leveraging Artificial Intelligence for up to 50 % reduction in road crashes/fatalities in the city of Nagpur over a period of two years

Study Team

Principal Investigators (PI):

Dr.S. Velmurugan, CSIR-CRRI
Dr. Anbumani Subramanian, INAI, IIIT Hyderabad
Ms. Juby Jose, Intel-India
Mr. Nirmal Parmar, Mahindra & Mahindra (M & M)

Co-PIs:

Dr. Mukti Advani, CSIR - CRRI
Mr. Dev Singh Thakur, INAI, IIIT Hyderabad
Dr. K. Ravinder, CSIR-CRRI
Dr. A. Mohan Rao, CSIR-CRRI
Mr. Govind Krishnan, INAI, IIIT Hyderabad
Dr. C. V. Jawahar, CVIT, IIIT Hyderabad

Members:

Mr. Varma S. Konala, INAI, IIIT Hyderabad
Dr. Neelima Chakrabarty, CSIR-CRRI
Mr. Suhas Patil, M & M
Dr. S. Padma, CSIR-CRRI
Mr. Prithvi Jonnada, INAI
Ms. Kamini Gupta, CSIR - CRRI
Mr. Mohammad Akil, CSIR - CRRI
Mr. Sikandar, CSIR - CRRI
Mr. Abhi Mandal, CSIR – CRRI
Mr. Manoj Murkute, INAI, IIIT Hyderabad

Students:

Mr. Faraz Khan, M. Tech student, NIT Kurukshetra
Mr. Malolan Balaji, M. Tech student, BITS Pilani
Mr. Raghav Chawla, M. Tech student, BITS Pilani

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Steering Committee Members:

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2. Dr. (Mrs.) N. Kalaiselvi, Director General (DG), Council of Scientific and Industrial Research (CSIR), New Delhi.
3. Dr. Satish Chandra, Former Director, CSIR - Central Road Research Institute (CRRI), New Delhi.
4. Dr. Manoranjan Parida, Director, CSIR - Central Road Research Institute (CRRI), New Delhi.
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Executive Summary

Nagpur city has the uniqueness of being the 'geographical center of India' by its location in India and also as two major national highways (NHs) namely, NH-44 and NH-53 pass through the city which act as major connectors for the traffic plying between North-South and East-West parts of the country.

A closer look at the road accidents from 2019 to 2021 indicate that road safety in Nagpur city has not registered any significant improvement. Among the crashes, 35% of fatal crashes involved heavy vehicles, followed by four-wheelers at 27%.

Government of India (GoI) is driving the vision of 50% reduction in road fatalities on Indian Roads by year 2030. Technology can act as a force multiplier in addressing the problems of road safety on India's roads. Artificial Intelligence (AI) based solutions have shown remarkable results worldwide in enabling safer Mobility and Transportation systems.

Project iRASTE (Intelligent Solutions for RoAd Safety through Technology and Engineering) was launched in Nagpur, India in September 2021 by Shri Nitin Ji Gadkari(Hon'ble Union Minister of Road Transport and Highways) to leverage Artificial Intelligence (AI) and help Nagpur city to achieve 50% reduction in road accident / fatalities. For the first time in India, Project iRASTE brought Artificial Intelligence (AI) Scientists and Road Engineering experts together to transform road safety engineering by leveraging the predictive power of AI.

The main thrust of accident prevention across the world has been to rely on 4E's of road safety that includes: (i) Education; (ii) Engineering; (iii) Enforcement; (iv) Emergency care. Project iRASTE was designed to have 4 main project vectors that connects the 4E's of road safety:

i. **Vehicle Safety** – Use of AI-based Advanced Driver Assistance System (ADAS) to improve safety of large commercial fleets.

ii. **Mobility Analysis** - Application of Artificial Intelligence to proactively identify the most unsafe areas beyond the known blackspots on Nagpur Road network, i.e., termed as Greyspots.

iii. **Infrastructure Safety** - Development of Detailed Project Reports (DPRs) towards rectification of the identified blackspots.

iv. **Education, Awareness, and Emergency Care -** To educate and enforce safety behaviour of drivers, installation of emergency care equipment at the Blackspots and Greyspots, and propagate awareness related to road safety.

Note: *Project iRASTE in Nagpur extended its efforts by introducing a 5th 'E' into Road Safety –* ***Encouragement****, to encourage NMC bus drivers to follow all traffic rules for safe driving.*

This report summarizes the initiatives and results of Project iRASTE Nagpur for the period Oct'21 to Dec'23.

Project iRASTE, which integrates technology and engineering solutions into the existing 4E's framework for road safety, has led to faster implementations and accurate monitoring. A summary of key result:

- Project iRASTE is India's largest and longest running study on Advanced Driver Assistance Systems (ADAS) for commercial vehicles.
- ADAS-equipped buses experienced 41% lower accidents from January to August 2023 compared to non-ADAS buses. The 'LDW Challenge' campaign resulted in a 50% decrease in road crash rates for ADAS equipped NMC buses compared to both ADAS and non-ADAS buses from June to August. This initiative has made NMC's ADAS-fitted buses nearly twice as safe as their non-ADAS buses.
- Additionally, operator risk score is tracked monthly and there has been a 30% reduction in risk score since the start of the project. This represents a major upgrade in driver skilling.
- 1337 drivers of Nagpur Municipal Corporation (NMC) and School Bus Drivers were trained on Defensive Driving with ADAS. 250 safety champions were awarded.
- The ability to leverage ADAS data by integrating with the existing road geometry resulted in the development of Greyspot Map for Nagpur city. 33 Greyspots have been identified.
- Greyspot prediction using up-to-date, daily road data is an approach that is more accurate and scalable than one-time manual surveys.
- Greyspot map of Nagpur city enables precise and prompt interventions related to Education, Enforcement, and Emergency Care.
- Comprehensive Design Improvements in the form of counter measures i.e., Detailed Geometric Design Plan (GDP) were delivered for the 38 Blackspot locations.
- As per Economic Benefit Assessment, it is estimated that about 60-66% reduction in the overall road crashes coupled with 40% reduction in road accident fatalities can be achieved on Nagpur city road network if the countermeasures are applied at the identified blackspots.
- In regard of implementation of safety interventions at the Blackspots, eight of them were selected in Nagpur city to provide detailed safety interventions including geometric, traffic, and emergency care improvements. Among the selected blackspots, at present geometrical remedial interventions are completed in the 3 blackspots such as Ajni Square, Chhatrapati Square, and Jaiprakash Nagar Square, and comprehensive traffic delineation & pedestrian safety interventions are complemented in 1 blackspot i.e., Wadhamna intersection
- Project iRASTE in collaboration with RoadMarc Foundation has initiated several Awareness campaigns and installation of Trystander cells at Blackspots and Greyspots:

    - In Feb'23, **"Avagatkara: Learn the Art of Living Road Accident-Free"** initiative was launched that engaged with youth, families, and communities to create awareness and educate residents to follow traffic rules at all times and avoid human errors. The project engaged around 75 families in one neighborhood. The 30-day public awareness program culminated in each participant taking an oath to follow the traffic rules every day.

    - **'Get First Aid Training, Become an Accident Defender'** program was launched with the goal was to train people with the basic first-aid techniques that bystanders can apply during the golden hour of a road accident to save lives. The team conducted training programs near traffic police stations with support from the Traffic Police personnel and had attendance of the people from neighboring localities. A more comprehensive version of the program called the "Good Samaritan Training" event was inaugurated by Hon'ble Mr. Nitin Gadkari, Minister of Road, Transport and Highways, which gathered an audience of 2000 people drawn from various schools, colleges, and social organizations in the city.

  - **'Trystander Cell'** program objective is to act quickly in the first hour (Golden Hour) of any accident near the Blackspot location. RoadMarc team installed Trystander Cells (kiosks with first aid kits, stretchers etc.) at 8 locations. They worked on the ground to register and train all the people and shopkeepers in both within a radius of 2 kilometers of each location. Through this program, life of 36 road crash victims were saved.

- Under 5th 'E' – Encouragement – We partnered with Traffic Rewards to pilot a new RFID-based technology that nudges the NMC bus drivers to follow traffic rules based on the principle of "positive reinforcement." RFID scanners, installed at ten traffic signals across Nagpur, identify the buses with the Traffic Rewards custom tags once they halt at the traffic intersections following the signals. As of Dec '23, 438 NMC buses have been tagged. The data from the sensors across all the vehicles in Nagpur show that there has been a 24% improvement in signal adherence.

Way Forward

Project iRASTE Nagpur was the first initiative in India to integrate AI into the 4E framework for road safety and was the largest and longest-running study of ADAS for commercial vehicles. Our iRASTE model has led to faster and more precise implementations with promising results: a 41% reduction in accidents in the NMC ADAS enabled bus fleet and a reduction in driver risk scores by 30%. A novel technique for Greyspot prediction and modelling was developed. We have gained experience in executing a multi-vector strategy to address the urgent challenge of road safety. Moving forward, our plan is to replicate this model in other cities and metropolitan regions in India and engage with the Union Ministry of Road Transport and Highways (MoRTH) to institutionalize the components that have yielded consistent results.

Publications

1. D. S. Thakur, M. Advani, S. Velmurugan, A. Goel, *(2022)* **“Identification & Prioritization of Possible Accident Locations in Nagpur City using Road Crashes Data”**, 10th National Conference on Nanoscience and Instrumentation technology, July 2022.

2. M. Advani, A. Subramanian, D.S. Thakur, J. Jose, S. Velmurugan, and A. Goel. **"Artificial Intelligence-based Collision Alert System to Identify the Most Unsafe Areas in Nagpur City"**, Proc. of 2nd Intl. Conf. On Transportation Infrastructure Projects : Conception to Execution (TIPCE), IIT Roorkee, Sep. 2022

3. D. S. Thakur, M. Advani, A. Subramanian, S. Velmurugan and A. Goel, **"Identifying Pedestrian Risk Zones from the Bus Fleet Equipped With ADAS Devices"**, Proc. of the Intl. Virtual Conf. on Smart and Sustainable Development of Urban Green Infrastructure in India and Canada (SSDUGI), Organized by NIT-Trichy, Mar. 2022 **[Best Paper Award]**

4. D. S. Thakur, M. Advani, S. Velmurugan, A. Subramanian, N. Chakrabarty and A. Goel, *(2022)* **"Artificial Intelligence (AI) based Assessment of Behavior of Bus Drivers in Nagpur city (India) - A Case Study"**, Proc. of Recent Advances in Traffic Engineering (RATE), SVNIT, Nov. 2022 **[Best Paper Award].**

5. Balaji, M., Velmurugan S and Padma S *(2022)*, **“Economic-Benefit Assessment of Black Spot Improvements”**, A paper presented and published in the 14th International Conference on Transportation Planning and Implementation Methodologies for Developing Countries (TPMDC) held at IIT, Bombay.

6. R. Chawla, Velmurugan S, Mukti Advani, and Ravinder K *(2022)*, **“Visualizing Blackspot Improvement at Nagpur”**, A paper presented and published in the 14th International Conference on Transportation Planning and Implementation Methodologies for Developing Countries (TPMDC) held at IIT, Bombay.

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8. D. S. Thakur, M. Advani, A. Subramanian, S. Velmurugan, Md. Ibrahim *(2023)*, **“Identification of Lane Departure Hotspots using ADAS-based Collision Alerts on an Indian Interurban Highway”**, 7 th Conference of Transportation Research Group of India (CTRG), Dec 2023.

9. D. S. Thakur, S. Velmurugan, M. Advani, A. Goel(2023), **“Identifying the Blackspots using Crash Severity Value of Road Crashes: Case Study”**, National Conference on Sustainable Development of Smart Cities Infrastructure (SDSCI), NIT Kurukshetra, May 2023.

10. F. Khan, S. Velmurugan, M. Advani, H.D. Chalak, (2023), **"Analyzing Road Crash Records and Deducing Corrective Measures in Nagpur City"**, Proc. of International Conference on Recent Trends in Engineering and Sciences (RTES), SVNIT Surat, May 2023. (Hindi Publication) (Vigyan Prakash: UGC Care).

11. F. Khan, M. Advani, S. Velmurugan, H.D. Chalak, (2023), **"Artificial Intelligence Based Collision Avoidance System to Identify Most Unsafe Midblock Road Sections in Nagpur City"**, Proc. of National Conference on Sustainable Development of Smart Cities Infrastructure (SDSCI), NIT Kurukshetra, May 2023.

12. N. Rangaswamy, Y. Dedhia, A. Singh, V. S. Tomar, D. S. Thakur, (2023). **"Building AI and Human Capital for Road Safety"**, 15th Annual Pre-ICIS Workshop Special Interest Group - ICT and Global Development, Hyderabad, December 2023.

13. V. Bairam, A. Ramesh, Ch. R. Sekhar (2023). **"Enhancing Road Safety of Intercity Public Transport Along Key Corridors Through Driver Monitoring System and Alert Analysis"**, 9th Conference on Transportation System Engineering and Management (CTSEM), October, 2023.

14. A. Dixit, D. S. Thakur, M. Advani, S. Velmurugan, A. Subramanian, (2024). **"ADAS-based Assessment of Speeding Behaviour of Bus Drivers"**, 2nd Annual Conference on Infrastructure and Built Environment: Towards Sustainable and Resilient Societies (IBSR), IIT Kharagpur, March 2024.

15. D. S. Thakur, K. Gupta, Md. Akil, N. Chakrabarty, M. Advani, S. Velmurugan, (2024). **"Exploring the Psychophysical Abilities of Indian Bus Drivers: A Case study"**, 1 st International Conference on Recent Advances in Infrastructure Development (RAID), NIT Calicut, Feb 2024. **(Presented)**

16. D. S. Thakur, M. Advani, A. Subramanian, S. Velmurugan, (2024). **"Evaluation of Impact of ADAS on Bus Driver's Rear-end Collision Behaviour"**, 15th World Conference on Injury Prevention & Safety Promotion (Safety 2024), September 2024. **(Accepted)**

17. S. Velmurugan, D. S. Thakur, (2024). **"Revolutionizing Road Safety using Artificial Intelligence: A Case Study"**, National Conference-cum-exhibition on Revolutionizing Road Infra with Modern Equipment, Technologies, Sustainable Material, and Policy Guidelines **(IRF – India Chapter), Feb'24-Mar'24.**

Achievements / Awards:

1. Nagpur Municipal Corporation (NMC) was bestowed with the **"Geospatial Excellence Award"** at **GeoSmart India 2022** for pioneering the accelerated 4Es approach to Road Safety for Project iRASTE.

2. The **'THE CRAZY TALES'** organization in New Delhi has honored Project iRASTE (Intelligent Solutions for Road Safety through Technology & Engineering) as the **'Best Road Safety Project'** of 2023. The recognition was bestowed upon the project due to its unwavering commitment and devoted efforts toward enhancing road safety. Project iRASTE serves as an extensive road safety management system employing Artificial Intelligence technologies, including ADAS, aimed at elevating road safety within Nagpur city and the broader area of Telangana state.

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List of Abbreviations:

iRASTE	Intelligent Solutions for RoAd Safety through Technology & Engineering
CSIR – CRRI	Council of Scientific and Industrial Research – Central Road Research Institute
IIIT Hyd	International Institute of Information Technology Hyderabad
INAI	Applied AI Research Centre
IOFS	Intel Onboard Fleet Services
NHAI	National Highway Authority of India
PWD	Public Works Department
IRC	Indian Road Congress
MoRT&H	Ministry of Road Transportation & Highways
ALIDTR	Ashok Leyland Institute for Driver Training & Research
NHs	National Highways
SHs	State Highways
ORs	Other Roads
NMC	Nagpur Municipal Corporation
NMA	Nagpur Metropolitan Area
SPV	Special Purpose Vehicle
NMPL	Nagpur Mahanagar Parivahan Limited
UMTC	Urban Mass Transport Company
CMP	Comprehensive Mobility Plan
NMRCL	Nagpur Metro Rail Corporation Limited
Nagpur – R	Nagpur – Rural
Nagpur – C	Nagpur – City
ULB	Urban Local Bodies
VRUs	Vulnerable Road Users
AI	Artificial Intelligence
ADAS	Advanced Driver Assistance System
4E's	Education, Enforcement, Engineering, Emergency Care
5^{th} E	Encouragement
NGO	Non-Governmental Organization
DPR	Detailed Project Report
GDP	Geometric Design Plan
CTVC	Classified Traffic Volume Count
PVC	Pedestrian Volume Count
LCV	Light Commercial Vehicle
HCV	Heavy Commercial Vehicle
MAV	Multi Axle Vehicle
2 – WLR	2-Wheeler
SI	Severity Index
GLM	Generalized Linear Regression Model
BLM	Binary Logistic Regression Model
DV	Dependent Variable
IV	Independent Variable
CP	Control Period
OP	Operation Period
FCW	Forward Collision Warning
HMW	Headway Monitoring Warning

LDW	Lane Departure Warning
PCW	Pedestrian & Cyclist Collision Warning
SLI	Speed Limit Indicator
M1, M2....	Month-wise Operation Period
FIR	First Information Report
GIS	Geographical Information System
NTP	Nagpur Traffic Police
BCR	Benefit – Cost Ratio
S & D	Speed & Delay
EIRR	Economic Internal Rate of Return
NPV	Net Present Value
FYRR	First Year Rate of Return
ROI	Return on Investment
RSA	Road Safety Audit
RQI	Road Quality Index
TS	Traffic Sign
TL	Traffic Light
LM	Lane Marking
RE	Road Edge
CW	Crosswalk
SL	Stop line
PP	Power pole
LW	Lane Width
JH	Jhansi Rani Square
AMB	Ambazari
PCI	Pavement Condition Index
nN_{3arm}	Normalized count of 3 arm intersections within the cell
nN_{4arm}	Normalized count of 4 arm intersections within the cell
nRL	Normalized total length of roads inside the cell
nFCW	Normalized 85^{th} %ile speed of FCW alerts within the cell
nPCW	Normalized 85^{th} %ile speed of PCW alerts within the cell
AICc	Akaike's Information Criterion
D	Distance travelled
BD	Braking Distance
SI_c	Severity Index of an Alert Combo
nT_g	Normalized Time Gap between first and second alert in the combo (sec)
nS_i	Normalized Speed of the first alert in the combo (km/h)
nRW	Normalized Road Width at which alert combo occurred (m)
RFID	Radio Frequency Identification

INTRODUCTION

1

Introduction

Nagpur is one of the fastest-growing metropolitan cities in India. The city has the uniqueness of being the 'Geographical Center of India' by its very location on the Indian map and due to the above, two major national highways (NHs) namely, NH-44 and NH-53 pass through the city which act as major connectors for the traffic plying between north- south and east-west parts of the country. In addition to the above road link, NH-69 originates from Nagpur connecting Obaiddullaganj near Bhopal. Apart from NHs, there are couple of State Highways (SHs) namely, SH – 3, 9, 246, 248, 255, 260, and so on passing through the city. The total length of the road network including serving the suburbs of the Nagpur city is about 1,907 Kms, out of which 1,150 Kms is located within the jurisdiction of Nagpur Municipal Corporation (NMC) and the remaining road network falls under the Nagpur Metropolitan Area (NMA).

NMC has formulated a Special Purpose Vehicle (SPV) named, Nagpur Mahanagar Parivahan Limited (NMPL) to ensure smooth operation of city bus services in the city. NMPL has a fleet of about 430+ buses that ply on 73 routes and serves nearly 1,05,000 commuters daily. Based on the study conducted by Urban Mass Transport Company (UMTC) in 2018 titled, "Updated Comprehensive Mobility Plan (CMP) for Nagpur City and Nagpur Metropolitan Region", on behalf of Nagpur Metro Rail Corporation Limited (NMRCL), it is inferred that the modal share in the city is dominated by motorized two wheelers with the overall share in the city road network is pegged at 42.6 % followed by auto rickshaws at 19.8 % and bus at 15.6 %, whereas cars contribute about 5.7 %. The above Updated CMP, 2018 study has also flagged major safety issues relating to transport road networks of the city:

a. Although the arterial roads in the city road network are wider, the inner-city roads leading to the market areas are narrowing, which carry large volumes of traffic resulting in traffic congestion during peak hours.

b. Absence of contiguous footpaths for pedestrians and unregulated pedestrian crossings as well as lack dedicated cycle tracks.

c. Unauthorized parking on both sides of the road in commercial areas and encroachments on roads by hawkers, shopkeepers and vehicle commuters impacting roadway capacity and safety.

d. Poor road geometrics as well as absence of road signs and markings even in intersection areas making them road crash prone locations

1.1 Road Crashes in Nagpur

Figure 1.1 presents the number of road crashes, number of persons killed, and number of persons injured in Nagpur since year 2008 to 2021. A close look at Figure 1.1 reveals that the number of road crashes and fatality rates for a city having around 24.1 Lakh population *(Census of India, 2011)* is slightly on the higher side.

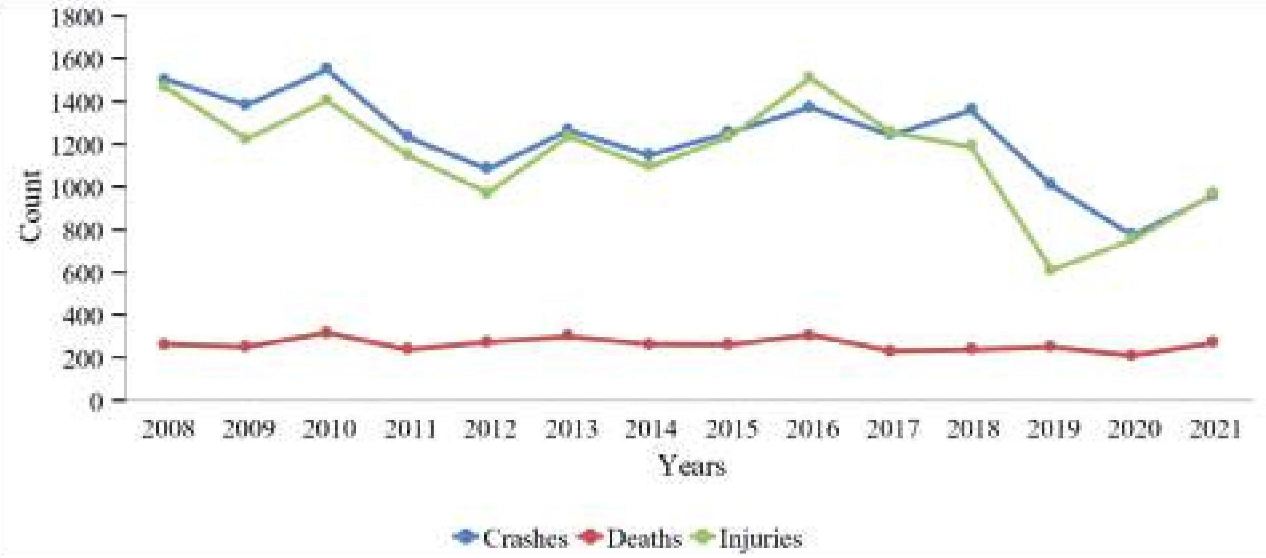


Figure 1.1 Profile of Number of Road crashes, Persons Killed and Injured in Nagpur Road Network: 2008 to 2021

(Source: Road Accidents in Maharashtra, 2021, Published by Accident Research Cell, Mumbai)

It is also evident from Figure 1.1 that between the periods from 2008 to 2010, the number of road crashes and serious injuries on the roads of Nagpur was hovering around 1400 to 1600 per year. Since year 2011 to 2018, road crashes hovered between 1200 to 1400 per year, and the injuries are hovering between 1000 to 1500 per year. The above two parameters have registered minor declining trends to 1007 crashes and 612 injuries in year 2019. The number of persons killed on the city roads of Nagpur during the above period was hovering around 200 to 300 per year and this Figure has registered minor decreasing trends and thus reaching less than 250 road deaths in the years 2017, 2018, and 2020. This is aptly reflected in the Crash Severity Index (CSI) i.e., persons killed per 100 road crashes, which is reported to be 24.8 and 27.1 in 2019 and 2020 respectively. The road crashes in the year 2020 revealed that 773 number was reported and thus recording 234 fewer road crashes (14.2 % reduction) as compared to 2019. However, this reduction can be largely due to the lockdown across the country for a couple of months due to CORONA-19 pandemic having lesser mobility and hence considered as an outlier. After that, in the year 2021, major increasing trend shown road crashes and injuries i.e., 958 and 964 respectively, and deaths are 268, which ultimately affected the CSI such as 28.0 which is increased by 3 %.

In view of the above prevailing road crash trends between 2006 to 2020 and thereafter from year 2021, in which the city had reported huge number of crashes, road deaths, and injuries; it can be inferred that the road safety situation in Nagpur city has not registered any significant improvement. Moreover, a close look at the above data showed that 35 % of fatal crashes involved heavy vehicles *i.e., 69 fatal crashes i.e., Goods Vehicles and Buses*, followed by cars accounting for 27 %, *i.e., 36 fatal crashes*. From the above Figures, it is obvious that heavy vehicles are one of the major contributors to the fatal road crashes in the city. Table 1.1 presents the profile of the road crashes in the city and suburban environs of the city reported in 2021 whereas spread of the various types of road crashes across urban and rural environs depicted in Figure 1.2 and 1.3 respectively. The following inferences are drawn from the above Table and Figures:

Table 1.1 Profile of Road Crashes in City and Rural Areas of Nagpur

Year	Type of land use	Number of			
		Total Crashes	Fatalities	Grievous Injured	Minor Injured
2021	Nagpur [R]	969	466	436	435
	Nagpur [C]	958	268	552	412

(Source: Road Accidents in Maharashtra, 2021, Published by Accident Research Cell, Mumbai)

a. The number of road deaths are higher in rural areas *(refer Figure 1.3)* which can be primarily attributed to large-scale speed violation and unavailability of supporting emergency medical care within the golden hour in case of serious injury / fatal crashes.

b. In both the rural and urban environs, the highest number of road crashes are occurring on 'Other roads' *i.e., other than NHs and SHs* followed by NHs implying thereby roads falling under the umbrella of the various Urban Local Bodies *(ULBs)* needs immediate attention

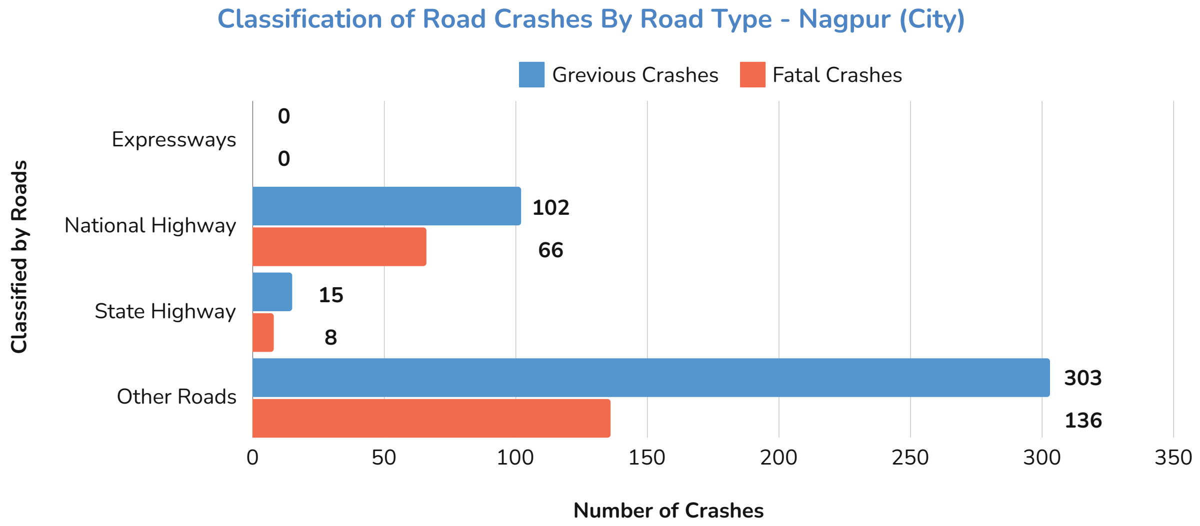


Figure 1.2 Road Crashes across Various Types of Roads within Nagpur Typical Urban Limits

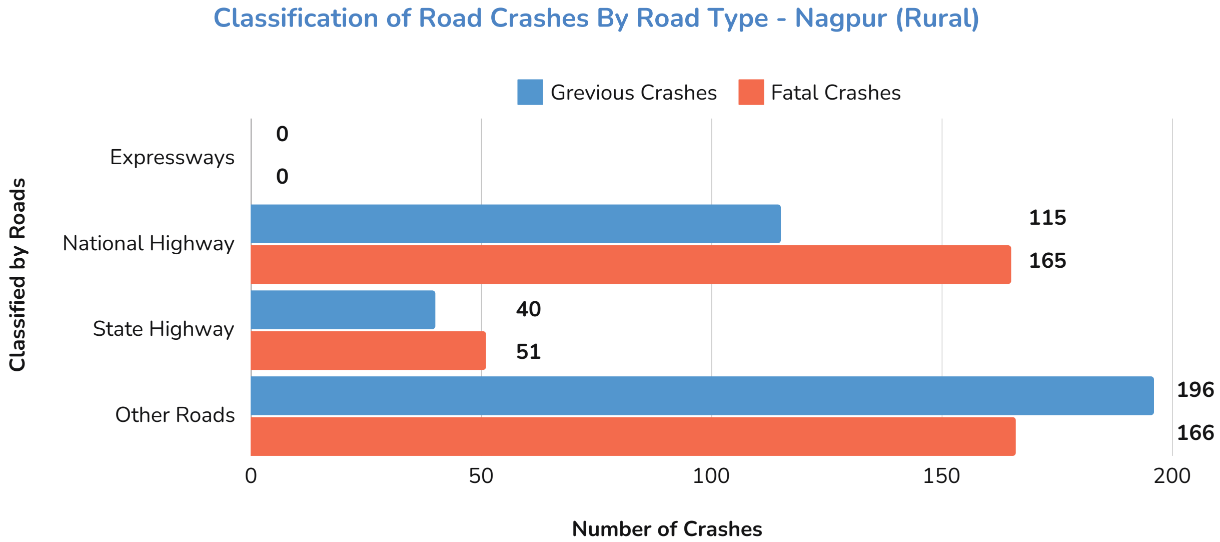


Figure 1.3 Road Crashes across Various Types of Roads in Nagpur Rural Limits

Table 1.2 Mode wise proportion of Road Crashes in City and Rural Environs of Nagpur.

Mode	Nagpur City (%)	Nagpur Rural (%)
Pedestrians	23	19
Bicycles	7	1
Two Wheelers	54	39
Auto Rickshaw	2	2
Car, Taxi, Van, LMV	10	22
Trucks / Lorries	3	6
Buses	1	2
Others (including unkown)	1	9

(Source: Road Accidents in Maharashtra, 2020, Published by Accident Research Cell, Mumbai)

A close look at Table 1.2 reveals that 87 % and 59 % of all road crashes involved pedestrians, bicycle, two-wheelers, and auto-rickshaws *(including e-rickshaws)* and other non-motorized vehicles *(which are insignificant in Nagpur)* are classified under vulnerable road users *(VRUs)* category in typical urban and peri-urban traffic environments. Further, the number of road crashes involving buses is between 1 to 2 %. On many occasions, the severity level of road crashes involving large vehicles like buses becomes high due to its large vehicle size as the driver faces many blind spots around the vehicle. The fall out of such blind spots coupled with the aspects associated with rash and negligent driving traits of the drivers is that it can inflict fatal / serious injury type of road crashes with other type of vehicles especially VRUs.

1.2 Need for the study

It is an established fact that in the present decade Artificial Intelligence (AI) based solutions have shown remarkable results worldwide in enabling safer Mobility and Transportation systems (Masello, Castignani, Sheehan, Murphy, & McDonnell, 2022). Accordingly, it was felt that the deployment of AI-based ADAS tool can act as a force multiplier in addressing the problems of road safety on India's roads. In view of the above crash statistics, the road crashes involving buses is one of the major areas of safety concern and hence a pilot project is attempted to deploy Artificial Intelligence (AI) driven solutions in NMC public transit buses aimed up to the 50 % reduction of the road fatalities / crashes by 2024 involving buses and it acts as an aid towards achieving nation's goal i.e., To halve the cases of road crashes by year 2024. To address the above, installation and evaluation of the Advance Driver Assistance System (ADAS) in NMC buses was undertaken by a consortium consisting of Council of Scientific and Industrial Research - Central Road Research Institute (CSIR - CRRI), New Delhi, M/s. Mahindra & Mahindra, INAI *(Applied Research Center for AI at IIIT-Hyderabad)*, International Institute of Information Technology (IIIT), Hyderabad, M/s. Intel India based on the technical knowhow and the domain expertise of each of the participating organizations. In this endeavour, Nagpur Municipal Corporation (NMC), was identified as the beneficiary road owning agency who would extend their local logistics support.

1.3 Focus Areas / Objectives

This pilot project covers the various aspects of enhancing safety using the AI based ADAS installed in public transit buses, simultaneous improvement of road infrastructure through the development of geometric design improvements plans for the identified blackspots and the greyspots (identified based on ADAS and road geometric data) as well as imparting driver training and awareness programs. The strategy deployed in Project iRASTE has been on the application of 4E's conforming to Global Standards. 4E's of Road Safety includes Engineering, Education, Enforcement, and Emergency care. In this regard, Project iRASTE has been designed to address the 4 main vectors that connect the 4E's of road safety:

1. **Vehicle Safety** – Enhancing safety using the AI based ADAS installed in public transit such as selected NMC buses.
2. **Infrastructure Safety** - Development of Detailed Project Reports (DPRs) in the form of Geometric Design Plans (GDPs) highlighting remedial measures towards the rectification of the identified blackspots. In addition, the development of Road Quality Index (RQI) utilizing the ADAS-based road infrastructure assets.
3. **Mobility Analysis** - Application of AI-based ADAS for proactive identification of Greyspots on Nagpur Road network using the compiled aggregate ADAS and road geometric data and thus conceive remedial measures.
4. **Education, Awareness, and Emergency Care** – To educate and imbibe safety behaviours working in association with Nagpur based NGO namely, RoadMarc Foundation and Ashok Leyland Driver Training Institute, Chindwara.

Note: *As an extension, Project iRASTE introduced 5 th 'E' of Road Safety i.e., Encouragement in Nagpur city.*

The project is undertaken spread over two phases with focus areas (1) and (2) covered in Phase-1 which encompasses the entire city of Nagpur. On the other hand, focus areas No. (3) to (4) was addressed in Phase-2 of the project in Nagpur city. This report summarizes the initiatives and results of Project iRASTE, Nagpur.

1.4 Study Methodology

As presented in Figure 1.4, this study involves the installation of ADAS devices in NMC buses which ply on Nagpur city roads. The alerts generated from these devices are stored on cloud and later extracted for further analysis to identify the locations, which can be termed as unsafe but do not fall under the category of blackspots. Eventually, they are termed greyspots implying thereby the need for undertaking the necessary measures at the identified greyspots to prevent them from turning into blackspots in the foreseeable future. To accomplish the objectives identified above, the following four major verticals are formulated for reporting purposes.

1) **Vehicle Safety:** This task includes the installation of ADAS device on fleet (majorly NMC bus fleet), collection, storage, extraction, and collation of data on various alerts generated through device.

Figure 1.4 presents the overall methodology planned for this study

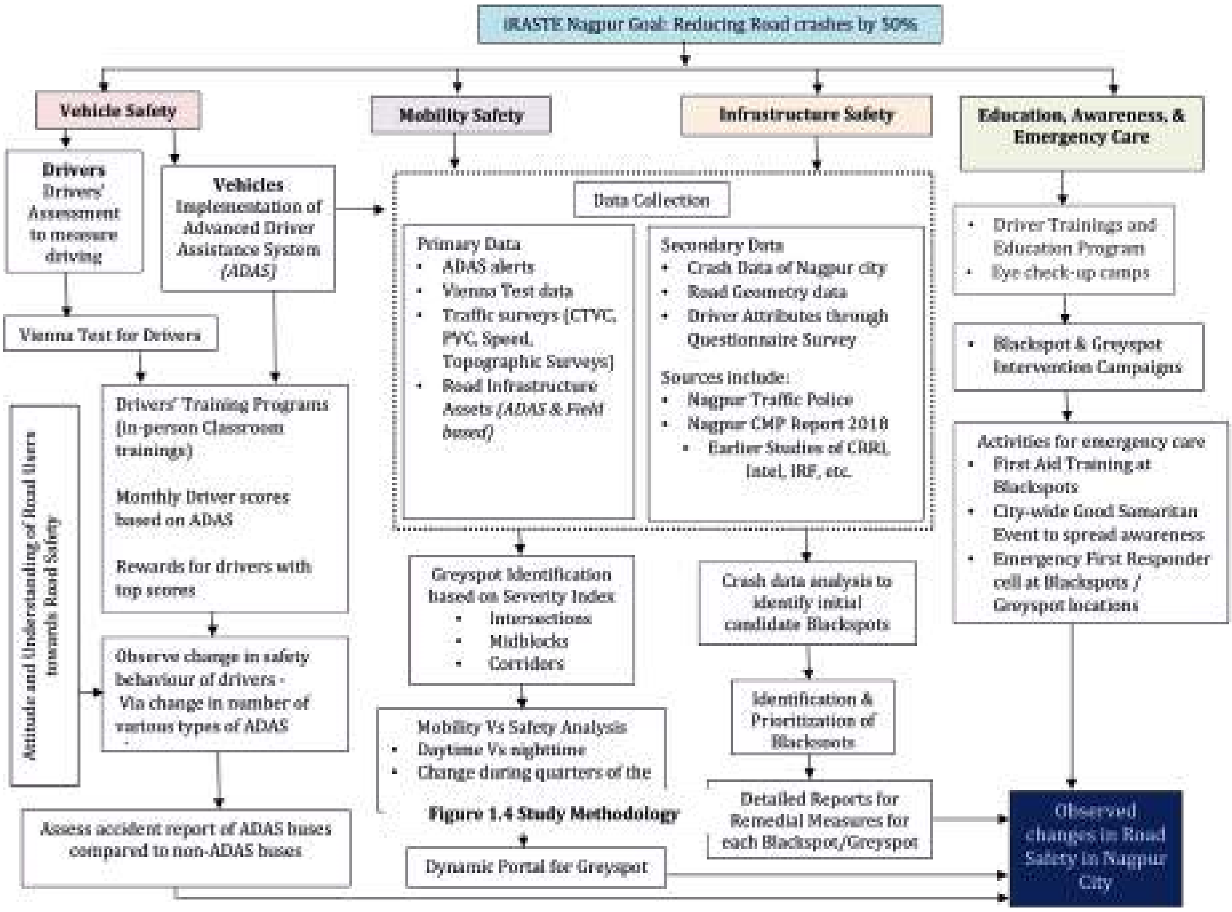


Figure 1.4 Study Methodology

2) **Mobility Safety:** Based on the alert data generated by ADAS devices, the greyspots on the road network traversed by the NMC fleet have been identified which is followed by devising cost effective engineering improvements for possible implementation.

3) **Infrastructure Safety:** This task focuses on the identification of blackspots based on FIR data and based on total station and traffic surveys, a detailed project report towards the rectification of the blackspots is prepared. Also, development of Road Quality Index (RQI) through digital mapping of road infrastructure assets.

4) **Driver Education, Training, Emergency Care, and Awareness Campaigns at Blackspots and Greyspots:** Parallel and central to the above three vectors is the concerted efforts put forth towards imparting drivers' training, education, and awareness towards achieving enhanced road safety. This task also included the categorizing of drivers based on Vienna Test and the relevant analysis to see the level of adoption of ADAS device among various drivers. Apart from drivers, awareness campaigns imparted amongst the road users and community at large are also covered in this task.

5) Under the **Encouragement**, Nagpur Municipal Corporation (NMC) bus drivers encouraged to prioritize safe driving, uphold good driving behaviour, and adhere to traffic rules. Their commitment to these good practices is continuously rewarded with incentives.

The works accomplished under each of the above-mentioned vectors are discussed in detail in the succeeding sections.

VEHICLE SAFETY

2

2. Vehicle Safety

Road crashes involving large vehicles like buses or trucks cause more fatalities to Vulnerable Road Users *(VRUs,such as pedestrians or two-wheelers)* as well as grave damage to public property. The top reasons attributed to such crashes include driver distraction, indiscipline of road users as well as poor road geometrics. Avoiding some of these crash reasons is under the direct control of the driver e.g., driver distraction, whereas some others require the driver to be acutely mindful to external factors on the road. **Hence defensive driving by drivers of large commercial vehicles has a major impact on the reduction of road crashes and fatalities in selected project corridors. Recent advances in AI-based vehicle safety technology such as Advanced Driver Assistance Systems (ADAS) assist drivers in defensive driving**. Alerts from ADAS devices improve driver reaction time by up to 2 times which reduces collision likelihood. Project iRASTE is the first initiative in India to study the impact of AI-based ADAS devices in improving the safety of large, commercially operated fleets in **real-world conditions**. Nagpur city was the first project corridor selected for implementation of Project iRASTE. This was followed by iRASTE implementation roll-out in Telangana state.

Project iRASTE is now the largest and longest running study of Advanced Driver Assistance Systems (ADAS) for commercial vehicles in India. This report summarizes observations on safe driving behaviour of drivers after introduction of Advanced Driver Assistance Systems (ADAS) devices in Nagpur city fleets. The findings from this project will serve as recommendations for large commercial fleets looking to improve vehicle safety by adopting AI-based safety technology. Furthermore, it will also assist policy bodies and technical standard bodies in India as they formulate regulations for safer vehicles on Indian roads. To accomplish this, the report first provides an overview of ADAS functionality; the second section provides an overview of the Nagpur city fleets selected for study; the third section explains study methodology; the fourth section discusses study results in detail; the fifth section highlights influence of factors encountered in real-world operations; the final section summarizes conclusions and next steps.

2.1 How do Advanced Driver Assistance Systems (ADAS) help?

AI-powered Advanced Driver Assistance System continuously monitors the road ahead and warns the driver a few seconds before a potential collision. Such real-time warnings improve driver reaction time by up to 2X. This in turn reduces the likelihood of collisions. The alerts warn the driver of risk from other vehicles as well as vulnerable road users like pedestrians or two-wheelers. The alerts also encourage defensive driving practices such as lane discipline and safe headway from vehicle ahead

Figure 2.2.1 ADAS safety alerts delivered to driver via audio and visual alerts. Speed limit indicator (SLI) is provided as a visual display of the ADAS

2.1.2 Illustrations of ADAS-enabled buses and ADAS safety alerts

The main components of an ADAS device include a camera unit focused on the road and a display unit. The single-camera unit has a powerful processor that processes video data locally and uses advanced AI algorithms to detect risk in real time. All computations are done locally which avoids the inefficiency of sending video data to a cloud for processing. Once the camera unit detects imminent risk, the driver is alerted via the display unit fixed at eye-level of the driver. The display unit generates visual as well as audio alerts that captures attention of the driver. The alert information is also sent to a cloud portal which archives all such events for detailed offline analysis. The ADAS solution used for the study was from Intel Onboard Fleet Services (IOFS), a leading provider of fleet safety solutions.

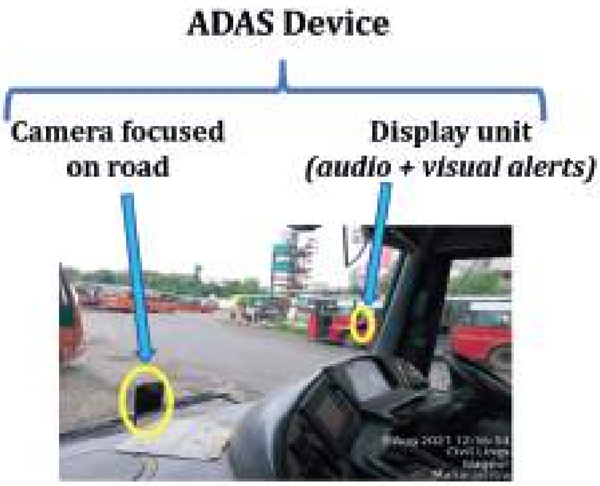


Figure 2.2 ADAS-enabled bus; The main components of an ADAS device include a camera unit focused on the road and a display unit.

Figure 2.3 ADAS unit alerts driver with unsafe distancewarning for VRUs; Pedestrians and Vehicles, including 2- wheelers are detected

Figure 2.4 Repeat warnings on unsafe distance ignored by the driver, resulting in a HMW. Offline analysis based on cloud portal data.

Figure 2.5 Driver applying hard brake, alerted by a FCW. Offline analysis based on cloud portal data

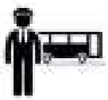
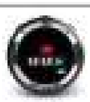
2.2 Overview of study fleets

As mentioned earlier, Nagpur city was the first city selected for implementation of Project iRASTE. In every state in India, government operates large commercial bus fleets that offer public transit services. Safety and timeliness of public transit services is an important metric indicating service quality. Hence 150 buses of Nagpur Municipal Corporation (NMC) in Nagpur offering intra-city transit services were selected as primary study fleet to assess effectiveness of AI-based ADAS devices. This roughly comprises one-third of the total NMC fleet. Further 50 school buses were selected as the second study fleet. Given sensitive nature of this fleet type, it was useful to study the impact of ADAS devices in training school bus drivers in defensive driving. Other fleets selected for ADAS installation included private fleets in Nagpur city offering employee transportation services and cab services.

Project preparation activities started in August 2021. The project then started pilot ADAS installation on 50 buses of NMC. Study methodology was validated on this pilot installation. This smaller pilot allowed the study team to learn about real-world operational challenges when working with a complex government fleet. Key parameters of study methodology were refined during this period. ADAS installation on all study fleets in Nagpur was completed by April 2022. Hence May 2022 – May 2023 is considered as the study period for reporting observations.

NMC bus fleet was selected as the primary study fleet. This report provides detailed observations from ADAS-enabled buses of Nagpur Municipal Corporation (NMC). Deeper focus on one large commercial fleet helps the study to make specific and detailed observations regarding effectiveness of ADAS in improving safety of large commercial fleets, especially government operated fleets.

Table 2.1 Key characteristics of ADAS-enabled NMC bus fleet

	150 ADAS-enabled buses	ADAS was installed on roughly one-third of NMC fleet that ply on fixed routes. During the same period, NMC also operated 200-250 non-ADAS buses. This allowed for comparison of road crash statistics of ADAS and non-ADAS buses during the same period.
	979 drivers	979 drivers drove ADAS-enabled buses during the study period. Drivers are allocated buses based on a dynamic schedule. 1:1 association is not maintained between a bus and driver. Given longer duration of the study, driver churn was also observed.
	65 Lakh Kilometers	ADAS-enabled buses drove 65 Lakh kilometers during the study period. This mainly covered city routes, though highway roads were also part of the service.
	5AM – 11PM	Typical fleet operation time window. 3 shifts: 5AM – 1PM, 1PM – 11PM, 8AM – 8PM
	12 Study Periods	The study involved observations across 12 time periods from May 2022 – May 2023, to allow for longitudinal analysis of results

School bus fleet data was primarily used to study defensive driving behaviour of drivers of this fleet type. Obviously, the road crashes involving school buses were found to be lower than the buses operated under NMC permit which may be directly attributed to lower vehicle kilometers of travel (VKT) and more safer driving habits. However, school bus is a sensitive fleet, with grimmer consequences in the unfortunate event of a road crash. This is a necessary condition for achieving ZERO-CRASH target for this sensitive fleet type.

Table 2.2 Key characteristics of ADAS-enabled school bus fleet

	50 ADAS-enabled school buses	ADAS was installed on 50 school buses operated by a single Nagpur city-based operator
	50 drivers	1:1 association between a bus and driver is maintained by the operator
	6 Study Periods	The study involved observations across 6 time periods from (mid) Aug 2022 – Feb 2023, to allow for longitudinal analysis of results.

Other fleets included private fleets in Nagpur city offering employee transportation services and cab services. Such a diverse installation allows the study to make observations in varied fleet types. However detailed report is prepared only for the first 2 study fleets, i.e., NMC buses & School buses

2.3 Study Methodology

The methodology for data analysis is shown in Figure 2.6.

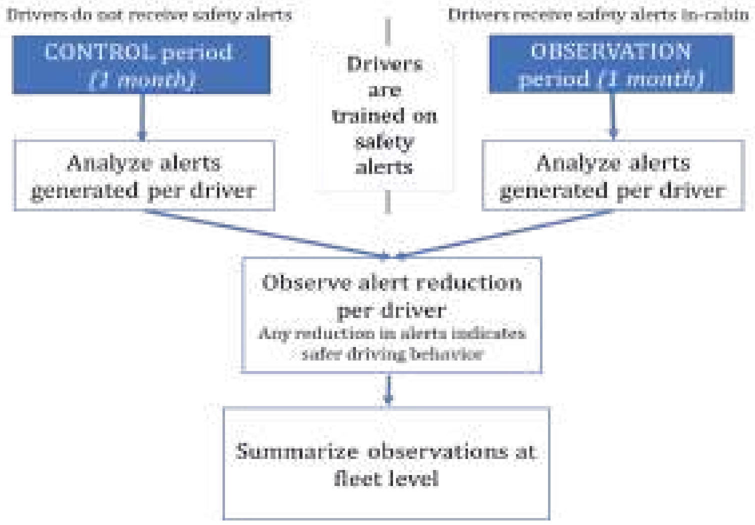


Figure 2.6 Methodology of data analysis

The study started with a Control Period, spanning a minimum of 1 month. This period is indicated by the acronym, CP in subsequent sections. During the Control period, drivers do not receive ADAS alerts in-cabin. However, alerts generated by drivers are recorded in the cloud. This data is used to prepare a baseline record of total alerts generated by every driver of ADAS buses. The alerts are then normalized by distance driven to obtain a risk score for the driver. Detailed information on driver risk score is provided in **Section 2.4.1.2**. At the end of the Control Period, all drivers are trained on ADAS and Defensive driving using ADAS alerts. Now the study enters Observation Period (OP). In this period, drivers receive ADAS alerts in-cabin. This includes audio and visual alerts. Risk score of every driver of ADAS buses is recorded during this period. Every Observation Period spans 1 month. A reduction observed in risk score of drivers is an indication of improvement in safe driving behaviour. This analysis has been extended to individual ADAS alerts aimed at assessing improvement in Lane Departure, Safe Headway, Pedestrian collision, and Forward collision alerts. **This study included 1 Control Period (CP) and 11 Observation periods (OP) for the primary study fleet, allowing for longitudinal analysis.**

2.3.1 Challenges

The operational complexity of NMC service doesn't allow fleet managers to maintain 1:1 association between drivers and buses. Drivers are also allocated buses based on a dynamic schedule. Hence all drivers don't drive one fixed route but drive multiple city routes. Due to this, route driven by a driver may have an influence on risk score. However, there is large overlap observed in driver routes. Hence even if drivers are allocated different routes, its effect on risk score is expected to be small. To further minimize the effect of route on risk score of a driver, Control and Observation periods span a large window of 1 month. This allows for sufficient randomness in route assignments such that risk score of a driver is not adversely impacted by route assignment. Another challenge encountered is in training drivers in ADAS. ADAS is a new safety technology introduced as part of Project iRASTE. A single training cannot cover all drivers effectively. Hence the support of NMC operators was enlisted to conduct periodic ADAS refresher training to drivers during the Observation periods.

2.4 Study Findings

2.4.1 NMC bus fleet

2.4.1.1 ADAS alerts overview

ADAS-enabled NMC fleet were driven in excess of 65 Lakh kilometers during the study period covering the various arterial / sub-arterial road network as well as national / state highways falling in the peri-urban part of Nagpur metropolitan area (refer Figure 2.7).

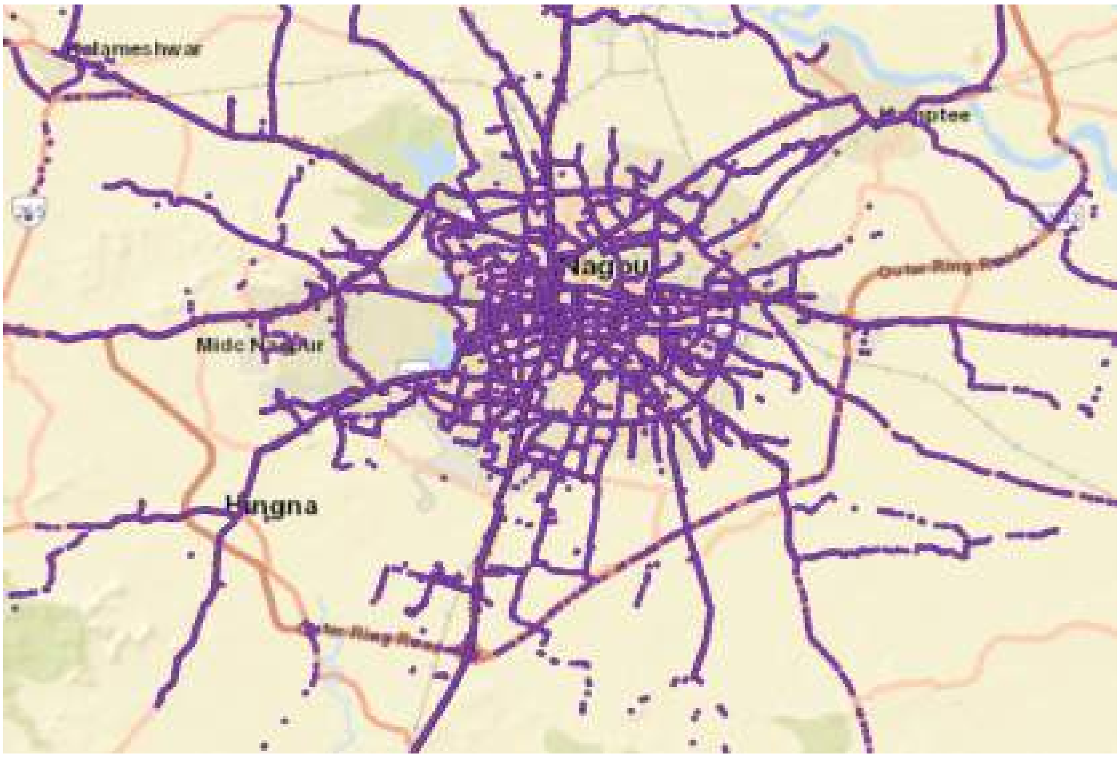


Figure 2.7 Coverage of Nagpur Road network by ADAS buses

Unsafe distance warnings such as Headway Monitoring Warnings (HMWs) were the highest recorded alerts in Nagpur city, followed by Pedestrian Collision Warnings (PCWs). This can be considered as a characteristic of urban roads. This distribution of ADAS alerts may change if study corridor comprises of other types of roads e.g., highways.

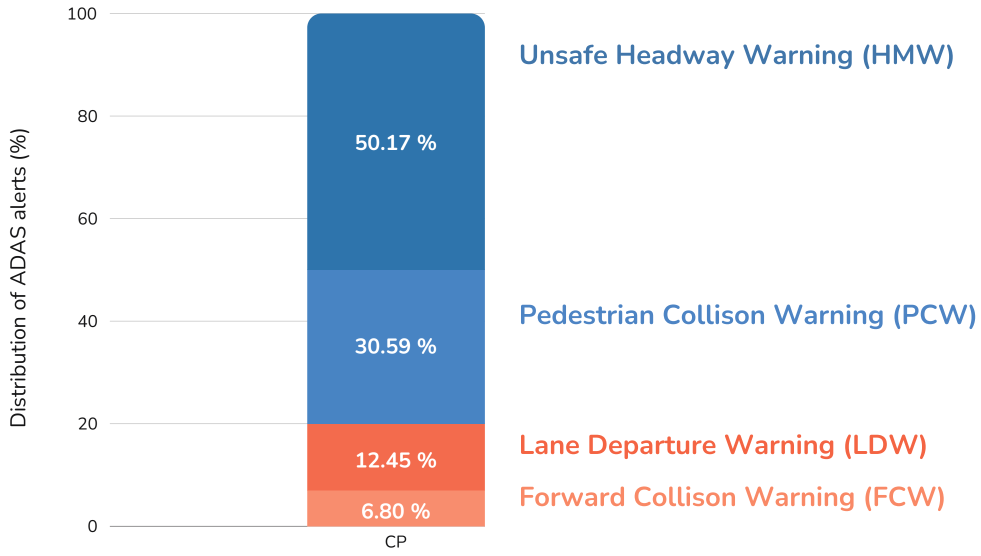


Figure 2.8 Distribution of ADAS alerts during Control Period (CP) in Nagpur city (road network comprises primarily of urban roads)

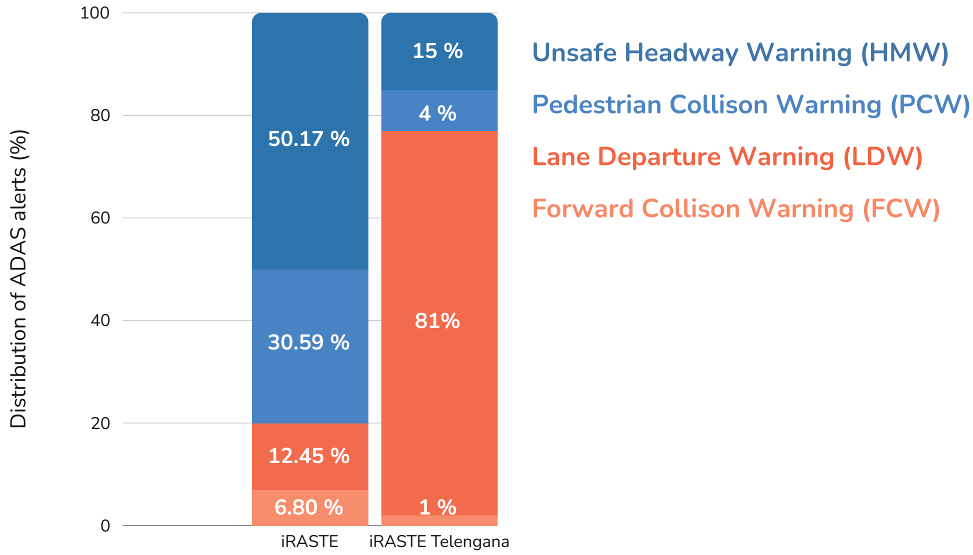


Figure 2.9 Comparison of ADAS alerts distribution on urban roads (iRASTE Nagpur) and highway roads (iRASTE Telangana). Detailed observations on alert distribution across urban and highway roads will be included in iRASTE Telangana report.

2.4.1.2 Risk score computation based on ADAS alerts

Today road crash statistics of a fleet is the primary source of data for assessing risk level of a fleet. Unfortunately, this is a lagging indicator, i.e., it can be measured only after the road crash has happened. Hence interventions required to prevent road crashes become a reactive measure. This is particularly problematic for commercial fleets which see very high churn in drivers, with new drivers forming a large percentage of the employee base. Without a reliable leading indicator of fleet risk, training needs cannot be assessed. Data from ADAS devices provide a means of reliably computing risk score of a fleet. **Risk score based on ADAS data is a leading indicator of road crash risk and can be used by fleet operators to design proactive interventions** such as driver training, personalized coaching, performance rewards etc. The following section explains how risk score of a fleet is computed in study corridor.

As mentioned earlier, ADAS device provides 4 types of audio/visual alerts to drivers in-cabin. These include Forward Collision Warning (FCW), Pedestrian Collision Warning (PCW), Lane Departure Warning (LDW) and Unsafe Headway Warning (HMW). Moreover, speed limit indicator (SLI) is provided as a visual indicator / 36 warning only on the ADAS display unit, wherever such road signs are encountered on the road network traversed. To compute risk score of the fleet, firstly risk score is computed for every individual driver. Driver risk score is computed as a sum of 4 alerts (FCW, PCW, LDW, HMW) generated by the driver, normalized by distance over which alerts were generated as presented in equation 2.1. SLI alert is not included in risk score computation as speed signs may not be reliably available for every road segment. Once driver risk score is computed, fleet risk score is computed as the median of all individual driver scores as presented in equation 2.2. The use of median prevents the influence of outliers.

$$\text{Driver Risk Score} = \frac{\sum (FCW\ ,\ PCW\ ,\ LDW\ ,\ HMW\ )}{\text{Distance over which alerts are generated}} \quad \text{..............Eq. 2.1.}$$

$$\text{Fleet Risk Score} = \text{Median of individual driver risk scores} \quad \text{.......................Eq. 2.2.}$$

Risk score is computed for every period, including Control period and Observation periods. Lower the risk score, lower is the likelihood of road crashes. As explained in study methodology section, each period spans 1 month. This allows for sufficient randomness in route assignments such that risk score of a driver is not adversely impacted by route assignment. Normalization of alert count by distance ensures that risk score is comparable across drivers who drive different distances in a month. A distance filter of 320KM is also applied in every period, i.e., only a driver who has driven a minimum of 320KM in a month is considered for risk score assignment. This value of distance filter allows for sufficient randomness in routes, based on distance driven by a driver per day.

Limitations

The risk score is not normalized to a standard scale, e.g., 1-100. Equal weightage is assigned to every alert type. The absolute value of risk score thus computed is dependent on alert characteristics of the fleet. Hence risk score in this study is used only within a fleet type to observe improvements and to set performance targets. Such a risk score can also be used to compare performance across fleets with similar operating characteristics such as shift timing, frequency, route features etc. However, it should not be used to compare performance across fleets that have different operating characteristics. For example, risk score of NMC fleet is not directly comparable with risk score of school bus fleet.

2.4.1.3 Classroom training to Cabin training: A major upgrade in driver skilling

Traditionally, driver skill gaps have been addressed via classroom training, test tracks or other spot checks in the field. Driver performance improves post the intervention but drops soon after. In Project iRASTE, the team took the opportunity to move away from Classroom training to real-time Cabin training. **Along with introduction of new vehicle safety technology, it is also important to redesign existing driver training workflows**. With Cabin training, the objective was to combine existing classroom training with on-the-job training via driver risk scores. The coaching schedule for drivers was adapted as shown in Figure 2.10 whereas Figure 2.11 depicts the comparison classroom training versus cabin training and a brief overview of the three training programs.

Figure 2.10 Coaching schedule for drivers in Cabin training approach.

Classroom Training Approach	Cabin Training Approach
Training are conducted in special settings only - classroom, test track etc. Training frequency varies across fleets	Classroom training is combined with on-th-job training in the vehicle cabin via driver risk scores
Training outcomes are not immediately measurable	Risk scores are available monthly as an objective measure of training outcome (eg., objective driver scores used by services like Uber encourage improved driver performance)
Training content is standard, is not customized to learning ability of the driver	Monthly risk scores and individual alert performance encourage personalized coaching
Special setting for taining disrupts operator schedule	Training is primarily on-the-job

Figure 2.11 Driver training and recognition programs are critical for program success.

A small sample ethnographic study was also conducted in all driver training programs (DTP) from year 2022 to 2024, to get driver feedback on ADAS technology and perceived benefits.

2.4.1.4 Observations on drivers' adoption of ADAS

With Cabin training based on ADAS, the objective is to combine existing classroom training with on-the-job training via driver risk scores. It is important to continuously analyze individual driver scores to assess perceived ease-of-use and perceived usefulness of new technology and workflows.

Perceived ease-of-use of ADAS technology

Perceived ease-of-use was assessed by analyzing what percentage of drivers are able to improve their risk score after 3 month of experience with ADAS technology. On average, 60 % of drivers were able to follow ADAS alerts and reduce risk score within just 3 months. At the end of 12 study periods, 80 % of drivers have been able to achieve overall reduction in their risk score.

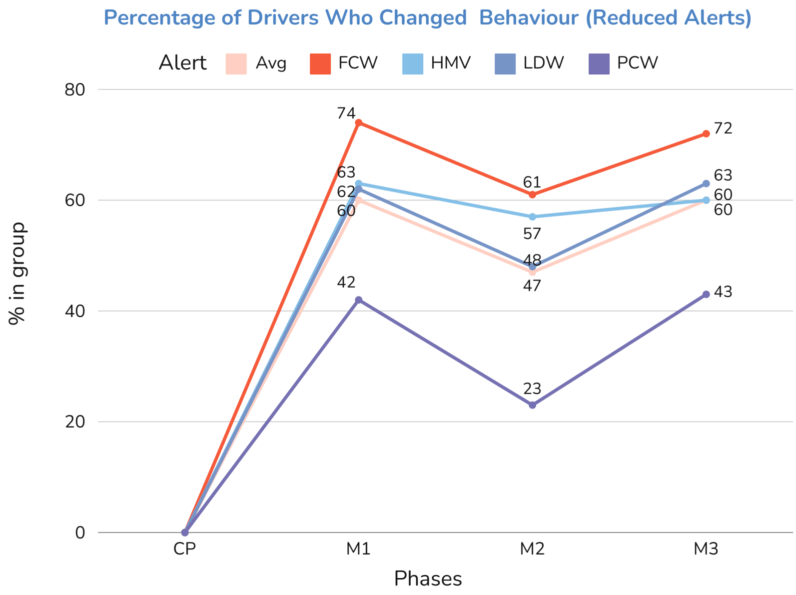


Figure 2.12 On average, 60% drivers were able to follow ADAS alerts and reduce risk score within just 3 months. At the end of 12 study periods, ~80% drivers were able to achieve overall reduction in their risk score.

Perceived usefulness of ADAS technology

Perceived usefulness of ADAS technology to an operator was assessed by analyzing driver risk score distribution in ADAS versus non-ADAS buses. Cabin training makes coaching real-time, learner-centered, and personalized, representing a major upgrade in driver skilling. Improvements in fundamental driving discipline such as safe headway is noteworthy. This allows fleet operators to boost performance of the average driver, irrespective of number of years of driving experience. During CP period, it was observed that roughly 53% of drivers recorded above average scores. This is consistent with tests conducted using Vienna test system. Prior to installation of ADAS devices, Vienna test procedure on a sample of NMC drivers also showed that roughly 50% drivers scored above average. However, 75 % of drivers recorded above-average scores at the end of the observation periods, which is a significant jump from CP period. Thus, this provides a way to boost skill level of the entire fleet in a sustained manner.

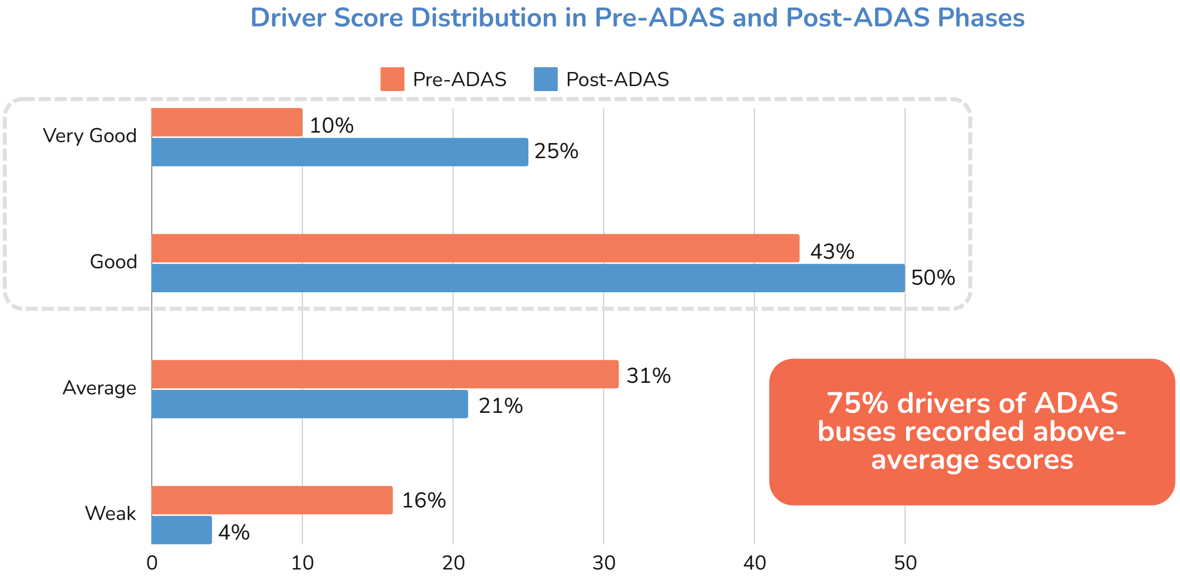


Figure 2.13 Driver score distribution in Mar'23 at the end of 3 rd iRASTE training session; 75 % drivers recorded Above-average score in post-ADAS period, as against 53% in pre-ADAS period. This represents a major upgrade in driver skilling.

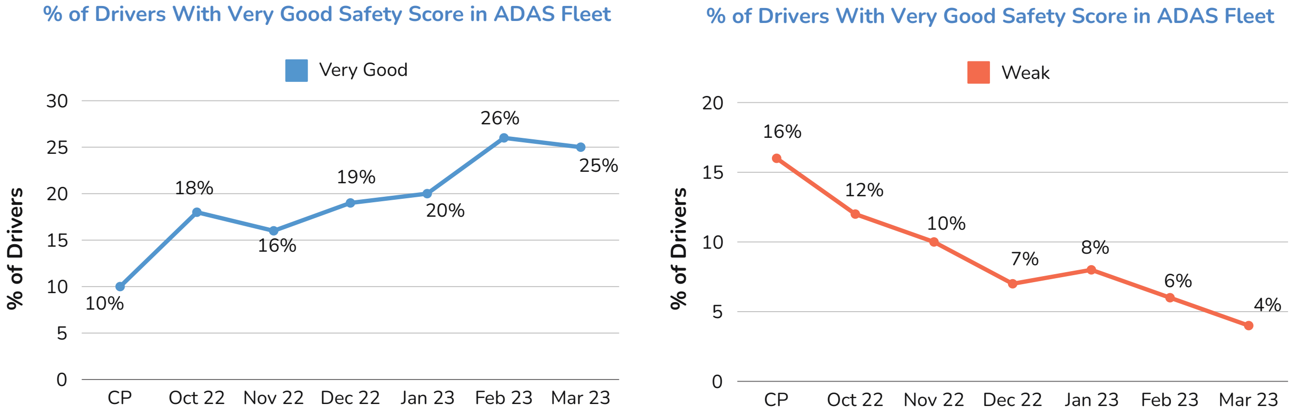


Figure 2.14 Cabin training approach has shown steady improvement in driver performance.

2.4.1.5 Observations on safe driving behaviour with ADAS devices

After installation of ADAS units, risk score is computed for the fleet as explained in Section 2.4.1.2. Figure 2.12 shows the risk score trend of ADAS-enabled NMC fleet over a 12-months period.

"Lower the risk score, lower is the likelihood of road crashes."

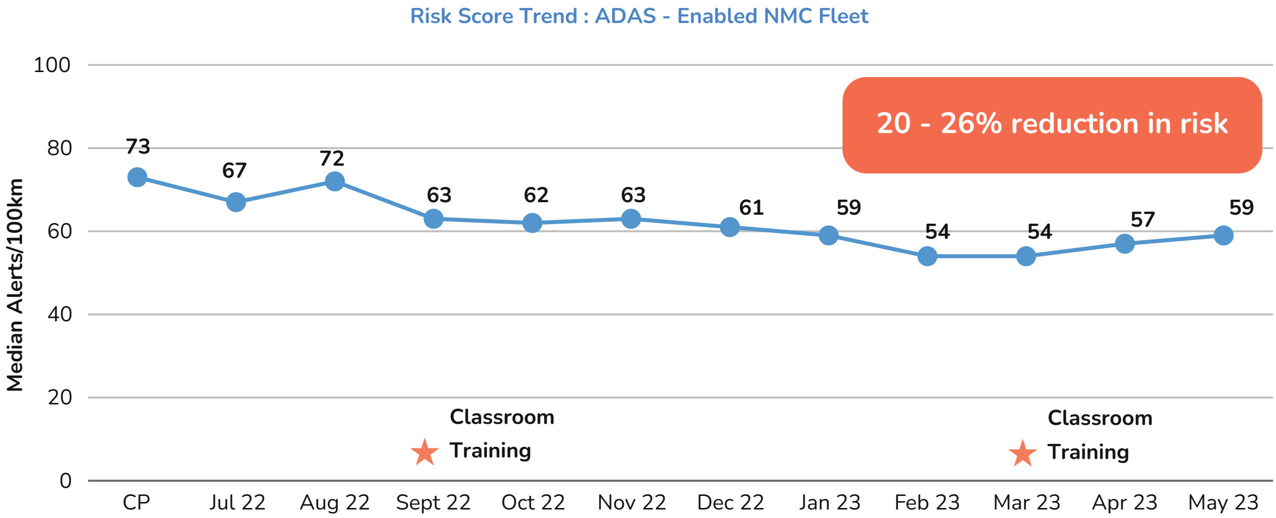


Figure 2.15 Risk score trend of ADAS-enabled NMC fleet over a 12-month period. 20-26% reduction in risk was observed over this period.

The risk score chart indicates that in CP period, this fleet generated 73 ADAS alerts per 100 KMs, which is closer to 1 alert every 1 km. In the initial observation periods, the risk score fluctuated which indicates that drivers were adapting to the new technology. By September 2022 risk score stabilized, which also coincided with a classroom training conducted. Since then, the fleet has demonstrated consistent decline in risk. By the end of the observation period, the same fleet was generating an ADAS alert only once in every 2 kms. **A declining trend in risk score is a leading indicator of reduction in crash risk.**

A risk score of 50-55 can be considered as good for this fleet plying on urban roads. However, with continuous training and reward programs, it may be possible to reduce risk score even further.

Note: *The study experienced some field maintenance issues in the month of July 2022. High number of device disconnections were observed which hampered reliable data analysis for this month. Eventually, longitudinal analysis discarded data from this period. Extensive driver and technician awareness sessions were conducted which minimized the impact of these issues in subsequent periods.*

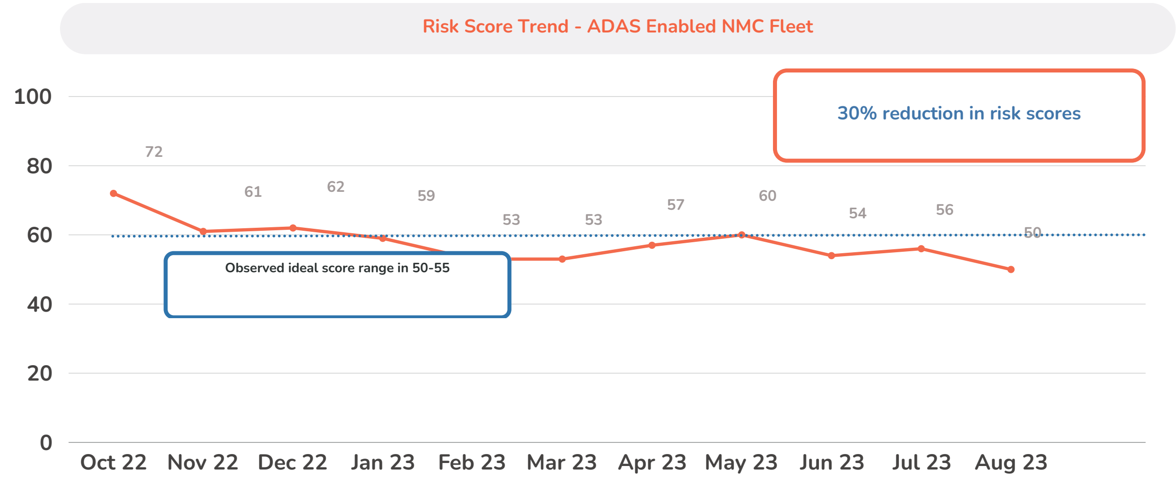


Figure 4: Driver risk scores

Figure 2.16 Updated Risk score of Bus Drivers till August 2023.

It can be seen that risk score has stabilized in the range 50-55. Hence this range has been considered as ideal score range for Nagpur city. Any deviation from this range should be investigated closely to identify new implementation challenges in the field.

A deeper analysis was also conducted to understand the trend of individual ADAS alerts during the 12-month period. Decline of Unsafe headway alerts by 23% is commendable in urban driving conditions. This is a critical driving disciplines for city drivers. **33 % decline in Forward collision alerts indicates a decline in near-miss incidents on road.**

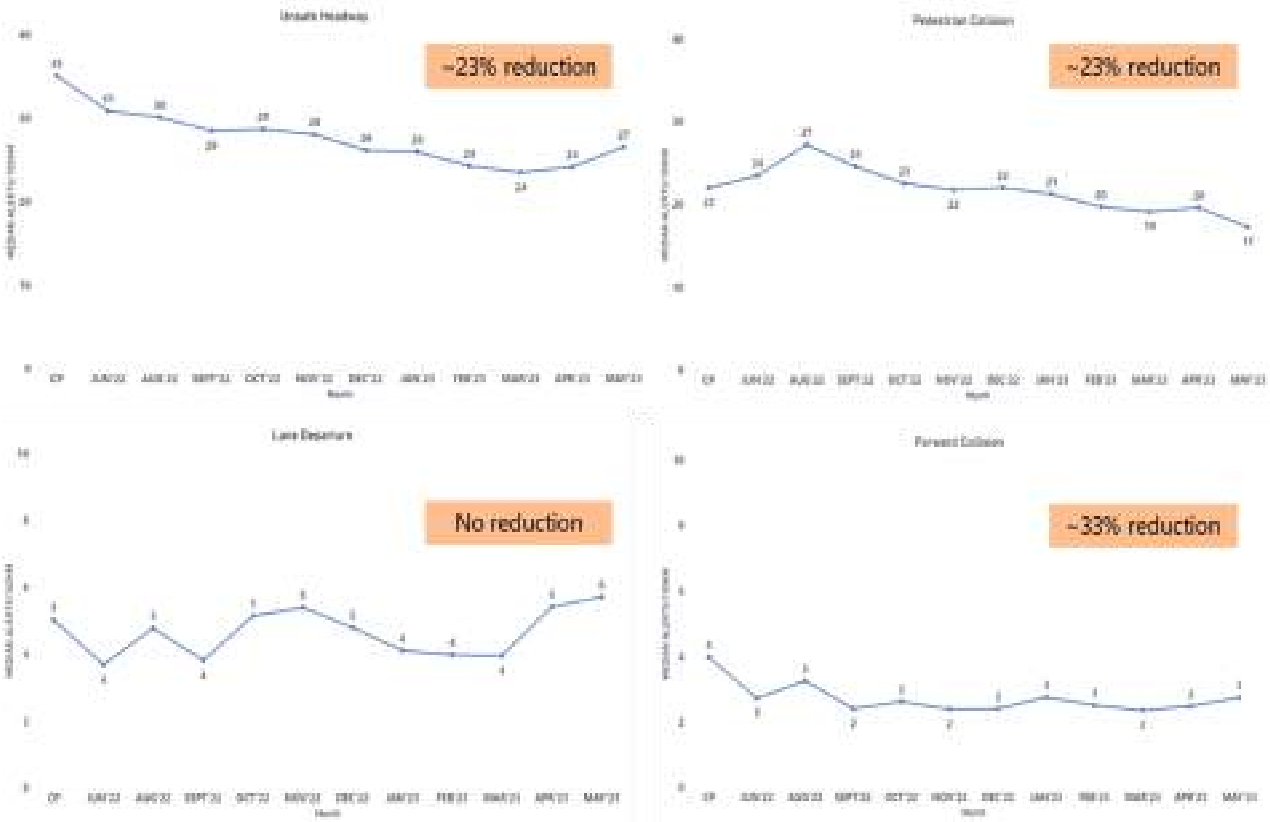


Figure 2.17 Trend of 4 ADAS alerts after ADAS installation. Defensive driving behaviour like Unsafe headway registered good highest decline. This is a critical driving disciplines for city drivers

2.4.1.6 Observations on Road Crash statistics in ADAS vs non-ADAS buses

As drivers become more familiar with ADAS technology, relative accident rate of ADAS buses drop sharply. In 2023, an assessment was made of crash statistics in ADAS vs non-ADAS buses in NMC service. ADAS was installed on 150 buses of NMC that ply on fixed routes. During the same period, NMC also operated 200-250 non-ADAS buses, including electric buses. This allowed for comparison of road crash statistics of ADAS and Non-ADAS buses during the same period.

Road Crash data was obtained from NMC bus operators that happened during the period from June 2022 to August 2023. These included road crashes involving both ADAS and Non-ADAS buses. This allowed for road crash rate comparison in the same time period. On the other hand, the road crash data of electric buses was not analyzed as they were relatively new in service.

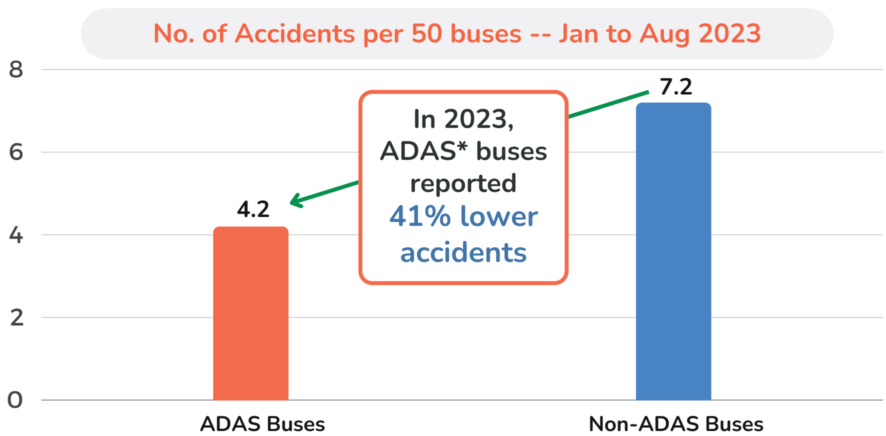


Fig 2.18 Road Crash rate per 50 buses. In the 1st 8 months of 2023, ADAS buses reported 41% lower accidents than non-ADAS buses.

Day-to-day management of NMC service is done by 3 operators. A total of 38 on-road accidents were reported by the three operators during Jan'23 – Aug'23. 12 accidents were reported in ADAS buses, and 26 accidents were reported in non-ADAS buses. However, these figures are not directly comparable as total number of ADAS buses and non-ADAS buses were not the same during this period. To enable comparison, accident figures were normalized to "Accidents per 50 buses" as seen in Figure 2.18. In the first 8 months of year 2023, ADAS buses reported 41% lower accidents than non-ADAS buses.

Additionally, analysis was done to assess how accident rate has improved over the project period. This is shown in Figure 2.19.

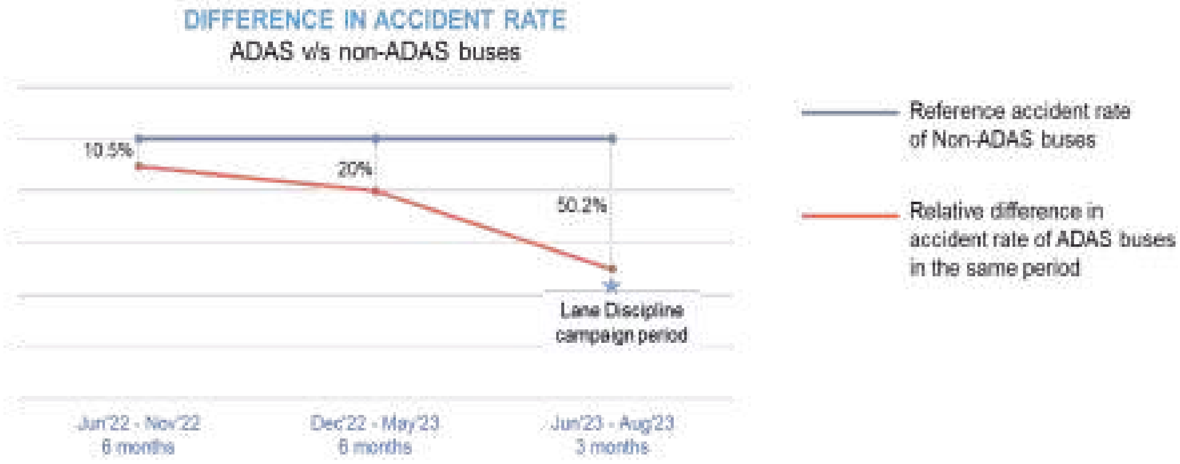


Figure 2.19 Relative accident rate of ADAS v/s non-ADAS buses during project period. Atthe beginning ofthe project, accident rate of ADAS buses was roughly the same as non-ADAS buses. However, by Jun'23 – Aug'23 period, ADAS buses were observed to be twice as safe as compared to non-ADAS buses.

As seen in above Figure 2.19, Jun'23 – Aug'23 saw 50% difference in accident rate between ADAS and nonADAS buses. During the period of Jun'23 – Aug'23, iRASTE team initiated an innovative campaign with all ADASequipped NMC bus drivers targeting a decrease in road crashes. Focused on one of the ADAS alerts i.e., Lane 43 Departure Alerts (LDW), iRASTE initiated the **'Lane Discipline Challenge'** campaign, aimed to minimize lane departure warnings / alerts, and enhance the overall driving behaviour of bus drivers in the road network. Drivers actively participated in this campaign by reducing alerts, contributing to a notable 50 % decrease in road crashes among ADAS equipped buses as compared to non-ADAS buses, as illustrated in Figure 2.19. The iRASTE team not only emphasized safety but also recognized exemplary driving behaviour by awarding top drivers with a 'Certificate of Appreciation' and Cash Rewards, reinforcing positive driving practices in the road network.

Limitations

- Data on total Kms recorded by non-ADAS buses was unavailable to the study team. This prevented normalization of Road Crash rate based on Kms driven. Hence Road Crash rate has been normalized based on number of buses.
- Accident data received by project team included incidents such as stone throw at bus, fuel theft, fights between driver and passengers, accidents inside depot etc. Such incidents were manually removed from accident analysis to include only on-road accidents.

2.4.1.7 Road Crash Forensics

Offline analysis of ADAS alerts can provide some inputs to augment our understanding of crash reasons. Figure 2.20 is an illustration of alerts generated prior to an road crash at Trimurtee Chowk. Though the illustration is not able to point the specific crash reason, it helps to confirm road crash time and location. In these cases, a road-facing dash-camera can provide invaluable evidence related to a crash.

Figure 2.20 Illustration of ADAS alerts recorded prior to a crash

2.4.1.8 Study limitations

a. All drivers of ADAS buses didn't have uniform experience with ADAS.

Driver inexperience with ADAS can adversely impact driver risk scores. ADAS was installed on roughly one-third of NMC fleet that ply on fixed routes. Since drivers are assigned based on a dynamic schedule, it is possible that a driver with relatively less experience with ADAS is assigned to drive an ADAS-enabled bus.

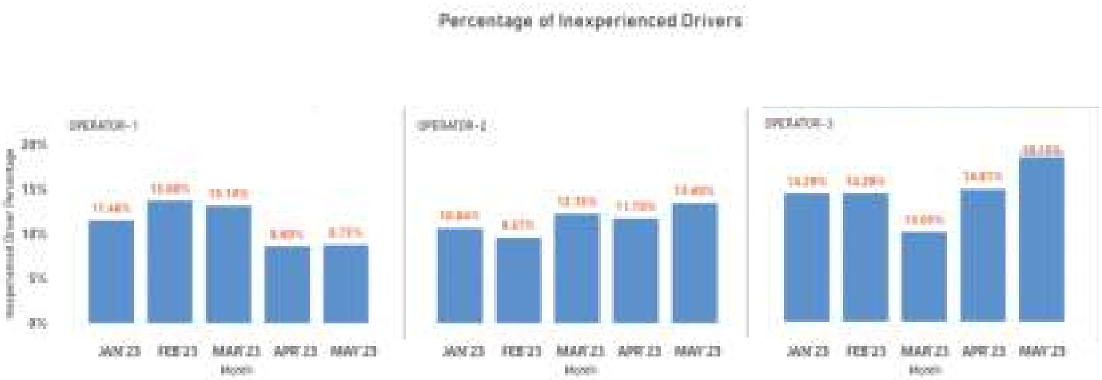


Figure 2.21 Percentage of drivers in a sample period who are relatively inexperienced with ADAS. In this example, 8-19% drivers in this period didn't have sufficient ADAS experience.

Real-world scheduling challenges prevent fleet managers from assigning the same set of drivers to ADAS buses. **Driver inexperience with ADAS can adversely impact driver risk scores.** This problem is further compounded by driver churn, i.e., new drivers entering the system or old drivers leaving. If a new driver doesn't receive ADAS training upon joining, the driver may spend multiple periods before becoming familiar with the technology.

However, this is an unavoidable phenomenon when dealing with large fleet operations. In this study, this was mitigated by having an efficient driver training program.

b. Route assignment may affect driver's ability to improve risk score.

To minimize the effect of route on risk score of a driver, Control and Observation periods span a large window of 1 month. This allows for sufficient randomness in route assignments such that risk score of a driver is not adversely impacted by route assignment. However, the effect of route on driver performance should be taken up for future studies.

c. More frequent training and rewards cycle can improve driver performance

During the study period, classroom trainings and rewards cycle was undertaken once every 6 months. However, during new technology adoption phase, a more frequent training and rewards cycle should be adopted.

2.4.2 School bus fleet

2.4.2.1 ADAS alerts overview

Unsafe distance warnings (HMW) were the highest recorded alerts in school bus fleet recording 40 %. This was followed by Lane Departure Warnings (LDW) accounting for 29 % composition in a sensitive fleet such as school bus. The recording of the high proportion of the two types of alerts was reported to the school authorities 45 as well as sensitization workshop programs were conducted amongst the school bus drivers pressing the need for their reduction.

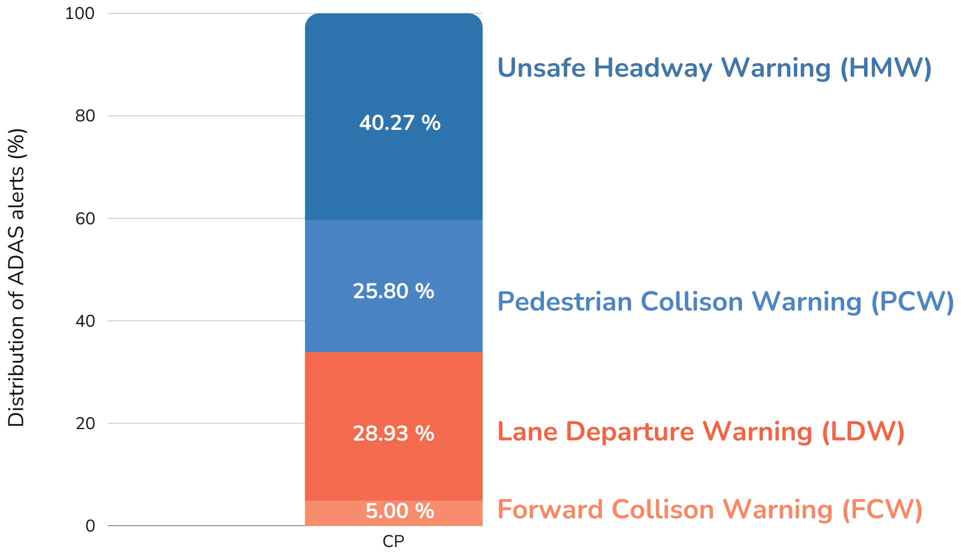


Figure 2.22 Distribution of ADAS alerts during Control Period (CP) in school bus fleet in Nagpur city (roads covered includes of a mix of urban roads and highway roads)

2.4.2.2 Observations on safe driving behaviour with ADAS devices

After the installation of ADAS units, risk score is computed for the fleet as explained in Section 2.4.1.2. Figure 2.23 shows the risk score trend of ADAS-enabled school bus fleet over a 6-month period.

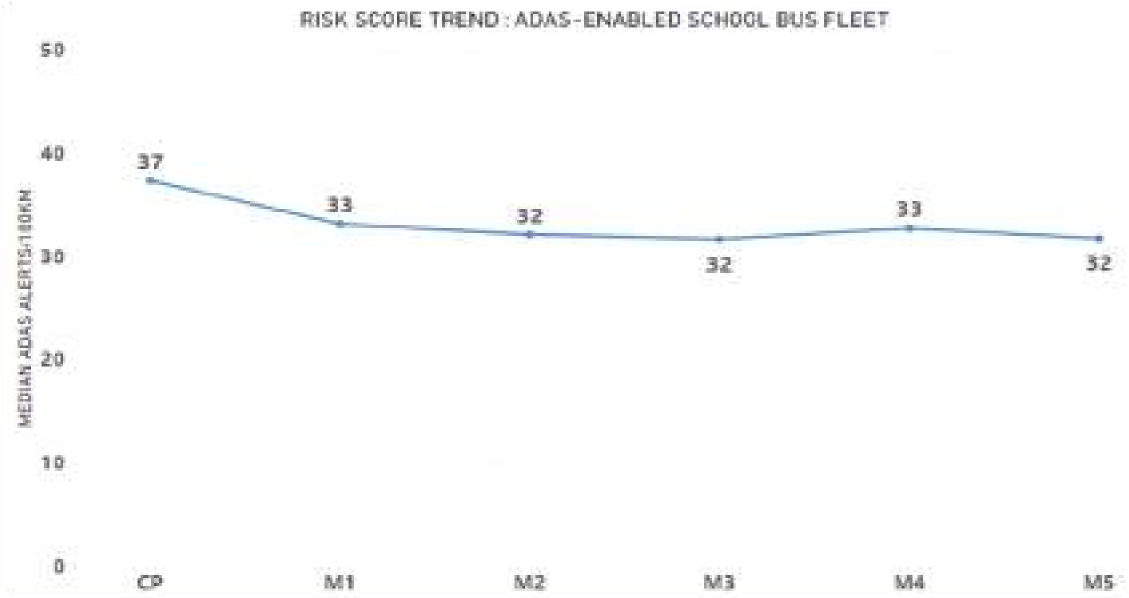


Figure 2.23 Risk score trend of ADAS-enabled school fleet over a 6-month period. 13% reduction in risk is observed over this period.

The risk score chart indicates that in CP period, this fleet generated 37 ADAS alerts per 100 KMs. The fleet has demonstrated consistent decline in risk. By the end of the observation period, the same fleet was generating 32 ADAS alerts per 100KMs, which represents a 13% reduction in risk. **A declining trend in risk score is a leading indicator of reduction in crash risk.**

The absolute value of risk score of school bus fleet much smaller than that of NMC fleet. However as explained in 4.1.2 the risk scores are not directly comparable as the two fleet have varied operating characteristics. However, risk score trend of school bus fleet indicates that the fleet has achieved a steady state with respect to risk score. Hence, we will focus our attention to performance on individual ADAS alerts with specific focus on defensive driving behaviours like safe headway and lane discipline.

NOTE: *The study of school bus fleet was initiated later than NMC fleet in August 2022. Control and Observation periods were not aligned on month boundaries. Hence the Observation periods are marked with period indicators such as M1, M2 and so on. The last period M5 ended by Feb 2023. Post that due to annual examinations and summer vacations, operation of school bus fleet has been erratic and hence these periods have been excluded from the report.*

A deeper analysis was also conducted to understand the trend of individual ADAS alerts during the same period as presented in Figure 2.24.

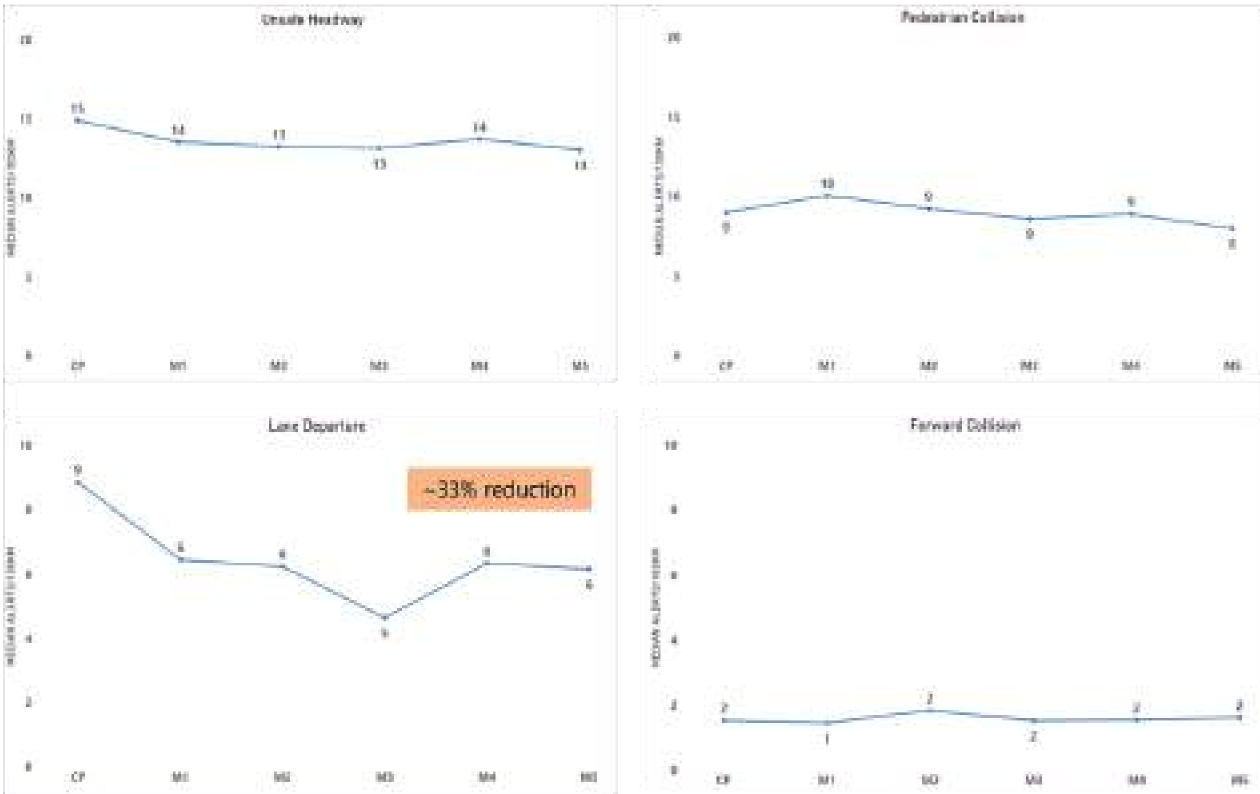


Figure 2.2.24 Trend of 4 ADAS alerts after ADAS installation. Defensive driving behaviour like lane discipline and safe headway registered the highest improvement. These are critical driving disciplines for city drivers.

2.4.2.3 Dispelling Myths about lane indiscipline in India

The study of school buses in Nagpur indicates that LDW is the 2nd highest type of ADAS warning generated by school bus drivers. It is observed that though instances of lane indiscipline are definitely higher on highways, even a fleet as sensitive as school buses plying on both type of roads are prone to lane indiscipline.

Adequate training on the importance of lane discipline and how to maintain it on the road is often missed. As part of iRASTE, consistent monitoring and feedback was provided to school bus drivers on this key safety discipline. Lane departure trend line in Figure 2.24 shows that with active involvement of fleet operators, it was possible to reduce instances of lane indiscipline by almost 33%. During this study, school bus drivers responded very well to training and technology initiatives.

2.5 Conclusions

The results of this study demonstrate the effectiveness of AI-based ADAS devices in improving safety of large commercial fleets. In addition, as a outcome of 'LDW Challenge' campaign, noted 50 % reduction in road crash rate compared to ADAS and Non-ADAS equipped NMC buses. Another important contribution of this study is the ADAS-based Cabin training approach. This represents a major upgrade in driver skilling with 7 out of 10 drivers reporting above-average scores after 12 observation periods. Improvements in defensive driving practices like safe driving distance and alertness to Vulnerable Road Users (VRUs) are noteworthy. Periodic reinforcement of safe driving behaviors among drivers via trainings and digital campaigns is absolutely essential to sustain this improvement. This requires fleet operators to periodically track and incentivize safety performance of drivers of ADAS-enabled fleet who exhibit better compliance of road safety.

MOBILITY SAFETY

3

3. Mobility Safety Analysis

This section of the report deals with the analysis based on alert data generated from Artificial Intelligence (AI) powered Advanced Driver Assistance System (ADAS) devices which are equipped in the Nagpur Municipal Corporation (NMC) bus fleets. ADAS system on the buses are expected to generate huge volumes of ADAS alert data all along the road network traversed by the buses. So, this study focuses on analyzing these alerts to identify the most unsafe areas beyond the known Blackspots i.e., termed as **"Greyspots"** and thus can devise the proactive corrective measures so that the probability / possibility of road crashes especially road fatalities can be averted in the identified greyspots and prevent these locations from turning into future blackspots. For this analysis, apart from ADAS data, static data including road network with geometrical parameters are being considered. Fig 3.1 presents the broad methodology adopted for identifying Greyspots.

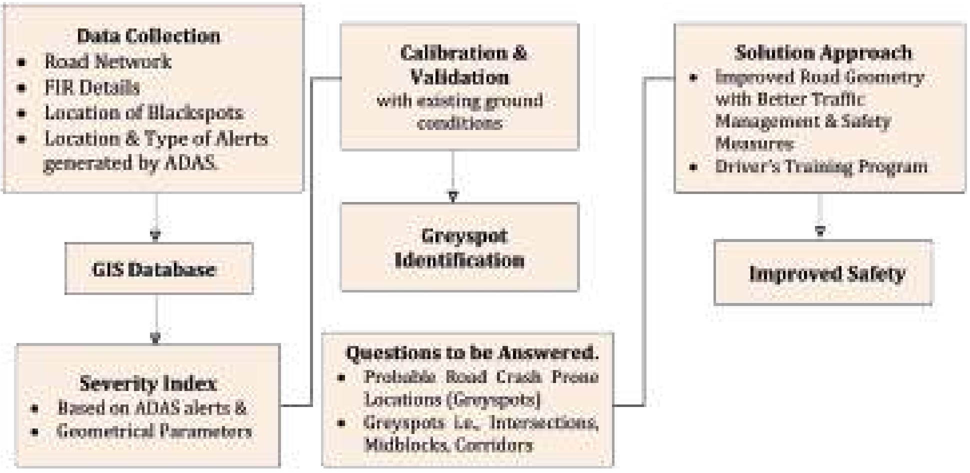


Figure 3.1 Suggested methodology for the identification of Greyspots.

As presented in Figure 3.1, data have been collected from four major sources as listed below

a) Road network for Nagpur city was collected from local authorities (Nagpur Municipal Corporation). This was updated based on Google Earth sources as well as primary sources / field visits. Road network is of total length of ~1907 km including suburbs. This comprises roads where buses do ply as well as where buses do not ply.

b) ADAS alerts comprising of various alert types, date & time, and location coordinates (Latitude / Longitude) obtained through the ADAS devices (from Mobileye1) installed on the NMC buses. Among the various types of alerts generated from the ADAS installed in the buses, the Forward Collision Warnings (FCW), Headway Monitoring Warnings (HMW), Lane Departure Warnings (LDW), and Pedestrian Collision Warnings (PCW) have been utilized in this study. During the observed period in our study (Operation Period i.e., 2023: Q1), a total of 1081797 alerts were observed from 211 buses. This includes 5.31 % FCW, 44.43 % HMW, 17.54 % LDW, and 32.71 % PCW.

c) First Information Report (FIRs) related to road crashes were collected from Nagpur Traffic Police (NTP). These FIRs originally in Marathi language, were converted to English. Further crash locational data given in the FIRs were converted into geo-positional information (latitude / longitude) to make it compatible for Geographical Information System (GIS). These FIRs encompasses the road crash and fatality data from

January 2019 to May 2023 provided by NTP during the study. Total of 3224 FIR records have been collected and used for all analysis and identified 38 Blackspots conforming to the Traditional Protocol of Ministry of Road Transport and Highways (MoRT&H) that says "Blackspot is a location wherein either 5 road crashes or 10 fatalities occurred within 500-meter road-section during the last 3 calendar years. Figure 4.6 presents the identified 38 Blackspots overlapped on road network and road crash locations.

d) Additionally, 12-hour (08:00 to 20:00 hrs.) Classified Traffic Volume Count (CTVC) study were carried out using videography survey at 21 blackspot locations out of 38 to capture the number of vehicles and their movement on the road network. Also, to estimate the intensity of traffic on the intersecting roads as well as on the midblock sections of the same. Further, the vehicle types converted into a standard unit called Passenger Car Unit (PCUs) because of having different sizes and characteristics of vehicles in the city. Passenger Car equivalents for various vehicle types adopted as prescribed in Indian Road Congress Code IRC-106:1990 titled, "Guidelines for Capacity of Roads in Urban Areas". Table 3.1 shows the aggregated count of traffic volumes of all 21 locations of Nagpur city that illustrates the volume count of different vehicles handled in Nagpur city was observed to be 1208650 Vehicles (792100 PCUs) which was further converted into a single standard passenger car termed as Passenger Car Unit (PCU). In addition, morning peak hour traffic is found to occur between 11:00 – 12:00 hrs. catering to about 64400 Vehicles (73300 PCUs) per hour and the evening peak-hour traffic occurs between 19:00 – 20:00 hrs. catering to about 76950 Vehicles (69900 PCUs). Detailed data of CTVC survey presented in Table 4.6.

Table 3.1 Aggregated Classified Traffic Volume Count (CTVC) data

		Morning Peak Traffic		Evening Peak Traffic	
Time period 08:00 to 20:00		Time period 11:00 to 12:00		Time period 19:00 to 20:00	
Vehicles	PCUs	Vehicles	PCUs	Vehicles	PCUs
1208653	792091	64359	73292	76915	69861

3.1 Road Network on GIS Platform

Road network Shapefile (GIS compatible file) was collected from NMC and same was upgraded correcting missing links within it. As shown in Figure 3.2, road network of Nagpur city covers all the road types.

Figure 3.2 Road Network of Nagpur City on GIS Platform

3.2 Grid formation over the road network

To measure the level of severity at any location of the study area i.e., Nagpur city, it has been divided into 51 square cells (grids) of 500-meter sides. The size is decided after knowing the level of accuracy usually recorded in the police records, i.e., FIR (First Information Reports). After that, information regarding intersection type i.e., 3 arms, 4 arms, 5 arms are being extracted from this "Joined cells + Road shapefile" for further analysis. Figure 3.3 presents the 500 m sides cells over the road network, and the selected cells (blue cells) presents the cells with intersecting arms.

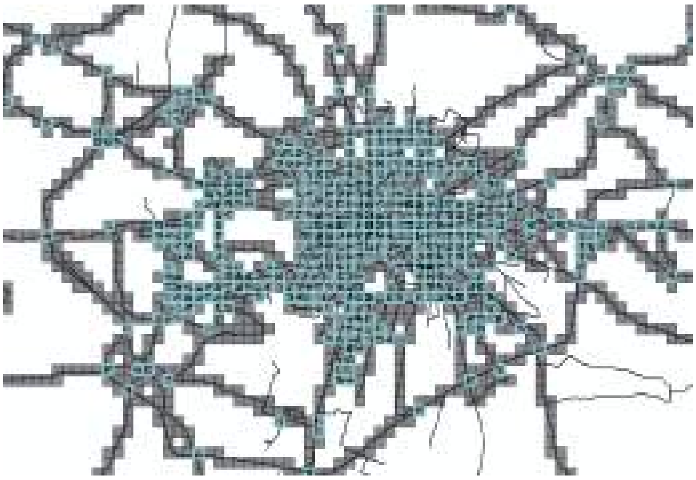


Figure 3.3 Intersection Types within the Road Network of Nagpur City on GIS Platform

3.3 Road crashes on the Nagpur City Road Network

Initially, the list of road crashes obtained during the last 3 years from multiple sources, was compared to remove the duplicate names, if any. Further, the reported FIRs along with the associated locations were further checked and ascertained whether the reported crash location can be categorized as a Blackspot conforming to the protocol of the MoRT&H and in this regard a total of 3224 FIRs were considered for analysis. Figure 3.4 presents the snapshot of FIR data coded on the GIS platform. Apart from locational information, each record has data regarding the number of persons involved in crashes, fatalities, injuries, count & type of vehicles involved, etc.

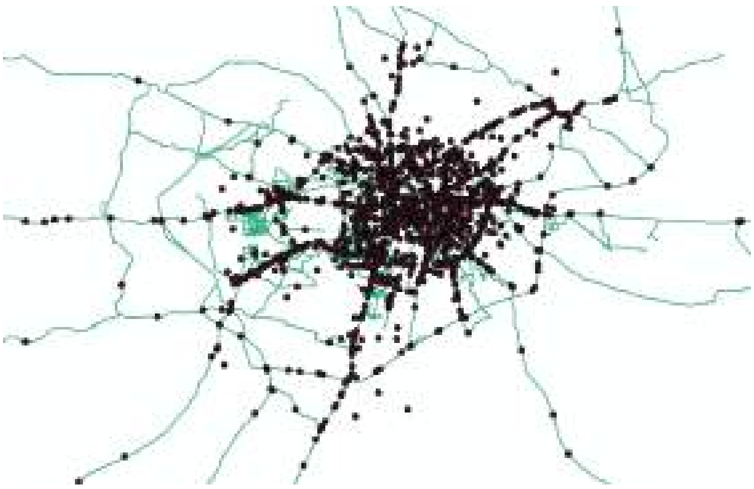


Figure 3.4 FIR locations and Related Information on GIS platform

Figure 3.5 describes the detailed statistics of the recorded road crashes for the year 2019, 2020, 2021, and 2022

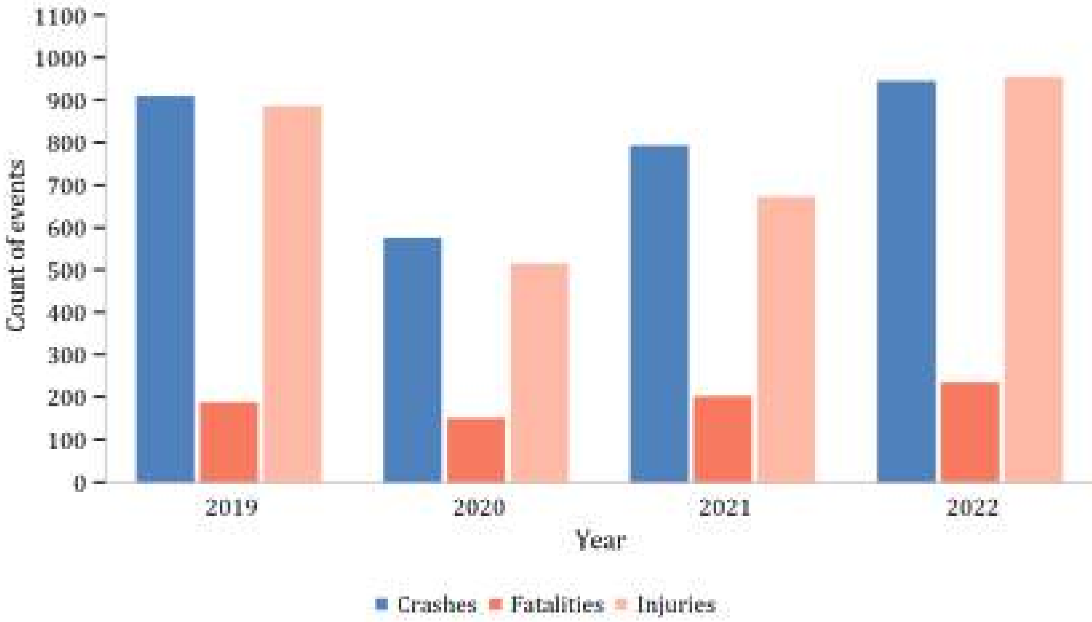


Figure 3.5 Summary of Recorded Crashes

Based on FIR locations and level of severity, 38 locations have been identified as blackspots as they conform to the MoRT&H protocol and the same has been brought on GIS platform as shown in Figure 3.6.

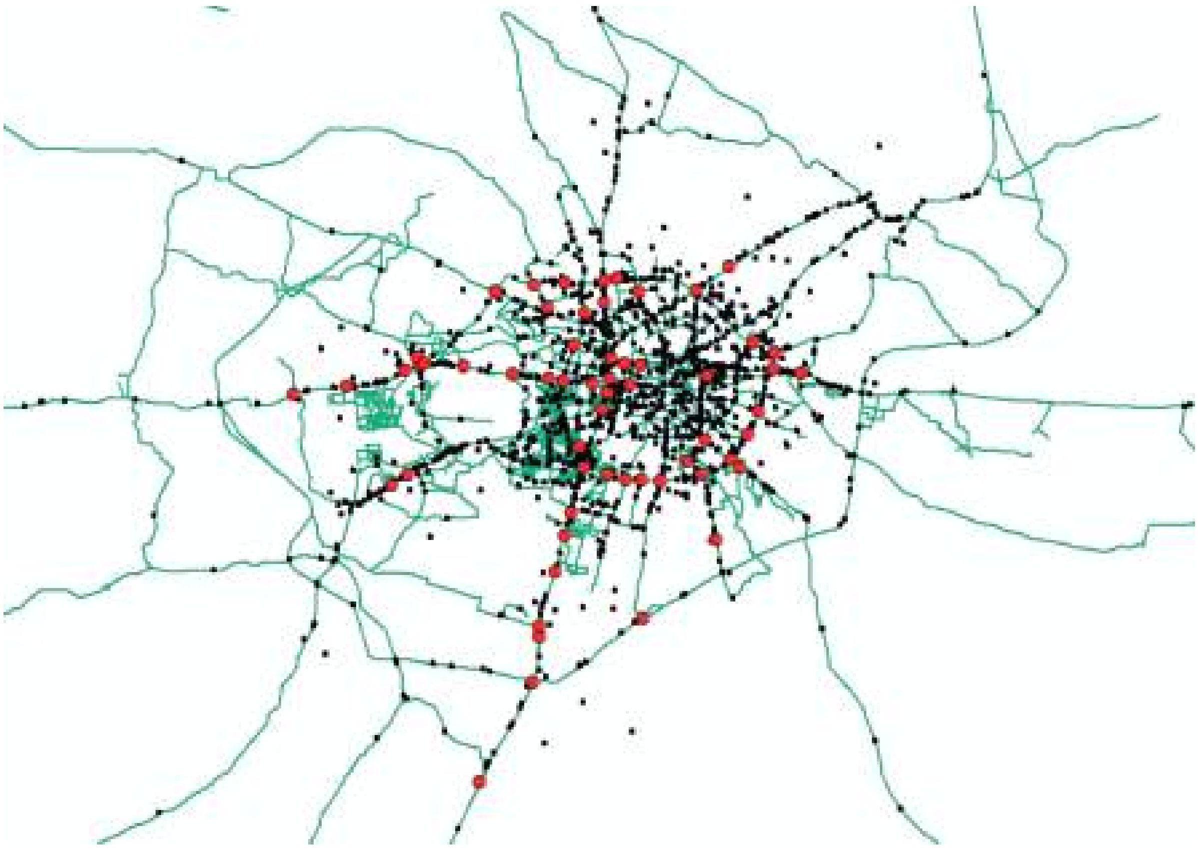


Figure 3.6 Blackspots on the GIS Platform

3.4 ADAS Alerts

ADAS alerts (FCW, HMW, LDW, and PCW) generated by the bus fleet were stored on the cloud and considered in the analysis for identifying the Greyspots. Generated ADAS alerts have been imported over the GIS platform for better visualization of the Operational Period (OP) from **1st Jan-2023 to 31st Mar-2023** such as 2023: Q1 as shown in Figure 3.7.

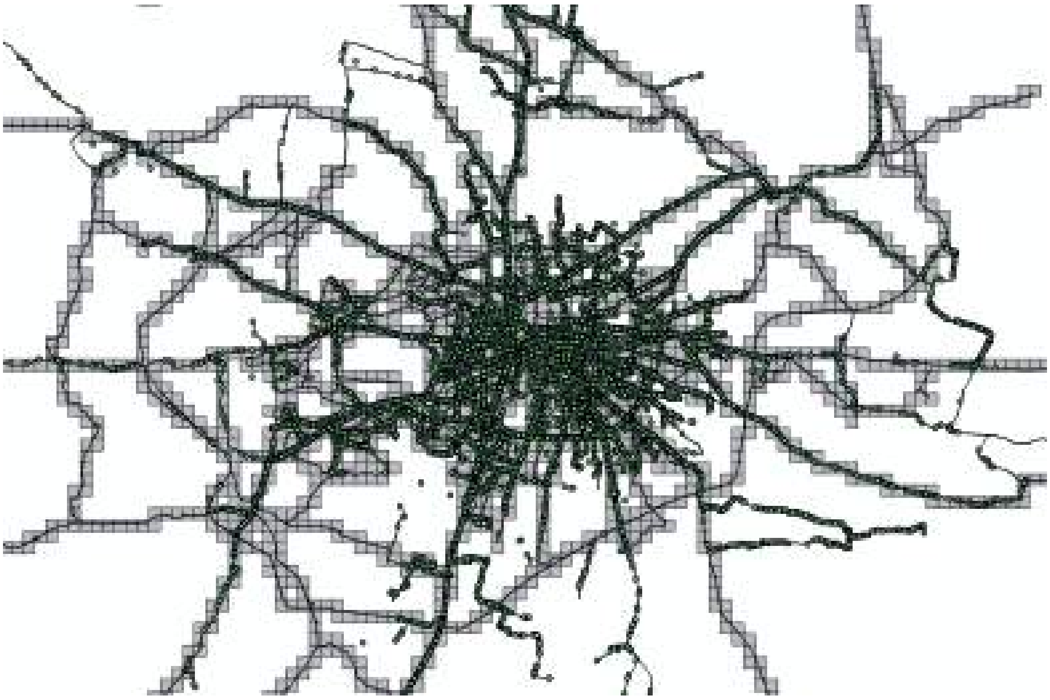


Figure 3.7 ADAS alerts generated during Phase-2 highlighted on the GIS platform

The statistics of ADAS alerts generated for the considered OP (i.e., 2023: Q1) and other periods from the start of the year 2022 to the half of the year 2023 are presented quarter-wise in Table 3.2.

Table 3.2 ADAS Alert Data Statistics

Duration of alerts generation		24 hrs				Total alerts generated
Quarters	Time period	FCW	HMW	LDW	PCW	
2022Q1	1st January to 31st March, 2022	23942	219484	55544	124608	423578
2022Q2	1st April to 30th June, 2022	55275	454136	206142	277441	992994
2022Q3	1st July to 30th September, 2022	57965	511481	186993	396669	1153108
2022Q4	1st October to 31st December, 2022	61524	563491	214034	365663	1204712
2023Q1	1st January to 31st March, 2023	57492	480618	189781	353906	1081797
2023Q2	1st April to 30th June, 2023	55309	454342	206145	278011	993807

Figure 3.8 presents the statistics of generation of ADAS alerts (in counts) on various periods as described in Table 3.2.

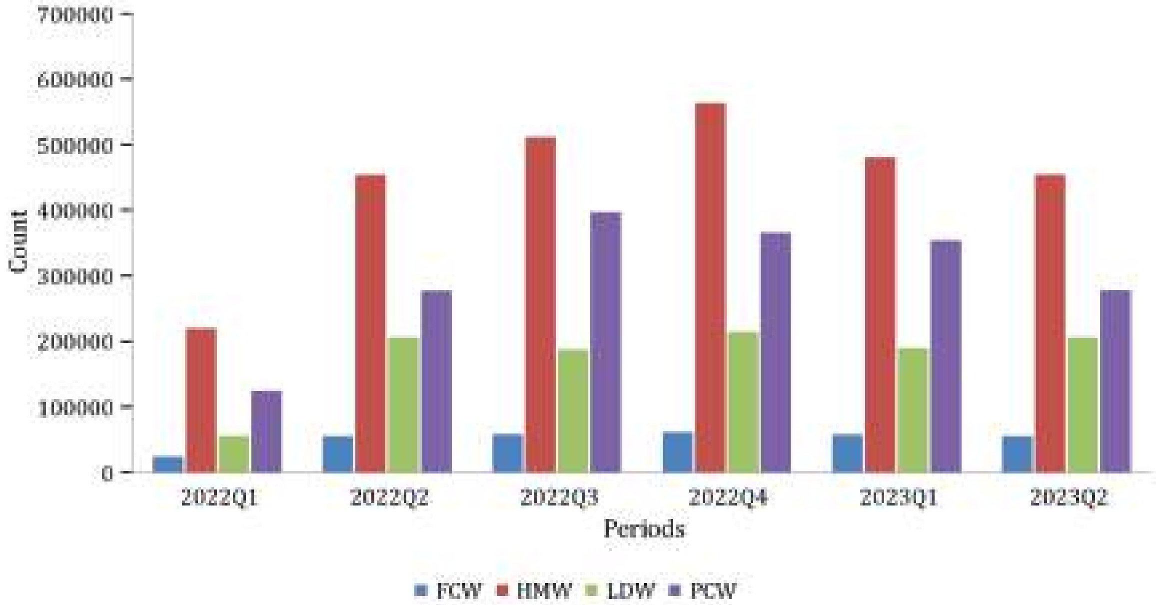


Figure 3.8 Generation of ADAS alerts in various phases (Quarter-wise).

Figure 3. presents the comparison of all ADAS alerts such as FCW, HMW, LDW, and PCW generated at the intersection and midblock regions during the considered OP i.e., 2023: Q1. As presented, FCW, HMW, and PCW alerts are always higher in proportion at the intersections than at the midblock compared to the LDW alerts generated.

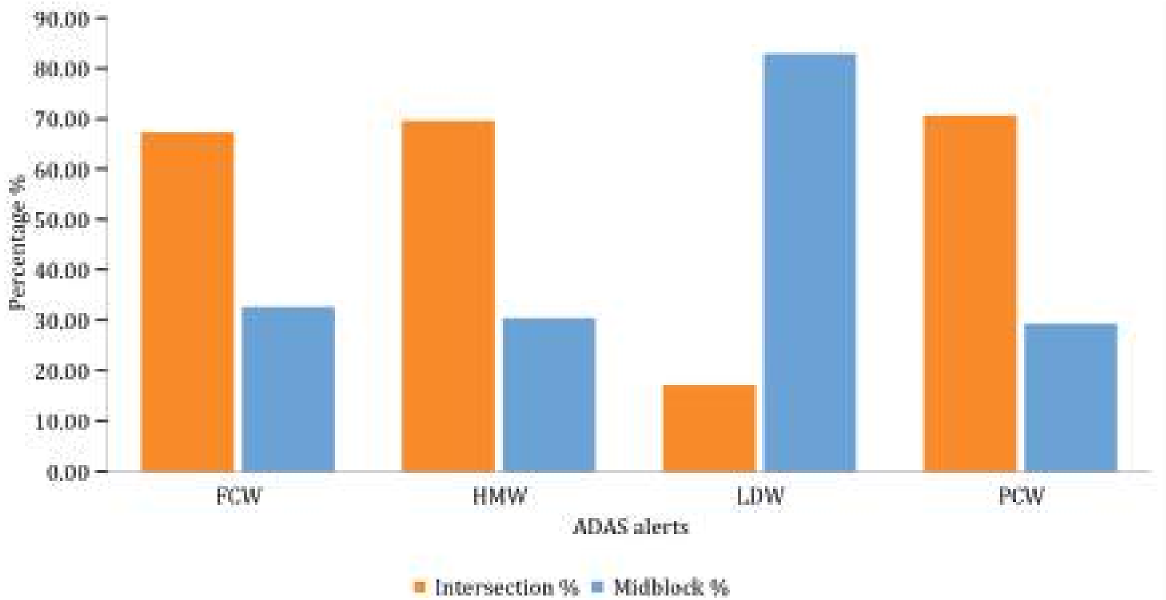


Figure 3.9 Comparison of alert proportions on Intersections and Midblocks.

Figure 3.10 presents the comparison of the proportion of all four ADAS alerts generated during the day and night time period. As presented, most alerts such as FCW, HMW, LDW, and PCW alerts are always higher in proportion during the daytime than the nighttime generated throughout 24 hrs

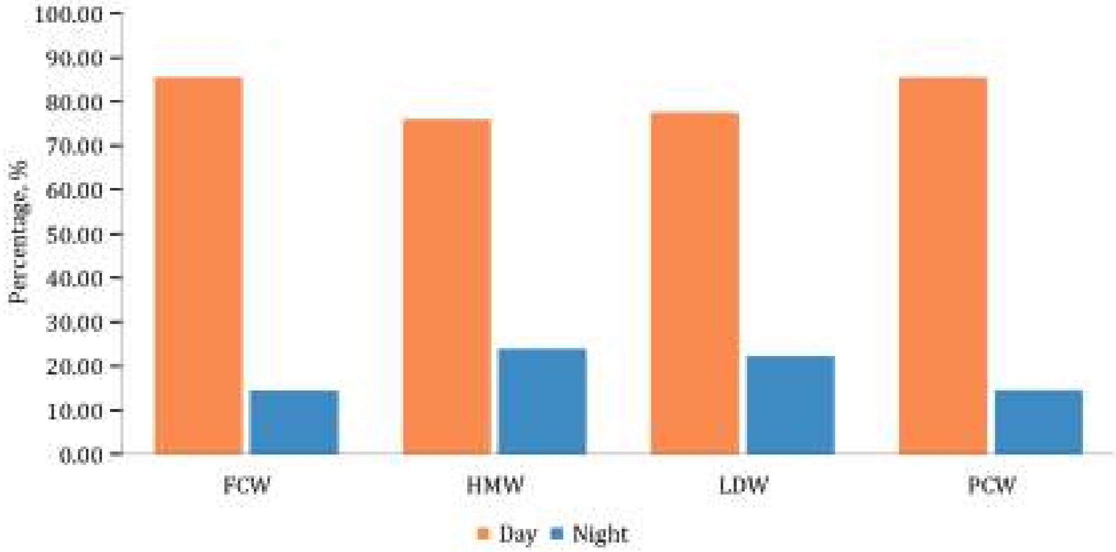


Figure 3.10 Comparison of Alert proportions during Day and Night-time.

Figure 3.11 presents the comparison of the speed data of all four mentioned ADAS alerts. It shows that there is a major difference in speed occurring between the intersection and midblock regions in FCW, HMW, and LDW alerts, and a very minor speed difference depicted in PCW alerts generated during the 24 hrs.

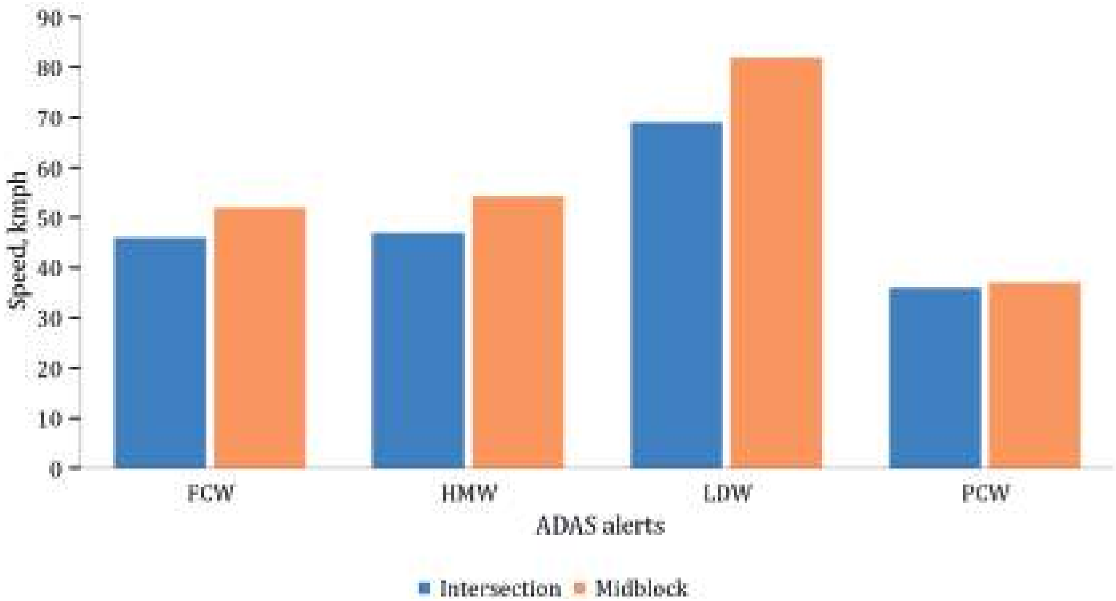


Figure 3.11 Comparison of the speed of ADAS alerts on Intersections and Midblocks

Figure 3.12 presents the detailed distribution of ADAS alerts among the 3 arms, 4 arms, 5 arms, and midblock regions. It illustrates that, in FCW, HMW, and LDW alerts, speed is high in 3 arm intersections and continuously reducing from 3 arms to 4 arms, and 4 arms to 5 arms regions. Speed distribution in PCW alerts is almost same in all these intersection and midblock regions. In addition, the speed of ADAS alerts generated is all-time high in the midblock regions.

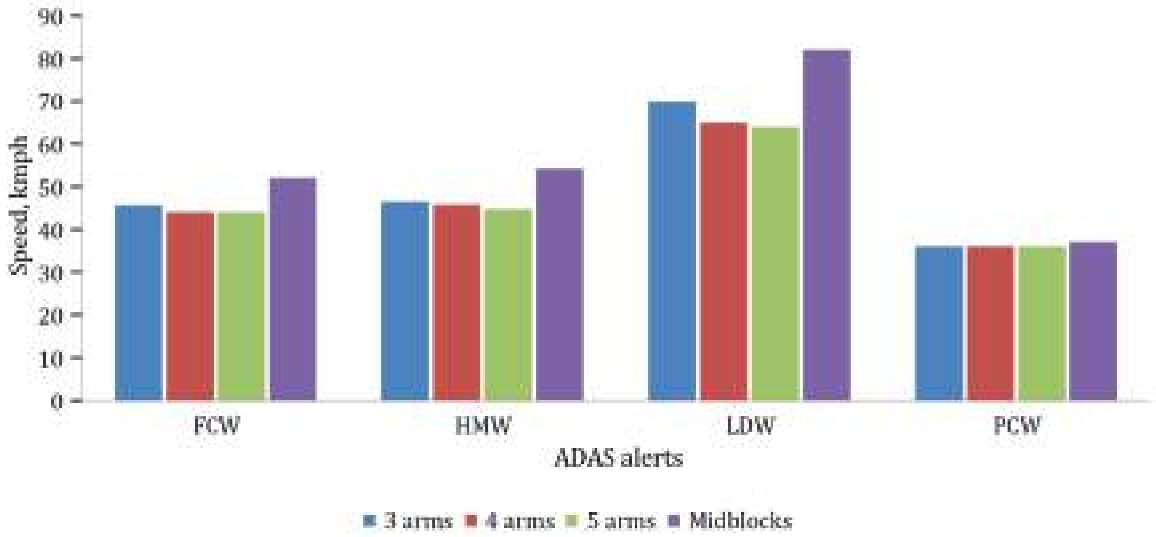


Figure 3.12 Comparison of the speed of alerts among different Intersecting arms and Midblock

From above Figures 3.9 to 3.12, it can be inferred that FCW, HMW, and PCW alerts are mostly generated at the intersection locations and the LDW alerts are mostly generated at the midblock regions. As per Indian driving context, HMW alerts i.e., Headway Monitoring Warnings are more significant in the Midblock regions not in the intersection locations, PCW i.e., Pedestrian Collision Warnings are only significant in the intersection locations where the pedestrian crossing facilities are present mostly, FCW i.e., Forward Collision Warnings are significant in both intersection and midblock environs, and the LDW alerts i.e., Lane Departure Warnings are more significant in the midblock regions.

3.5 Measuring the Level of Severity – Severity Index (SI)

To identify the most unsafe locations other than Blackspots which are called Greyspots, study area i.e., Nagpur city is being divided into cells (grids) of size 500m*500m. For each of these cells, the number of ADAS alerts, speed data of ADAS alerts, road geometry parameters are being calculated using advanced tools of GIS. The number of cells having a road inside is counted to be 3024. Out of these, cells having FCW, HMW, LDW, and PCW alert (s) (named as Dynamic parameters) only are considered further for calculating severity index (SI) values. Apart from alerts, geometrical information of the study area includes the number of intersecting arms, sum of roads, and width of roads within the cell is calculated (named as Static parameters). In the study area which covers 3024 cells, it is observed that 9 are having 5 intersecting arms, 176 cells are having 4 intersecting arms, 334 cells are having 3 intersecting arms, and the sum of road length for the study area is 1682.3 km. In the static parameters, mostly intersecting points are present in the urban region of the city, and midblock regions are mostly present in the outer regions of the city. Based on these information for each of the cells and understanding the characteristics of ADAS alerts data, two regression models have been developed; first one is Generalized Linear Regression model to identify the SI values of Intersection cells (named as Intersection model) and other one is Binary Logistic Regression model (named as Midblock model) to evaluate the SI values of Midblock cells. Further these models have been utilized to identify the Greyspot locations

The reason for developing two separate models to identify Greyspots is that, when we analyzed static parameter such as intersecting arms, road length with dynamic parameter such as ADAS alerts to develop a model which has the capacity to identify the severity of the locations (cells) of Nagpur city, it was observed that the model primarily predicted Greyspots at intersection locations rather than in Midblock locations (for e.g., out of the top 20 Greyspots identified by the model, a staggering 19 were located at intersections and 1 at Midblock). This may be due to the dominance of static portion of the model(number of intersecting arms, sum of road length) dominating the dynamic portion (FCW and PCW alerts) of the model. As per the above observation that the initial Greyspot model primarily focused on predicting Greyspots at intersections rather than Midblock areas, so it has become evident that a new model is necessary to identify the Midblock Greyspots specifically.

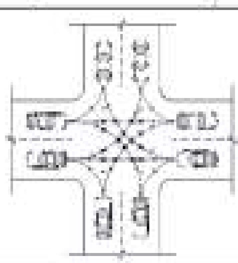
So, after all these observations and from the initial analysis of ADAS alerts (refer figure 9 to 12), we considered PCW & FCW alerts only for Intersection model and three ADAS alerts such as FCW, HMW, and LDW are used to develop a Midblock model.

3.5.1 Intersection model for Greyspots

An Intersection model is being developed by utilizing both static i.e., count of 3 arms, 4 arms, and the sum of roads within the cell, and dynamic parameters i.e., speed value of two ADAS alerts namely, FCW & PCW. The developed severity index is primarily to calculate the number of possible conflicts between two road users (vehicle users and pedestrians) which is the function of geometry type, traffic management option (presence of unsignalized intersection, free left turning, 3/4/5 arm intersection with signals), and traffic volume. All this information has been collected for 20 locations. This is further compared with the number of alerts generated at a particular location through regression analysis

Table 3.3 presents the number of conflicts for the typical unsignalized 3 and 4 arms intersections. Depending on the number of arms and the level of control (signal/ free left turning/ channelization/ etc.) at any intersection, this can be recalculated

Table 3.3 Number of Conflict Point at 3 and 4 arm intersection

	Diagram	Number of Conflict Points
3 arm unsignalized intersection		3 merging 3 diverging 3 crossing Total = 9 points
4 arm unsignalized intersection		4 merging 4 diverging 16 crossing Total = 24 points

Since the number of possible crashes is the function of geometry *(i.e., number of conflict points)* and traffic volume, a Generalized Linear Regression Model (GLM) has been developed *(refer Equation 3.1)* considering the product of traffic volume and the number of conflict points within the cell as a Dependent Variable (DV), and Independent Variables *(IV)* includes the road geometry types *(3 arms & 4 arms)*, road network length within the cells, and the 85th percentile (%ile) speed values of FCW and PCW alerts. *(Note: All the dependent & independent parameters were normalized on a scale of 0 to 1)*. The developed Equation 3.1 is being further utilized for the locations where geometry and alert data are available to identify the most unsafe areas such as Greyspots

$$\text{Severity Index (SI)} = 1.034 * nN_{3arm} + 0.814 * nN_{4arm} + 2.281 * nRL + 1.339 * nFCW_{85thMaxSpeed} + 1.268 * nPCW_{85thMaxSpeed} \quad \text{……… Eq.3.1.}$$

where,
nN3arm = Normalized count of 3 arm intersections within the cell
nN4arm = Normalized count of 4 arm intersections within the cell
nRL = Normalized total length of roads inside the cell
nFCW = Normalized 85th % ile speed of FCW alerts within the cell
nPCW = Normalized 85th % ile speed of PCW alerts within the cell

The severity index is being measured for each of the cells of the study area which is of size 500m*500m. Developed GLM model is presented as Equation 3.1 includes five significant variables ($p<0.05$). The level of 58 accuracy for the developed equation is in terms of AICc value i.e., 236.06 *(minimum value gathered from all the iterations)*.

Based on the obtained coefficients (B-values) and frequency of alerts appearing at various locations on roads, the severity Index (SI) value has been calculated for each of the cells *(3024)* for the period of 3 months from 1 January 2023 to 31st March 2023 *(2023: Q1)*, which ranges from 0 *(min)* to 5.2 *(max)*. Then the areas with maximum values have been identified by sorting in descending order using advanced GIS tools. For the considered study area, the 20 most unsafe locations have been identified using SI values. After achieving an acceptable level of accuracy, validation is done by comparing the 20 most unsafe locations with the existing crash-prone areas such as Blackspots of Nagpur city by making a road inventory. Further, these locations have been validated based on ground observations also.

After ground validation of these 20 most unsafe locations, a threshold point for these severity values i.e., 3.5 is finalized based on the issues identified *(refer section H)* and the severity value of the locations. So, after this analysis, it was deduced that locations with severity values more than equal to 3.5 will be considered as **"Intersection Greyspots"**

3.5.2 Midblock model & corridor analysis

After the assessment of the limitations of the previously developed greyspot identification model which identifies only the Intersection locations, a new model for identifying Midblock Greyspots is developed. Since the generation of each type of alert is dependent on the surrounding geometrical conditions as well as traffic conditions, LDW alerts generated at higher speed, and this is being presented in Figure 3.13.

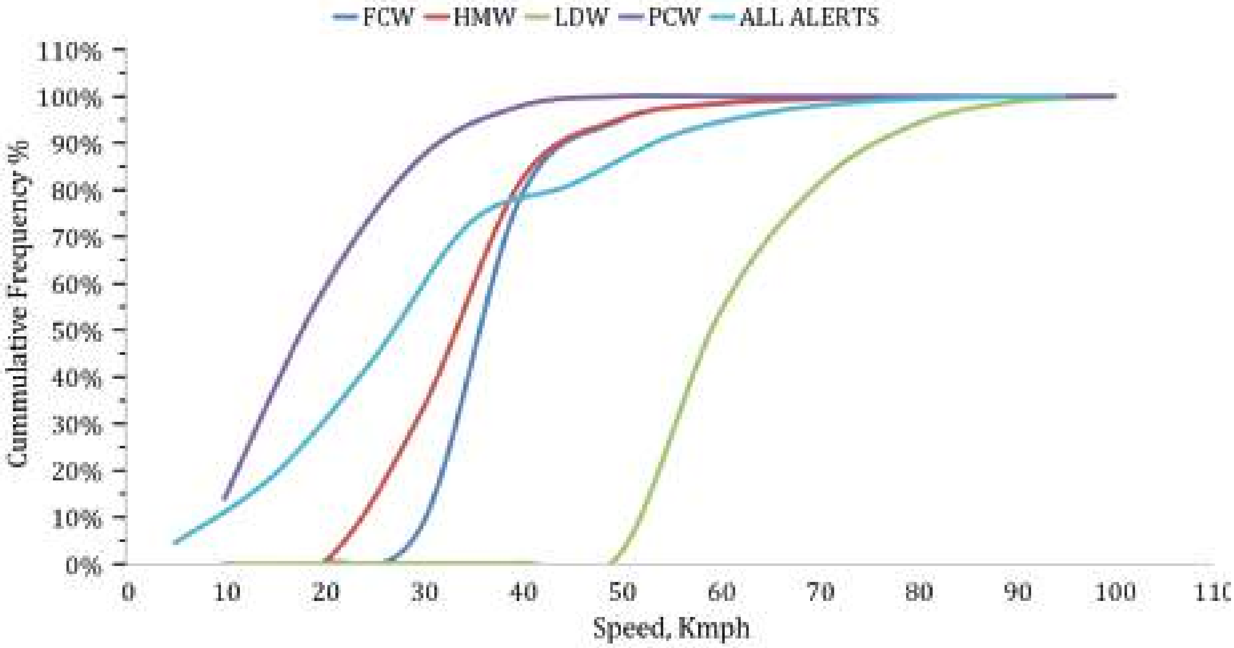


Figure 3.13 Cumulative Speed Frequency graph for alerts

Further, as expected, wider roads have more LDW alerts compared to narrower roads. Figure 3.14 presents the distribution of alert generation across various types of road widths throughout all quarterly time periods. It becomes evident that the highest number of alerts are generated on roads that have a width exceeding 15 meters (means in 6 lane roads). This finding indicates that wider roads generate more alerts than narrower ones. It is important to note that this observation is based on the analysis of alert generation data across all quarterly time periods, suggesting a consistent trend.

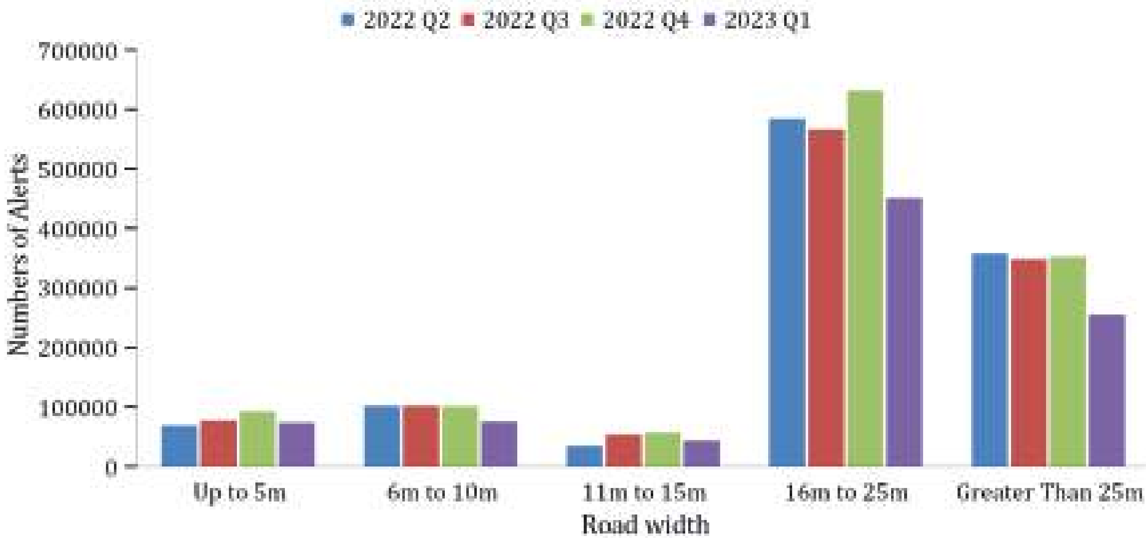


Figure 3.14 Distribution of Alert Generation across various Types of Road Widths over the Study Period

Accordingly, the concept behind the development of the Severity Index is being adopted to take care of road width and the combination of various ADAS alerts with LDW alerts. As any alerts coupled with LDW which is occurring at higher speed becomes unsafe.

Alert combo generated at different speeds and at different road ranging in its width will lead to safe / unsafe situations. To differentiate between safe and unsafe alert combinations, it is essential to consider the distance travelled between the generation of the first and second alerts. This distinction helps to evaluate whether the driver has sufficient distance to safely respond to the alerts and potentially avoid a collision. Two key factors are considered: the distance travelled (D) and the theoretical braking distance (BD). Once these two parameters are calculated, a comparison is made to determine whether the alert combination is safe or unsafe. If the distance travelled between the first and second alerts is less than the theoretical braking distance (DBD), it suggests that the vehicle has a sufficient distance to react and potentially avoid a collision. In such instances, the alert combination is regarded as safe. After that, to determine the severity of an alert combination, a Binary Logistic Regression (BLR) analysis is performed. This statistical analysis considers several covariate parameters such as the Speed of the first alert of the combination (in kmph), road width (in meters), and time gap between first and second alert of the combination (in seconds) as independent variables and the safe / unsafe combinations (unsafe = 1 & safe =0) as a dependent variable. After that, all variables are first normalized on a 0 to 1 scale and then performed the BLR analysis. The equation for calculating the Severity Index of an alert combination is represented as Equation 3.2.

$$SI_c = (-93.567 \times nT_g) + (79.574 \times nS_i) + (3.68 \times nRW) \quad \text{.............................} \textbf{\textit{Eq. 3.2}}$$

where,
SIc = Severity Index of an Alert Combo
nTg = Normalized Time Gap between first and second alert in the combo (sec)
nSi = Normalized Speed of the first alert in the combo (km/h)
nRW = Normalized Road Width at which alert combo occurred (m)

This study utilizes the two critical combinations of the three ADAS alerts such as LDW, HMW, and FCW i.e., (a) LDW+FCW and (b) LDW+HMW, which are generated within 5 seconds of time gap as a major parameter. The time window of 5 seconds is chosen to capture alerts that occur near each other, indicating a continuous and potentially hazardous situation. PCW (Pedestrian Collision Warning) alerts were not used for the formation of alert combinations, as it is seen that LDW, FCW, and HMW are the ones generally generated at Midblock whereas PCW alerts are mostly generated at intersections where the pedestrian interactions are more. Along with this, road geometry data such as Road width (in meters) and speed of these combined ADAS alerts are used for the analysis.

After obtaining the severity values for each alert combination using Equation 3.2, the alert combo database is uploaded to a Geographic Information System (GIS) platform for spatial analysis. To incorporate spatial information and assess the severity at a broader scale, the alert combos are joined with cells (grids) measuring 500x500 meters sides, and only Midblock grids are used for this analysis as this model is defined to predict the unsafe midblocks cells only. By joining the alert combos with the grids, the severity of each grid can be determined. The severity of the grids is calculated by considering only the severity values of unsafe alert combinations within each grid.

Further, through multiple iterations and evaluations, it was determined that the method of taking the 85th %ile of the severity values of the unsafe alert combos within a grid yielded the most suitable approach for calculating the severity of the grid.

This method considers the distribution of severity levels and focuses on capturing the highest-severity incidents within the grid while accounting for the overall distribution of values. By employing this approach, the severity of each grid can be determined for all quarterly time periods separately.

After this analysis, specifically top 20 locations are identified as the most unsafe midblock locations for various quarterly time periods. This repeatability analysis between different quarterly time periods shows an intersecting pattern. Despite the changing specific locations, it is observed that these top severe locations tend to be located along the same road, forming a corridor of high-severity incidents as shown in Figure 3.15. Therefore, a corridor analysis is started.

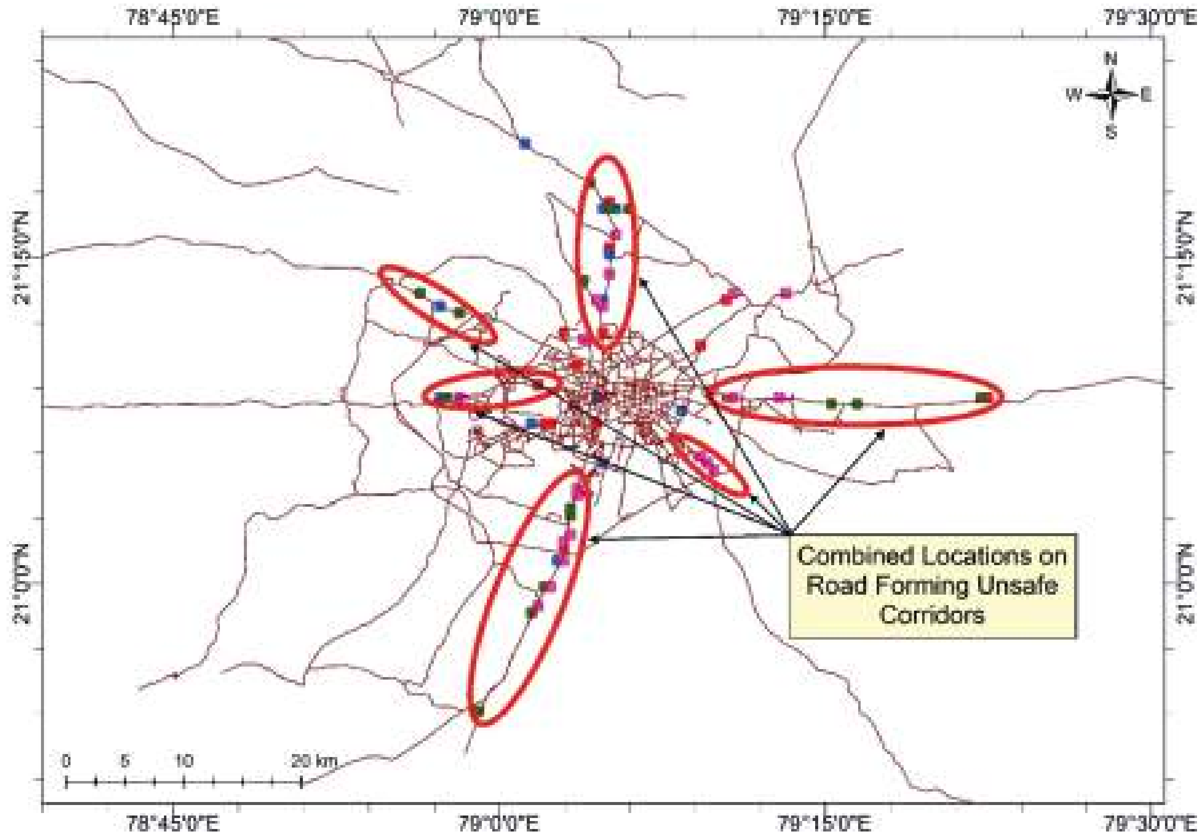


Figure 3.15 Formation of corridors by top severe locations.

The corridor analysis focuses on identifying the specific road segment or route where the highest 61 concentration of severe incidents occurs. To conduct a comprehensive analysis of road corridors within Nagpur City, a total of 42 corridors were predefined and considered. These corridors are strategically selected to cover all the important roads, and key transportation routes in Nagpur city, and the formation of alert combos on those roads. Figure 3.16 provides a visual representation of these predefined 42 corridors, offering an overview of their spatial distribution across the city.

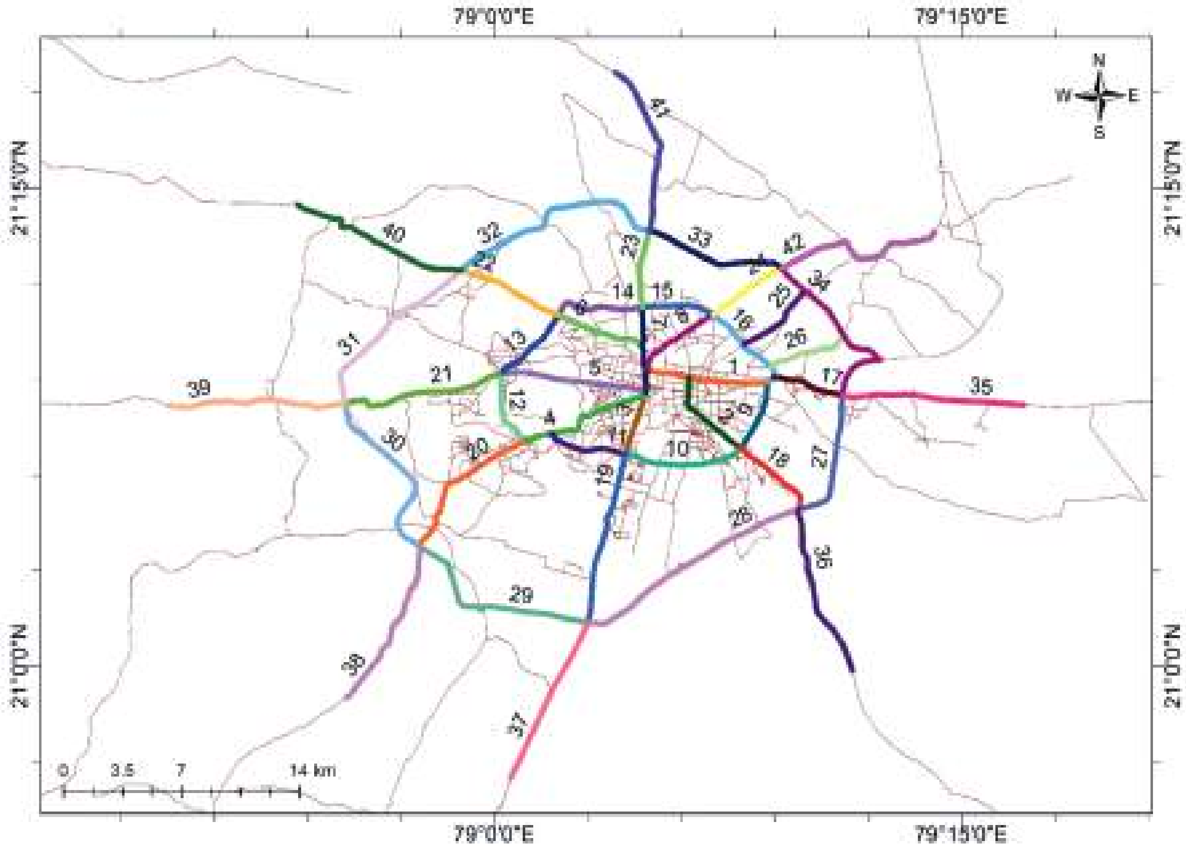


Figure 3.16 Predefined 42 Corridors on Nagpur Road Network

Once the corridors have been identified, the next step is to calculate the severity of each corridor. This involves quantifying the overall severity of incidents within a corridor to gain insights into the safety conditions along its length. "The severity of corridors is determined by summing up the severity values of the Midblock grids that fall within each corridor and dividing this sum by the length of the corridor". Dividing the sum of the Midblock grid severities by the length of the corridor allows for normalization and standardization across corridors of different lengths. This normalization accounts for the variation in corridor lengths, enabling a fair comparison and assessment of the severity levels across different corridors within the study area. After calculating the severity of each corridor, the top 5 corridors are denoted as **"Most Unsafe Corridors"**. The most unsafe corridors of time period 2023: Q1 & 2023: Q2 are presented in Figure 3.17 and 3.18 respectively.

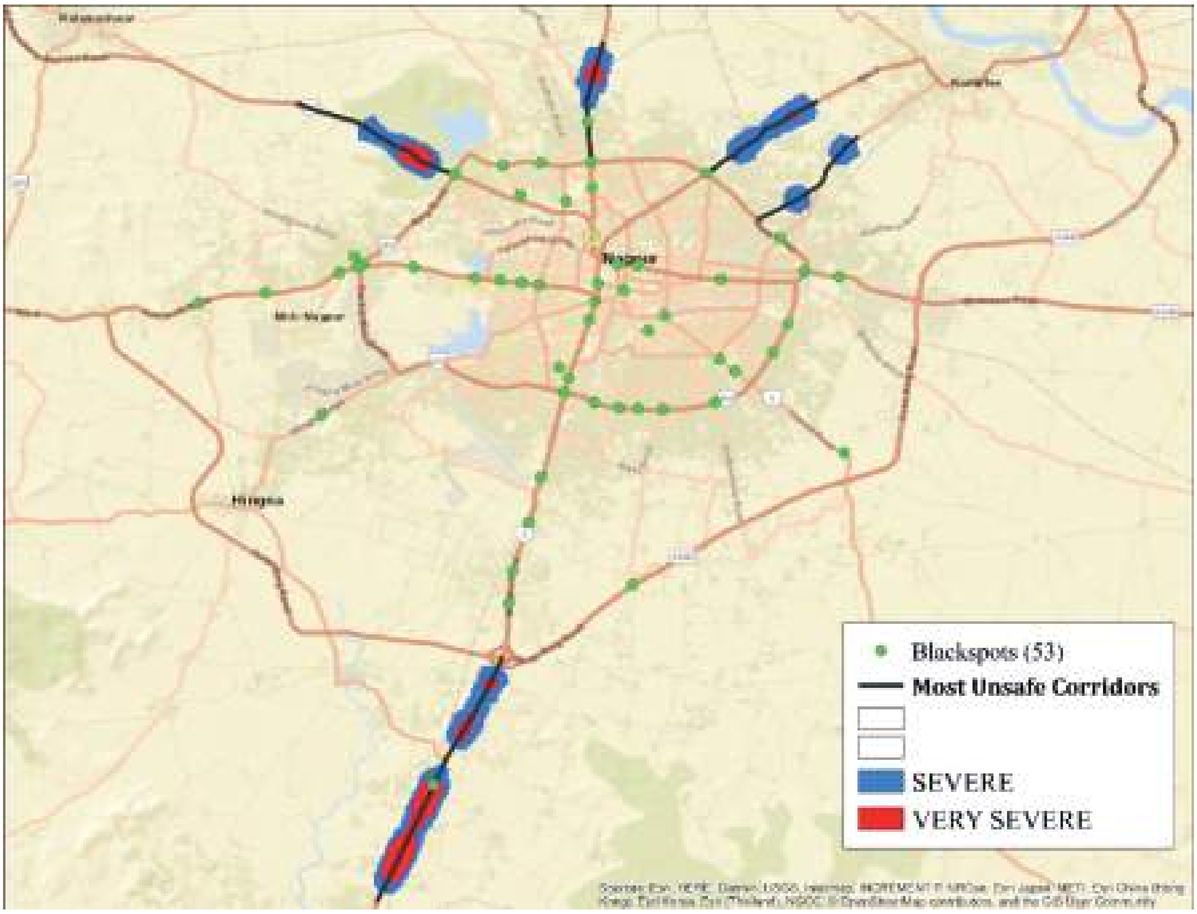


Figure 3.17 Top 5 most unsafe corridors of the 2023 Q1 period.

Table 3.4 presents the list of the top 5 most unsafe corridors with length and starting & ending geolocations.

Table 3.4 List of Top 5 Most Unsafe Corridors of 2023: Q1 period

S. No.	Corridor Name	Length (km)	Start Point		End Point	
			Latitude	Longitude	Latitude	Longitude
1	Kamptee Road (NH 44)	4.670	21.184	79.117	21.208	79.153
2	Chandrapur-Nagpur Road (NH 47)-B	10.000	21.023	79.050	20.941	79.009
3	Old Kamptee Road (SH 260)	4.764	21.168	79.133	21.196	79.167
4	Koradi Road (NH 47)-A	4.485	21.188	79.079	21.228	79.083
5	Katol Road (NH 353J)	6.061	21.183	79.034	21.207	78.982

After that, the most unsafe corridors are also identified for the new three months' time-period denoted as 2023:Q2 as presented in Figure 3.18

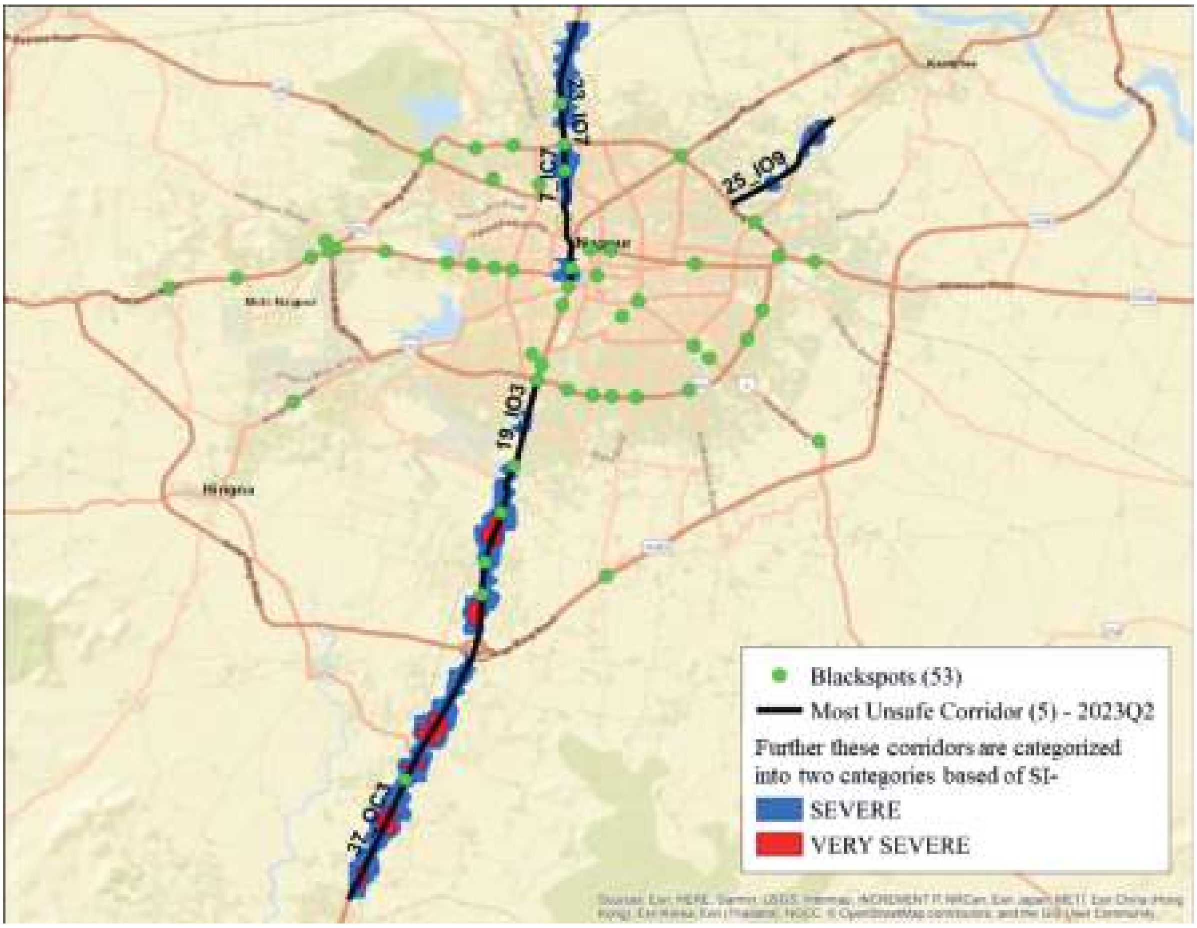


Figure 3.18 Top 5 most unsafe corridors of the 2023 Q2 period

Following that, the attributes such as length and starting & ending geo-locations of top 5 Most Unsafe Corridors of 2023: Q2 period are listed in Table 3.7.

Table 3.5 List of top 5 most unsafe corridors of 2023: Q2 period

S. No.	Location Name	Length (km)	Start point		End point	
			Latitude	Longitude	Latitude	Longitude
1	Chandrapur-Nagpur Road (NH 47)-B	10.009	21.02296	79.0497	20.94132	79.0086
2	Chhatrapati square to Gausi-Manapur junction	10.043	21.1108	79.07011	21.023	79.04963
3	Koradi Road (NH 47)-A	4.485	21.1878	79.07917	21.22754	79.08284
4	Old Kamptee Road (SH 260)	4.764	21.16834	79.13329	21.19605	79.16666
5	Jhansi rani square 1 to Jinga Bai Takli	5.033	21.14347	79.08086	21.18783	79.07919

To ensure the accuracy and reliability of the results obtained in the corridor analysis, these are further validated with the existing Blackspots. A comparison analysis between the blackspots and the most unsafe corridors of two quarterly time periods i.e., 2023: Q1 & 2023: Q2 identified in the results demonstrates that 5 blackspots & 11 blackspots of Nagpur city were located within the most unsafe corridors respectively.

In addition, comparing the results of the corridor analysis between 2023: Q1 and 2023: Q2, it is observed that there 64 is a degree of similarity in the top severe corridors between these two periods. Specifically, the analysis reveals that 3 out of the top 5 severe corridors identified in 2023: Q1 are also present among the top 5 severe corridors in 2023: Q2, represents a matching rate of 60%. The consistency in identifying these corridors across the two quarters indicates that these specific road sections continue to exhibit high severity levels and pose significant risks to road users. Despite potential fluctuations in the severity rankings or the appearance of new severe corridors, the presence of these matching corridors highlights their persistent nature in terms of safety concerns. By incorporating this validation process, the reliability of the study's outcomes are enhanced, providing a solid foundation for further analysis and decision-making.

After obtaining the results from the corridors analysis, the need arises to ground check of these corridors to identify the issues present in the same. Specifically, the first and last corridors that were obtained from the analysis of the top 5 unsafe corridors in 2023: Q1 were selected i.e., Corridor – 1 Kamptee Road (NH 44) and for Corridor – 2 Katol Road (NH 353J). To initiate the process, ground observations were conducted for both selected corridors. These observations aimed to gather first-hand information and gain a comprehensive understanding of the issues present in these corridors. After that some engineering solutions and remedial measures are devised to address the issues identified in those corridors. Detailed information of identified issues & suggested engineering solutions are present in Table 3.11 & 3.12.

To gain further insights from the severity patterns along each corridor, heat maps are prepared *(refer Figure 3.17 & 3.18)* to visualize the distribution of incidents and identify the top severe locations *(red in colour)* within the corridors. These severe locations are termed as **"Midblock Greyspots"** .

3.6 Results

Based on the above greyspot models, a combined list of locations including the list of intersections and midblock locations encompassing also the top 5 unsafe corridors traversed by the ADAS-equipped NMC fleet of buses was prepared. Table 3.4 presents the list of top 5 most unsafe corridors in Nagpur city which is normalized based on their severity values on a scale of 0 to 1 scale. Further, through ground observations of top 15 to 20 locations, threshold range values are decided based on the issues observed in the locations and accordingly, the locations reporting values in excess of 0.4 and above are denoted as **"Greyspots"**. Further, these locations are categorized into three categories namely, Mild, Severe, and Very Severe based on their severity values and the ground observations. Table 3.5 presents the categorization of Greyspots in terms of Severity value.

Table 3.6 Three-scale categorization of Greyspots

Range of Severity value	Category of Greyspot
0.40 to 0.70	MILD
0.70 to 0.85	SEVERE
0.85 to 1.00	VERY SEVERE

Based on the above, identified greyspots are depicted in Figure 3.19, which includes top 33 locations of Nagpur city among which are 24 Intersections and 9 Midblock locations. Out of these calculated greyspots, 8 locations (existing) are matching with the existing accident-prone locations known as Blackspots which also have been present in the list of greyspots as existing ones, so the effective greyspot locations are 25 (new ones) among which are 16 Intersections and 9 Midblock locations. Table 3.6 shows the list of identified greyspots (Top 33, new & existing) including intersections and midblock with their geo-location (Latitude / Longitude), severity, and road section type. Further, it was noted during the course of greyspot analysis that newer locations have cropped up as greyspots during the past 6 months, which raises concern warranting immediate action by the concerned stakeholders.

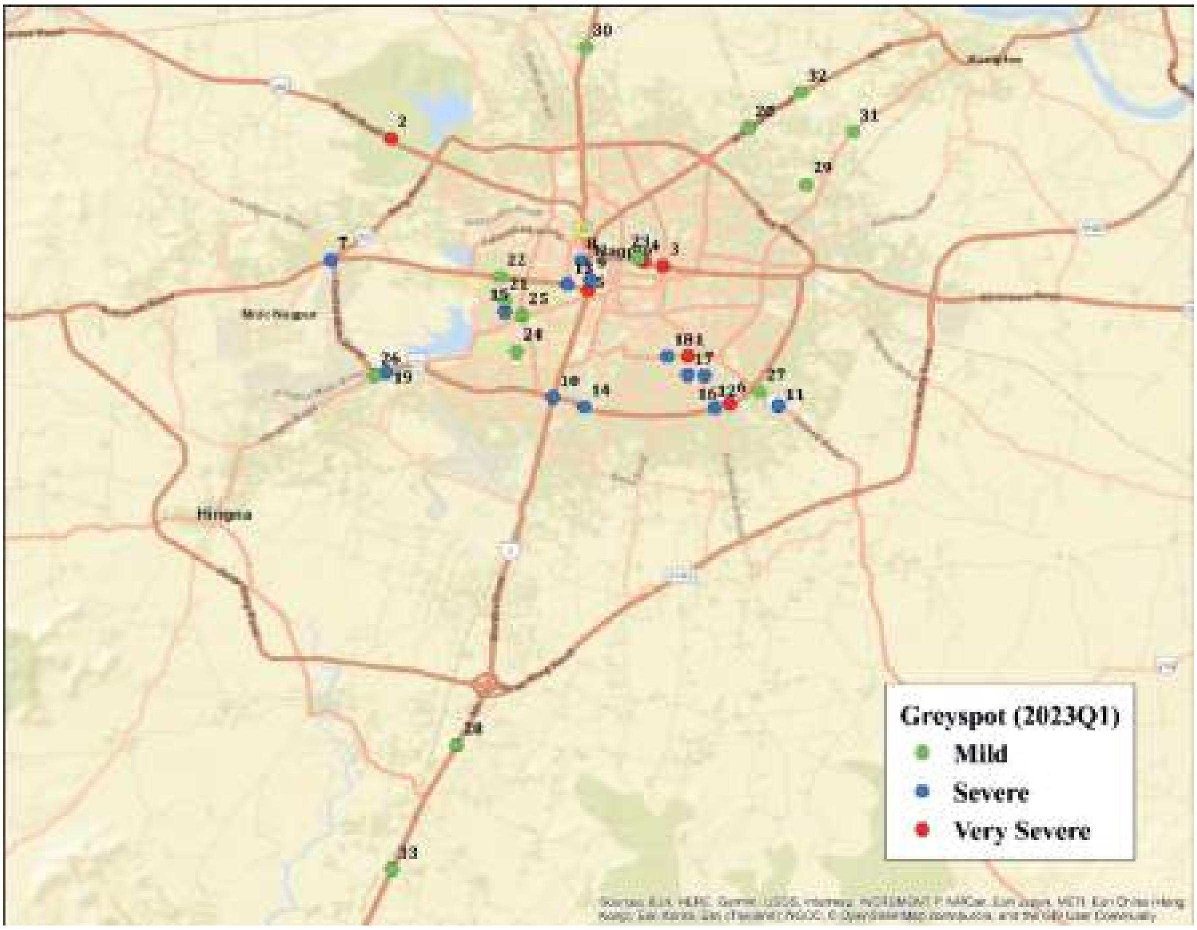


Figure 3.19 Identified Greyspots incl. Intersection & Midblock (new & existing) for 2023: Q1 period.

Table 3.7 Detailed list of top 33 Greyspot Locations of 2023: Q1 period and their Severity.

Rank	Location name	Geo-location		Severity	Road section type	Remarks
		Latitude	Longitude			
1	Raghuji Nagar (Chota tajbagh chowk)	21.123422	79.111365	Very Severe	Intersection	New
2	Gorewada safari to Bodhala	21.189905	79.020567	Very Severe	Midblock	New
3	Agrasen Square	21.150943	79.103744	Very Severe	Intersection	New
4	Gitanjali Square	21.152096	79.097942	Very Severe	Intersection	New
5	Jhansi Rani Square	21.14354	79.080749	Very Severe	Intersection	Existing
6	Powerhouse chowk	21.108898	79.124219	Very Severe	Intersection	New
7	Wadi T point / Auto HUB to Toll Naka	21.152862	79.002245	Severe	Intersection	Existing
8	RBI Square	21.152658	79.078818	Severe	Intersection	New
9	Morris T point	21.146745	79.08135	Severe	Intersection	Existing
10	Chattrapati Square	21.110804	79.070089	Severe	Intersection	Existing
11	Atul Lawn, Dighori	21.108313	79.139031	Severe	Intersection	New
12	Mhalgi Nagar Square	21.107623	79.119614	Severe	Intersection	Existing
13	Bardi, Civil lines (Maharajbagh Chowk)	21.145244	79.074407	Severe	Intersection	New
14	Shrinagar Chowk	21.107895	79.079643	Severe	Intersection	Existing
15	Shivaji Nagar (Ramnagar Chowk)	21.137011	79.055349	Severe	Intersection	New
16	New Bidi Peth (Mahakalkar Sabhagraha)	21.117485	79.116455	Severe	Intersection	New
17	Ayodhya Nagar Square	21.117775	79.111231	Severe	Intersection	New
18	Tukdoji Putla Square	21.12335	79.104979	Severe	Intersection	New
19	Vasudev Nagar Square	21.118545	79.019093	Severe	Intersection	New
20	Kadbi square to New Khalsa	21.193048	79.129831	Mild	Midblock	New
21	Ram Nagar to Chota ram nagar	21.140332	79.055418	Mild	Midblock	New
22	Ravi Nagar	21.147665	79.053917	Mild	Intersection	Existing
23	Mayo Square	21.153361	79.096268	Mild	Intersection	Existing
24	Sir Visveswaraya square	21.124952	79.058975	Mild	Intersection	New
25	Shankar nagar square	21.135921	79.060619	Mild	Intersection	New
26	Bhagat square	21.117712	79.01541	Mild	Intersection	New
27	Shiv Nath temple intersection, Dighori	21.112566	79.133216	Mild	Intersection	New
28	Sahara City bus stop to Gurudwara, Magrul	21.00443	79.040617	Mild	Midblock	New
29	Kalamna toll Naka bus stop to Bhawani Mata mandir, Kalamna	21.175808	79.147488	Mild	Midblock	New
30	Eden Garden to Khemka motors	21.217864	79.080166	Mild	Midblock	New
31	111 Ganga granites, Bhilgaon to Vithoda saoji restaurant	21.191892	79.161838	Mild	Midblock	New
32	Shere Punjab Dhaba to Jagat Prakash B.Ed. College	21.203985	79.145924	Mild	Midblock	New
33	Mancherial - Chandrapur - Nagpur Road to Borkhedi	20.966611	79.020897	Mild	Midblock	New

After that, Greyspots (including Intersection & Midblock) are also identified for the new three months' time-period denoted as **2023: Q2** using both models separately. After the calculations, results are combined into one sheet and presented through GIS map.

Figure 3.20 shows the combined top 34 greyspot locations that includes 25 intersections and 9 midblock locations. Out of the above, 11 locations *(existing)* are matching with the existing accident-prone locations known as Blackspots which have been excluded from the list of greyspots, so the effective greyspot locations are 25 *(new ones)* among which are 18 Intersections and 7 Midblock locations.

Figure 3.20 Identified Greyspots incl. Intersection & Midblock (new & existing) for 2023: Q2 period.

Table 3.8 shows the list of identified greyspots (Top 34, new & existing) including intersections and midblock with their geo-location (Latitude / Longitude), severity, and road section type.

Table 3.8 Detailed list of top 33 Greyspot Locations of 2023Q2 period and their Severity.

Rank	Location name	Latitude	Longitude	Severity	Road Section Type	Remarks
1	Raghuji Nagar (Chota tajbagh chowk)	21.12342	79.11137	Very Severe	Intersection	New
2	IORA Palms, Nagpur-Tuljapur Highway	20.99585	79.03536	Very Severe	Midblock	New
3	Powerhouse chowk	21.1089	79.12422	Very Severe	Intersection	New
4	Gitanjali Square	21.1521	79.09794	Very Severe	Intersection	New
5	Agrasen Square	21.15094	79.10374	Very Severe	Intersection	New
6	Zhansi Rani Square	21.14354	79.08075	Very Severe	Intersection	Existing
7	Wadi T point / Auto HUB to Toll Naka	21.15286	79.00225	Severe	Intersection	Existing
8	Atul Lawn, Dighori	21.10831	79.13903	Severe	Intersection	New
9	RBI Square	21.15266	79.07882	Severe	Intersection	New
10	Chattrapati Square	21.1108	79.07009	Severe	Intersection	Existing
11	Morris T point	21.14675	79.08135	Severe	Intersection	Existing
12	Mhalgi Nagar Square	21.10762	79.11961	Severe	Intersection	Existing
13	Bardi, Civil lines (Maharajbagh chowk)	21.14524	79.07441	Severe	Intersection	New
14	New Bidi Peth (Mahakalkar Sabhagraha)	21.11749	79.11646	Severe	Intersection	New
15	Near Dongargaon	20.9829	79.02837	Severe	Midblock	Existing
16	Shrinagar Chowk	21.1079	79.07964	Severe	Intersection	Existing
17	Ram nagar to Chota ram nagar	21.14033	79.05542	Severe	Intersection	New
18	Ayodhya Nagar Square	21.11778	79.11123	Severe	Intersection	New
19	Tukdoji Putla Square	21.12335	79.10498	Severe	Intersection	New
20	Near ICAR, Mahesh Dhaba, Nagpur-Rural	21.03501	79.05178	Severe	Midblock	Existing
21	Shivaji Nagar (Ramnagar chowk)	21.13701	79.05535	Severe	Intersection	New
22	Bhagat square	21.11771	79.01541	Mild	Intersection	New
23	Shankar nagar square	21.13592	79.06062	Mild	Intersection	New
24	Shishu mandir school, old Kailash nagar	21.11388	79.11041	Mild	Intersection	New
25	Liberty Cinema intersection, civil lines	21.15722	79.07974	Mild	Intersection	New
26	Bhagat Square	21.11855	79.01909	Mild	Intersection	New
27	Shiv Nath temple intersection, Dighori	21.11257	79.13322	Mild	Intersection	New
28	Gandhi nagar square	21.13336	79.05561	Mild	Intersection	New
29	Mayo Square	21.15336	79.09627	Mild	Intersection	Existing
30	Mancherial - Chandrapur - Nagpur Road to Borkhedi	20.96661	79.0209	Mild	Midblock	New
31	Narayana Vidyalaya, Nagpur-Tuljapur Highway	21.06188	79.05659	Mild	Midblock	New
32	Borkhedi	20.94693	79.01127	Mild	Midblock	New
33	111 Ganga granites, Bhilgaon to Vithoda saoji restaurant	21.19189	79.16184	Mild	Midblock	New
34	Astha Vinayak milestone, Jamtha	21.01595	79.0468	Mild	Midblock	New

3.7 Similarity and Dissimilarity analysis among Greyspots

In this section, we reviewed the identified "Greyspots" and "Unsafe Corridors" of two time periods (2023Q1 & 2023Q2). Table 3.8 lists the total count of"Greyspots" and "Unsafe Corridors" for these two time periods, along with the percentage of overlap between them. According to table 3.9, there are around 76 % of greyspot locations matching, with intersection locations matching 92 % and midblock locations matching 33.33 %. Additionally, 3 unsafe corridors are common during these two periods, exhibiting a 60 % matching accuracy.

Table 3.9 Count of Greyspots and matching percentage.

	Greyspots			Most Unsafe Corridors (Top 5)
	Total	Intersection Locations	Midblock Locations	
2023: Q1	33	24	9	5
2023: Q2	34	25	9	5
Common	25	22	3	3

3.8 Ground Observations of Top Severe Greyspots and Most Unsafe Corridors

A team of engineers from CSIR - CRRI and INAI, IIIT Hyderabad visited the Greyspot locations & Most Unsafe Corridors, reporting significant severity values in Nagpur city and surveyed the ground conditions. Table 3.10 illustrates the observed issues and suggested remedial measures for the Greyspots (New locations), and Table 3.11 & 3.12 illustrates the observed issues and suggested remedial measures for the two most unsafe corridors among five corridors respectively, aimed at the concept of **“Prevention is better than cure”** so that location will not become blackspots. Based on the above reconnaissance visit, it is inferred that the following could be the common contributory factors for their appearance on the greyspot list:

a) Speed violation due to the absence of soft traffic calming measures (in the form of Transverse Bar Marking measuring up to 15 mm thickness) at the midblock locations.
b) Damaged road infrastructure & poor traffic management measures that are in place.
c) Lack of facilities for pedestrians forcing a large proportion of pedestrians to walk on the carriageway as well as the absence of designated zebra crossing at potential locations.
d) Inappropriate position & type of traffic signal, visibility, etc.
e) Poor geometry at the intersections. f) Encroachment issues due to street vendors, stalls, market, etc., and on-street parking issues.

Table 3.10 presents the identified issued and the cost-effective remedial measures which can be implemented at the top 16 greyspots visited by the iRASTE: Nagpur team.

Table 3.10 Issues and remedial measures for Greyspots of Nagpur City

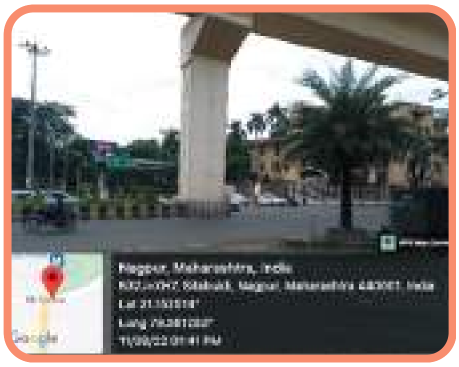
Rank	Greyspots	Observed Issues	Suggested Remedial Measures
1	Raghuji Nagar (Chota Tajbagh)	i. Short medianheight.	i. Repair all the damaged parts of the junction.
		ii. Manhole damaged in the left turning.	ii. Increase median height.
		iii. Sharp turning at the intersection (T)	iii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		iv. Road level difference towards Taj Bagh Road arm.	iv. Provide proper road markings, road signs, and all other road furniture.
		v. Damaged minor road.	v. Speed calming measures/Rumble strips at the major and minor roads.
		vi. Visibility issue due to shops/boards on the turning.	vi. Improve left turn and other turning areas.
		vii. Movement of buses on the minor road of Raghuji colony creates several visibility issues.	vii. Provide Retro-reflective paint/strips on the obstructions.
		viii. Vanished Road markings, fewer road sign boards, and no speed calming measures on all the arms.	
		ix. No traffic signals.	
		x. More speed violations on the major road.	
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
3	Agrasen Square	i. Metro entry staircase on the left turn of the road.	i. Shift the metro entry from the left turning.
		ii. Damaged channelizing island and roadside kerbs, and footpaths.	ii. Repair all the damaged sections of the junction.
		iii. Junction is not at the level.	iii. Improve Road level/junction level.
		iv. Level difference on minor roads.	iv. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		v. Visibility issues are due to the presence of big metro piers & rotary and in the turning areas.	v. Provide proper road markings, road signs, and all other road furniture.
		vi. Wrong traffic signal position and height.	vi. Rumble strips at the major road.
		vii. No road markings, fewer road sign boards, and no speed calming measures on all the arms.	vii. Improve left turn and other turning areas.
			viii. Provide Retro-reflective paint/strips on the obstructions.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
4	**Gitanjali Square**	i. Damaged channelizing island, roadside kerbs, and footpath.	i. Junction, as well as geometry, must be addressed.
		ii. Traffic signal is off and placed in the wrong position at an inappropriate height.	ii. Repair all the damaged parts of the road.
		iii. No road markings, fewer road sign boards, and no speed calming measures on all the arms.	iii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		iv. Speed violation on the major road.	iv. Provide proper road markings, road signs, and all other road furniture.
		v. Visibility issue due to the presence of big metro piers & rotary, shops/stalls on the turning.	v. Rumble strips on the major road.
			vi. Improve left turn and other turning areas.
			vii. Provide Retro-reflective paint/strips on the obstructions.
			i. Junction, as well as geometry, must be addressed.
			
			

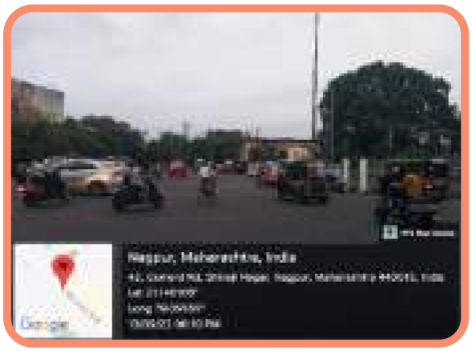
Rank	Greyspots	Observed Issues	Suggested Remedial Measures
4	Gitanjali Square	i. Damaged channelizing island, roadside kerbs, and footpath.	i. Junction, as well as geometry, must be addressed.
		ii. Traffic signal is off and placed in the wrong position at an inappropriate height.	ii. Repair all the damaged parts of the road.
		iii. No road markings, fewer road sign boards, and no speed calming measures on all the arms.	iii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		iv. Speed violation on the major road.	iv. Provide proper road markings, road signs, and all other road furniture.
		v. Visibility issue due to the presence of big metro piers & rotary, shops/stalls on the turning.	v. Rumble strips on the major road.
			vi. Improve left turn and other turning areas.
			vii. Provide Retro-reflective paint/strips on the obstructions.
			i. Junction, as well as geometry, must be addressed.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
6	**Powerhouse Intersection**	i. Damaged channelizing island and roadside kerbs, and footpaths.	i. Repair all the damaged parts of the junction like kerbs, potholes, islands, etc.
		ii. Potholes are present on the left turning, edge of the road, and in one left arm.	ii. Close all the median cuts that are present at the curve.
		iii. Median cuts are at the curve.	iii. Remaining other geometrical safety measures will be done by PWD.
		iv. Oblique intersection.	iv. Geometric design improvement required Provide proper road markings, road signs, and all other road furniture.
		v. Improper left turn.	v. Rumble strips on the major road.
		vi. Level difference at the junction.	vi. Improve left turn and other turning areas.
		vii. Footpath is absent.	vii. Provide Retro-reflective paint/strips on the obstructions.
		viii. Speed violation on a major road.	
		ix. No road markings and speed calming measures.	
		x. Visibility issue on the turnings.	Visibility funnels need to be enhanced
		xi. Paver blocks are present at the junction.	
			
			

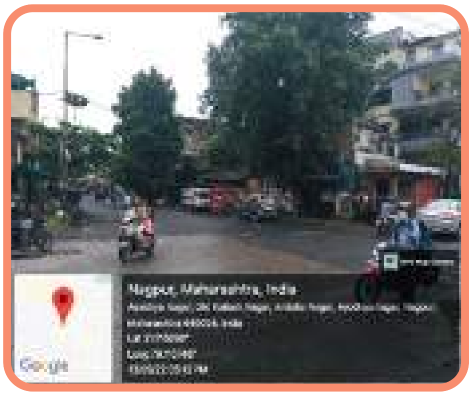
Rank	Greyspots	Observed Issues	Suggested Remedial Measures
8	**RBI Square**	i. Damaged roadside kerbs, footpaths, and channelizing islands.	i. Junction, as well as geometry, must be addressed.
		ii. Road level difference, water logging problem.	ii. Repair all the damaged parts of the road.
		iii. Fewer Road markings and road furniture.	iii. Other safety measures will be taken by PWD.
		iv. No speed-calming measures.	iv. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		v. Visibility issue due to the presence of big metro piers & rotary, shops/stalls on the turning.	v. Provide proper road markings, road signs, and all other road furniture.
		vi. Vertical traffic signal is placed in the wrong position with inappropriate height.	vi. Provide Rumble strips/speed-calming measures in all arms.
			vii. Improve left turn and other turning areas.
			viii. Provide Retro-reflective paint/strips on the obstructions.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
11	Atul Lawn, Dighori	i. Long median cut (>20m).	i. Shorten the median cut.
		ii. Sharp turn in one minor road.	ii. Improve left/free left turn.
		iii. No free left turn.	iii. Junction improvement must be addressed by PWD.
		iv. Oblique intersection.	iv. Provide all road furniture, road markings, and speed-calming measures.
		v. Less road furniture, no stop line, no speed calming measures.	v. Provide Rumble strips/speed-calming measures on the major road.
		vi. Speed violation on major roads.	vi. Improve turning areas.
		vii. No traffic signals.	vii. Chevron markings in the connecting oblique minor roads.
		viii. Visibility issue near minor and roads.	viii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
			ix. Provide Retro-reflective paint/strips on the obstructions.
			
			

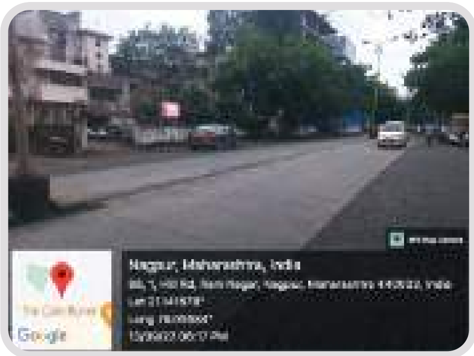
Rank	Greyspots	Observed Issues	Suggested Remedial Measures
13	Bardi (Maharaj Bagh Square)	i. Road condition is poor at the junction.	i. Repair all the damaged parts of the junction.
		ii. Several islands, footpaths, and kerbs are damaged.	ii. Junction, as well as geometrical improvement is required, which will be done by PWD.
		iii. Level difference on minor college roads.	iii. Improve free left turnings.
		iv. Roads in the turning area are poor.	iv. Improve footpaths.
		v. Speed violation.	v. Provide all road furniture, road markings, and speed-calming measures.
		vi. No road furniture and markings, absence of speed calming measures.	vi. Provide Rumble strips/speed-calming measures on all arms.
		vii. Two consecutive traffic signals are present (~600 m).	vii. Provide Retro-reflective paint/strips on the obstructions.
		viii. Visibility issue to vehicles coming from minor college road because sharp turn present.	viii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
			ix. Provide a signboard of 'college ahead'.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
15	**Shivaji Nagar (Ram Nagar Square)**	i. Road level difference.	i. Repair all the damaged parts of the junction.
		ii. Several Channelizing islands, footpaths, and kerbs are damaged.	ii. Junction, as well as geometrical improvement is required, which will be done by PWD.
		iii. Connecting roads are narrow with no free left turn.	iii. Provide free left turnings.
		iv. Junction is not at level.	iv. Provide all road furniture, road markings, and speed-calming measures.
		v. No road markings & furniture, and no speed calming measures on all the arms.	v. Provide Rumble strips/speed-calming measures on all arms.
		vi. Speed violation.	vi. Provide Retro-reflective paint/strips on the obstructions.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
16	**New bidi Peth (Mahakal Sabhagraha)**	i. Several median cuts in the curve	i. Close all the median cuts which are at the curve
		ii. Paver blocks on the junction	ii. Repair all the damaged sections of the junction
		iii. Oblique intersection	iii. Junction, as well as geometry, must be addressed
		iv. Damaged minor road	iv. Provide proper road markings, road signs, and all other road furniture
		v. Visibility issue due to the presence of shops/stalls on the turning, big garbage bin in the junction, presence of trees/poles, and big statue on mid of the road	v. Chevron markings in the connecting oblique minor roads
		vi. No road markings & road sign boards, and no speed calming measures on all the arms	vi. Provide Rumble strips/speed-calming measures on the major road
		vii. Speed violation on the major road	vii. Improve turning areas
			viii. Provide Retro-reflective paint/strips on the obstructions
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
17	**Ayodhya Nagar T Point**	i. Road level difference.	i. Median is required.
		ii. Sharp T intersection.	ii. Provide free left turn.
		iii. Damaged turning.	iii. Repair all the damaged parts of the intersection.
		iv. No median available.	iv. Other safety measures will be taken by PWD.
		v. In some places, the footpath is not present.	v. Provide proper road markings, road signs, and all other road furniture.
		vi. Visibility issue due to shops/stalls on the turning.	vi. Provide Rumble strips/speed-calming measures in all arms.
		vii. Movement of buses on the Ayodhya Nagar colony road, creates several visibility issues.	vii. Provide sign board of T-Intersection ahead.
		viii. No road markings & furniture, and no speed calming measures on all the arms.	viii. Improve left turn and other turning areas.
		ix. No traffic signals.	ix. Provide Retro-reflective paint/strips on the obstructions.
		x. More speed violations on the major road.	
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
18	**Tukdoji Putla Square**	i. Long median cut present (>35m).	i. Shorten the long median cut.
		ii. Left turn damaged, several potholes are damaged on the turning area at the junction.	ii. Repair all the damaged parts of the junction.
		iii. Difference in road level in one arm.	iii. Junction, as well as geometrical improvement is required, which will be done by PWD.
		iv. One oblique minor connecting road is present.	iv. Provide all road furniture, road markings, and speed-calming measures.
		v. Median cuts are provided near the junction.	v. Provide Rumble strips / speed-calming measures on all arms.
		vi. Damaged manholes and channelizing island at the junction.	vi. Chevron markings in the connecting oblique minor road.
		vii. Visibility issue due to shops / stalls / poles / tower / box on the turning and footpath.	vii. Provide vertical and cantilever traffic signals in the appropriate position with an optimum height.
		viii. Visibility issue due to more shop banners on the roadside.	viii. Provide Retro-reflective paint / strips on the obstructions.
		ix. No road markings & furniture, and no speed calming measures on all the arms.	
		x. Traffic signal is present in the wrong position, with less height.	
		xi. More speed violations on the major & minor roads.	
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
21	**Ramnagar to Chota Ramnagar**	i. Major road with a high-level difference.	i. Median height should be increased.
		ii. Median height is short.	ii. Provide smooth left turnings.
		iii. Long median cut (>35m).	iii. Repair all the damaged parts of the junction.
		iv. Paver block in T point.	iv. Junction, as well as geometrical improvement is required, which will be done by PWD.
		v. Sharp turning in minor roads.	v. Improve footpaths.
		vi. Level difference on connecting roads.	vi. Provide all road furniture, road markings, and speed-calming measures.
		vii. No road markings & no road furniture, and no speed calming measures on major & minor roads.	vii. Provide Rumble strips/speed-calming measures on all arms.
		viii. Speed violation on both major & minor roads.	viii. Provide Retro-reflective paint/strips on the obstructions.
		ix. Visibility issue.	ix. Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
		x. Minor road traffic obstructing other vehicles.	x. Provide a signboard of 'GO SLOW'.
		xi. Improper streetlights at the intersection.	
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
24	Sir Visveswaraya Square	i. Many cuts are present in the minor roads near the junction.	i. Provide smooth left turnings.
		ii. Level difference in the minor roads (RHS side).	ii. Repair all the damaged parts of the junction.
		iii. Depressed junction.	iii. Repair pavement distresses.
		iv. Short length of the median on LHS side minor road.	iv. Provide signboards of Side Road Left, and TBM/Breaker near the cuts on the minor roads.
		v. Damaged channelizing islands, and kerbs.	v. Improve footpaths at the junction area.
		vi. Many pavement distress are present at the junction.	vi. On both minor roads, provide Yellow Colour Zig-zag markings on the curbside
		vii. Congested left turn, and on the RHS side free left turn is not present.	vii. Extend the length of the median on minor roads (LHS).
		viii. Both minor roads are undivided with no road markings.	viii. Place the signal in the right position and also cantilever signal should be provided.
		ix. Traffic signals are positioned in the wrong place.	ix. Provide all road furniture, road markings, and speed-calming measures.
		x. Vanished Road markings & no road furniture, fewer traffic signboards, and no speed calming measures on major & minor roads.	x. Provide Rumble strips (TBM)/speed-calming measures on all arms, and also near the median cut.
		xi. Speed violation on both major & minor roads is the major factor.	xi. Provide Retro-reflective paint/strips on the obstructions.
		xii. Visibility issue due to the presence of trees, telephone boxes, and Ads.	xii. Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
			xiii. Provide signboards of 'GO SLOW'.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
25	**Shankar Nagar Square**	i. Left arm minor road has a level difference.	i. Provide smooth left turnings.
		ii. Median cut near the intersection.	ii. Repair all the damaged parts of the junction.
		iii. Damaged channelizing islands, kerbs, and median on the RHS side.	iii. Block median cuts near the intersection.
		iv. RHS side minor road is undivided with no road markings.	iv. Improve footpaths at the junction area.
		v. Main gate of United Insurance Company at the junction on a free left turn.	v. On that minor road, provide lane markings (Yellow colour).
		vi. Traffic signal positioned in the wrong place.	vi. Shift that insurance company gate to another location.
		vii. Vanished Road markings & less road furniture, fewer traffic signs, and no speed calming measures on major & minor roads.	vii. Place the traffic signal in the right position and also cantilever signal should be provided.
		viii. Speed violation on both major & minor roads is the major factor.	viii. Provide all road furniture, road markings, and speed-calming measures.
		ix. Visibility issue due to the presence of metro piers.	ix. Provide Rumble strips (TBM)/speed-calming measures on all arms.
			x. Provide Retro-reflective paint/strips on the obstructions.
			xi. Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
			xii. Provide signboards of 'GO SLOW'.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
26	**Hingna Naka Intersection (Bhagat Square)**	i. Large median opening at the curve location (at the Hingna Naka location) is the biggest problem.	i. Provide smooth left turnings.
		ii. Various small minor roads join major roads near the intersection.	ii. Repair all the damaged parts of the junction.
		iii. Damaged or No footpaths, kerbs, drains.	iii. Provide signboards of Side Road Left, and TBM/Breaker near the cuts on the minor roads.
		v. On minor roads, median construction work is going on.	v. Start the traffic signal and place it in the right position and also cantilever signal should be provided.
		vi. Traffic signals are positioned in the wrong place, and currently it is off, so it creates a huge congestion problem.	vi. Provide all road furniture, road markings, and speed-calming measures.
		vii. No road markings & no road furniture, fewer traffic signboards, and no speed calming measures on major & minor roads.	vii. Provide Rumble strips (TBM)/speed-calming measures (10, 15, 20 mm) on all arms, and also near the median cut at the curve location.
		viii. Speed violation on both major & minor roads is the major factor.	viii. Provide Retro-reflective paint/strips on the obstructions.
		ix. Visibility issues due to the presence of big metro piers.	ix. Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
			x. Provide signboards of 'GO SLOW'.
			
			

Rank	Greyspots	Observed Issues	Suggested Remedial Measures
27	**Gajanan Temple, Khadgaon (Midblock)**	i. Many small minor roads join the major roads.	i. Repair all the damaged parts of the junction.
		ii. No footpaths, kerbs, drains on the RHS side, and damaged median on the straight road.	ii. Improve footpaths at the junction area. Provide zebra crossing and improve the footpath for better pedestrian movement.
		iii. No road markings & furniture, less traffic signboards, and no speed calming measures on major & minor roads.	iii. Provide signboards of Side Road Left, and TBM/Braker near the cuts on the minor roads. Provide sign board of 'GO SLOW'.
		iv. Speed violation on both major, minor, and curve roads is the major factor.	iv. Provide all road furniture, road markings, and speed calming measures. Provide Retro-reflective paint/strips on the obstructions. Provide lane dividation markings (yellow colour) at the curve locations or continue the median from the straight to curve location.
		v. Visibility issues in the curve locations and wrong side driving.	v. Provide Rumble strips (TBM)/speed-calming measures (10, 15, 20 mm) throughout the stretch and also near the median cut at the curve & straight locations
		vi. No pedestrian crossing and walking facility, footpaths in the turning regions are damaged and fully encroached.	vi. Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
			
			

Furthermore, under the corridor analysis, to address the issues identified in the top 5 most unsafe corridors, devised engineering solutions for remedial measures. Specifically, the first and last corridors that were obtained from the analysis of the top 5 unsafe corridors in 2023:Q1 were selected for remedial measures. Corridor – 1 Kamptee Road (NH 44) and Corridor – 2 Katol Road (NH 353J) were selected. To initiate the process, ground observations were conducted for both selected corridors. These observations aimed to gather first-hand information and gain a comprehensive understanding of the issues present in these corridors. The issues and suggested solutions as their remedial solutions are presented in the below Table 3.11 & 3.12.

Table 3.11 Corridor 1 – Problems and their suggested solutions.

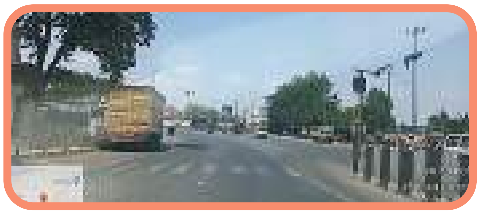
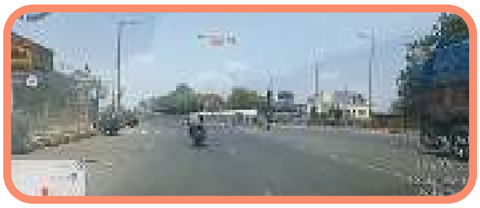
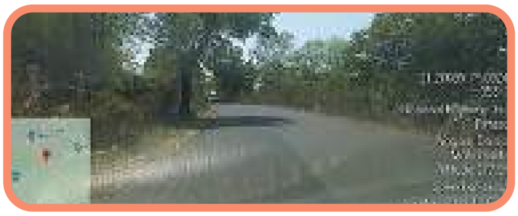
CORRIDOR-1 (Kamptee Road - NH 44)		
Issues	**Problems**	**Suggested Solutions**
Geometric	• Median cuts are at the curve. • Unauthorized left turn • On the side of a major road, the footpath is absent. • Level difference on the road	• Close or shift all the median cuts that are present at the curve. • Closing all unauthorized cuts in the median and left side. • Provide proper walking facilities for pedestrians
Delineation	• Speed violation on the major road • No road markings, speed calming measures • Visibility issue on the turnings • Damaged road furniture	• Provide proper road markings, road signs, and all other road furniture. • Rumble strips at the major road • Provide Retro-reflective paint/strips on the obstructions near turning
Pedestrian / Vehicle	• Improper pedestrian • crossing facility • Congested footpaths and No parking/auto stand for vehicles. • More movement of heavy vehicles	• Provide proper zebra crossing and improve the footpath. • Develop parking areas for auto and other vehicles
Enforcement	• Congested footpaths and on-street parking • Shops/stalls on the roadside/footpath • Movement of pedestrians/vehicles on the side of the road or wrong direction of the road • Heavy vehicles are generally parked on the side of the road. • Two-Wheeler without protective gear	• Remove encroachment from the road/footpath. • Shift all the trees/poles which lie on the road. • Encourage pedestrians/road users to follow traffic rules using informatory sign boards or by organizing any campaign. • Encourage two-wheelers to wear protective gear
		

Table 3.12 Corridor 2 – Problems and their suggested solutions.

CORRIDOR-2 (Katol Road - NH 353J)		
Issues	**Problems**	**Suggested Solutions**
Geometric	• No footpaths, kerbs, or drains on the roadside. • No median on the road. • No shoulder provided on edges of the road.	• Provide footpaths near intersections. • Improve drainage system. • Provide shoulders on the edges of the road.
Delineation	• No road markings & no road furniture, fewer traffic signboards, and no speed calming measures on major & minor roads. • Speed violation on both major & minor roads is the major factor. • Visibility issues in the curve locations.	• Provide all road furniture, road markings, and speed-calming measures. • Provide Rumble strips/speed-calming measures. • Provide Retro-reflective paint/strips on the obstructions. • Provide warning traffic signals (Amber light) in the appropriate position with an optimum height.
Pedestrian / Vehicle	• No pedestrian crossing and walking facility. • Footpaths in the turning regions are damaged and fully encroached. • No proper auto stand or other vehicle parking area. • No bus stops. • Wrong-side driving. • Other vehicles also perform over speeding on major roads (Curve region).	• Provide zebra crossing and improve the footpath for better pedestrian movement. • Develop parking areas for auto and other vehicles. • Provide a bus stop area. • Provide lane dividing markings (yellow colour) at the curve locations.
Enforcement	• High encroachment on all the footpaths/roadside and more on-street parking. • Residents built shops, and houses on the footpath and roadside areas. • Some shops/stalls on the roadside/footpath/turning.	• Remove encroachment from the road/footpath/turning. • Shift all the trees/poles/boxes which lie on the road/turnings. • Shops at the midblock, provide proper parking spaces for vehicles.
	    	    

3.9 Data Dashboard

Also, we have developed a web-based dashboard to show the identified Greyspot locations. Figure 3.21 shows a snapshot of the locations present in Table 3.7 on a dashboard map. In addition, a map of these greyspots with the existing blackspots is also available on the dashboard, for reference. This map is shown in Fig. 3.22.

Figure 3.21 Identified greyspots in the Nagpur city. https://inaix.iiit.ac.in/nagpur-iraste/dashboard

Figure 3.22 Blackspots and the identified Greyspots in the Nagpur city. https://inaix.iiit.ac.in/nagpuriraste/dashboard.

3.10 Road Users' Opinion

As part of this study, road users' opinion survey was conducted during 15th to 31st December 2021. This was conducted through on-site personal interviews at all the listed blackspot locations as shown in Figure 3.21.

Figure 3.23 On-site Personal Interviews of Road Users

This survey could collect information from a total of 2638 including pedestrians, cyclists, and two-wheeler riders. The collected information was regarding their opinion regarding the level of safety they feel at different locations and their reasons. This also includes their suggestion to improve the same. Table 3.10 shows the sample statistics regarding the collected data.

Table 3.13 Sample Distribution of Road Users' Personal Interviews

Location Type	Intersection	Midblock
Count of Locations	30	8
Sample size	2320	318
Gender Distribution	Male- 66.42%, Female- 33.19%	Male- 71.61%, Female- 28.39%
Age Distribution	15-29 yrs. – 53.71% 30-44 yrs. -38.92% 45-59 yrs. – 6.16% >60 yrs. – 1.16%	15-29 yrs. – 40.69% 30-44 yrs. -42.27% 45-59 yrs. – 15.14% >60 yrs. – 1.89%

At intersections, 45.34 % of pedestrians have said that they don't feel there is any safe waiting area before crossing roads. 35 % of road users suggest speed tables/raised crosswalks while 29 % of the road users suggest FOBs for enhancing safety while crossing. Most of the road users find it difficult to cross against the intersections without signals. About 55 % of pedestrians and cyclists are bothered with free left turns out of which 50 % of them have shown positive interest in tabletop crossing with blinkers. 75 % of cyclists like the idea of a separate cycle lane/track. 73% of Two-wheeler drivers like the idea of a separate track for two-wheelers. Only 2 % of pedestrians have shown interest in increasing the pedestrian time at intersections, this might be due to the lesser understanding of pedestrians on utilization of pedestrian phase time.

At mid-blocks, only 12 % of road users believed that vehicle drivers always give way to cross the roads. 60% of pedestrians do not get a safe waiting area while crossing the road at mid-blocks. Car and Two-wheelers have been found to be most difficult to cross against. 34 % of road users find mid-blocks without signal difficult to cross. In the age group (> 60 yrs.), 60 % of pedestrians are comfortable with crossing roads in a group rather than crossing individually. Raised crosswalks and FOBs seem to be most common suggestions for enhancing safety while crossing.

3.11 Summary

We have integrated several sources of data in a GIS database including multiple types of ADAS alerts, road network, with geometrical attributes, FIR data, blackspot information, etc. based on primary and secondary data, various models have been developed to identify unsafe locations apart from known blackspots which are called as Greyspots i.e., Intersections, Midblock and Unsafe Corridors. We have identified 25 greyspots (potential to become future blackspots) in the city of Nagpur. Though these Greyspots are dynamic in nature, a web-based dashboard is being created for easy access to the information and changing situations over months/days/hours. This real-time dashboard with maps and locations can be accessed at https://inaix.iiit.ac.in/nagpur-iraste/dashboard.

INFRASTRUCTURE SAFETY

4

4. Infrastructure Safety

Infrastructure Safety vector was initiated with a reconnaissance visit made by the CSIR - CRRI team consisting of **Dr. S. Velmurugan (Chief Scientist, CSIR – CRRI) and Dr. K. Ravinder (Chief Scientist, CSIR – CRRI)** from 5th to 7th August, 2021 and from 11th to 14th September 2021. During the above visit, the team held detailed discussions with the officials of Nagpur Municipal Corporation (NMC) and representatives of Road Safety Committee of Nagpur *(Refer Figure 4.1 and 4.2)* namely, Honourable Member of Parliament, Dr. Vikas Mahatme and Sh. Chandrasekhar Mohite to understand the broad characteristics of traffic, issues related to traffic management, and enforcement at each of the identified 38 blackspots.

Figure 4.1 Meeting with NMC Municipal Commissioner, NMC Officials with the iRASTE team on 5th August, 2021

Figure 4.2 Meeting with Dr. Vikas Mahatme, Hon'ble MP Rajya Sabha and Shri Chandrasekhar Mohite, Member, Road Safety Committee at Nagpur on 12th September, 2021

These blackspots have been identified based on the analysis of the First Information Report *(FIRs)* related to road crashes obtained from the Nagpur Police. The FIRs encompassing the road crash and fatality data from 1.1.2019 to 30.11.21 provided by the Nagpur Traffic Police (NTP) were analyzed in the study. These FIRs originally in Marathi language translated to English and based on the location details given in the FIR, it was geo coded *(by incorporating the latitude / longitude)* so as to make it compatible for depiction on Geographical Information System *(GIS)* platform. A total of 2225 FIR records have been used in this analysis. based on the analysis of the FIR data, 38 spots identified as Blackspots, since they conform to the protocol of the Ministry of Road Transport and Highways *(MoRT&H)* i.e., *Location wherein either 5 road crashes or 10 fatalities occurred within 500 m distance during the last 3 calendar years* is identified as a blackspot. Subsequent to the above identification, as presented in Figure 4.3, blackspot rectification strategy*(ies)* in the form of feasible and cost-effective engineering treatment conceived for each of the above locations.

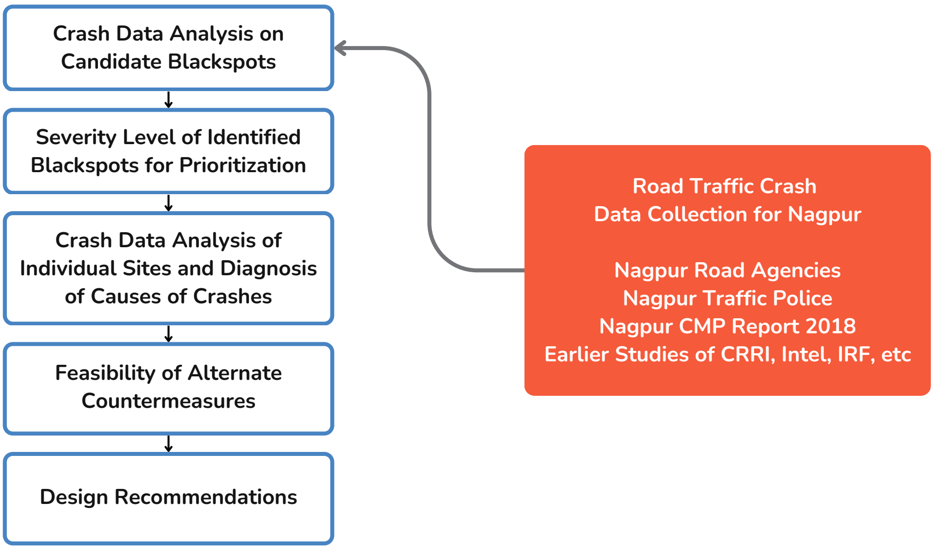


Figure 4.3 Blackspot Identification and Treatment

4.1 Crash Data Analysis

Table 4.1 depicts a three-year (2019-2021) overview of road crashes in Nagpur City, with three primary components (number s of people died, number of people with all major & minor injuries) with no notable improvements detected during these three years. There is a small decrease in road crashes in 2020 because of a major covid-19 lockdown, but during that period no meaningful change in the number of road crash deaths is detected.

Table 4.1 Statistics of Crash data from 2019 to 2021

Year	Crashes	Fatalities	Injuries
2019	910	188	887
2020	576	151	515
2021	793	202	673

Then the number of vehicles and the combination of vehicles involved in these road crashes was further investigated by creating a Vehicle-to-Vehicle matrix. Table 4.2 depicts the Vehicle-to-Vehicle matrix which was involved in the crashes, and it is clear from this table that Trucks, LCVs, Cars, and Two-wheelers were involved in most of the crashes. In addition, road crashes between two-wheelers to two-wheelers, and car-to-car were more common, and a larger number of crashes happened between pedestrians, two-wheelers, and cars.

Table 4.2 Vehicle-to-Vehicle matrix

	TRUCK	CAR	BUS	TWO-WHEELER	AUTO	CYCLE	E-RICKSHAW	LCV	PEDESTRIAN
TRUCK	5	37	1	144	6	12	0	5	17
CAR	37	35	13	469	24	28	4	24	86
BUS	1	13	1	38	3	2	0	0	11
TWO-WHEELER	144	469	38	270	58	38	6	130	127
AUTO	6	24	3	58	5	5	1	9	10
CYCLE	12	28	2	38	5	1	0	8	4
E-RICKSHAW	0	4	0	6	1	0	0	2	2
LCV	5	24	0	130	9	8	2	2	19
PEDESTRIAN	17	86	11	127	10	4	2	19	

Following that, the road crashes in various zones of the NMC region were analyzed. Figure 4.4 shows that most of the crashes happen in Laxmi Nagar, Lakadganj, Dharampeth, and Mangal Wari zones with the larger number of road deaths.

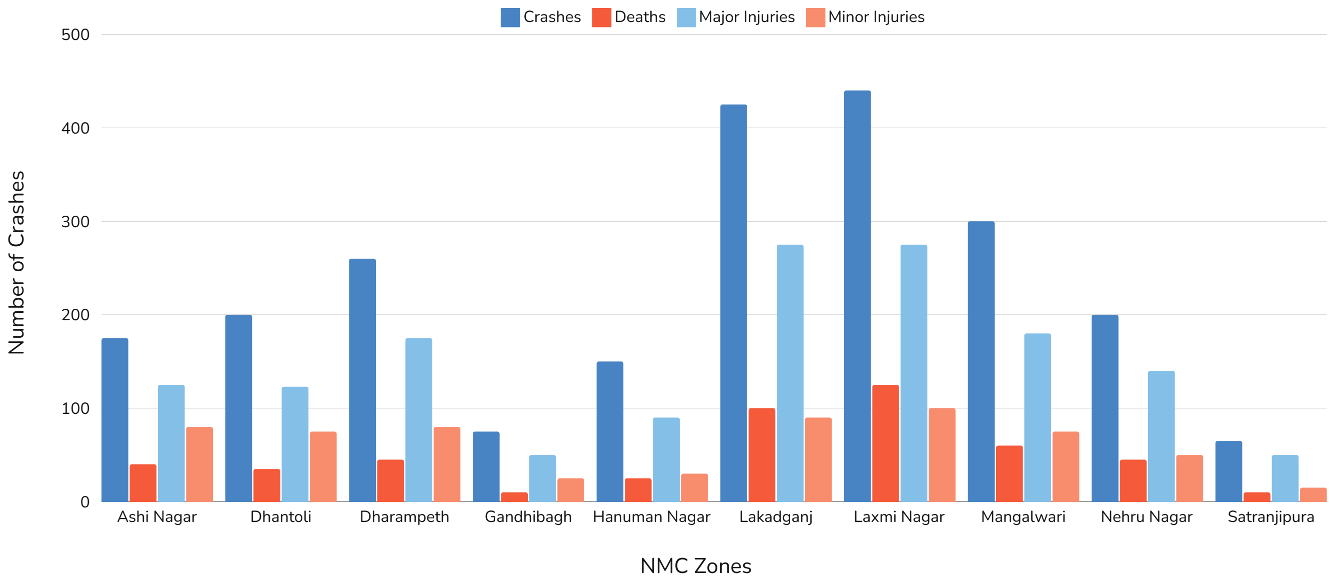


Figure 4.4 Summary of zone-wise road crashes in the NMC region

4.2 Identification of Blackspots on the Nagpur Road Network

Based on the First Information Report *(FIR)* furnished by the Nagpur Police for the period from 1.1.2018 to 31.12.2020, 38 locations *(consisting of 31 intersections & 7 Midblocks)* were identified *(depicted in Figure 4.5)* as blackspots *(refer Table 4.3)* conforming to the Ministry of Road Transport and Highways *(MoRT&H)* protocol. It may be noted that the MoRT&H protocol states that the locations wherein either 5 road crashes or 10 fatalities occurred within 500 m distance during the last 3 calendar years shall be identified as a blackspot. It may be noted that a minimum of 1 road crash / fatality / serious injury type cash or more was reported at 118 locations from which the list of 38 blackspots was identified.

Figure 4.5 Pictorial Illustration of Black Spot Locations.

Table 4.3 List of Blackspots Identified based on FIR data.

S. No.	Blackspot Location Name	Latitude	Longitude	Road section type	Total crashes	Fatalities	Major injuries	Minor injuries
1	Telephone Exchange to C.A road	21.1487	79.12154	Midblock	35	3	29	27
2	Maruti Seva Square, Kamptee Road	21.18391	79.11693	Intersection	27	11	19	2
3	Prakash High School	21.14944	79.16056	Midblock	25	8	17	0
4	Juni Pardi Naka Chowk	21.15139	79.14889	Intersection	33	13	25	6
5	Chattrapati Square	21.11083	79.07011	Intersection	45	12	37	9
6	Dongargaon	20.98047	79.02711	Midblock	5	0	1	0
7	Dongargaon to Bothali	21.05141	79.05312	Intersection	5	1	4	2
8	Rajiv Nagar intersection	21.10365	78.99068	Intersection	16	6	10	0

S. No.	Blackspot Location Name	Latitude	Longitude	Road section type	Total crashes	Fatalities	Major injuries	Minor injuries
9	8th mile	21.14415	78.97213	Intersection	6	2	4	4
10	Wadhamna	21.14072	78.95026	Intersection	5	2	3	0
11	Wadi T point (Dhamna)	21.15287	79.00227	Intersection	12	3	12	1
12	Dattawadi Square	21.15075	78.99644	Midblock	20	7	15	0
13	Khandghav Turning	21.15621	79.00116	Intersection	6	2	4	0
14	Shivanghav Fata	21.08285	79.06251	Intersection	9	2	7	1
15	NEERI Point	21.11933	79.0684	Intersection	17	2	14	2
16	Zhansi Rani Square (2)	21.14124	79.08029	Intersection	41	7	35	5
17	Campus Intersection	21.14911	79.04082	Intersection	11	4	10	0
18	Ravi Nagar	21.14744	79.0562	Intersection	26	5	14	7
19	Jinga Bai takli to Zhanda Chowk	21.18761	79.07888	Intersection	39	12	25	8
20	Pagalkhana Square to Mankapur Square	21.17908	79.07912	Mid-Block	18	8	8	5
21	Ayyappa Mandir to Gorewada Square	21.18733	79.06241	Mid-Block	14	3	10	3
22	Police Talawe	21.17454	79.07071	Intersection	15	3	9	2
23	Auto HUB to Toll Naka	21.15352	79.00419	Intersection	12	4	10	1
24	Gittikhadan to Dinshaw	21.17656	79.05564	Midblock	28	5	17	5
25	New Toll Naka to Toll Naka	21.1864	79.04997	Intersection	9	2	6	2
26	Gorewada to Toll Naka	21.18361	79.03417	Intersection	15	3	12	3
27	Mayo Square	21.15317	79.09403	Intersection	16	4	11	3
28	Veerghav Square (Omkar Nagar)	21.10549	79.09442	Intersection	10	2	7	2
29	Mhalgi Nagar Square	21.10766	79.11961	Intersection	18	4	18	1
30	Manewada Square	21.10522	79.10247	Intersection	18	2	19	3
31	Shrinagar Chowk	21.10771	79.07994	Intersection	20	2	14	3
32	Mahesh Dhaba	21.04082	79.052	Midblock	10	6	3	3
33	Chinchbhavan Square	21.0675	79.05833	intersection	15	3	14	5
34	Kharbi Chowk	21.12425	79.13848	Intersection	21	6	16	4
35	Shitla Mata Square	21.12194	79.12111	Intersection	27	6	27	3
36	Wathoda Square	21.13361	79.14333	Intersection	17	5	11	2
37	Chikli Square	21.1623	79.14106	Intersection	31	14	18	5
38	Maruti Seva Square, Amravati Road	21.15271	79.02068	Intersection	5	2	2	2

At the above-identified blackspots, topographical survey was carried out by using Total Station (TS) System to understand the existing geometric profile. The above topographical surveys were aimed at preparing the base plans i.e., existing geometric profile of the identified blackspots covering up to a maximum of 500 meters on either side of blackspot in the case of midblock whereas in the case of intersections up to 250 m on each of the approach arms of the intersections. The above prepared base plan was used by CSIR - CRRI study team for incorporating the preparing the detailed geometric design improvements in the form of Detailed Project Report (DPR). Apart from road geometric data, classified traffic volume count (CVC) data and pedestrian volume count (PVC) data was collected at 21 blackspot locations through video-graphical survey, and spot speed of different kinds of vehicles collected at 25 blackspot locations through speed-guns which is detailed in the succeeding sections.

4.3 Assessment of Traffic Characteristics

To assess the existing traffic characteristics, the following traffic studies were carried out at various locations of Nagpur city:

- Classified Traffic Volume Counts (CTVC)
- Pedestrian Volume Count (PVC)
- Spot speed surveys
- Speed and Delay Studies

The above-mentioned traffic studies were conducted aimed at understanding the traffic trends and speed characteristics on the selected locations. The succeeding section elaborates the analysis results in terms of quantum of the observed traffic flow and speed characteristics. 12-hour Classified Traffic Volume Count (CTVC) and 8-hour Pedestrian Volume Count (PVC) studies were carried out at all the 21 blackspot locations out of 38 locations, and spot-speed survey was carried out at 25 blackspot locations out of 38 blackspot locations to capture the number of vehicles, pedestrians, and the travel / spot speed of the vehicles using the road network and to estimate the intensity of traffic on the intersecting roads as well as on the midblock sections of the same. For better visualization of the survey locations such as 21 & 25 blackspots where CVC, PVC, and spot speed survey were happened, all these locations are imported on the GIS platform with 38 blackspot locations as presented in Figure 4.6.

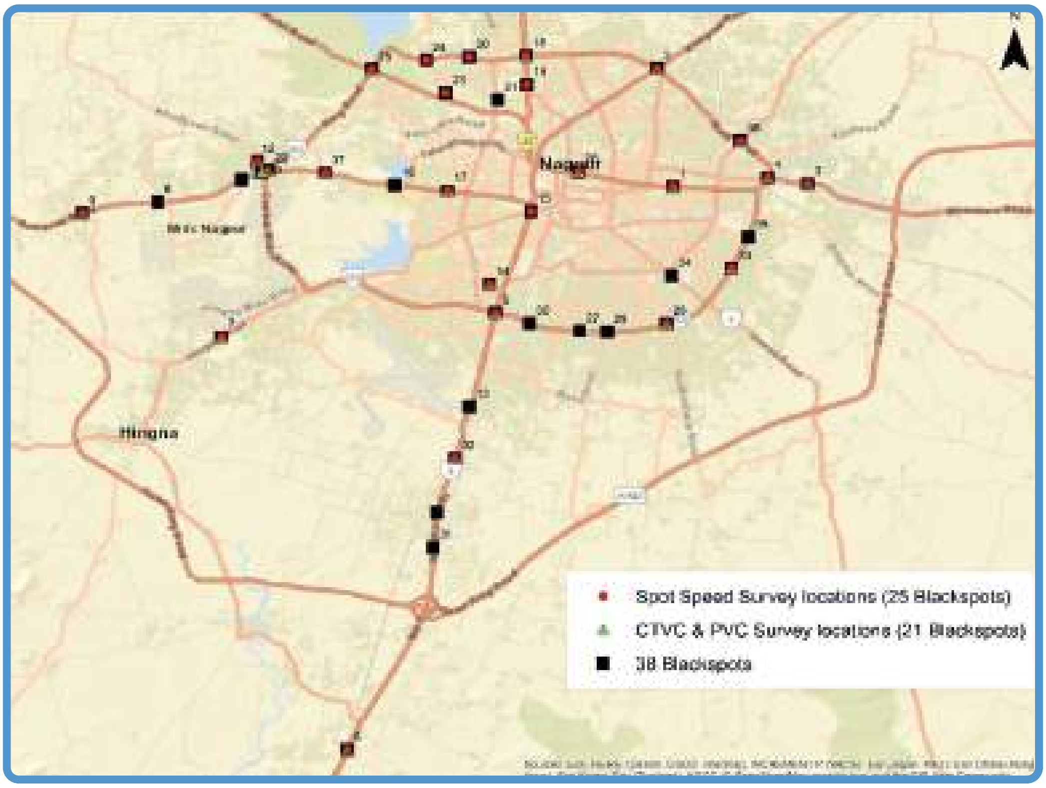


Figure 4.6 CTVC and PVC survey locations at Nagpur city.

Table 4.4 shows the location details of all locations with their road section type and geo-positional information where these all three kinds of traffic survey happened.

Table 4.4 Selected Locations with geo-position information for the Conduct of various Traffic Surveys

S. No.	Blackspot name	Latitude	Longitude	Road Section Type	CTVC	PVC	Spot speed
1	Telephone Exchange to C.A road	21.1487	79.12154	Midblock	✓	✓	✓
2	Maruti Seva Square, Kamptee Road	21.18391	79.11693	Intersection	✓	✓	✓
3	Prakash High School	21.14944	79.16056	Midblock	✓	✓	✓
4	Juni Pardi Naka Chowk	21.15139	79.14889	Intersection	✓	✓	✓
5	Chhatrapati Square	21.11083	79.07011	Intersection	✓	✓	✓
6	Dongargaon	20.98047	79.02711	Midblock	✓	✓	✓
7	Rajiv Nagar intersection	21.10365	78.99068	Intersection	✓	✓	✓
9	Wadhamna	21.14072	78.95026	Intersection	✓	✓	✓
12	Khandghav Turning	21.15621	79.00116	Intersection	✓	✓	✓
14	NEERI Point	21.11933	79.0684	Intersection	✓	✓	✓
15	Jhansi Rani Square (2)	21.14124	79.08029	Intersection	✗	✗	✓
17	Ravi Nagar	21.14744	79.0562	Intersection	✓	✓	✓
18	Jinga Bai takli to Zhanda Chowk	21.18761	79.07888	Intersection	✓	✓	✓
19	Pagalkhana Square to Mankapur Square	21.17908	79.07912	Midblock	✗	✗	✓
20	Ayyappa Mandir to Gorewada Square	21.18733	79.06241	Midblock	✗	✗	✓
22	Auto HUB to Toll Naka	21.15352	79.00419	Intersection	✓	✓	✓
23	Gittikhadan to Dinshaw	21.17656	79.05564	Midblock	✗	✗	✓
24	New Toll Naka to Toll Naka	21.1864	79.04997	Intersection	✗	✗	✓
25	Gorewada to Toll Naka	21.18361	79.03417	Intersection	✓	✓	✓
26	Mayo Square	21.15317	79.09403	Intersection	✓	✓	✓
28	Mhalgi Nagar Square	21.10766	79.11961	Intersection	✓	✓	✓
32	Chinchbhavan Square	21.0675	79.05833	intersection	✓	✓	✓
33	Kharbi Chowk	21.12425	79.13848	Intersection	✓	✓	✓
36	Chikli Square	21.1623	79.14106	Intersection	✓	✓	✓
37	Maruti Seva Square, Amravati Road	21.15271	79.02068	Intersection	✓	✓	✓

4.3.1 Classified Traffic Volume Count

Classified Traffic Volume Count (CVC) data was collected using videography on a typical working day time period from 8:00 am to 8:00 pm so as to cover the morning and evening peak flow along with inter-peak which is basically off-peak flow. Afterwards, the above video data extracted at the office as per the designed proforma presented in Annexure B and Annexure C. Enumerators deployed for the collation of the traffic were imparted training on the aspect of traffic volume data collection and vehicle types intended to be covered in this study. The above collected data punched on to the computer and analyzed using Excel spreadsheets. The vehicle types having different sizes and characteristics converted into a standard unit called Passenger Car Unit (PCUs). Passenger Car equivalents for various vehicle types adopted as prescribed in Indian Road Congress Code IRC-106:1990 titled, “Guidelines for Capacity of Roads in Urban Areas” and these PCU values are presented in Table 4.5.

Table 4.5 PCU Factors Adopted for the Study (IRC:106-1990).

Fast Moving Vehicles	
Vehicle Type	**PCU Factor**
2 wheelers	0.5
Auto Rickshaw	1
Tempos/ Pickup	1
Car, jeep, taxi & van	1
Mini Bus	1.5
Standard Bus	3
Light Goods Vehicle (LCV)	1.5
2 - Axle Truck	3
3 - Axle Truck	3
Multi Axle Truck	4.5
Agriculture Tractor	1.5
Agriculture Tractor & Trailer	4.5

Slow Moving Vehicles	
Vehicle Type	**PCU Factor**
Bicycle	0.5
Cycle Rickshaw	2
Animal Drawn Cart	6
Hand Cart	3

The 12-hour traffic composition and PCUs at the selected blackspot locations of Nagpur city is presented in Table 4.6.

Table 4.6 Summary of the Observed 12-Hour Traffic Composition at Selected Black Spots of Nagpur City

S. No.	Blackspot name	Type	Passenger Vehicle							Goods Vehicles				Slow Moving Vehicles			Total
			Small Cars	Big Cars	2 WLR	Auto	E-rickshaws	Minibus	Buses	3 /4 Wheelers -Goods	LCVs	HCVs	MAVs	Cycle	Cycle Rickshaws	Others	
1	Telephone Exchange to C.A road	Vehicle	5818	1958	34787	2040	1150	49	52	2134	152	48	21	1989	216	143	50557
		PCU	5818	1958	17393.5	2040	1150	74	156	3201	228	144	945	995	432	858	34541
2	Maruti Seva Square, Kamptee Road	Vehicle	10034	4294	54613	5050	1344	164	488	4099	1022	1178	482	2416	163	408	85755
		PCU	10034	4294	2732	5050	1344	246	1464	6148	1533	3534	2169	1208	326	2448	67105
3	Prakash High School	Vehicle	6011	2555	26336	1671	239	130	586	3405	1232	742	502	2153	36	150	45748
		PCU	6011	2555	13168	1671	239	195	1758	5107	1848	2226	2259	1077	72	900	39086
4	Juni Pardi Naka Chowk	Vehicle	12961	5609	64840	9131	2260	274	1167	6840	2768	2655	829	7533	365	441	117673
		PCU	12961	5609	32420	9131	2260	411	3501	10260	4152	7965	3730.5	3767	730	2646	99543
5	Chhatrapati Square	Vehicle	15894	2930	51428	3729	392	179	1241	1525	564	328	48	1926	60	74	80318
		PCU	15894	2930	25714	3729	392	269	3723	2287	846	984	216	963	120	444	58511
6	Dongargaon	Vehicle	9286	2208	14930	316	5	140	857	1620	1444	2426	1912	78	3	108	35333
		PCU	9286	2208	7465	316	5	210	2571	2430	2166	7278	8604	39	6	648	43232
7	Rajiv Nagar intersection	Vehicle	4888	922	35742	2438	64	56	357	1623	356	265	80	2577	11	46	49425
		PCU	4888	922	17871	2438	64	84	1071	24355	534	795	360	1289	22	276	33048
8	Wadhamna	Vehicle	4633	1641	14718	871	8	92	311	2118	1104	655	197	222	1	57	26628
		PCU	4633	1641	7359	871	8	138	933	3177	1656	1965	886.5	111	2	342	23723
9	Wadi T point (Dhamna)	Vehicle	16829	2849	48326	3800	300	71	389	5190	1799	817	291	611	66	94	81432
		PCU	16829	2849	24163	3800	300	106.5	1167	7785	2698.5	2451	1310	306	132	564	64460
10	Khandghav Turning	Vehicle	1059	317	9315	375	38	13	19	1449	497	347	38	579	11	20	14077
		PCU	1059	317	4657.5	375	38	19.5	57	2174	745.5	1041	171	290	22	120	11086
11	NEERI Point	Vehicle	7049	2508	15179	728	37	60	24	615	67	32	0	464	11	3	26777
		PCU	7049	2508	7589.5	728	37	90	72	922.5	100.5	96	0	232	22	18	19465
12	Ravi Nagar	Vehicle	13945	2943	40518	3938	119	87	564	1887	261	105	6	1345	37	118	65873
		PCU	13945	2943	20259	3938	119	130.5	1692	2831	391.5	315	27	673	74	708	48045

S. No.	Blackspot name	Type	Passenger Vehicle							Goods Vehicles				Slow Moving Vehicles			Total
			Small Cars	Big Cars	2 WLR	Auto	E-rickshaws	Minibus	Buses	3 /4 Wheelers -Goods	LCVs	HCVs	MAVs	Cycle	Cycle Rickshaws	Others	
13	Jinga Bai takli to Zhanda Chowk	Vehicle	8813	1971	38798	2700	369	98	393	2431	1137	781	445	1385	41	133	59495
		PCU	8813	1971	19399	2700	369	147	1179	3647	1705.5	2343	2002.5	692.5	82	798	45848
14	Auto HUB to Toll Naka	Vehicle	16829	2849	48326	3800	300	71	389	5190	1799	817	291	611	66	94	81432
		PCU	16829	2849	24163	3800	300	106.5	1167	7785	2698.5	2451	1310	306	132	564	64460
15	Gorewada to Toll Naka	Vehicle	8639	2093	24772	795	41	60	310	1832	887	772	213	201	10	36	40661
		PCU	8639	2093	12386	795	41	90	930	2748	1330.5	2316	959	100.5	20	216	32664
16	Mayo Square	Vehicle	8152	1826	50966	8482	1511	123	295	2240	222	30	1	1508	146	100	75602
		PCU	8152	1826	25483	8482	1511	184.5	885	3360	333	90	5	754	292	600	51957
17	Mhalgi Nagar Square	Vehicle	8948	1867	58906	4328	757	87	476	2862	524	422	8	4740	86	85	84096
		PCU	8948	1867	29453	4328	757	130.5	1428	4293	786	1266	36	2370	172	510	56345
18	Chinchbhavan Square	Vehicle	13585	2980	21577	807	47	184	946	1656	747	361	189	241	8	79	43407
		PCU	13585	2980	10788.5	807	47	276	2838	2484	1120.5	1083	851	121	16	474	37470
19	Kharbi Chowk	Vehicle	6310	1476	61085	3229	1076	88	357	3258	632	535	98	6170	73	181	84568
		PCU	6310	1476	30542.5	3229	1076	132	1071	4887	948	1605	441	3085	146	1086	56035
20	Chikli Square	Vehicle	4637	1195	37434	2376	1231	31	114	6807	1333	971	385	4205	195	416	61330
		PCU	4637	1195	18717	2376	1231	46.5	342	10211	1999.5	2913	1733	2103	390	2496	50389
21	Maruti Seva Square, Amravati Road	Vehicle	10912	2374	31712	2194	54	61	441	3228	565	196	6	677	14	107	52541
		PCU	10912	2374	15856	2194	54	91.5	1323	4842	848	588	27	339	28	642	40118

4.3.2 Pedestrian Volume Count studies

Pedestrian Volume Count (PVC) was also collected at the aforesaid location of CVC by covering only 4-hour duration each of morning and evening peak periods from 8:00 am to 12:00 pm and 4:00 pm to 8:00 pm. A compilation of the pedestrian flow along and across the road is presented in Table 4.7.

Table 4.7 Observed Quantum of Pedestrian Flow at Selected Road Sections in Nagpur City.

Loc. No.	Name of Location	Approach	Daily Pedestrian Vol. – both side (8 hours)		Peak Hour Pedestrian Vol. (Morning Peak)		Peak Hour Pedestrian Vol. (Evening Peak)	
			Across	Along	Across	Along	Across	Along
1	Telephone Exchange to C.A Road	Juni Pardi Naka Road	26	773	8	111	8	134
2	Maruti Seva Square Kamptee Road	Jail Road	234	979	50	174	37	188
		Cantt Road	403	1675	56	223	91	342
		Sipri Road	840	1292	112	193	137	228
		BKD Chowk	547	616	88	84	80	111
		Govind Chowk	547	616	44	148	35	195
3	Parkash High School	Juni Pardi Naka Road	382	2704	89	556	36	375
4	Juni Pardi Naka Chowk	Prajapati Chowk	687	1245	102	197	122	197
		Vardhmaan nagar	210	1035	35	158	46	150
		Kalamna	557	879	80	132	92	151
		Prakash High School	612	1069	91	196	97	166
5	Jhansi Rani Square (1)	Maharaj Bagh Chowk	411	7665	53	1032	113	1350
		Morish Collage Chowk	2009	3513	276	622	364	477
		Lohapul	766	4180	83	591	146	707
		Sitabuldi Metro Station	1360	2634	217	329	200	415
		Jhansi rani square -II	2108	5918	250	708	326	1004
6	Chattrapati Square	Jhansi Rani Chowk	1158	973	129	129	231	171
		Narendra Nagar	1077	1805	130	283	245	314
		Wardha	1653	2720	233	361	320	512
		Pratap Nagar	868	640	121	100	152	120
7	Dongargaon	Elite Chowk	171	253	20	43	48	51
8	Rajeev Nagar	Hingna	1298	673	140	119	224	108
		MIDC	1556	814	237	108	229	143
		Nagpur	883	1553	104	238	176	237
10	Wadhamna	8th Mile	871	1039	126	124	127	183
		Wadhamna	493	1740	59	184	106	315
		Amravati	1401	671	216	76	185	150
13	Khadgaon Turning	Khadgaon Chowk	269	1762	54	262	41	275
15	NEERI Point	Laxmi Nagar	175	394	23	70	30	67
		Annabhav Sethi Chowk	76	454	16	84	10	73
		Ajni Square	175	416	29	77	29	69
19	Ravi Nagar	Maruti Seva square	412	1202	48	160	89	215
		Civil Line	326	753	45	102	56	120
		Jhansi Rani Square-1	294	871	37	132	49	130
		Gokul Peth	256	1596	35	194	49	271
20	Jinga Bai Takli to Zhanda Chowk	Gorewada	877	1098	123	172	126	164
		Betul	398	1221	52	203	56	176
		Chikli	347	1150	54	155	49	206
		Nagpur	492	1515	69	211	74	250

Loc. No.	Name of Location	Approach	Daily Pedestrian Vol. – both side (8 hours)		Peak Hour Pedestrian Vol. (Morning Peak)		Peak Hour Pedestrian Vol. (Evening Peak)	
			Across	Along	Across	Along	Across	Along
24	Auto Hub to Toll Naka	Amravati	259	1692	42	254	37	255
		Gorewada	251	1634	44	199	39	292
		Maruti Seva Square	331	1594	65	256	47	231
27	Gorewada To Toll Naka	Katol	84	295	13	49	12	38
		Jinga Bai Takli	53	129	6	22	13	24
		Friends Colony	107	229	16	35	21	41
		Amravati	81	324	12	61	16	71
28	Mayo square	Railway station	1120	2117	193	339	152	311
		Old Bhandara road	1689	2955	279	469	211	388
		Telephone Exchange	945	1096	137	157	141	162
30	Mhalgi Nagar Square	Ashirwad Nagar	369	1957	60	279	63	314
		Dighori	1449	1837	182	318	281	293
		Hudkeshwar	406	877	56	165	57	106
		Chhatrapati Square	1844	610	239	130	267	99
34	Chinchbhavan Square	Chhatrapati Square	729	568	86	70	226	335
		Chinchbhavan Square	1266	1661	151	130	226	335
		Wardha	486	1655	49	262	106	249
35	Kharbi Chowk	Kharbi	198	426	44	77	24	58
		Dighori	1068	901	149	150	164	136
		Hasan Bagh	223	1943	32	222	46	421
		Wardha	1582	1446	226	144	260	296
38	Chikli Square	Chikli Square	137	730	31	133	25	138
		RTO Office	599	286	98	67	74	43
		Kalamna Market	131	375	24	78	21	59
		Juni Pardi Naka	868	240	167	44	117	53
39	Maruti Seva Square, Amravati Road	Amravati	647	266	104	74	124	42
		Gorewada	158	271	28	32	22	59
		Ravi Nagar	372	520	65	102	68	79

4.3.3 Spot Speed studies

To understand the variation of speed profile, spot speed studies conducted using Laser Speed Guns at 25 vulnerable locations of the road network covering both directions of travel. Direction wise sample data of spot speeds of different vehicles were analyzed to get various speed characteristics namely, minimum speed, maximum speed, average speed, and different percentile speeds such as 15th, 50th, 85th and 95th in order to evolve appropriate speed control and safety measures. Table 4.8 presents the spot speed characteristics.

Table 4.8 Observed spot speed at various Speeding locations of Nagpur city.

S. No.	Blackspot name	Vehicle Type	Min speed	Max speed	Mean speed	15th %ile speed	50th %ile speed	85th %ile speed	95th %ile speed
1	Telephone Exchange to C.A road	Bus	17	57	35	24	30	35	50
		Heavy Vehicles	13	56	35	20	29	38	53
		LCV	9	60	34	20	29	38	45
		Cars	19	92	35	26	36	45	64
		Two-Wheeler	4	79	40	23	34	44	64
		Auto	17	49	31	17	26	34	44
2	Maruti Seva Square, Kamptee Road	Bus	20	50	32	18	26	34	41
		Heavy Vehicles	20	53	30	18	24	32	42
		LCV	19	51	31	18	25	33	43
		Cars	17	69	38	22	33	43	59
		Two-Wheeler	2	93	35	19	31	40	49
		Auto	17	63	30	18	25	33	42
3	Prakash High School	Bus	19	46	33	17	22	30	40
		Heavy Vehicles	21	49	33	18	23	32	43
		LCV	17	56	33	18	24	33	44
		Cars	19	92	35	19	29	38	49
		Two-Wheeler	17	72	35	18	26	37	48
		Auto	18	43	54	17	22	31	39
4	Juni Pardi Naka Chowk	Bus	22	48	32	18	25	34	40
		Heavy Vehicles	18	48	30	18	24	33	42
		LCV	8	55	32	18	26	35	44
		Cars	20	66	38	24	34	44	58
		Two-Wheeler	17	71	37	22	32	42	56
		Auto	17	46	31	18	36	34	42
5	Chattrapati Square	Bus	22	69	41	26	34	44	58
		Heavy Vehicles	22	69	40	22	32	44	62
		LCV	28	70	43	36	37	45	61
		Cars	19	91	39	24	33	43	58
		Two-Wheeler	3	96	37	22	32	43	58
		Auto	19	84	40	23	34	44	63
6	Dongargaon	Bus	25	82	47	28	42	52	64
		Heavy Vehicles	14	63	38	25	33	42	54
		LCV	17	57	41	24	34	43	54
		Cars	24	88	50	34	43	59	74
		Two-Wheeler	27	72	46	30	40	50	68
		Auto	21	49	31	18	24	34	43

S. No.	Blackspot name	Vehicle Type	Min speed	Max speed	Mean speed	15th %ile speed	50th %ile speed	85th %ile speed	95th %ile speed
7	Rajiv Nagar intersection	Bus	22	54	33	19	28	34	43
		Heavy Vehicles	18	44	29	17	29	32	42
		LCV	17	49	32	19	27	34	42
		Cars	17	70	37	24	36	41	53
		Two-Wheeler	17	67	35	20	30	40	52
		Auto	18	46	31	18	24	32	40
8	Wadhamna	Bus	26	76	48	32	42	52	64
		Heavy Vehicles	19	69	38	25	32	41	54
		LCV	19	73	41	25	36	44	62
		Cars	21	104	58	38	52	65	79
		Two-Wheeler	23	87	47	30	42	53	63
		Auto	22	53	36	22	28	39	45
9	Khandghav Turning	Bus	20	41	31	17	26	33	42
		Heavy Vehicles	16	39	27	16	21	26	34
		LCV	17	51	29	17	23	32	38
		Cars	19	55	32	18	26	37	52
		Two-Wheeler	16	58	31	18	24	34	44
		Auto	17	43	27	16	22	33	38
10	Jhansi Rani Square	Bus	19	47	28	18	23	32	37
		Heavy Vehicles	17	43	27	16	21	29	36
		LCV	17	46	29	17	23	32	41
		Cars	18	54	32	19	24	35	44
		Two-Wheeler	18	55	34	19	29	38	44
		Auto	17	48	29	17	22	32	38
11	Ravi Nagar	Bus	18	55	28	17	22	32	36
		Heavy Vehicles	19	30	25	16	19	24	26
		LCV	16	56	28	16	22	28	39
		Cars	16	64	32	18	24	36	46
		Two-Wheeler	17	65	31	18	24	36	43
		Auto	17	44	27	16	21	29	36
12	Jinga Bai takli to Zhanda Chowk	Bus	25	60	35	19	30	36	52
		Heavy Vehicles	21	56	33	18	26	34	46
		LCV	22	58	36	22	30	38	51
		Cars	3	85	47	32	42	53	64
		Two-Wheeler	4	86	43	28	37	44	59
		Auto	3	54	34	20	28	36	44
13	Pagalkhana Square to Mankapur Square	Bus	20	50	34	18	22	33	44
		Heavy Vehicles	17	41	34	15	20	28	38
		LCV	20	47	34	17	22	33	42
		Cars	17	64	34	22	30	39	49
		Two-Wheeler	19	66	34	18	28	37	46
		Auto	17	45	34	17	22	31	36
14	Auto HUB to Toll Naka	Bus	20	52	36	19	32	40	45
		Heavy Vehicles	19	55	30	18	24	32	42
		LCV	20	55	32	18	26	34	43
		Cars	4	63	36	20	32	40	55
		Two-Wheeler	18	62	33	18	28	37	47
		Auto	19	45	31	18	24	34	38

S. No.	Blackspot name	Vehicle Type	Min speed	Max speed	Mean speed	15th %ile speed	50th %ile speed	85th %ile speed	95th %ile speed
15	Gorewada to Toll Naka	Bus	24	65	41	24	35	48	58
		Heavy Vehicles	22	69	40	23	34	43	53
		LCV	21	73	44	28	38	50	53
		Cars	30	118	55	38	49	62	77
		Two-Wheeler	20	104	48	36	42	56	63
		Auto	20	56	38	23	33	43	56
16	Mayo Square	Bus	22	57	31	18	25	32	41
		Heavy Vehicles	23	43	31	18	26	37	45
		LCV	17	43	29	17	22	31	35
		Cars	17	55	33	19	27	36	44
		Two-Wheeler	17	61	32	18	25	36	44
		Auto	16	46	29	18	22	34	38
17	Mhalgi Nagar Square	Bus	19	53	34	18	28	34	44
		Heavy Vehicles	22	58	34	18	24	33	38
		LCV	17	64	34	17	25	34	44
		Cars	17	76	34	18	27	39	52
		Two-Wheeler	17	65	34	19	29	42	53
		Auto	17	49	34	16	24	33	43
18	Chinchbhavan Square	Bus	26	76	48	37	42	49	61
		Heavy Vehicles	29	69	43	29	38	44	57
		LCV	22	65	45	29	39	49	61
		Cars	24	100	58	40	52	63	79
		Two-Wheeler	4	83	51	35	44	53	64
		Auto	22	64	42	29	38	44	56
19	Kharbi Chowk	Bus	18	61	34	18	28	40	46
		Heavy Vehicles	21	61	34	18	26	38	52
		LCV	17	78	35	18	28	41	53
		Cars	18	77	40	19	34	53	63
		Two-Wheeler	17	67	34	18	24	42	56
		Auto	16	49	29	17	22	35	42
20	Chikli Square	Bus	20	57	35	18	28	42	52
		Heavy Vehicles	18	56	35	17	26	38	49
		LCV	17	54	35	17	25	35	50
		Cars	19	92	35	20	32	57	63
		Two-Wheeler	17	72	40	18	28	42	53
		Auto	16	54	35	16	22	32	43
21	Maruti Seva Square, Amravati Road	Bus	27	69	47	30	43	53	60
		Heavy Vehicles	27	59	40	26	33	42	53
		LCV	25	68	41	27	35	44	59
		Cars	22	94	52	35	46	60	76
		Two-Wheeler	20	98	45	28	39	52	63
		Auto	18	51	38	26	34	42	42

4.3.4 Speed and delay Characteristics of the five major corridors

Speed and delay was carried out covering 5 major road corridors (as presented in table 4.9) wherein the movement of NMC Aapli buses was primarily observed. The analyzed data from the above field surveys is presented in the following sections.

Table 4.9 Details of corridors of Speed & Delay survey

Corridor No.	Corridor route	Distance (km)	Run	
			Morning	Evening
1	Ring road starting from Chhatrapati square to Chhatrapati square via Chikli square, Juni Pardi Naka, Maruti seva Amravati square, Ayyappa temple, Gorewada to Toll Naka, Khadgaon turning and Digdoh.	44	✓	✓
2	From Wadhamna to Dongargaon via Dhamna, Campus intersection, Jhansi rani square, Chhatrapati square, Chinchbhavan Square.	37	✓	✓
3	From Jhansi rani square to Rajiv Nagar intersection.	12	✓	✓
4	From Gorewada Toll Naka to Mahalgaon via Police Talawe, NEERI point, Telephone exchange, Prakash high school.	17.1	✓	✓
5	Dighori square to Mayo square via Shitla Mata Temple.	7.2	✓	✓

4.3.4.1 Speed and Delay Characteristics of Corridor 1

- ·Maximum quantum of delay touched 1654.3 seconds during morning run (10:20 to 11:50 hrs.) in the downward direction and the reason behind delay was the traffic signal at Chikli square wherein the cumulative delay was 4 min 06 sec.
- ·Whereas the maximum delay reaches 1622.6 seconds during evening time (17:15 to 18:50 hours) in the downward direction and maximum delay on this run was reported at Chhatrapati square due to traffic signal which spanned 3 min 02 sec.
- ·Maximum journey speed was at morning time in downward direction run and it was 39 km/hr.

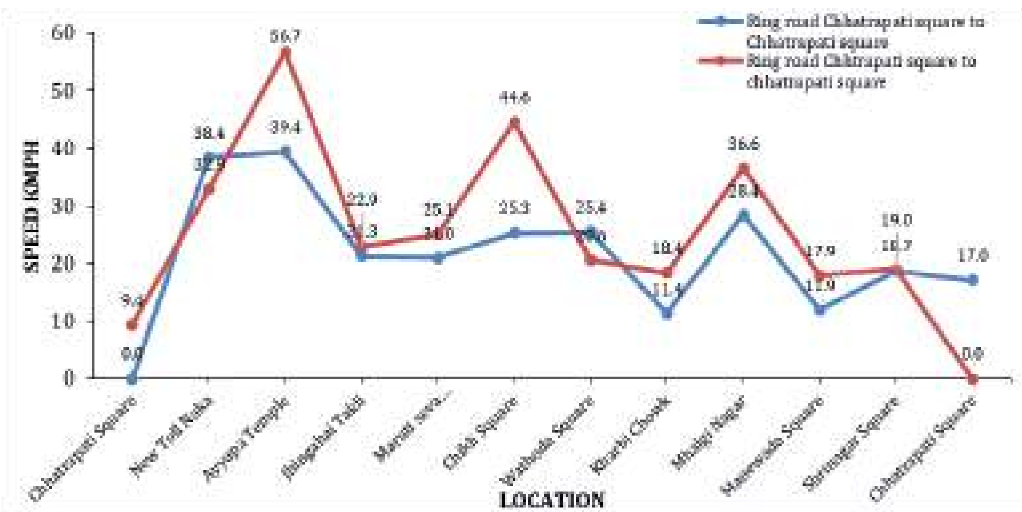


Figure 4.7 Speed Variation on Ring Road Chhatrapati square to Chhatrapati square (MORNING)

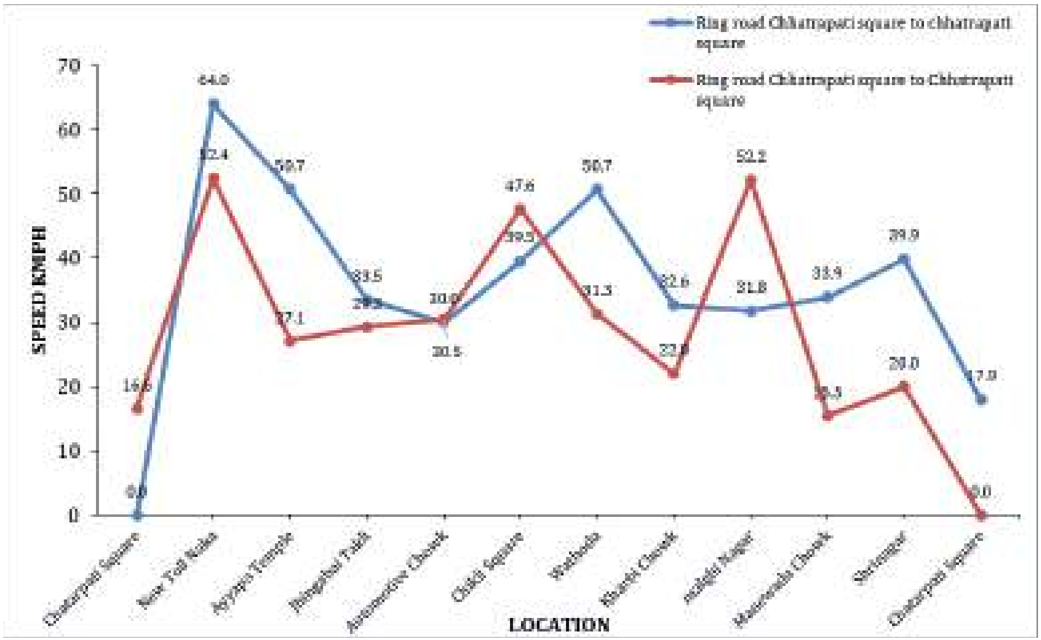


Figure 4.8 Speed Variation on Ring Road Chhatrapati square to Chhatrapati square (EVENING)

4.3.4.2 Speed and Delay Characteristics of Corridor 2

- ·Maximum quantum of delay touched 412 seconds during evening run (6:00 to 7:12 am) in the downward direction and the reason behind delay was the vehicle breakdown at Chinch Bhavan Square delay due to which delay of 139 seconds was reported.
- ·On the other hand, the maximum delay touched 401 seconds during morning (11:00 to 11:54 am) in the upward direction and maximum delay at this run was at Chhatrapati square due to traffic signal as well as on the ongoing road repair work which spanned up to 1 min 46 sec.
- ·Despite the above reported delay delays, the maximum journey speed was observed during the evening run in the upward direction run which was 42.8 km/hr.

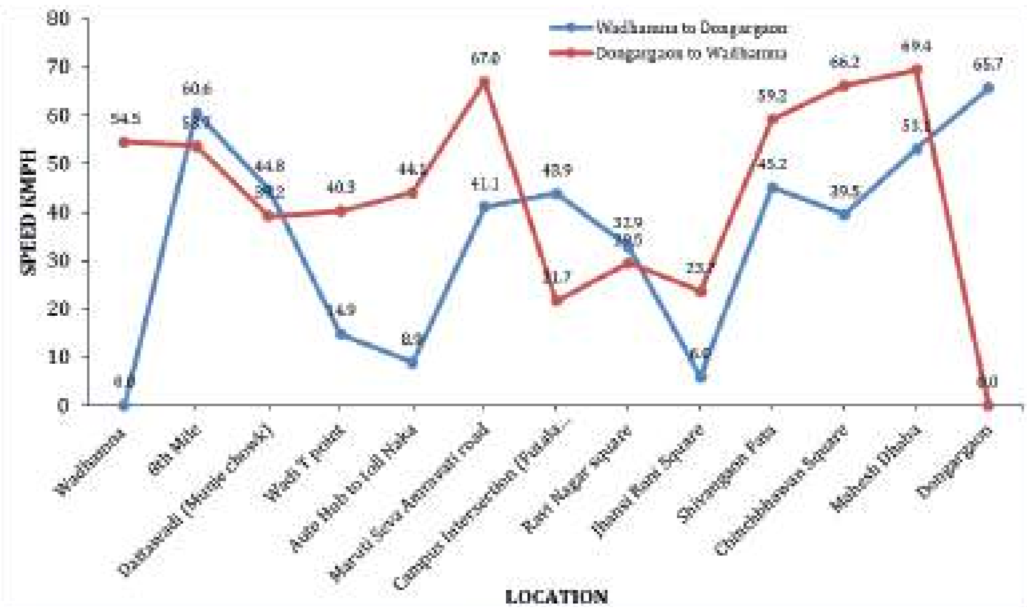


Figure 4.9 Speed Variation on Wadhamna to Dongargaon corridor (MORNING)

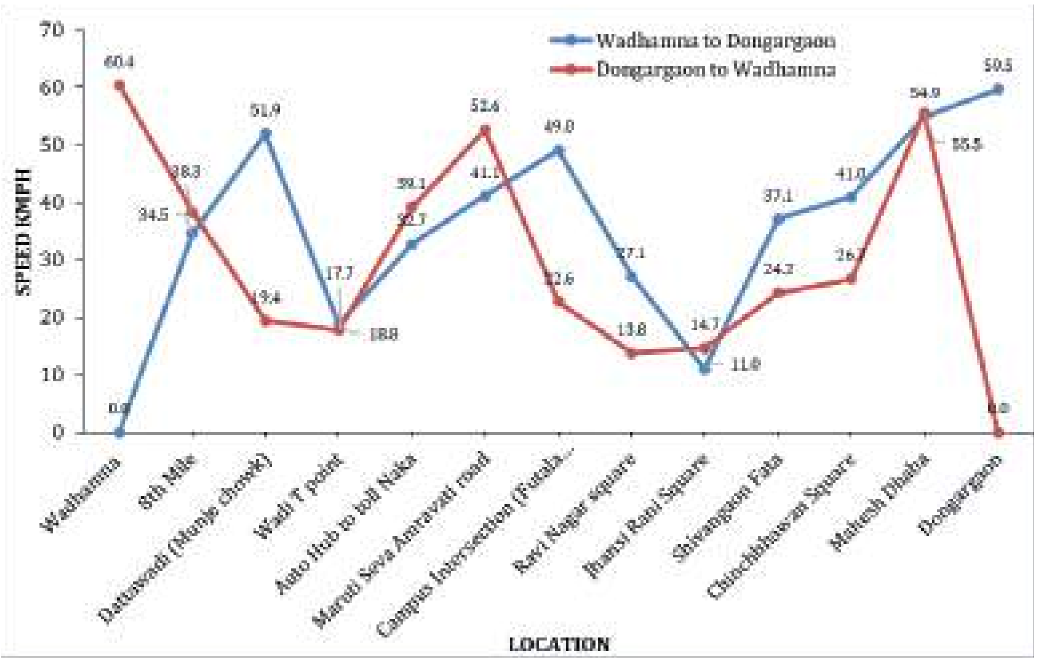


Figure 4.10 Speed Variation on Wadhamna to Dongargaon corridor (EVENING)

4.3.4.3 Speed and Delay Characteristics of Corridor 3

- ·Maximum quantum of delay touched 458.7 seconds during evening run (6:35 to 7:02) in the downward direction and the reason behind delay was the traffic signal at Alankar chowk delay which clocked 2 min 35 sec.
- ·Whereas the maximum delay reached 331 seconds during morning (9:55 to 10:54 hrs.) in the upward direction and maximum delay at this run was at Variety chowk due to traffic signal delay which reached 3 min 55 sec.
- ·Maximum journey speed was at morning time in upward direction run and it was 31.4km/hr.

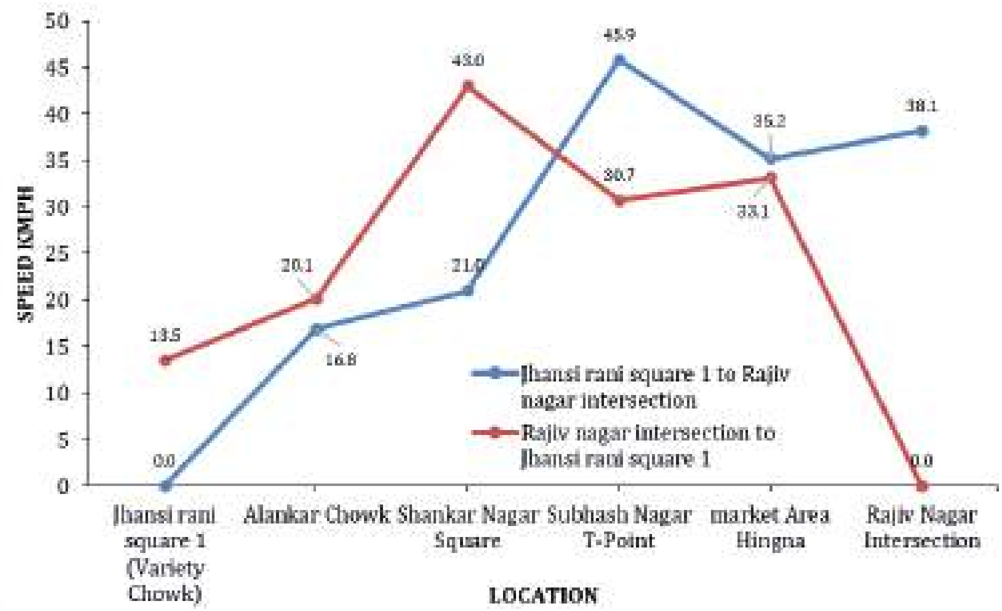


Figure 4.11 Speed Variation on Jhansi rani square 1 to Rajiv nagar intersection corridor (MORNING)

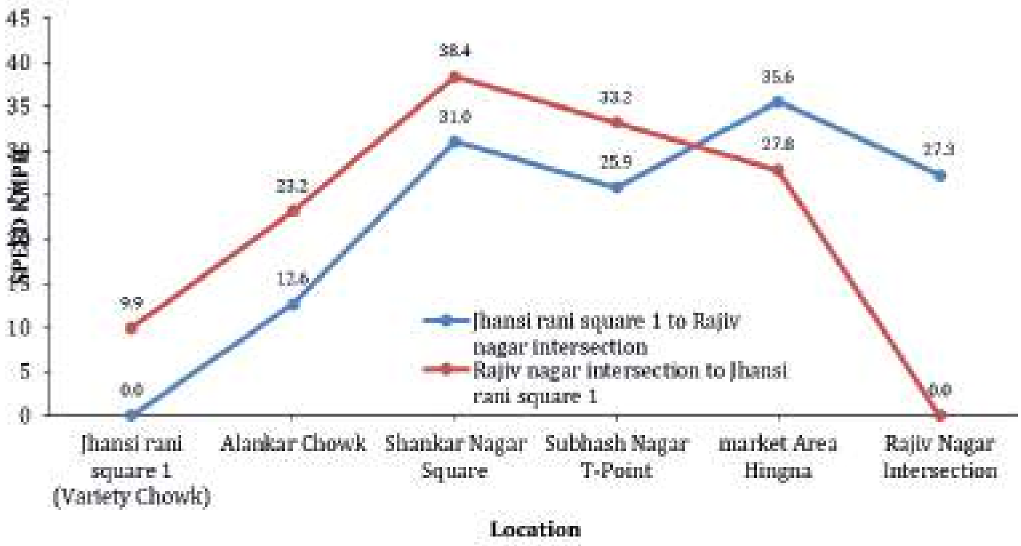


Figure 4.12 Speed Variation on Jhansi rani square 1 to Rajiv nagar intersection corridor (EVENING)

4.3.4.4. Speed and Delay Characteristics of Corridor 4

- ·Maximum quantum of delay was about 1019 seconds during evening run (17:42 to 18:30 hrs.) in the downward direction and the reason behind delay was the traffic jam at Mehndi Bagh T point wherein the delay extended up to 4 min 38 sec. At the same time, the maximum delay reached 703 seconds during morning (10:40 to 11:23 hrs.) in the upward direction and maximum delay at this run was at New Katol Naka primarily due to ongoing road repairing work as well as traffic signal spanning about was 3 min 04 sec.
- ·Maximum journey speed was at evening time in upward direction run and it was 25.95 km/hr.

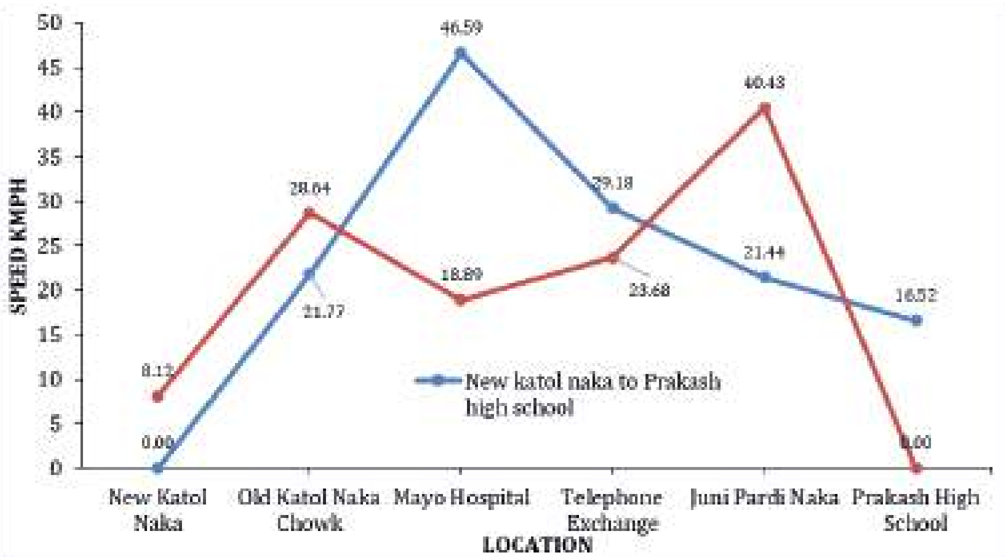


Figure 4.13 Speed Variation on New Katol Naka to Prakash high school corridor (MORNING)

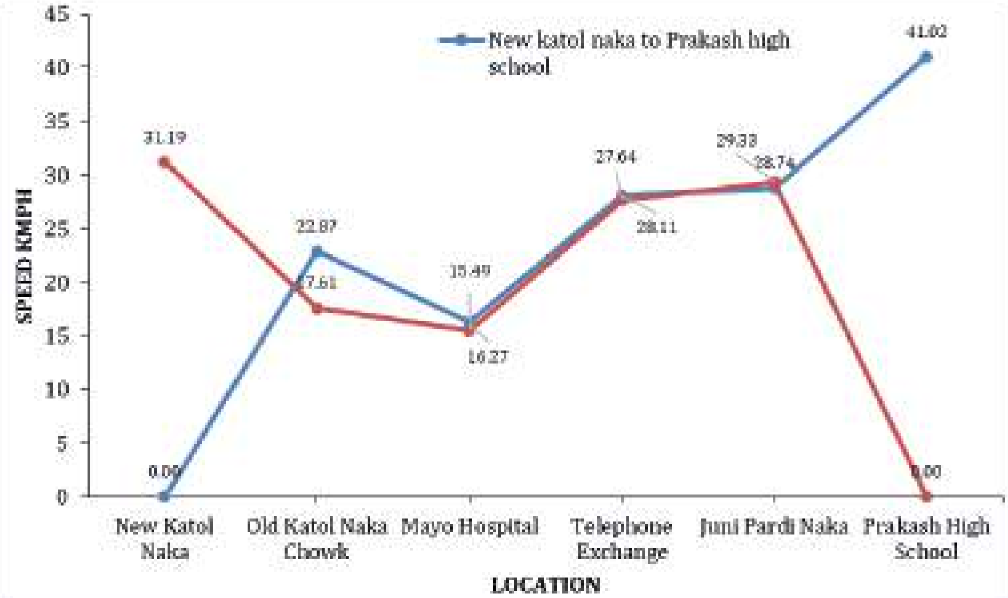


Figure 4.14 Speed Variation on New Katol Naka to Prakash high school corridor (EVENING)

4.3.4.5 Speed and Delay Characteristics of Corridor 5

- ·Maximum quantum of delay touched 280.2 seconds during morning run (11:45 to 12:02 hrs.) in the upward direction and the reason behind the delay was the traffic jam at Shitla Mata Chowk where the duration was 20 sec.
- ·Whereas the maximum delay reaches 673 seconds during evening (6:00 to 6:24) in the upward direction and maximum delay at this run was at new Ashok chowk which was primarily due to road repair work as well as traffic signal extending up to 5 min 56 sec.
- ·Maximum journey speed was at morning time in downward direction run and it was 28.2 km/hr.

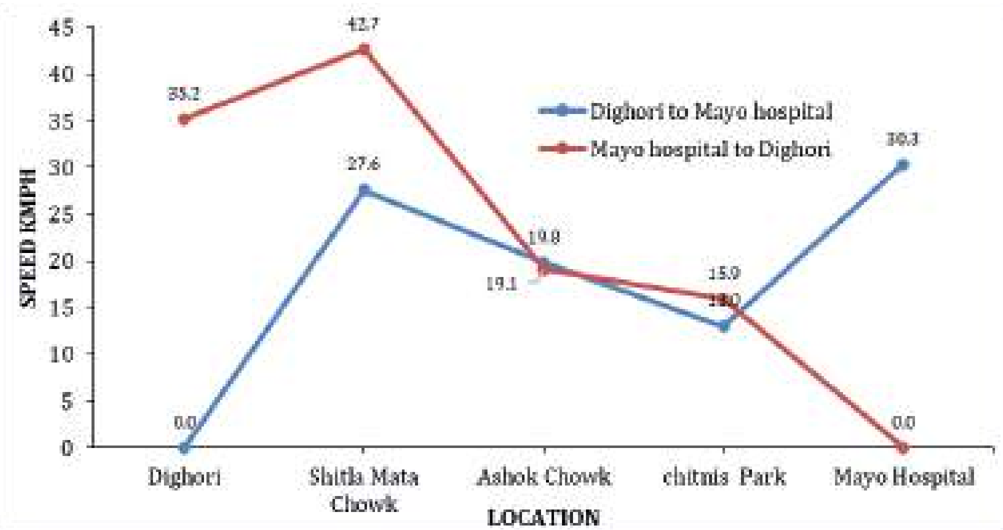


Figure 4.15 Speed Variation on Dighori to Mayo hospital corridor (MORNING)

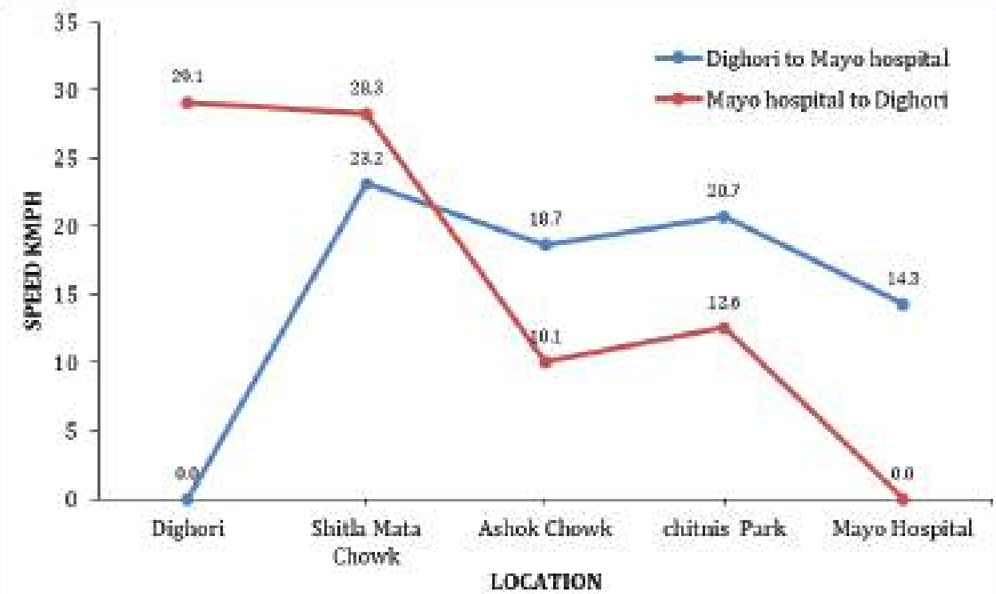


Figure 4.16 Speed Variation on Dighori to Mayo hospital corridor (EVENING)

Table 4.10 describes the road-wise analyzed running speeds, journey speeds, and delay duration for selected major corridors.

Table 4.10 Summary of all the speed and delay corridors

Corridor No.	Distance (km)	Running speed (km)	Delay duration (sec)	Journey speed (km)
1	44	43	1277	31.9
2	37	38.7	378	36.1
3	12	33	259	28.1
4	17.1	32.3	703	24.3
5	7.2	32.3	411	22.5

4.4 Geometric Design Plans (GDPs) for 38 Blackspots

As mentioned earlier, Detailed Project Report (DPR) in the form of Geometric Design Plans (GDP) were prepared by the CSIR - CRRI for the 38 blackspots and submitted to the relevant stakeholders in the month of September 2022 namely Nationals Highways Authority of India, (NHAI), Nagpur Municipal Corporation (NMC), National Highway (NH) Division of Maharashtra Public Works Department (PWD), World Bank Division of Maharashtra PWD as well as General Section of Maharashtra PWD. The physical surveys plan of the existing road section / intersection along with the GDP conceived for each of the 38 blackspots are presented in the succeeding sections.

4.4.1 Telephone Exchange to C. A. Road: Base Plan and GDP

Figure 4.17 depicts the physical survey plan depicting the present condition of this midblock location spanning between two major intersections on either side whereas Figure 4.18 presents the GDP conceived for the midblock location between Telephone Exchange to C.A. Road stretch spanning a length of 500 m on either side of the blackspot.

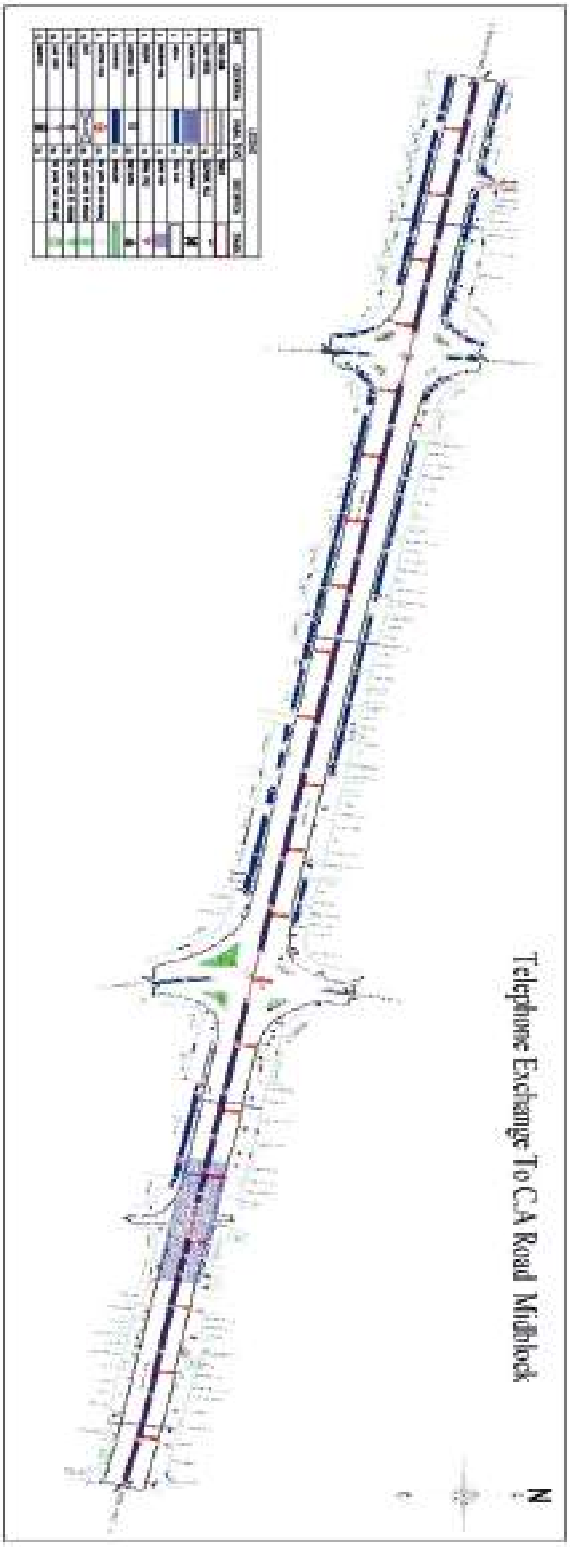


Figure 4.17 Physical Survey Plan of the Telephone Exchange to C.A. Road Stretch for 500 m on either side.

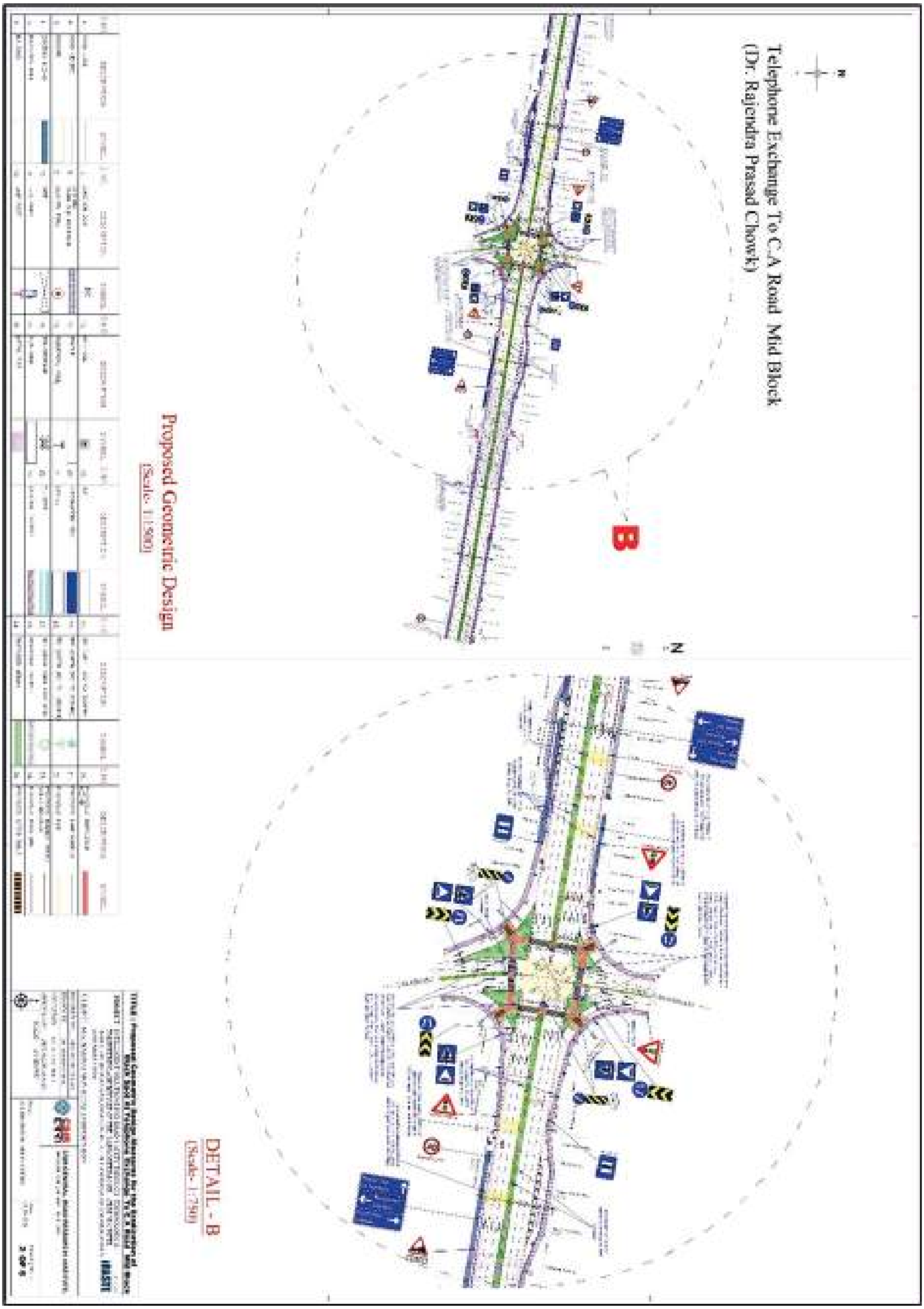


Figure 4.18 Detailed Geometric Design Plan (GDP) & Traffic Management Plan for Telephone exchange to C.A. Road stretch.

4.4.2 Maruti Seva Square, Kamptee Road: Base Plan and GDP

Figure 4.19 depicts the existing conditions of the Maruti Seva Square whereas Figure 4.20 presents the GDP conceived for the intersection spanning a length of 250 m on all the approach arms of the intersection which is a blackspot.

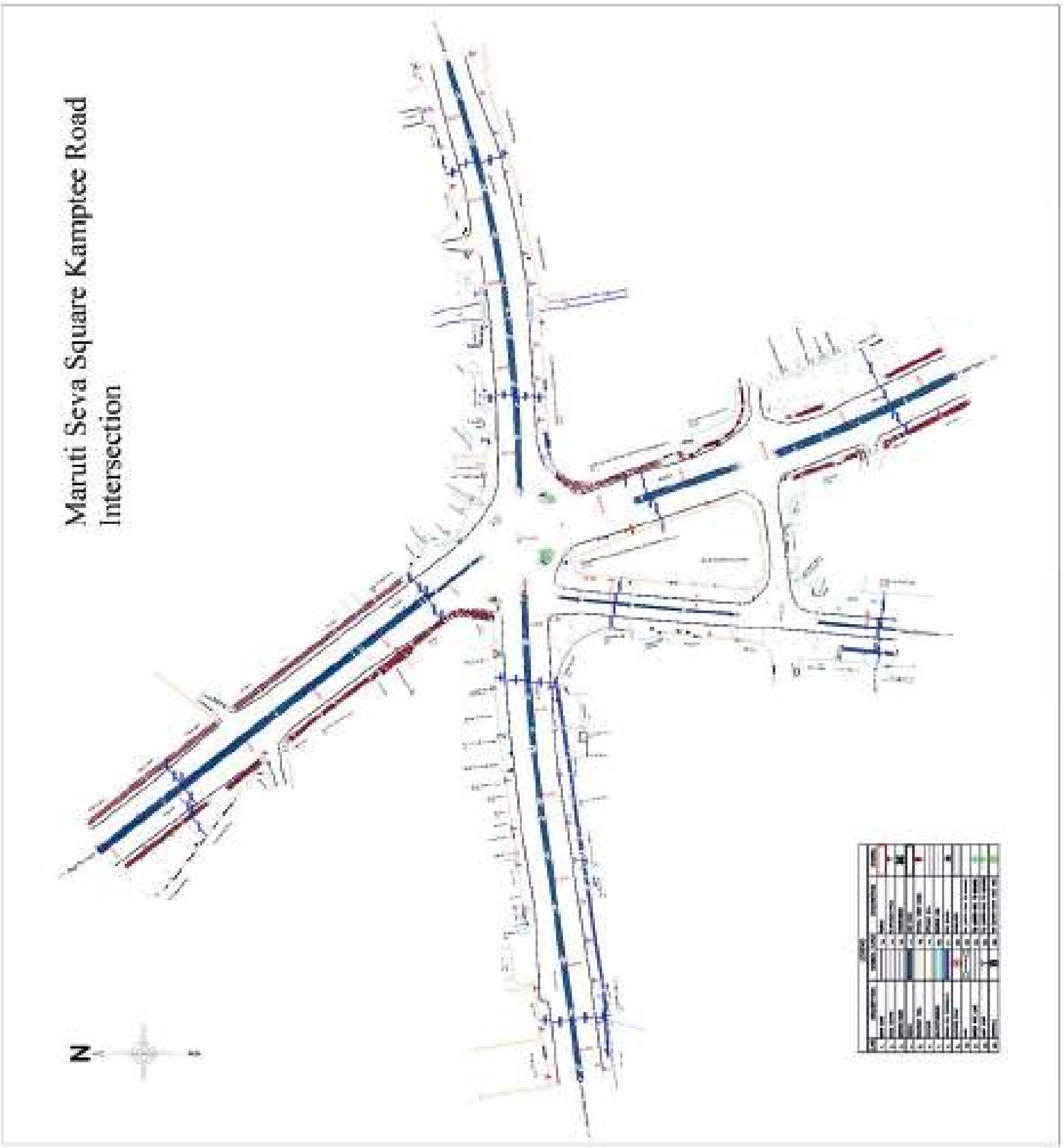


Figure 4.19 Physical Survey Plan of the Maruti Seva Square, Kamptee Road Stretch for 250 m on either side.

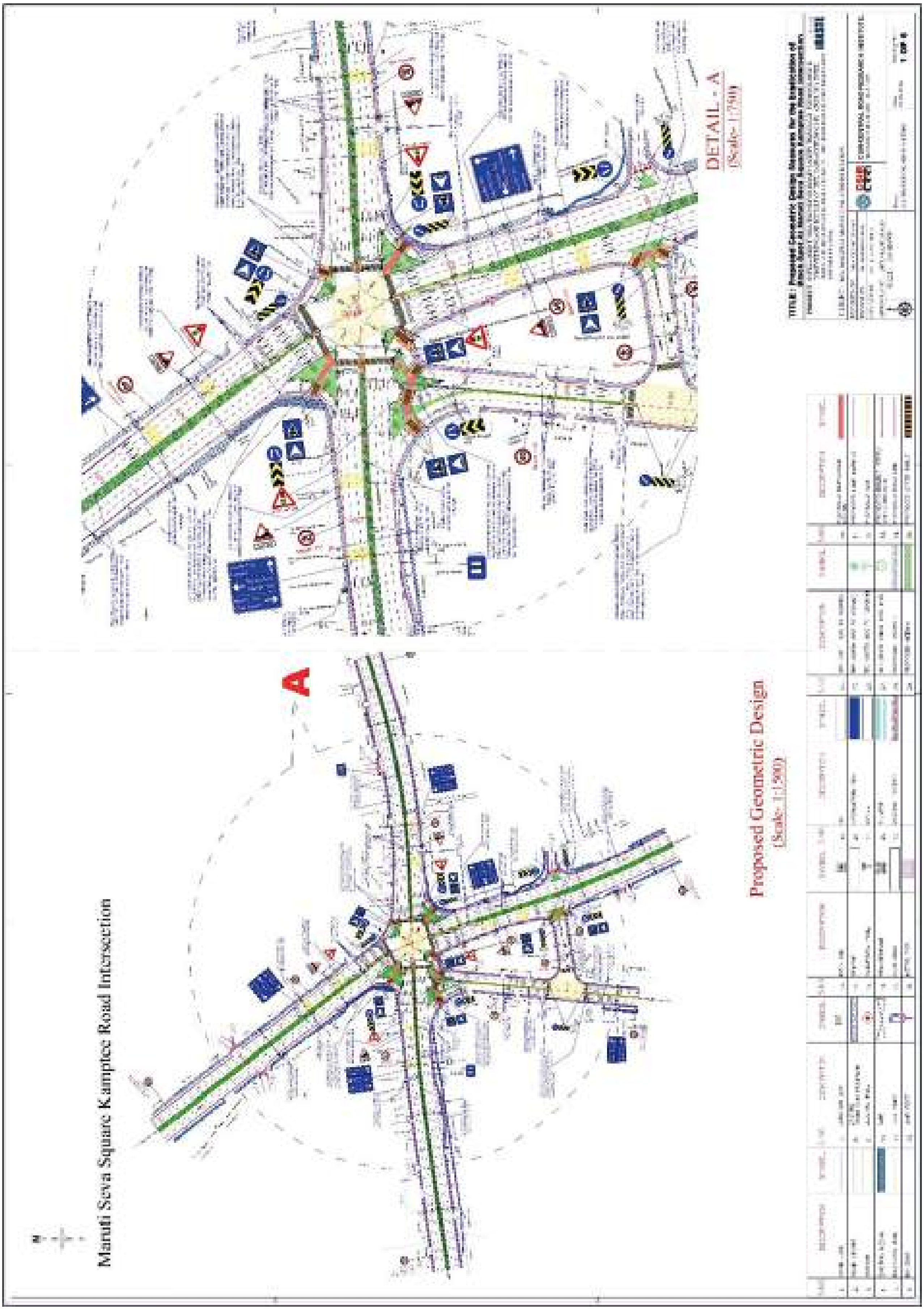


Figure 4.20 Detailed Geometric Design Plan (GDP) & Traffic Management Plan for Maruti Seva Square, Kamptee Road stretch.

4.4.3 Prakash High School: Base Plan and GDP

Figure 4.21 depicts the physical survey plan depicting the present condition of this midblock location located under NHAI jurisdiction whereas Figure 4.22 presents the detailed Geometric Design Plan (GDP) conceived for the road stretch adjacent to Prakash High School spanning a length of 500 m on either side of the school. It is expected that the implementation of the conceived design improvements on the above 1 km road stretch will help in addressing the road safety issues

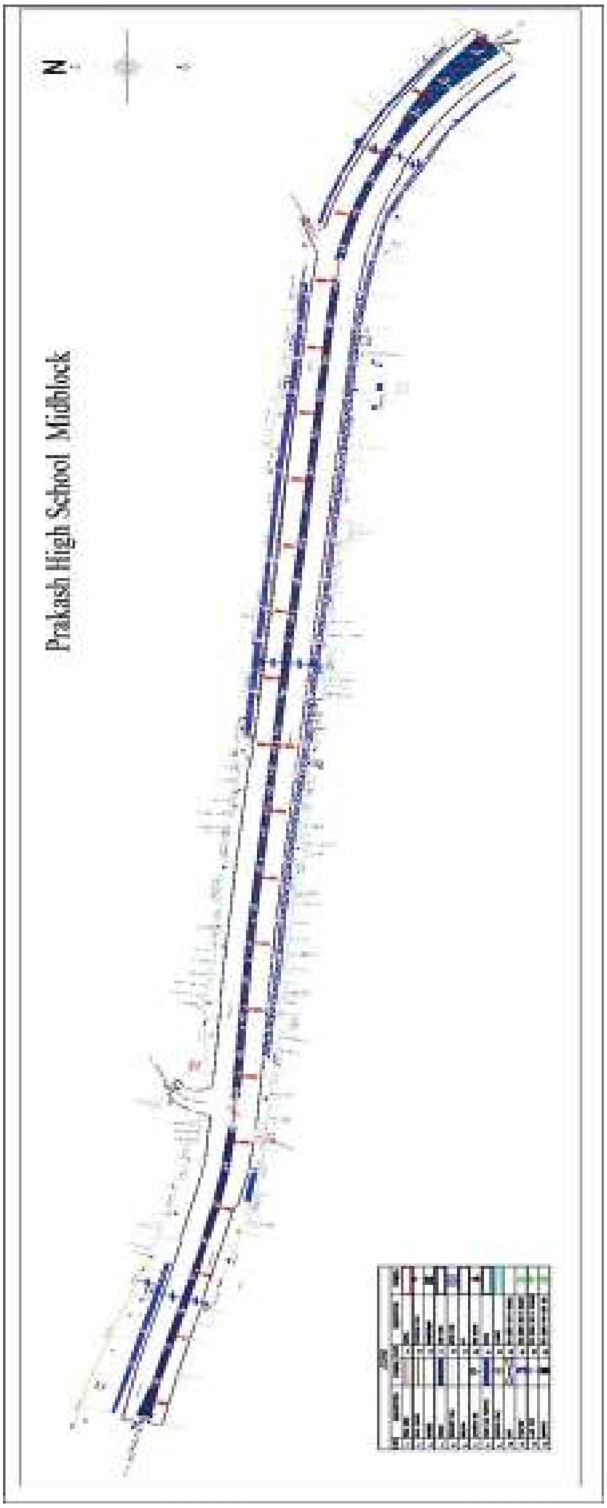


Figure 4.21 Physical Survey Plan of the Prakash High School Road Stretch for 500 m on either side.

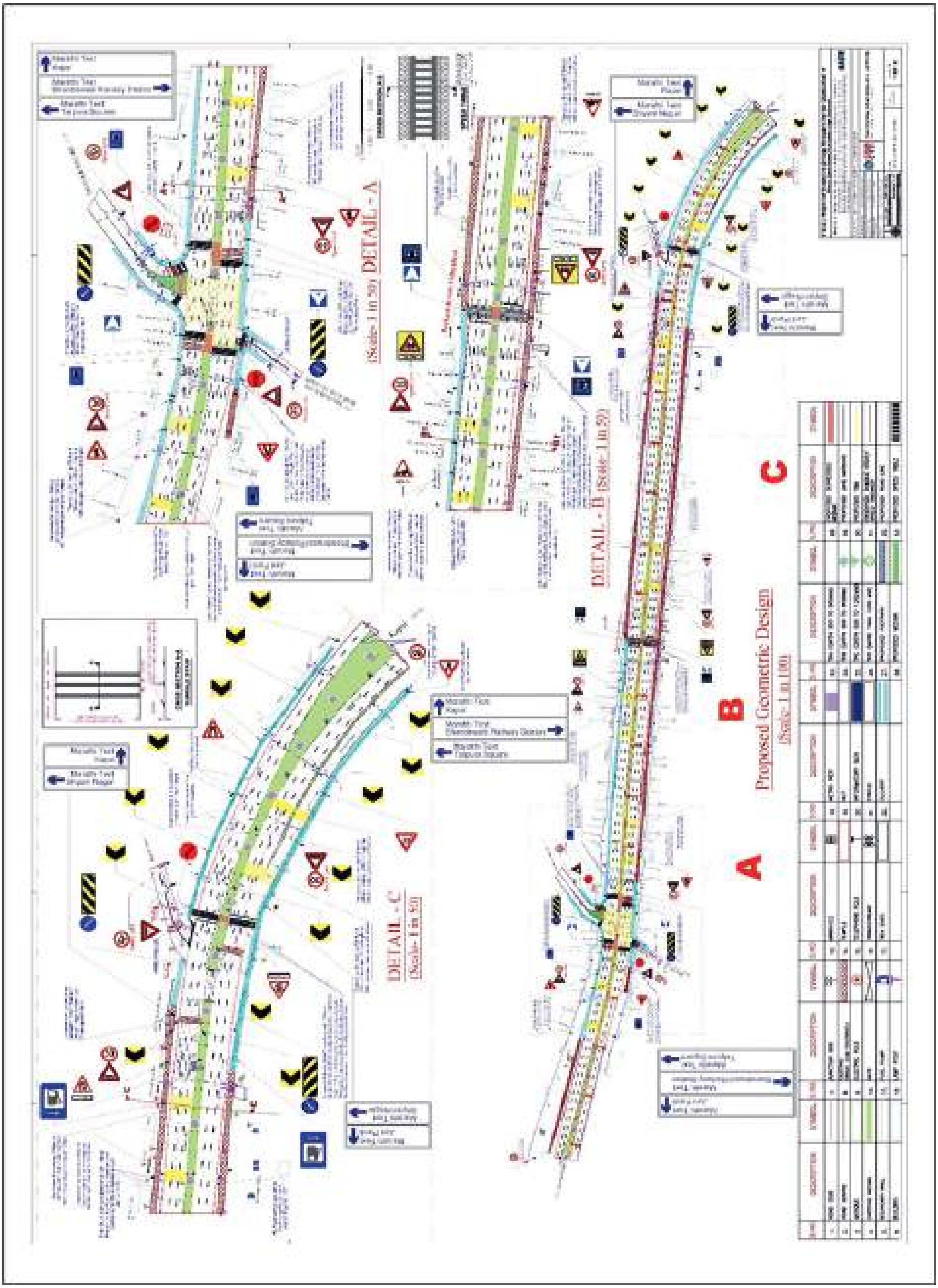


Figure 4.22 Detailed Geometric Design Plan (GDP) & Traffic Management Plan for Prakash High School Road stretch.

Figure 4.23 (a) (b) (c) presents graphical illustration of some of the GDP proposed for Prakash High School Road Stretch.

a. Proposed treatment about 80 M before Prakash High School

b. Proposed treatment at the Entrance to Prakash High School

c. Proposed junction treatment at Pardi Bazar Minor Intersection

Figure 4.23 (a-c) Illustration of Some of the Geometric Design Plans proposed for Prakash High School Road Stretch.

4.4.4 Juni Pardi Naka Intersection

On this location, due to the ongoing flyover construction since the September, 2021, it was felt that the observed safety issues on the ground will be addressed as the transformation of the road will happen soon and thus the existing safety issues will be addressed.

4.4.5 Chattrapati Square: Base Plan and GDP

Figure 4.24 depicts the physical survey plan depicting the present conditions whereas Figure 4.25 presents the detailed GDP conceived for the Chhatrapati square spanning a length of 250 m on all the approach arms of this 4-armed intersection which is a blackspot.

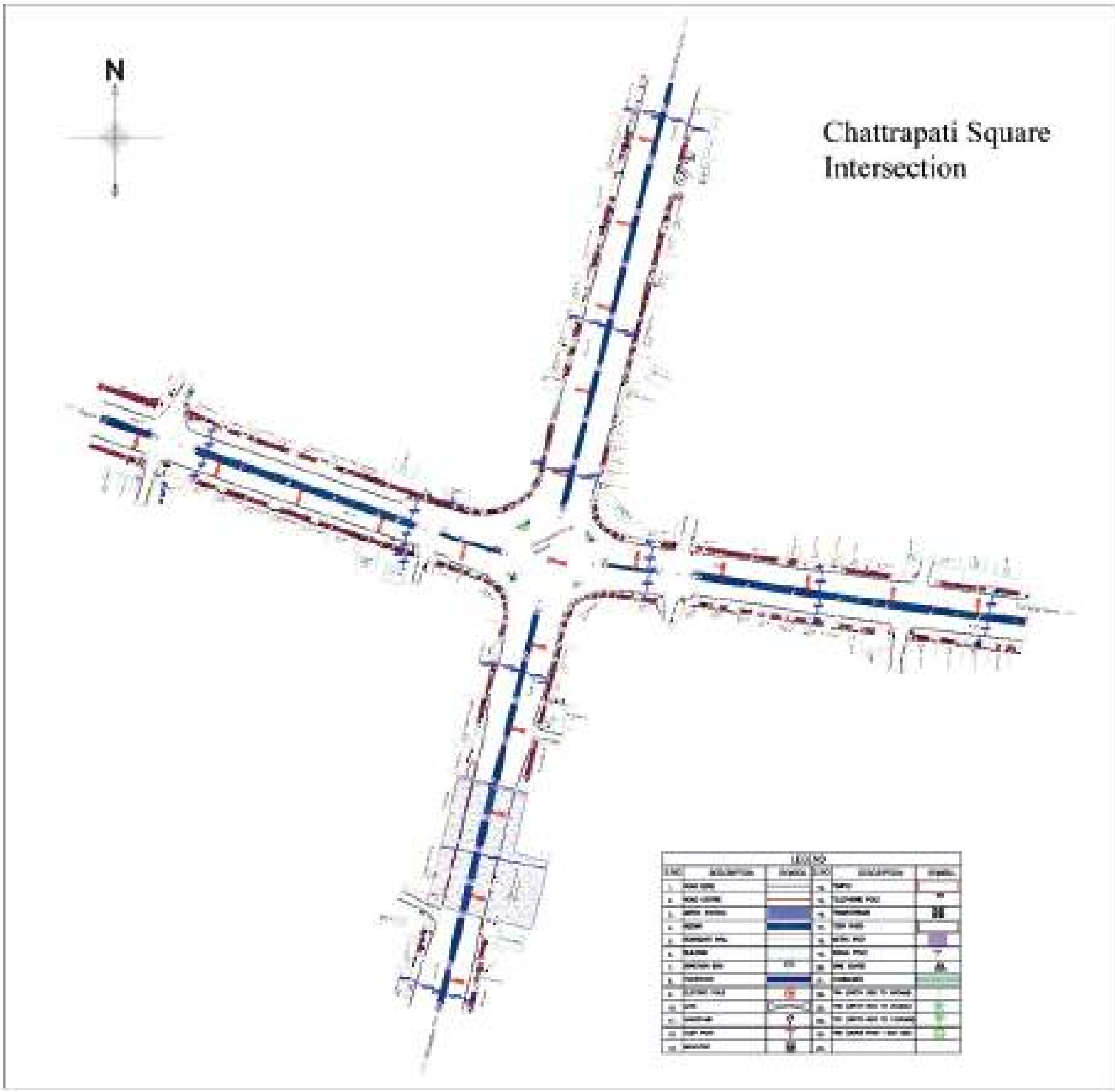


Figure 4.24 Physical Survey Plan of the Chhatrapati Square.

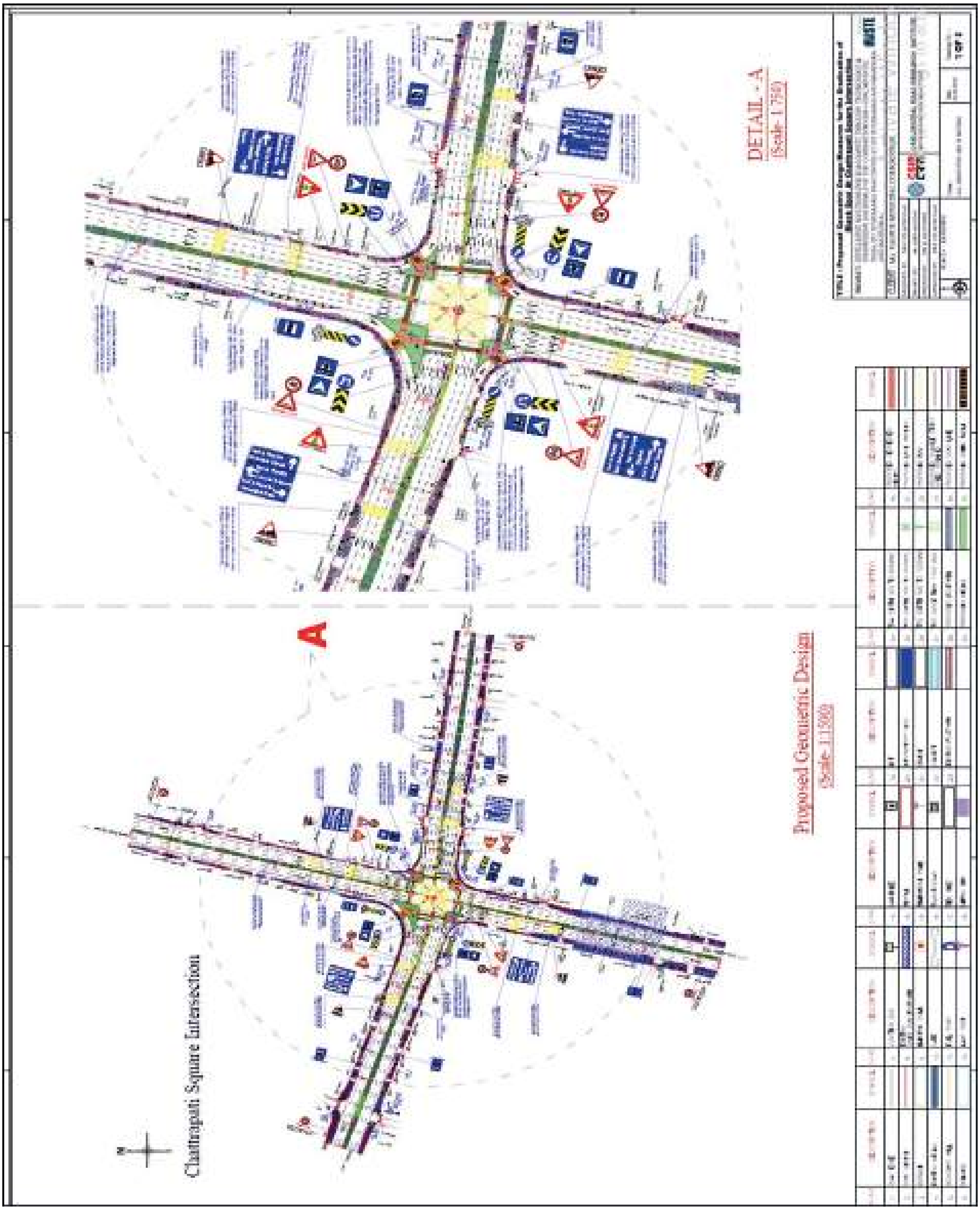


Figure 4.25 Detailed GDP for Chhatrapati Square.

4.4.6 Dongargaon: Base Plan and GDP

Figure 4.26 depicts the physical survey plan depicting the present conditions whereas Figure 4.27 presents the detailed GDP conceived for the midblock section of Dongargaon stretch spanning a length of 500 m on either side of the blackspot.

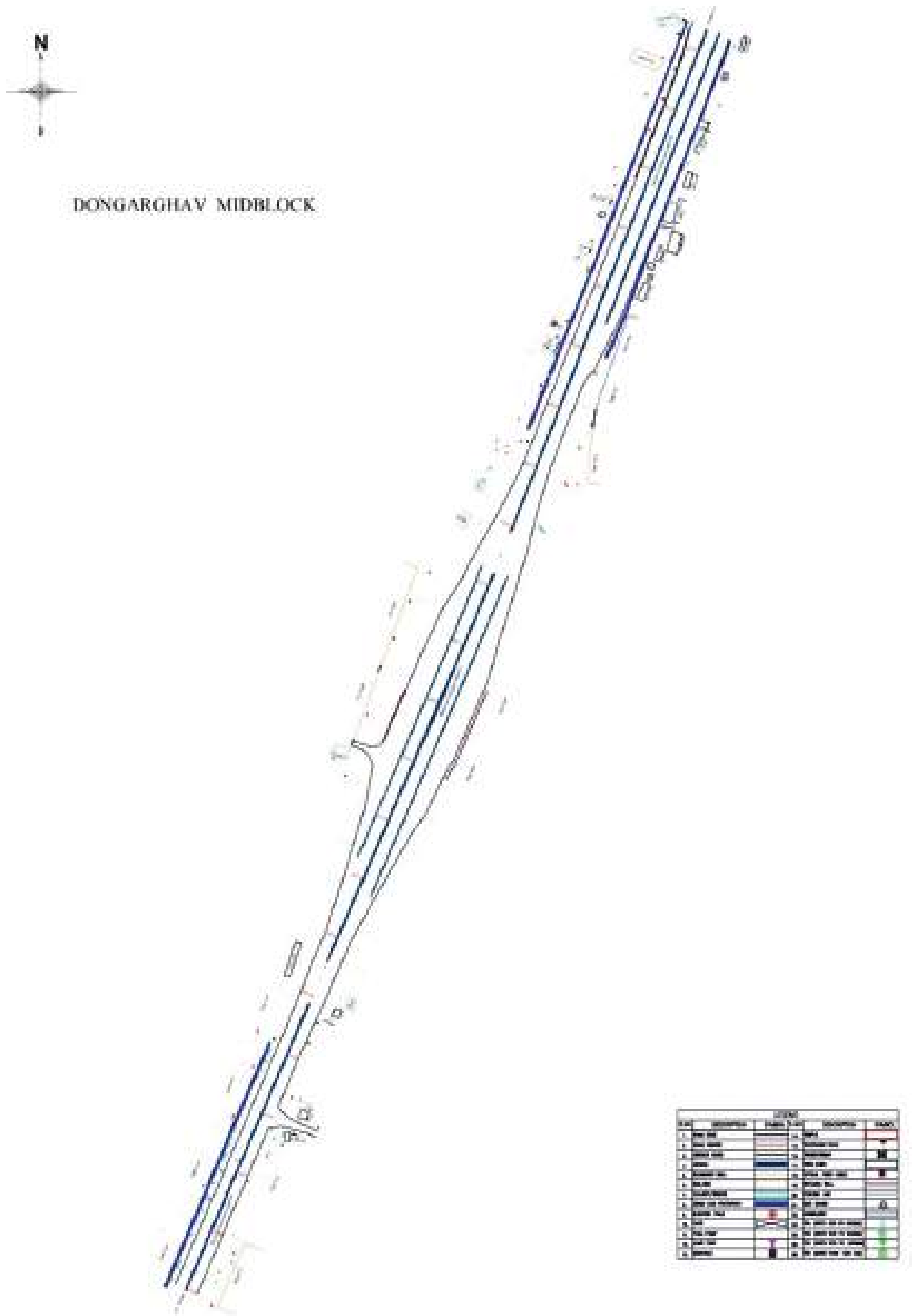


Figure 4.26 Physical Survey Plan of the Dongargaon Midblock Road Stretch

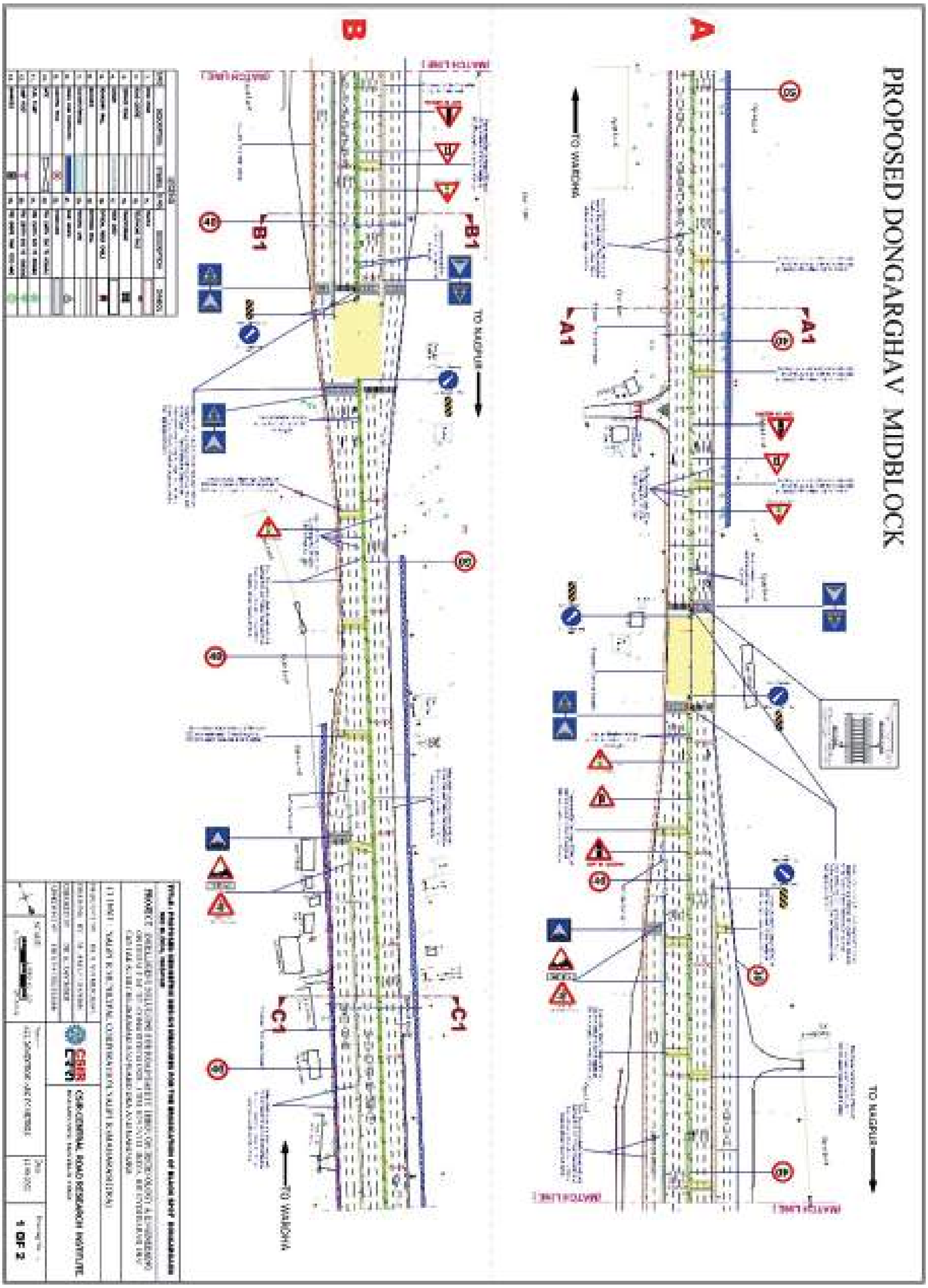


Figure 4.27 Detailed GDP for Dongargaon Midblock Road Stretch.

4.4.7 Dongargaon - Bothali Intersection: Base Plan and GDP

Figure 4.28 depicts the physical survey plan depicting the present conditions whereas Figure 4.29 presents the GDP conceived for the intersection Dongargaon to Bothali spanning a length of 250 m on either side of the blackspot.

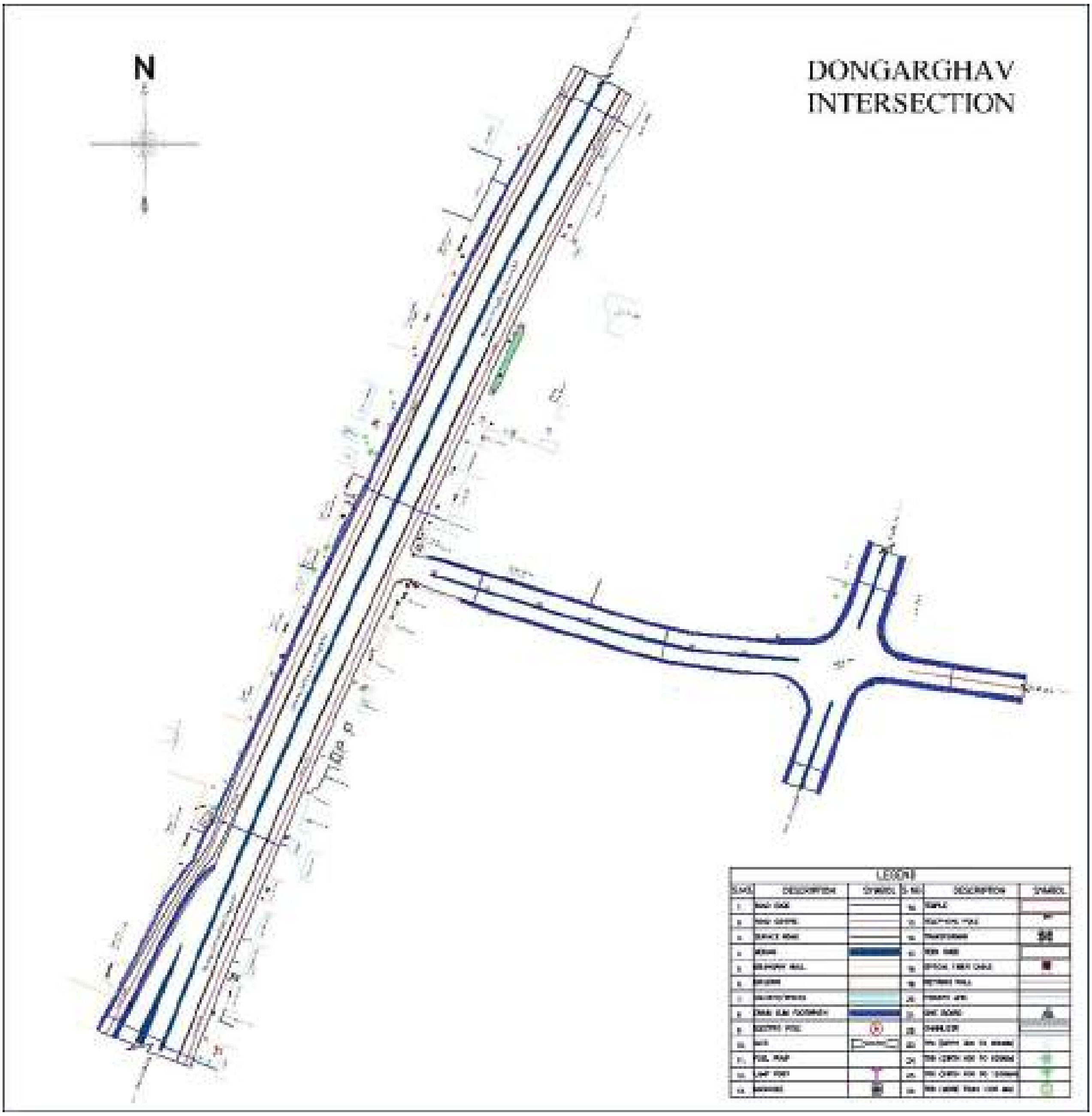


Figure 4.28 Physical Survey Plan of the Dongargaon - Bothali Road Intersection

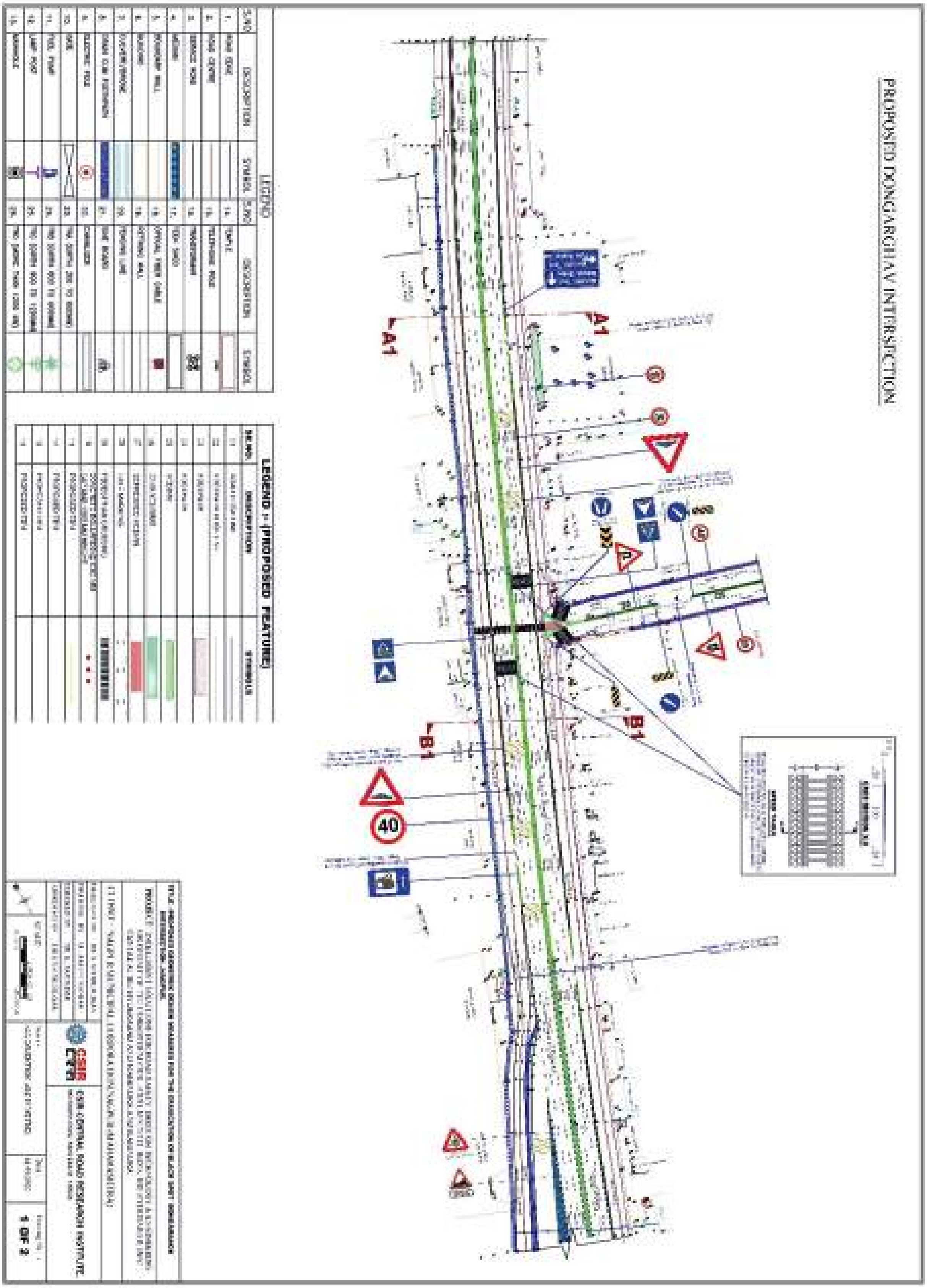


Figure 4.29 Detailed GDP of Dongargaon to Bothali Road Intersection

4.4.8 Rajiv Nagar Intersection: Base Plan and GDP

Figure 4.30 depicts the physical survey plan depicting the present conditions whereas Figure 4.31 presents the detailed GDP conceived for the Rajiv Nagar Intersection spanning a length of 250 m on all the approach arms of the blackspot.

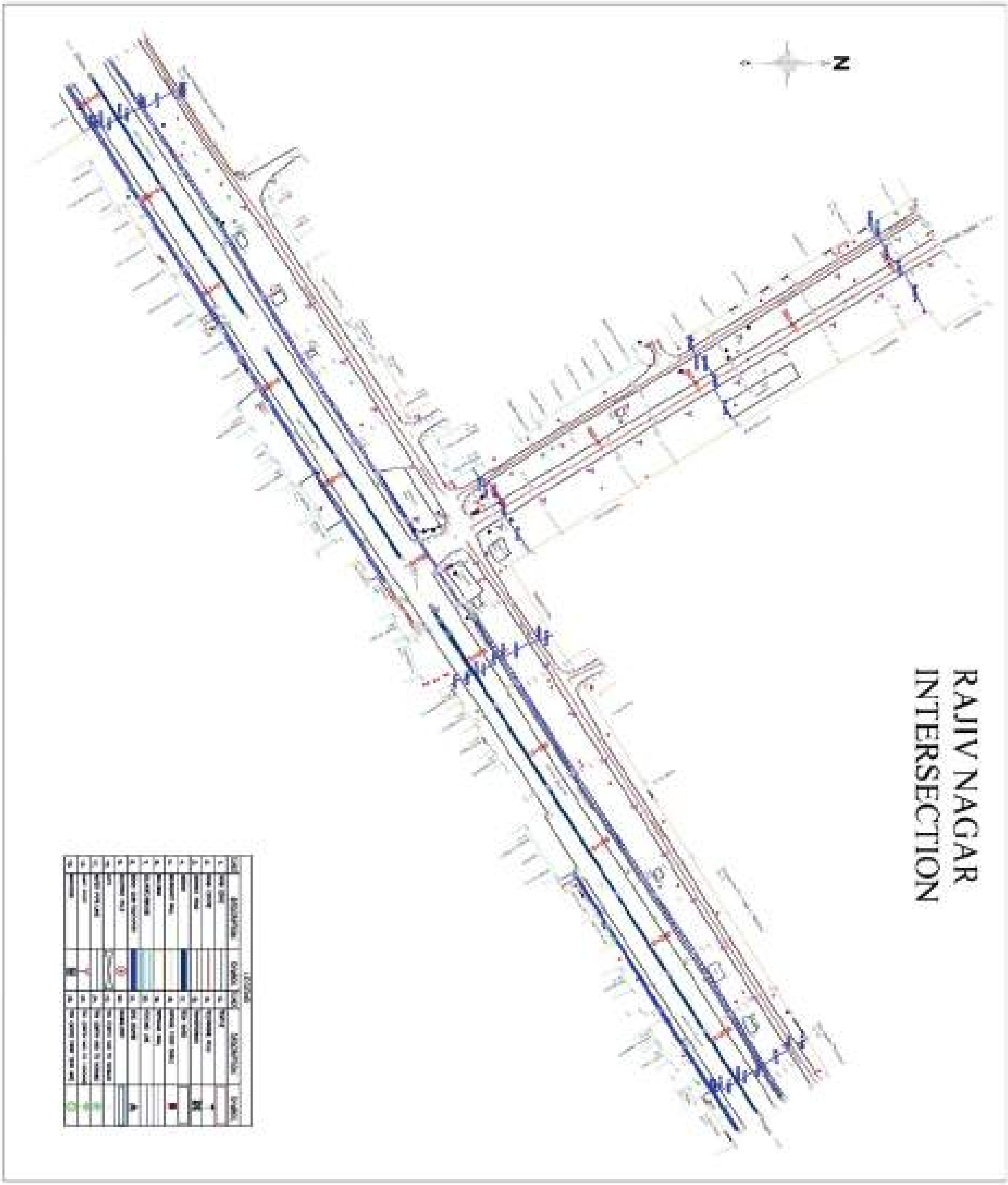


Figure 4.30 Physical Survey Plan of the Rajiv Nagar Intersection

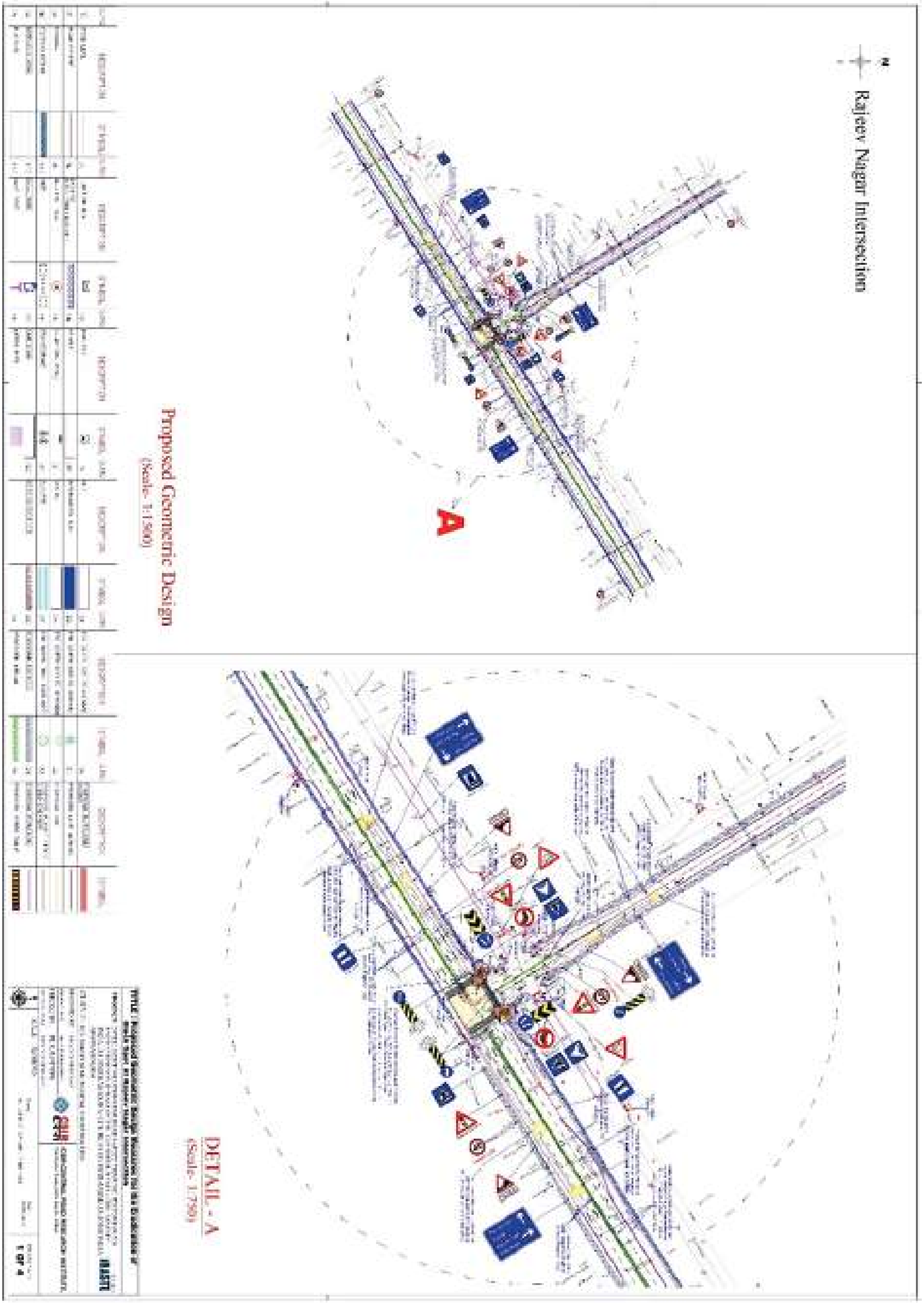


Figure 4.31 Detailed GDP or Rajiv Nagar Intersection

4.4.9 8th Mile Intersection: Base Plan and GDP

Figure 4.32 depicts the physical survey plan depicting the present conditions whereas Figure 4.33 presents the detailed GDP conceived for the 8th Mile Intersection spanning a length of 250 m on each of the approach arms of the blackspot.

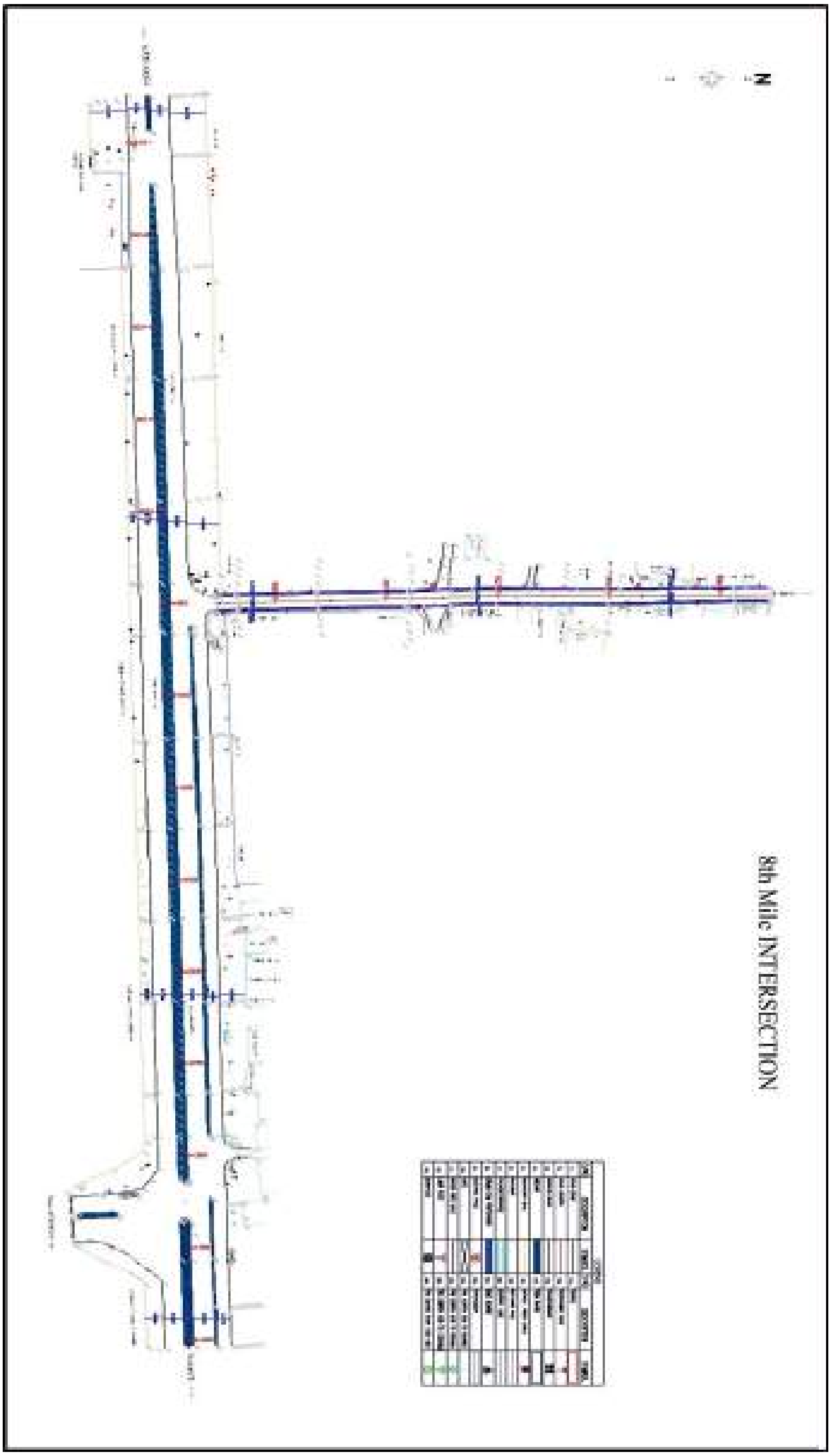


Figure 4.32 Physical Survey Plan of the 8th Mile Road Stretch for 500 m on either side.

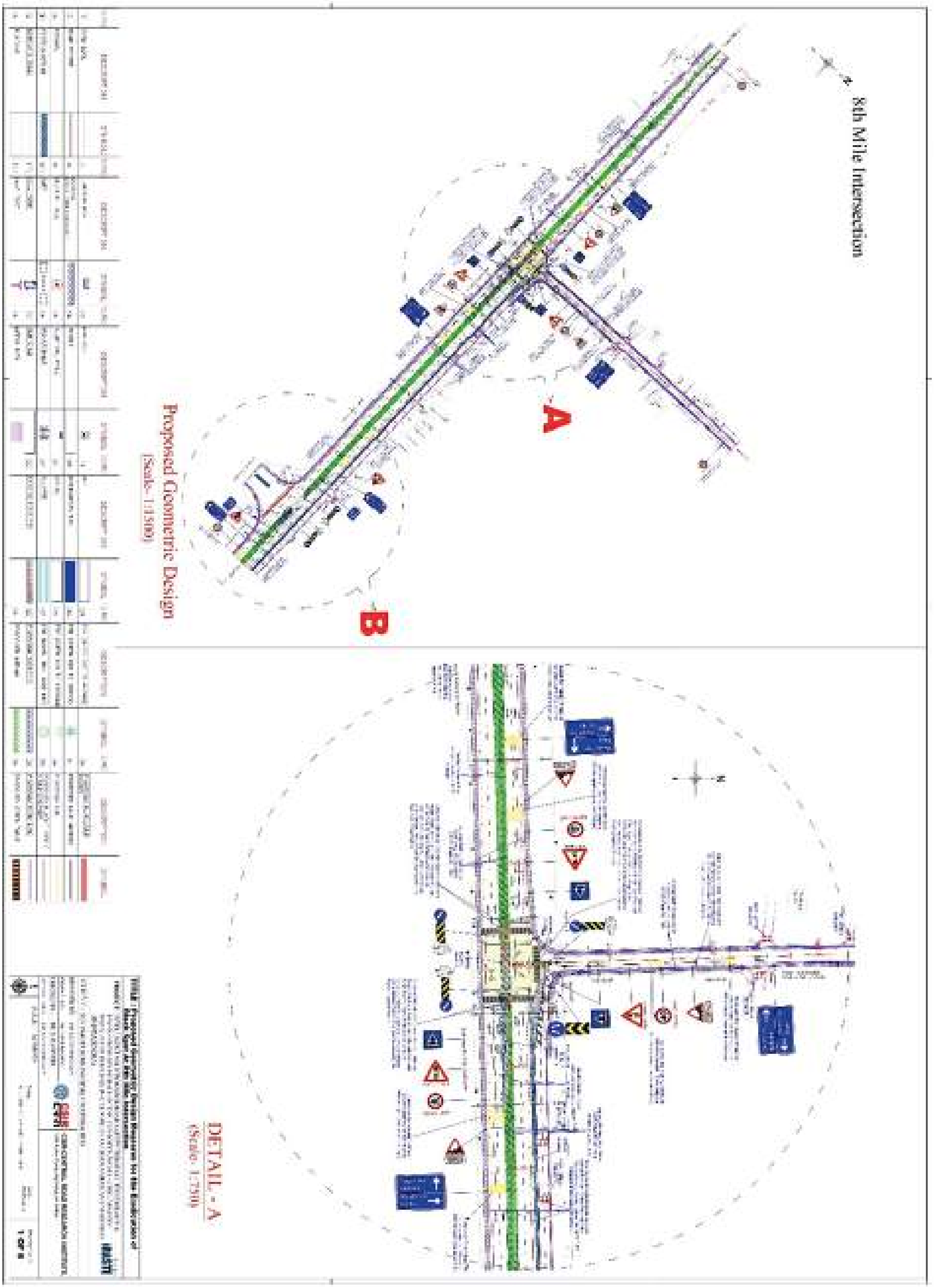


Figure 4.33 Detailed GDP for 8th Mile Intersection

4.4.10 Wadhamna: Base Plan and GDP

Figure 4.34 depicts the physical survey plan depicting the present conditions whereas Figure 4.35 presents the detailed GDP conceived for the Wadhamna Intersection spanning a length of 250 m on each of the approach arms of the blackspot.

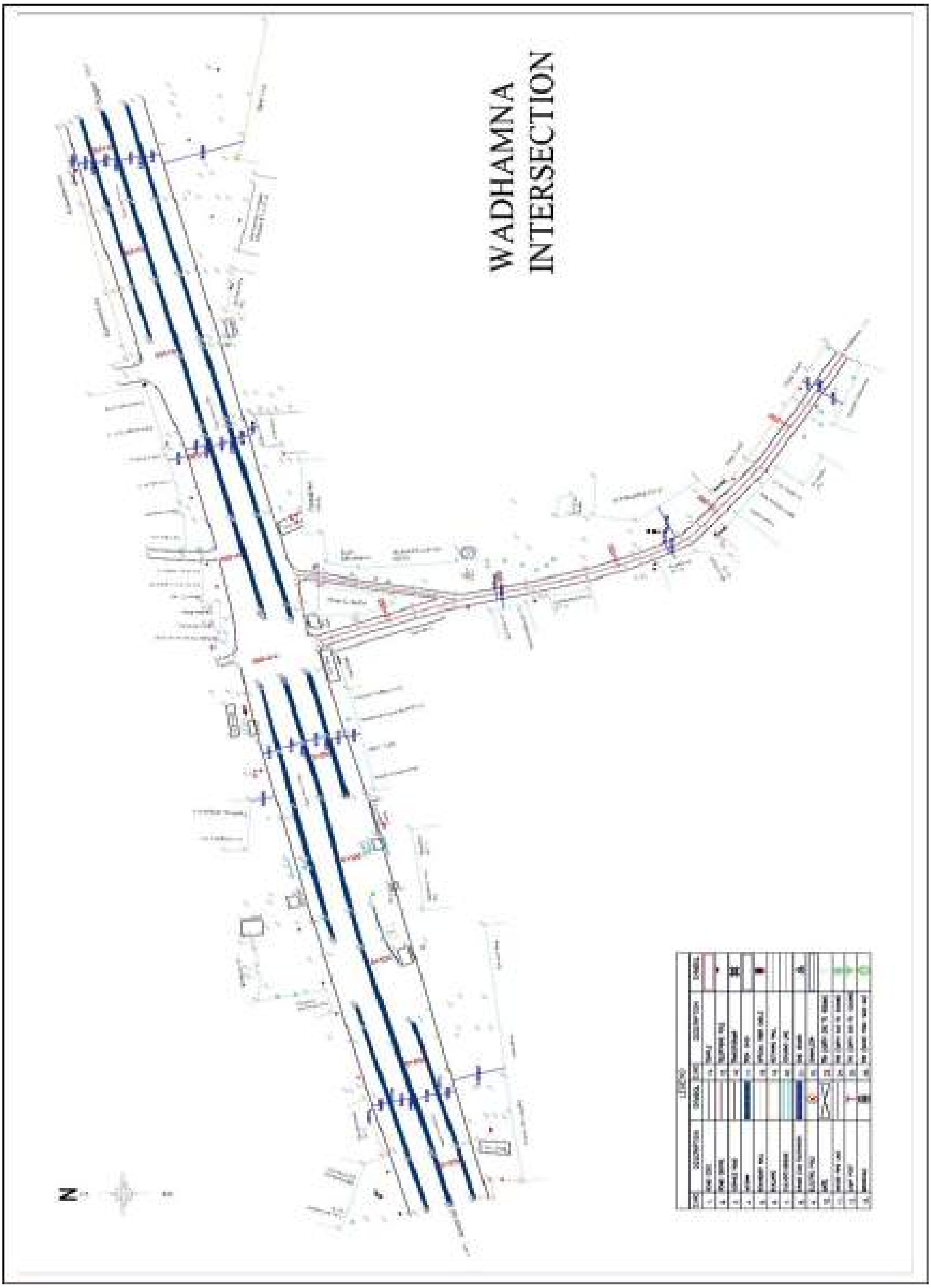


Figure 4.34 Physical Survey Plan of the Wadhamna Intersection

Figure 4.35 Detailed GDP for Wadhamna Intersection

4.4.11 Wadi T Point: (Dhamna): Base Plan and GDP

Figure 4.36 depicts the physical survey plan depicting the present conditions whereas Figure 4.37 presents the detailed GDP conceived for the Wadi T Point *(Dhamna)* road stretch spanning a length of 250 m on each of the approach arms of the blackspot.

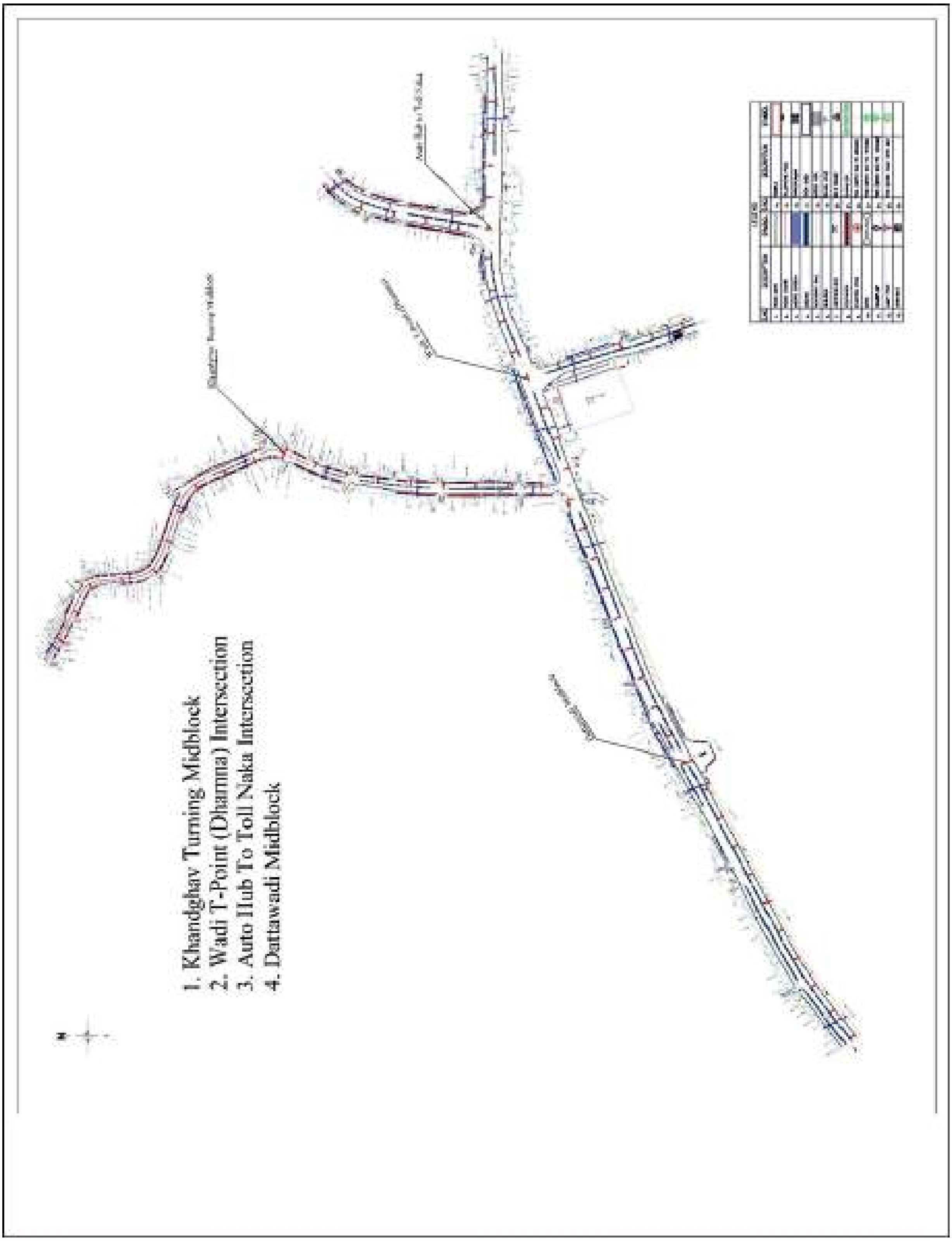


Figure 4.36 Physical Survey Plan of the Wadi T Point (Dhamna)

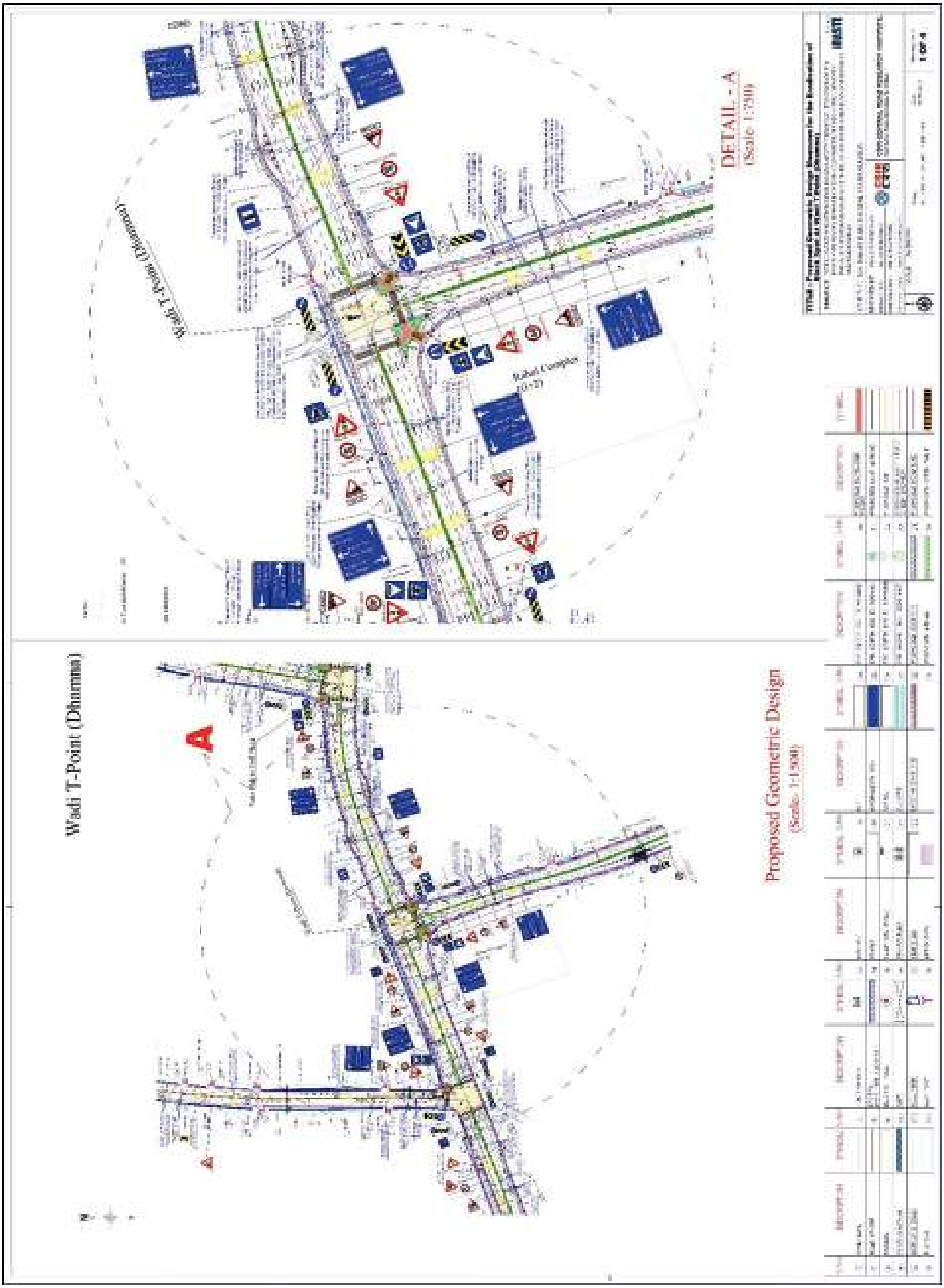


Figure 4.37 Detailed GDP for Wadi T Point (Dhamna) Road stretch

4.4.12 Dattawadi Square: Base Plan and GDP

Figure 4.38 depicts the physical survey plan depicting the present conditions whereas Figure 4.39 presents the detailed GDP conceived for the Dattawadi Square spanning a length of 250 m on each if the approach arms of the blackspot.

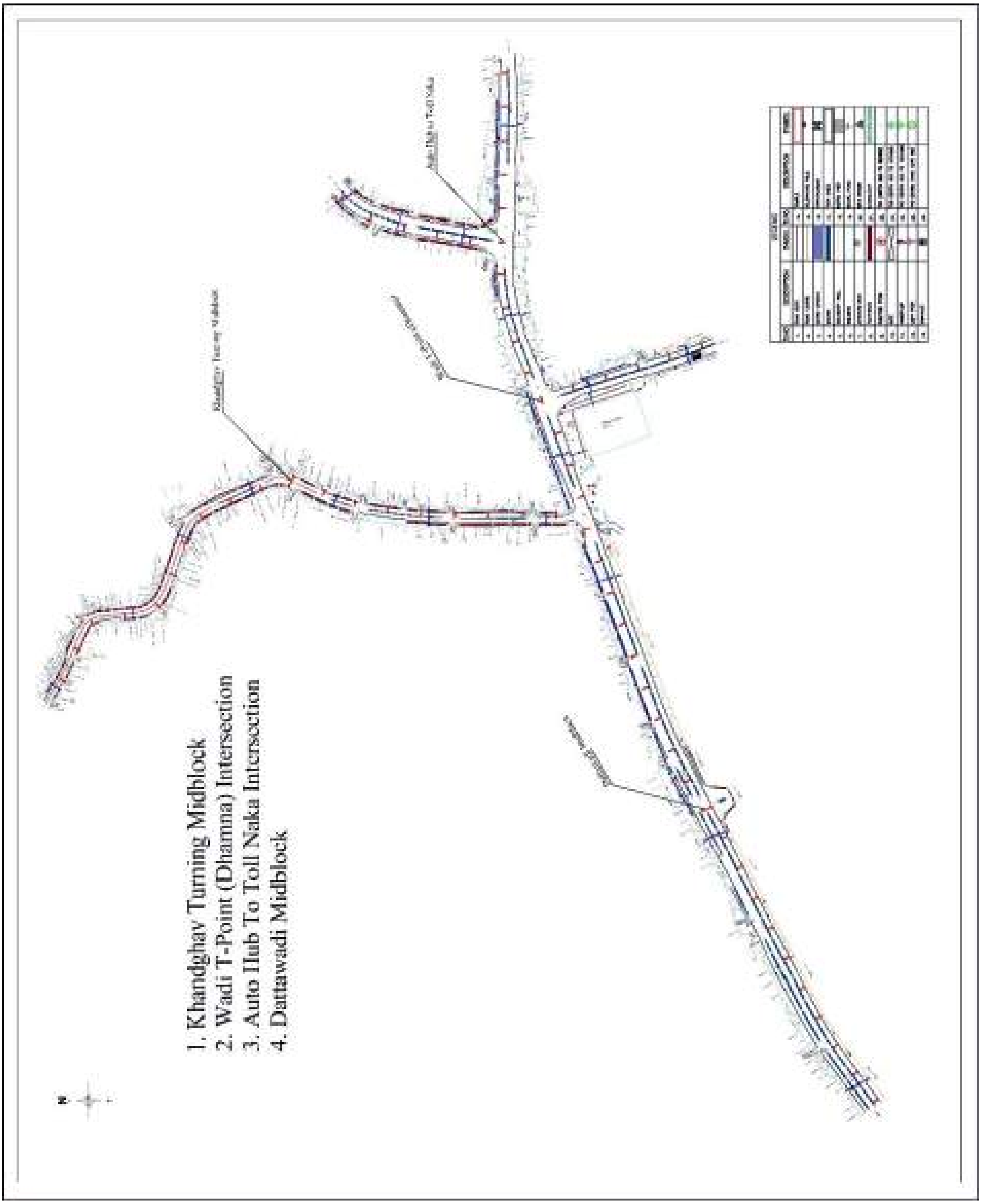


Figure 4.38 Physical Survey Plan of the Dattawadi Square

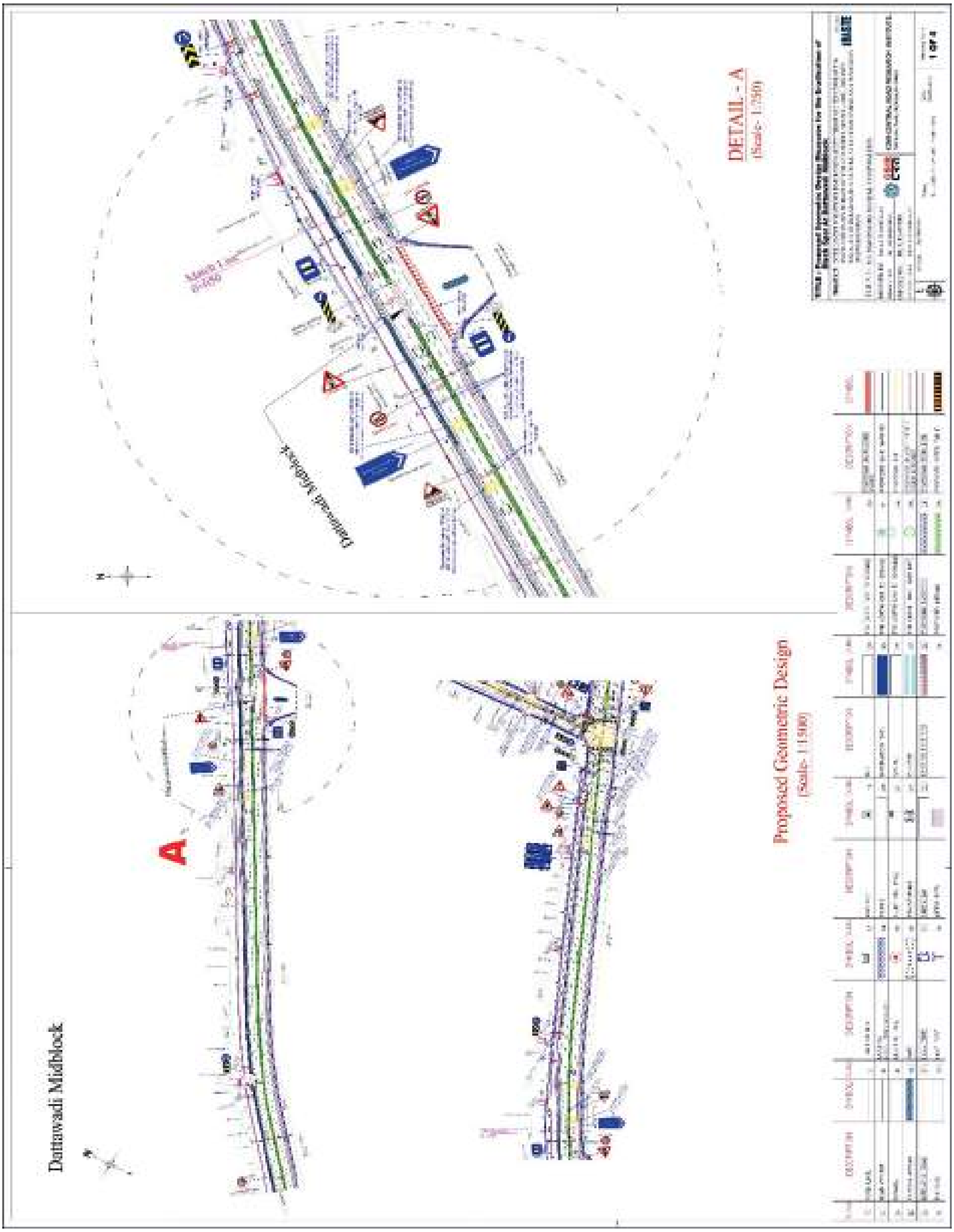


Figure 4.39 Detailed GDP for Dattawadi Square

4.4.13 Khadgaon Turning: Base Plan and GDP

Figure 4.40 depicts the physical survey plan depicting the present conditions whereas Figure 4.41 & 4.42 presents the detailed GDP conceived for the Khadgaon Turning Road stretch spanning a length of 250 m on each of the approach arms of the blackspot.

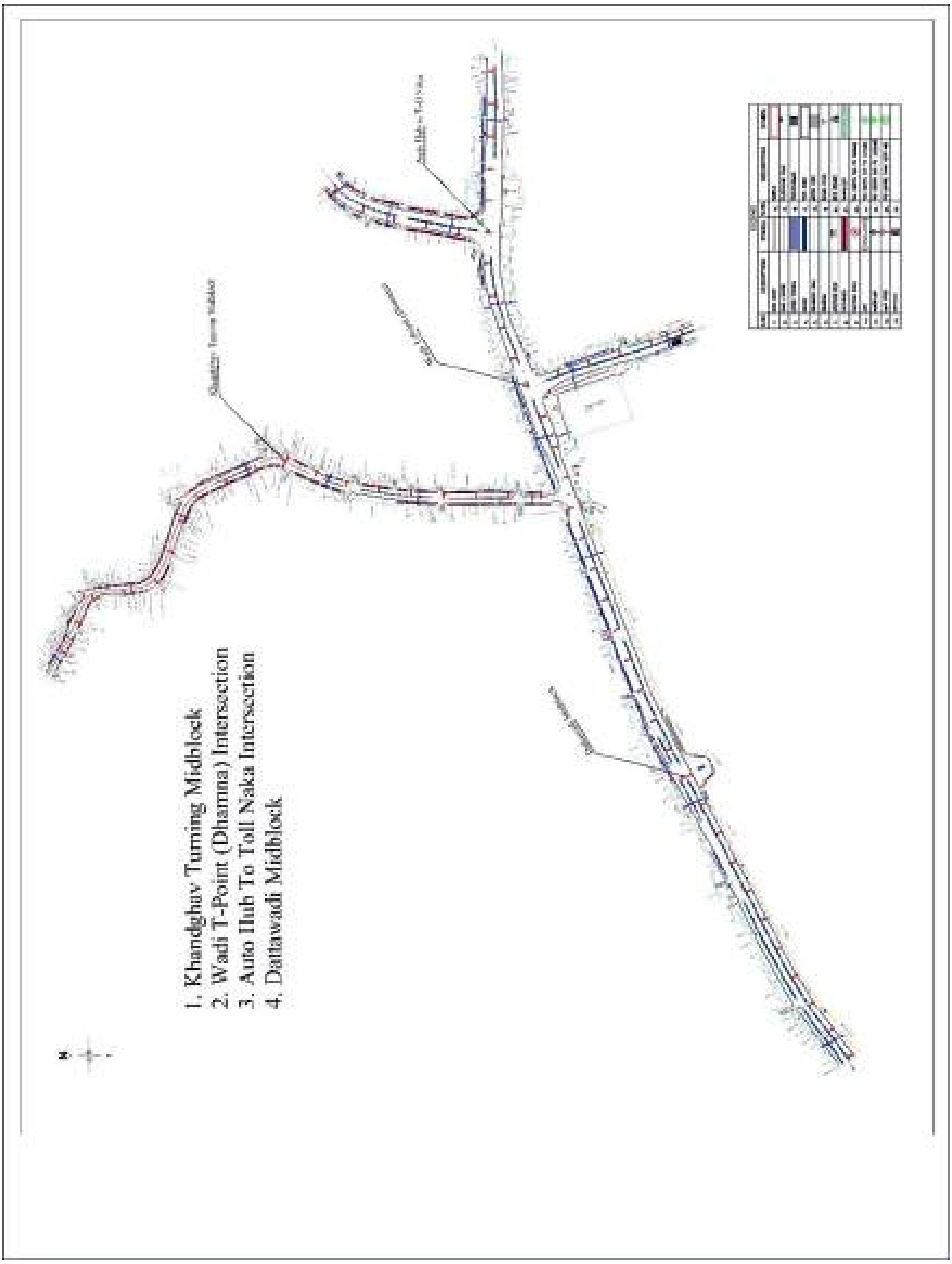


Figure 4.40 Physical Survey Plan of the Khadgaon Turning

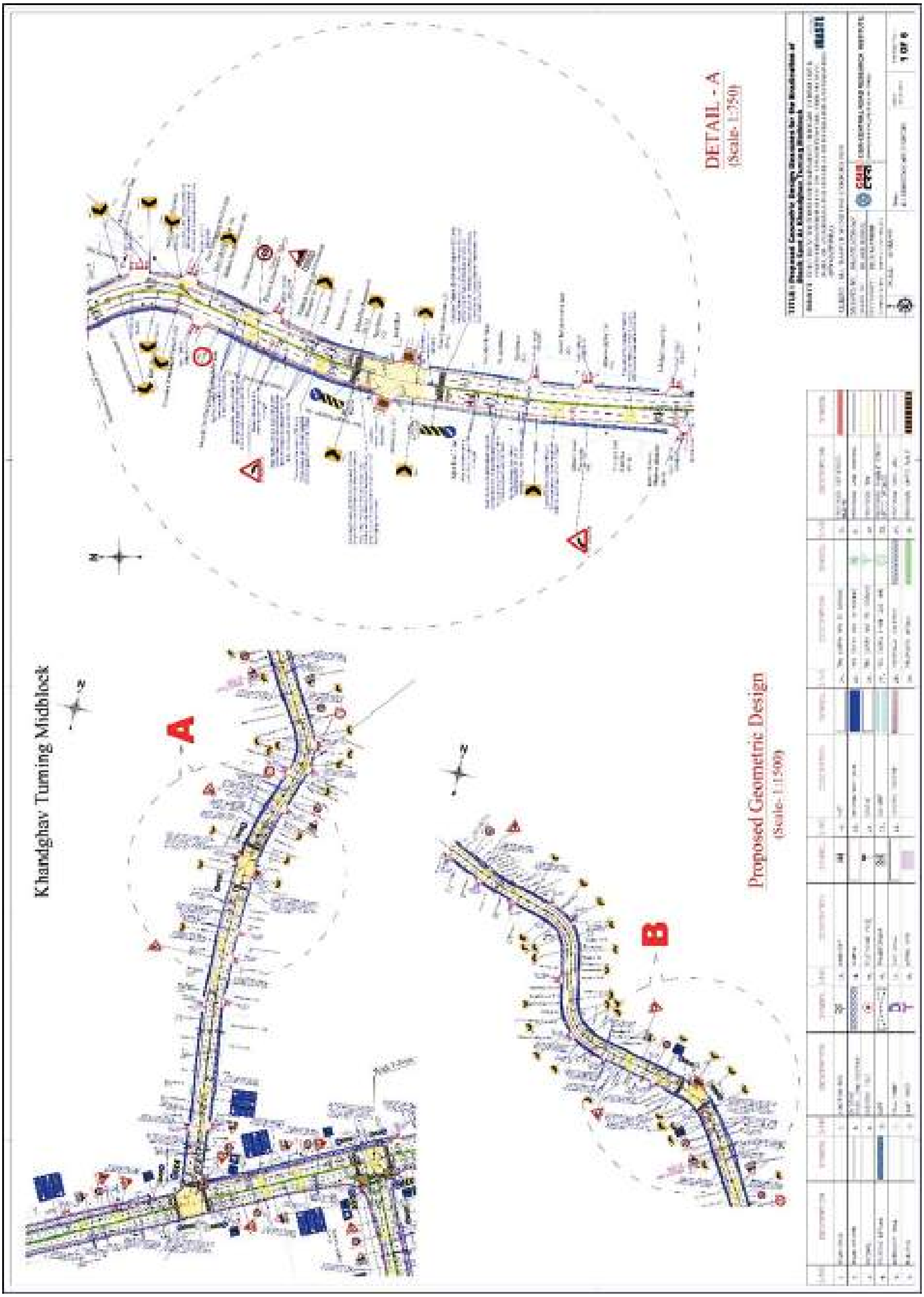


Figure 4.41 Detailed GDP for Khadgaon Turning Road stretch (View – 1)

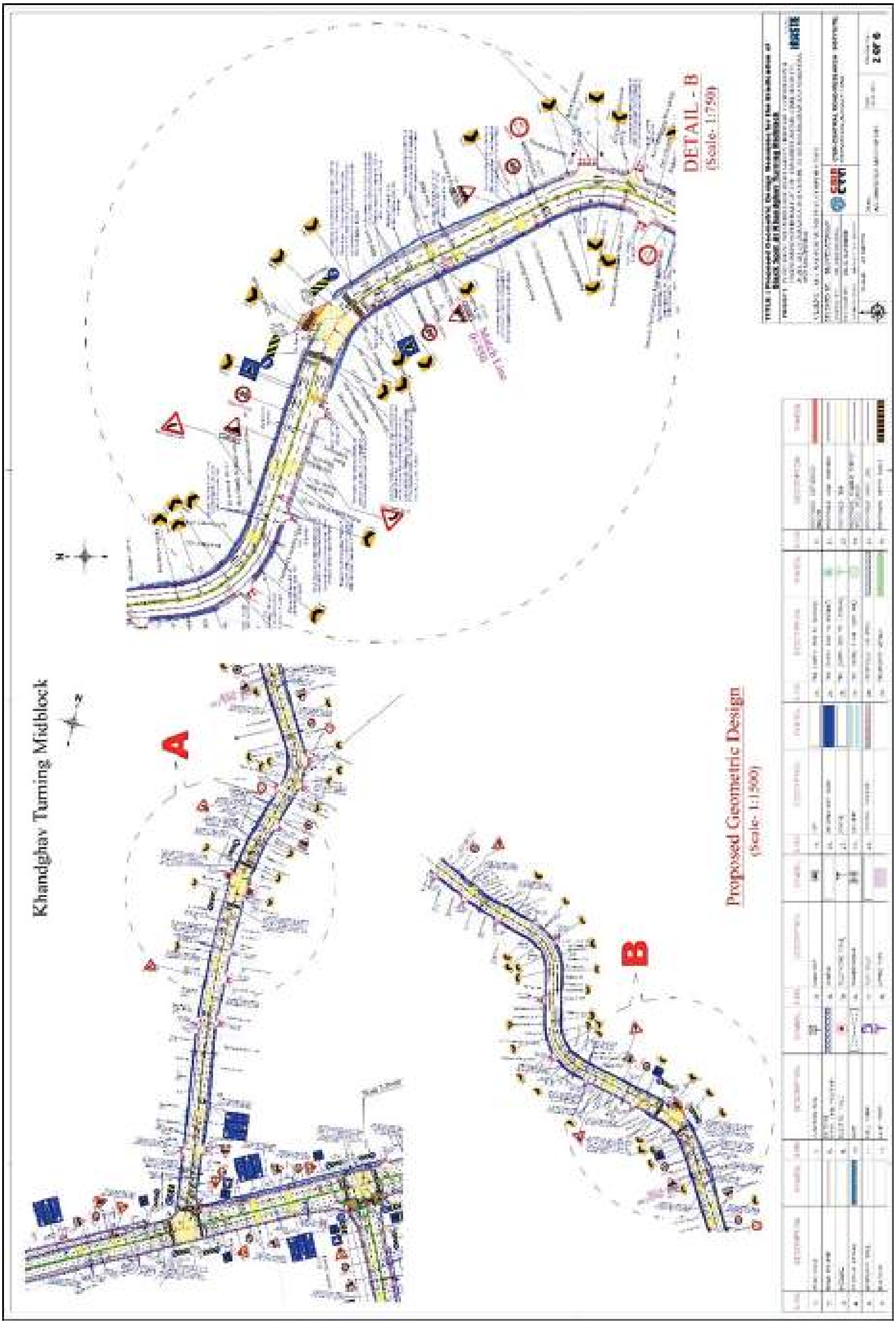


Figure 4.42 Detailed GDP for Khadgaon Turning: (View – 2)

4.4.14 Shivangaon Fata: Base Plan and GDP

Figure 4.43 depicts the physical survey plan depicting the present conditions whereas Figure 4.44 presents the detailed GDP conceived for the Shivangaon Fata Intersection spanning a length of 250m on each of the approach arms of the blackspot.

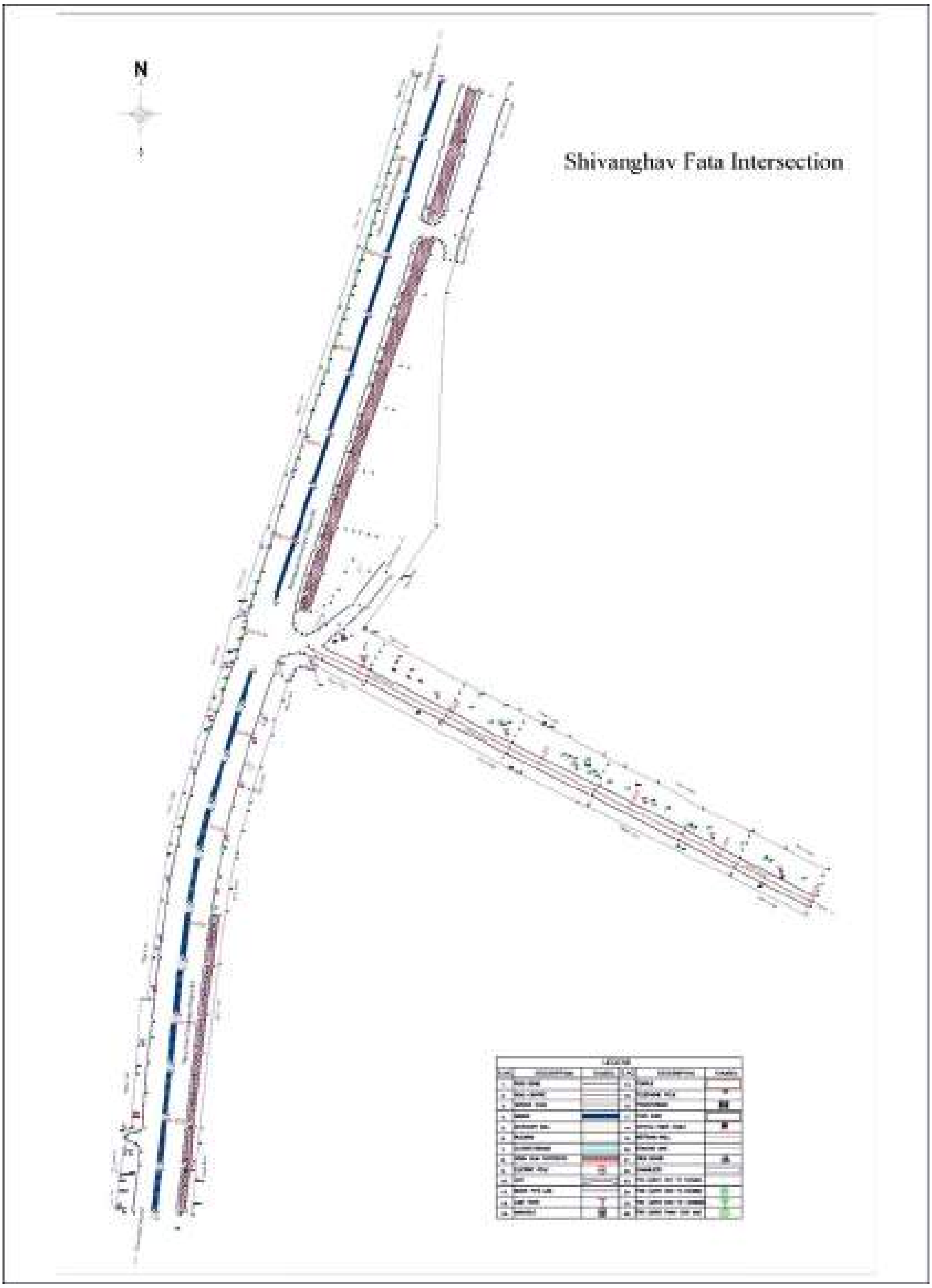


Figure 4.43 Physical Survey Plan of the Shivangaon Fata Intersection

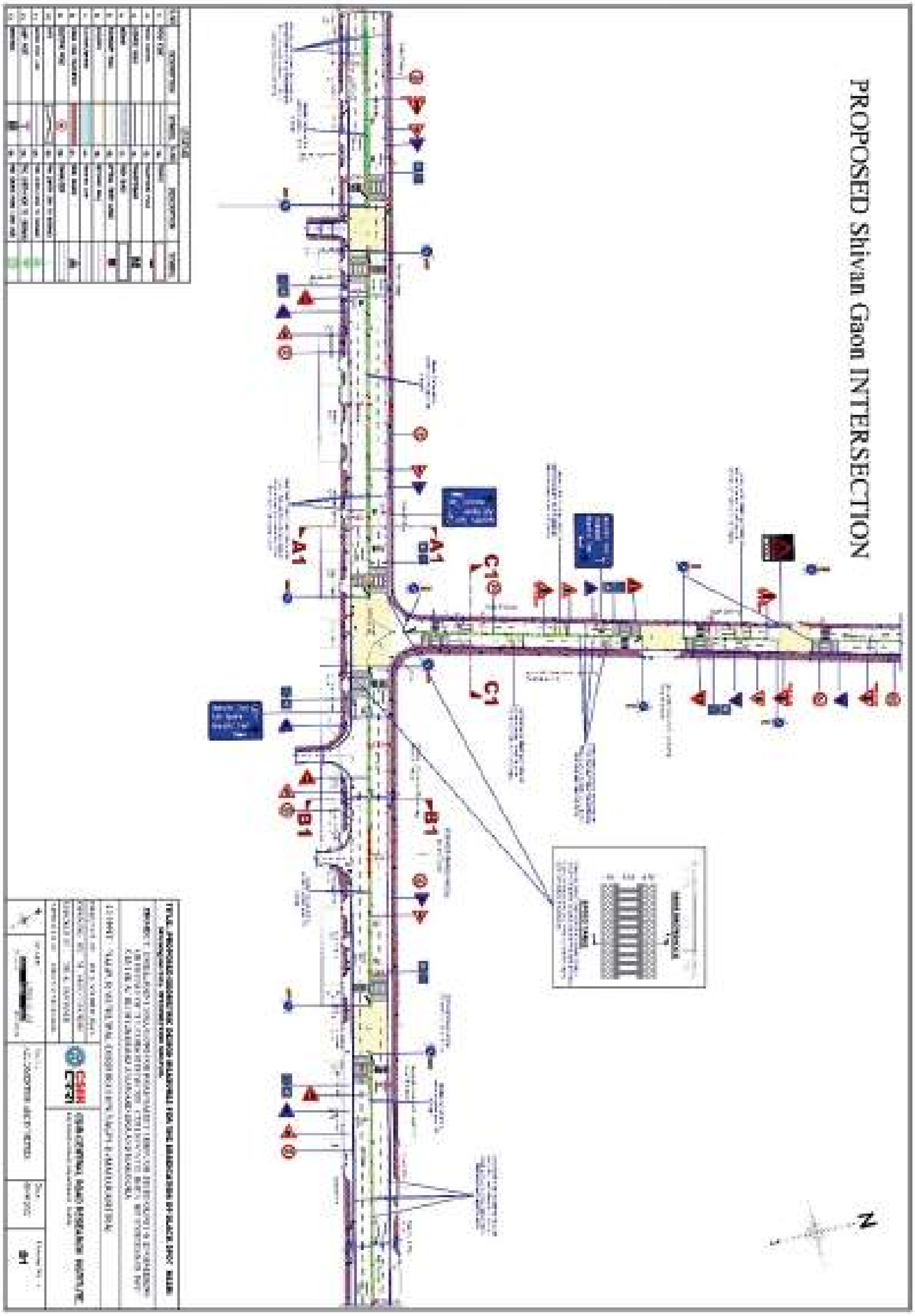


Figure 4.44 Detailed GDP for the Shivangaon Fata Intersection

4.4.15 NEERI POINT INTERSECTION: Base Plan and GDP

Figure 4.45 depicts the physical survey plan depicting the present conditions whereas Figure 4.46 presents the detailed GDP conceived for the NEERI Point Intersection spanning a length of 250 m on each approach arms of the blackspot.

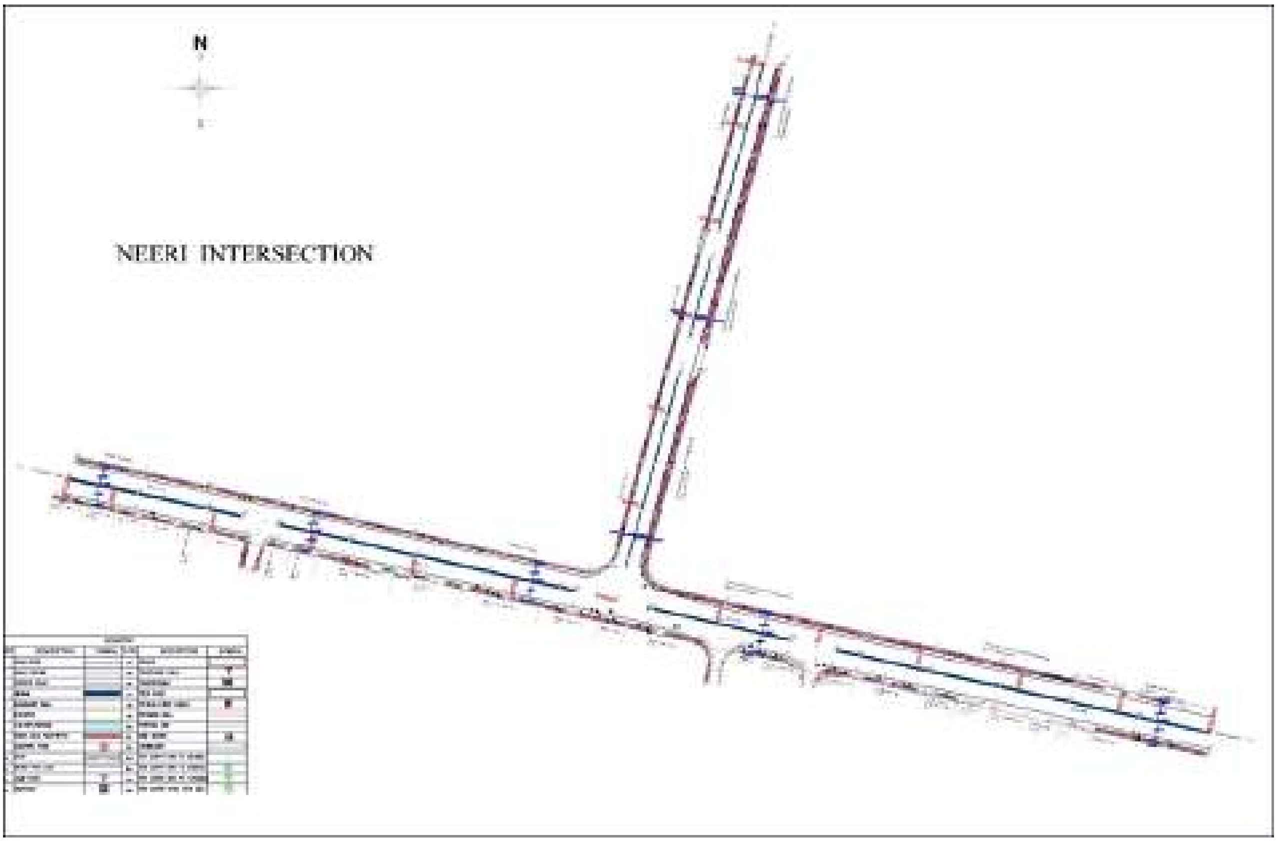


Figure 4.45 Physical Survey Plan of the NEERI Point Intersection

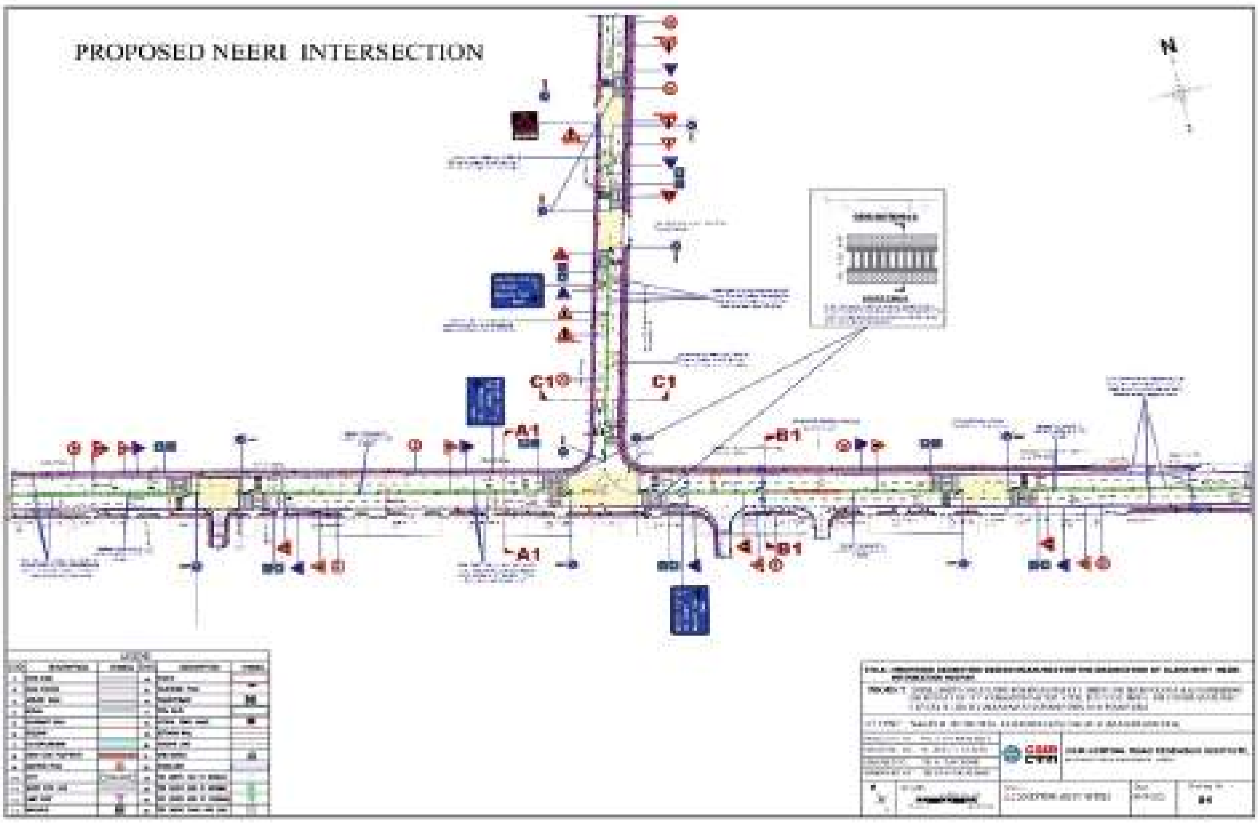


Figure 4.46 Detailed GDP for the NEERI Point Intersection

4.4.16 Jhansi Rani Square: Base Plan and GDP

Figure 4.47 depicts the physical survey plan depicting the present conditions whereas Figure 4.48 presents the detailed GDP conceived for the Jhansi rani square stretch spanning a length of 250 m on each of the approach arms of the blackspot.

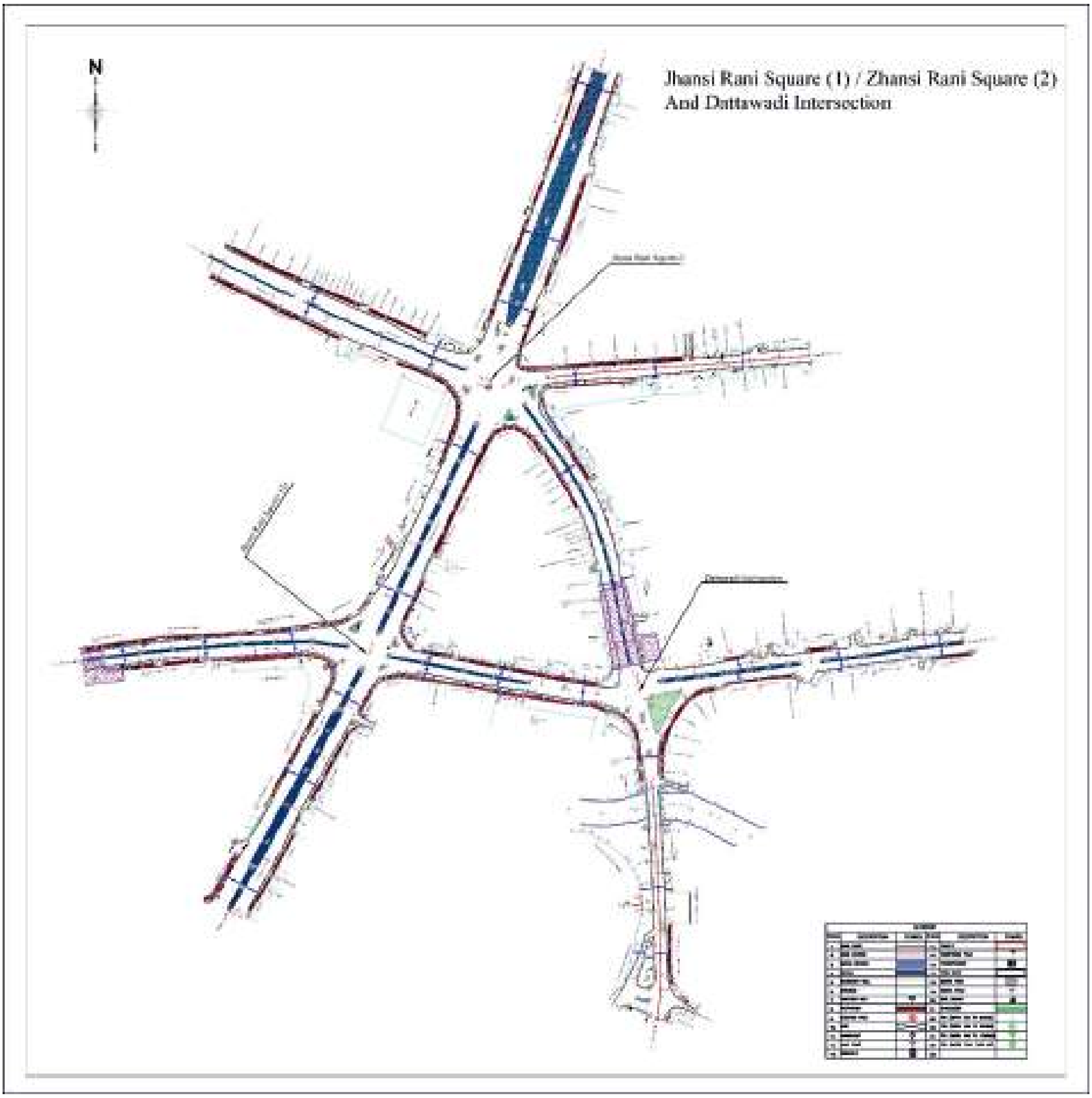


Figure 4.47 Physical Survey Plan of the Jhansi Rani Square

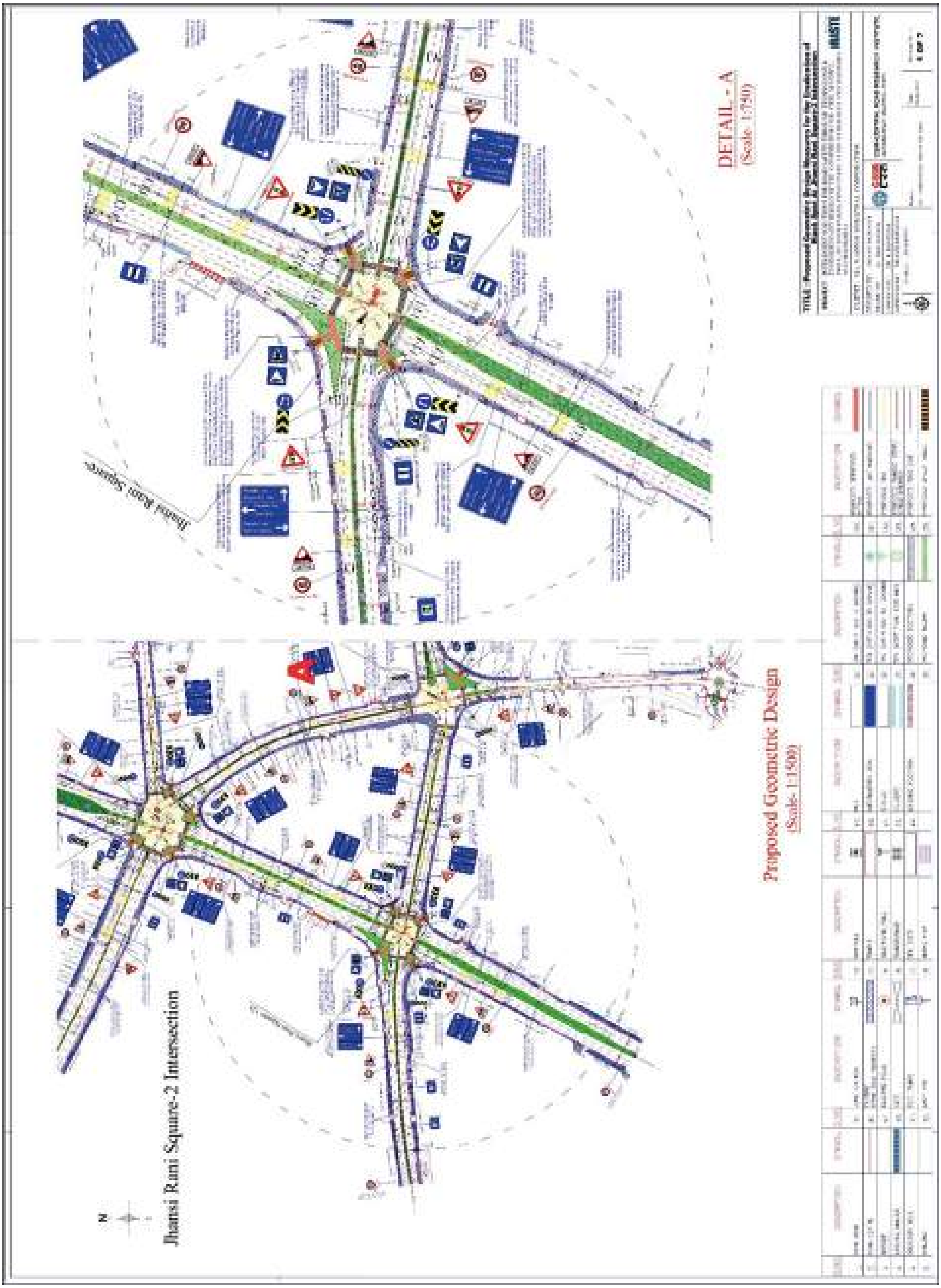


Figure 4.48 Detailed GDP for the Jhansi Rani Square

4.4.17 Campus Intersection: Base Plan and GDP

Figure 4.49 depicts the physical survey plan depicting the present conditions whereas Figure 4.50 presents the detailed GDP conceived for the Campus Intersection (Nagpur University Campus) spanning a length of 250 m on each of the approach arms of the blackspot.

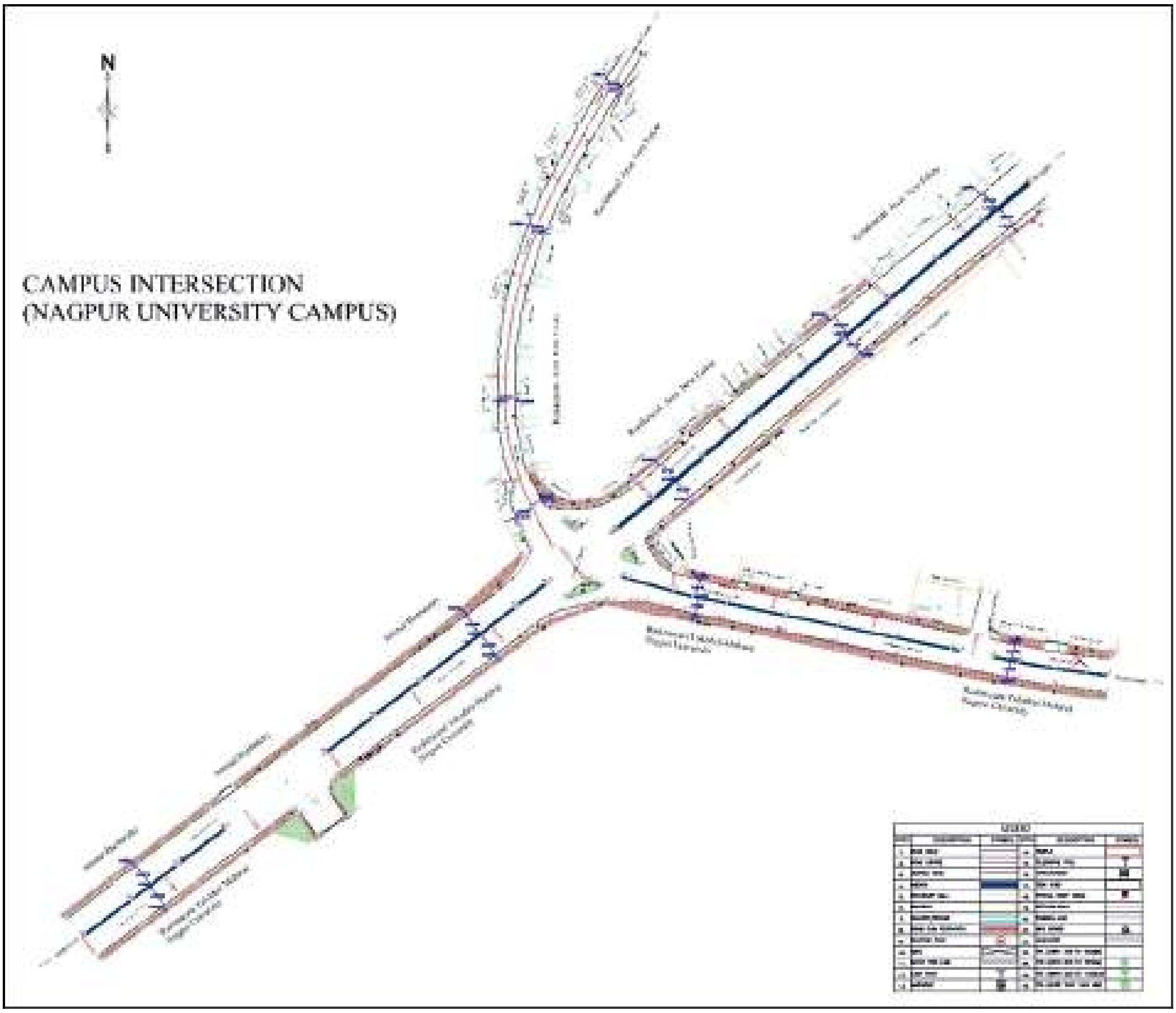


Figure 4.49 Physical Survey Plan of the Campus Intersection (Nagpur University Campus)

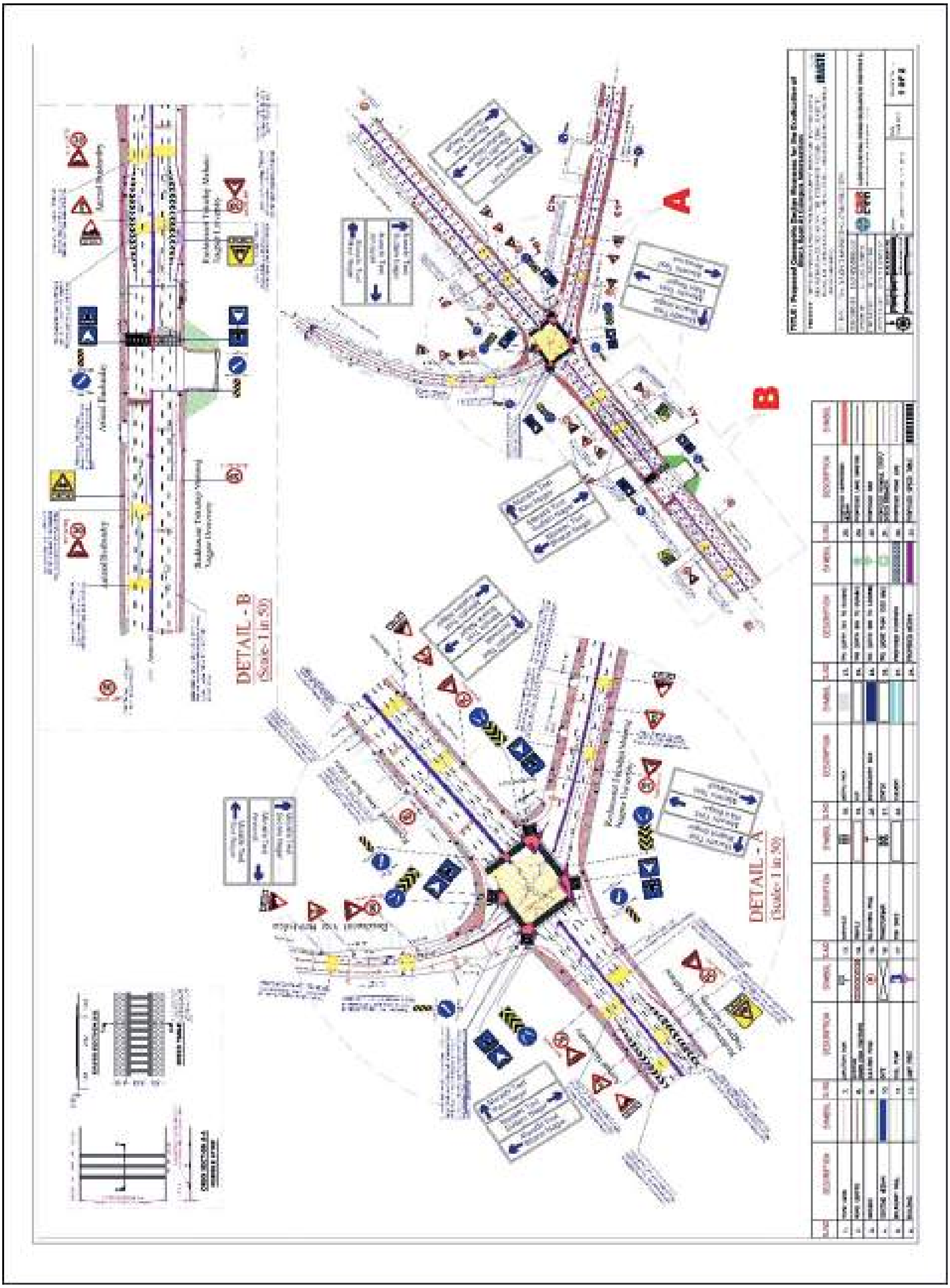


Figure 4.50 Detailed GDP for Campus Intersection (Nagpur University Campus)

4.4.18 Ravi Nagar Intersection: Base Plan and GDP

Figure 4.51 depicts the physical survey plan illustrating the present conditions whereas Figure 4.52 presents the detailed GDP conceived for the Ravi Nagar Intersection spanning a length of 250 m on each of approach arms of the blackspot.

Figure 4.51 Physical Survey Plan of the Ravi Nagar Intersection

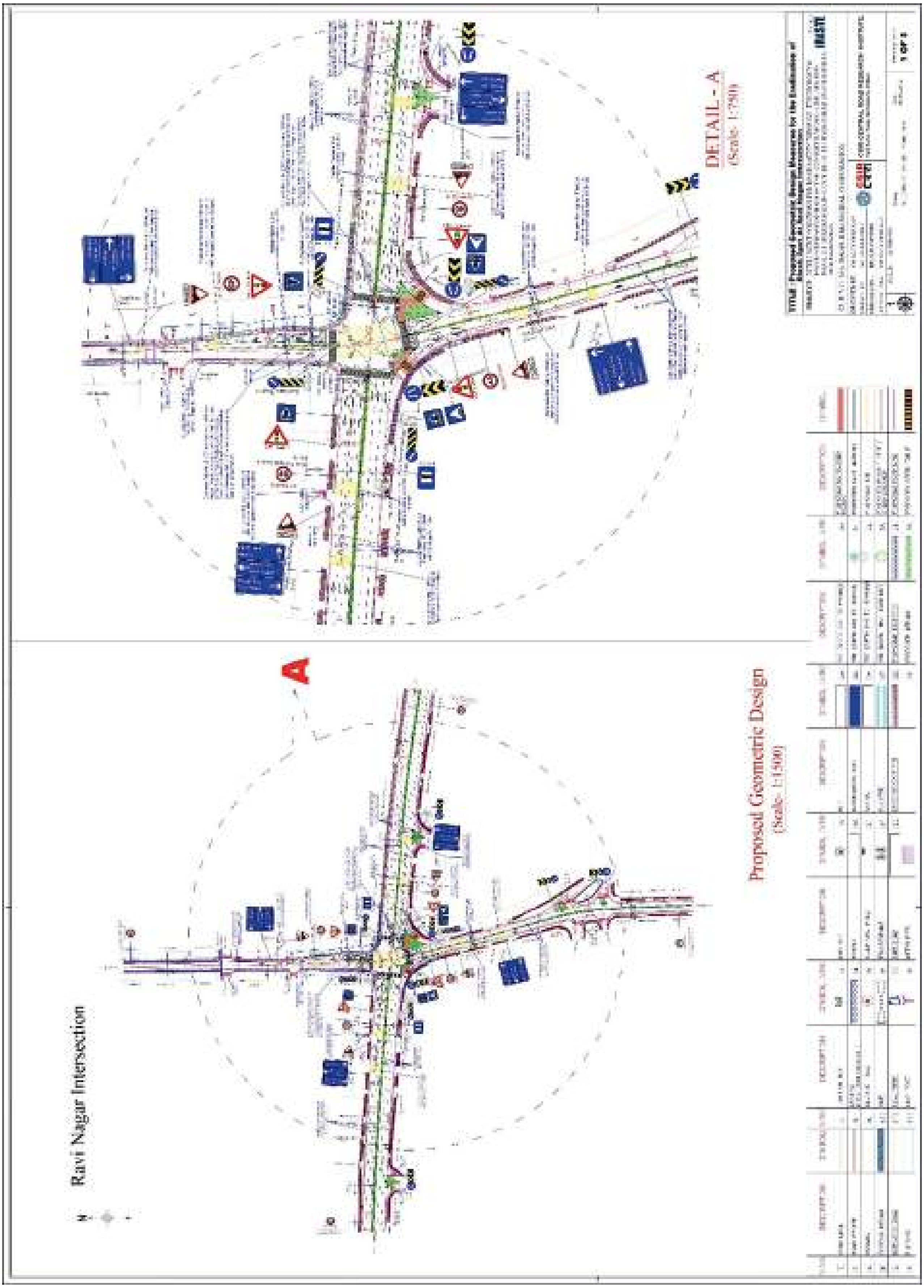


Figure 4.52 Detailed GDP for the Ravi Nagar Intersection

4.4.19 Jinga Bai Takli to Zhanda Chowk: Base Plan and GDP

Figure 4.53 depicts the physical survey plan depicting the present conditions whereas Figure 4.54 presents the detailed GDP conceived for the intersection of Jingabai Takli to Zhanda chowk stretch spanning a length of 250 m on each of the approach arms of the blackspot.

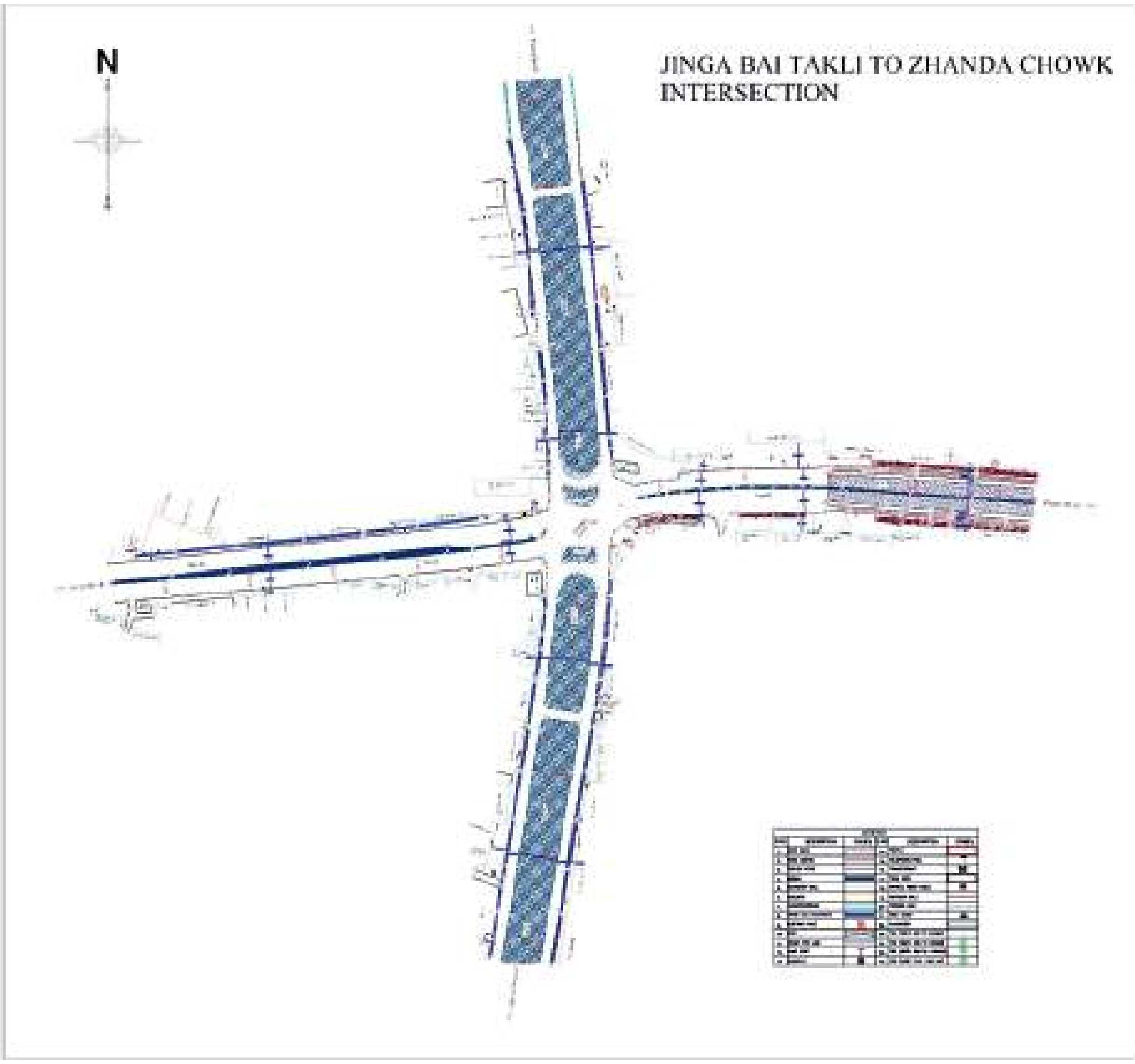


Figure 4.53 Physical Survey Plan of the Jinga Bai Takli to Zhanda Chowk

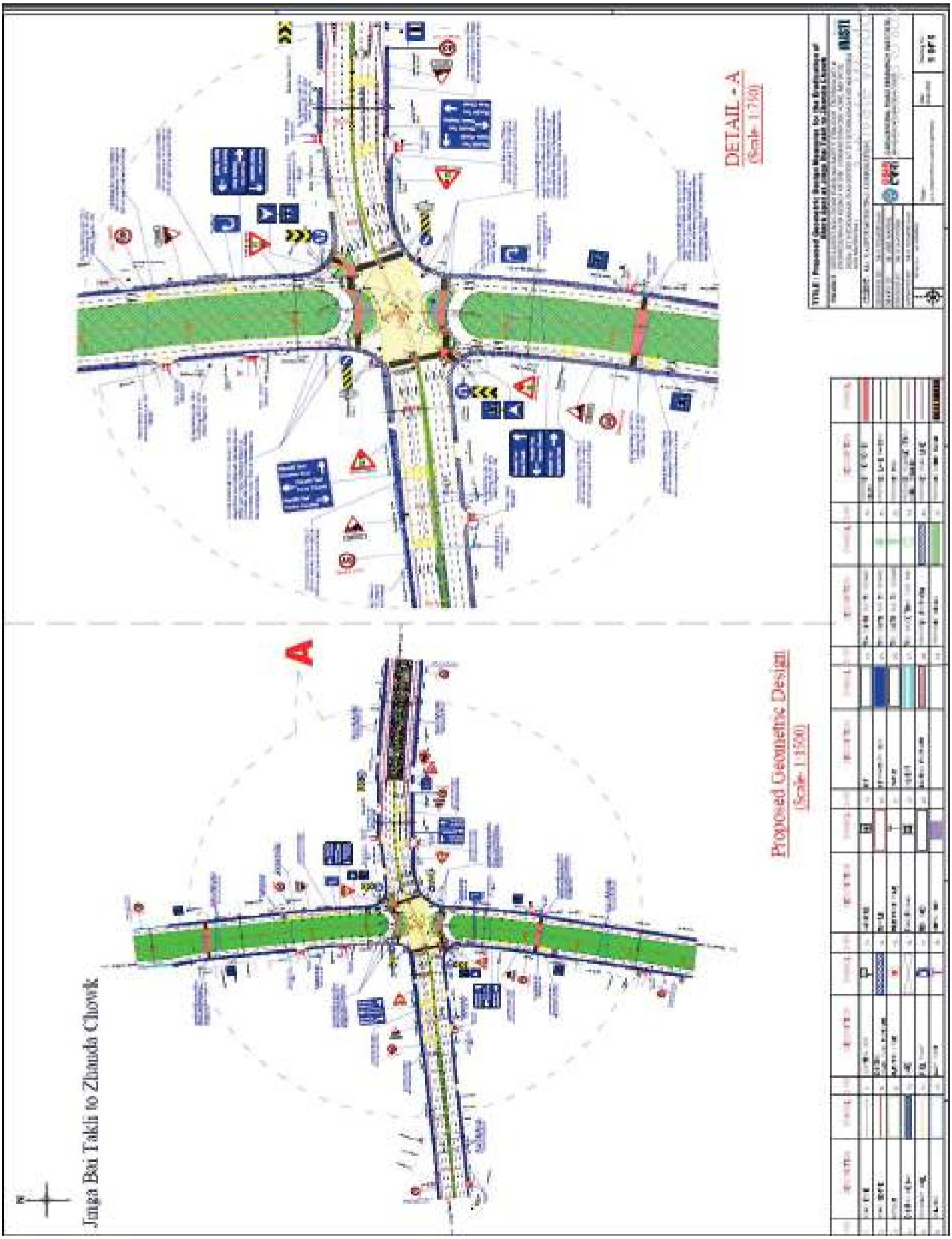


Figure 4.54 Detailed GDP for the Jinga Bai Takli to Zhanda Chowk

4.4.20 Pagalkhana Chowk to Mankapur chowk: Base Plan and GDP

Figure 4.55 depicts the physical survey plan of the midblock section from Pagalkhana Chowk to Mankapur Chowk depicting the present conditions whereas Figure 4.56 presents the detailed GDP conceived for the midblock section of Pagalkhana Chowk to Mankapur Chowk stretch spanning a length of 500 m on either side of the blackspot

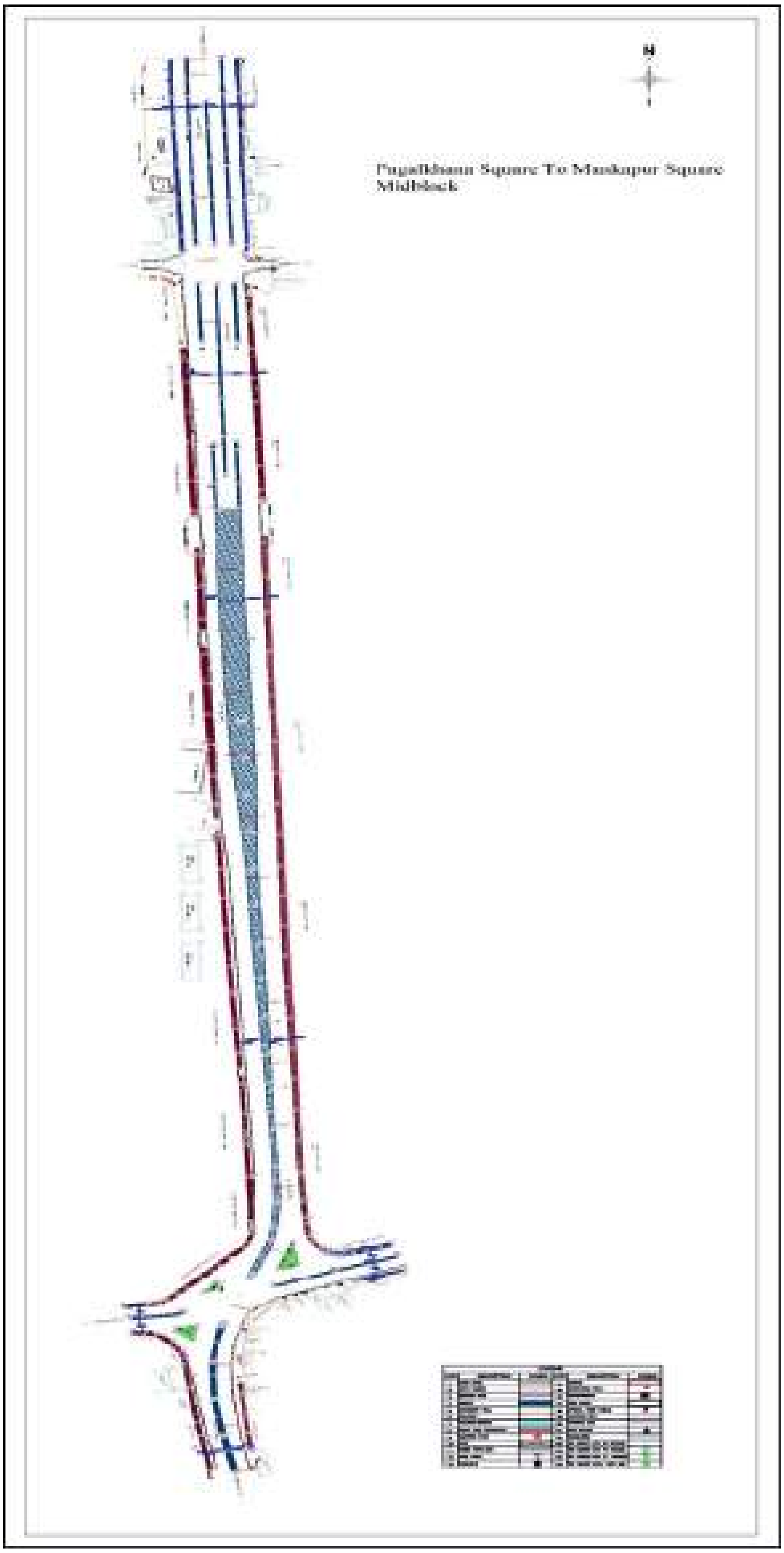


Figure 4.55 Base Physical Survey Plan of the Midblock stretch from Pagalkhana Chowk to Mankapur Chowk

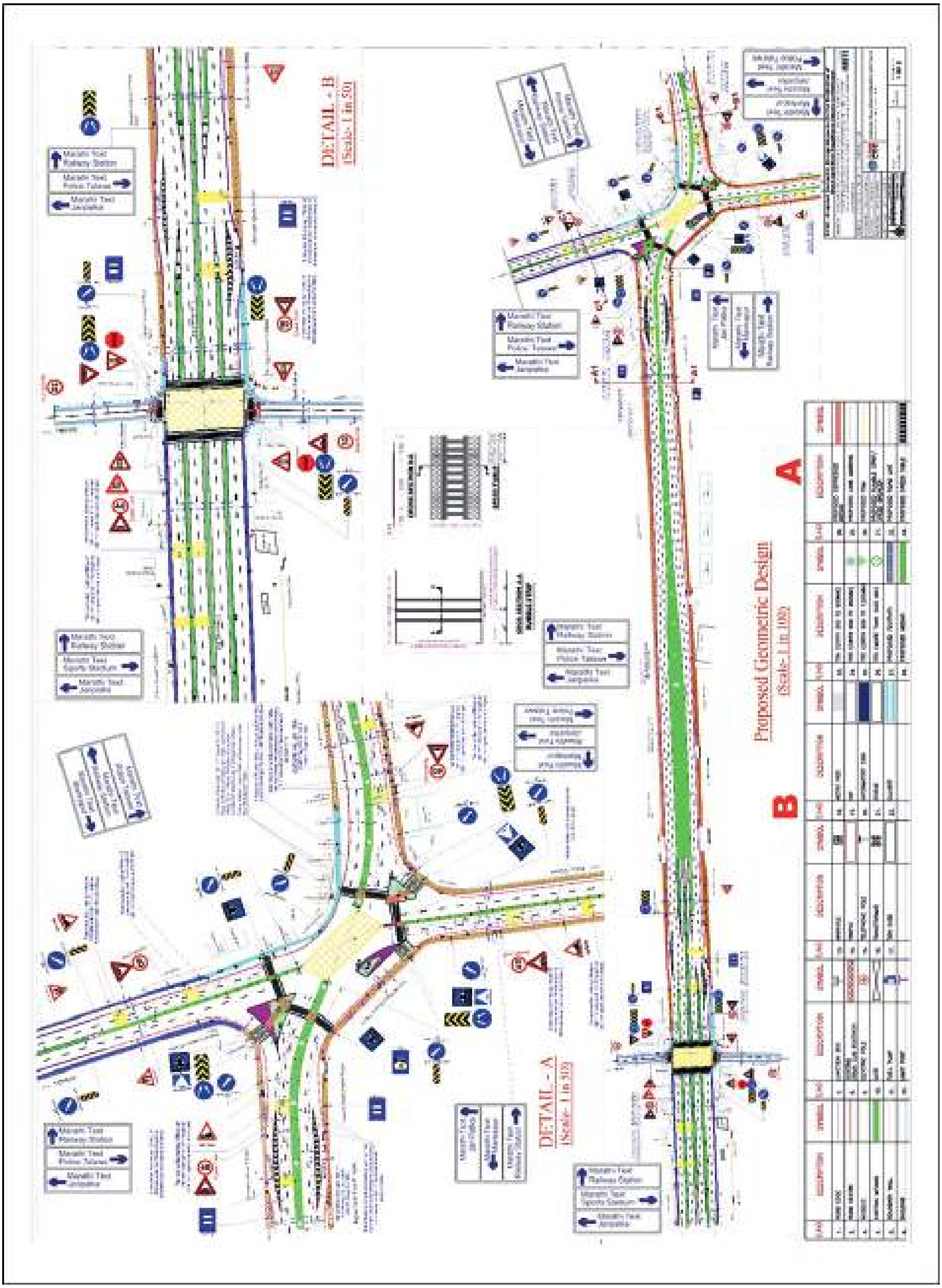


Figure 4.56 Proposed Detailed GDP for the Midblock Section of Pagalkhana Chowk to Mankapur Chowk

4.4.21 Ayyappa Temple to Gorewada Square: Base Plan and GDP

Figure 4.57 depicts the physical survey plan illustrating the present conditions on the road stretch from Ayyappa Temple to Gorewada Square whereas Figure 4.58 & 4.59 presents the detailed Geometric Design Plan (GDP) conceived for the same stretch spanning a length of 500 m on either side of the blackspot

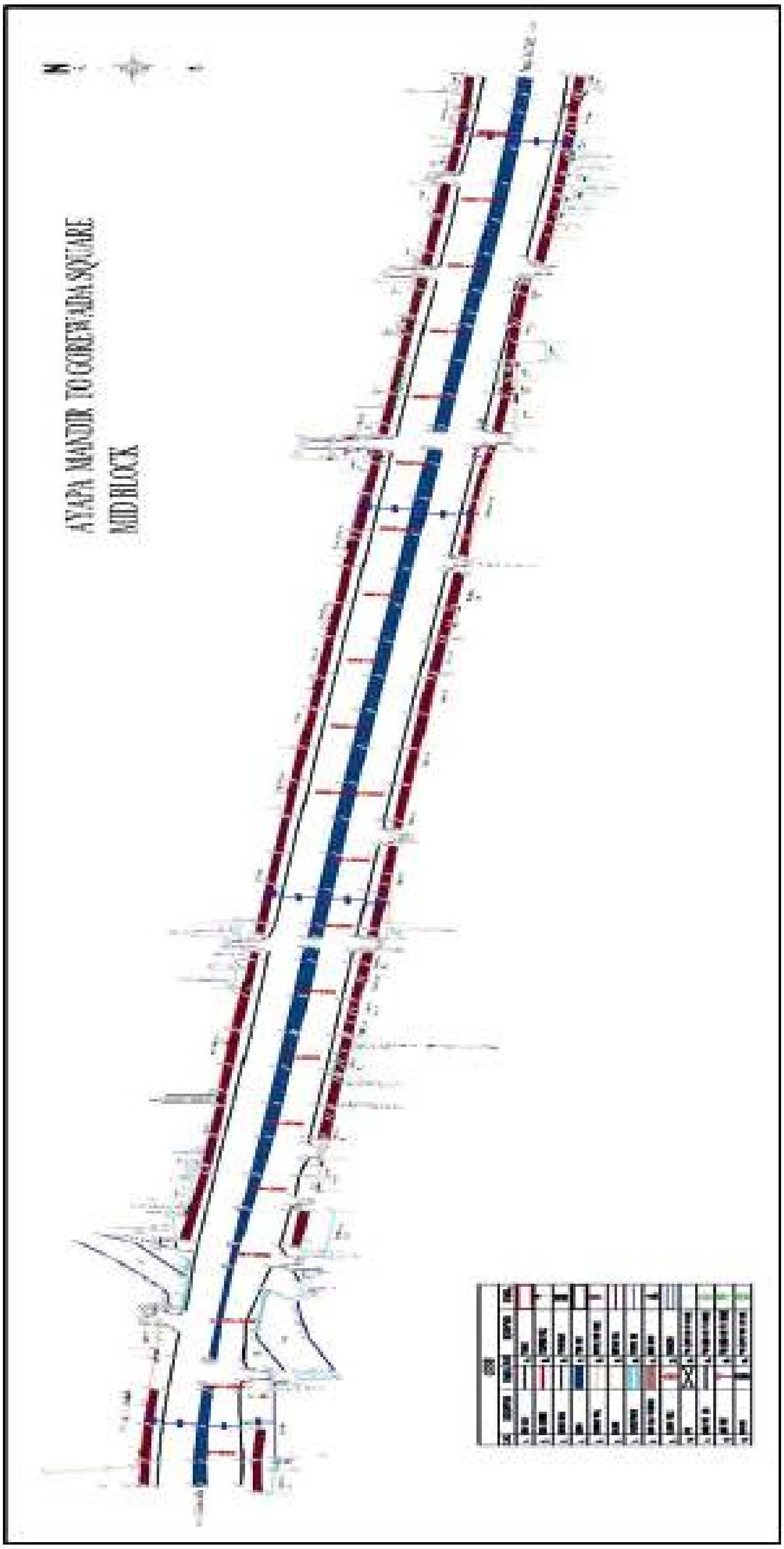


Figure 4.57 Physical Survey Plan of the Midblock Stretch from Ayyappa Temple to Gorewada Square

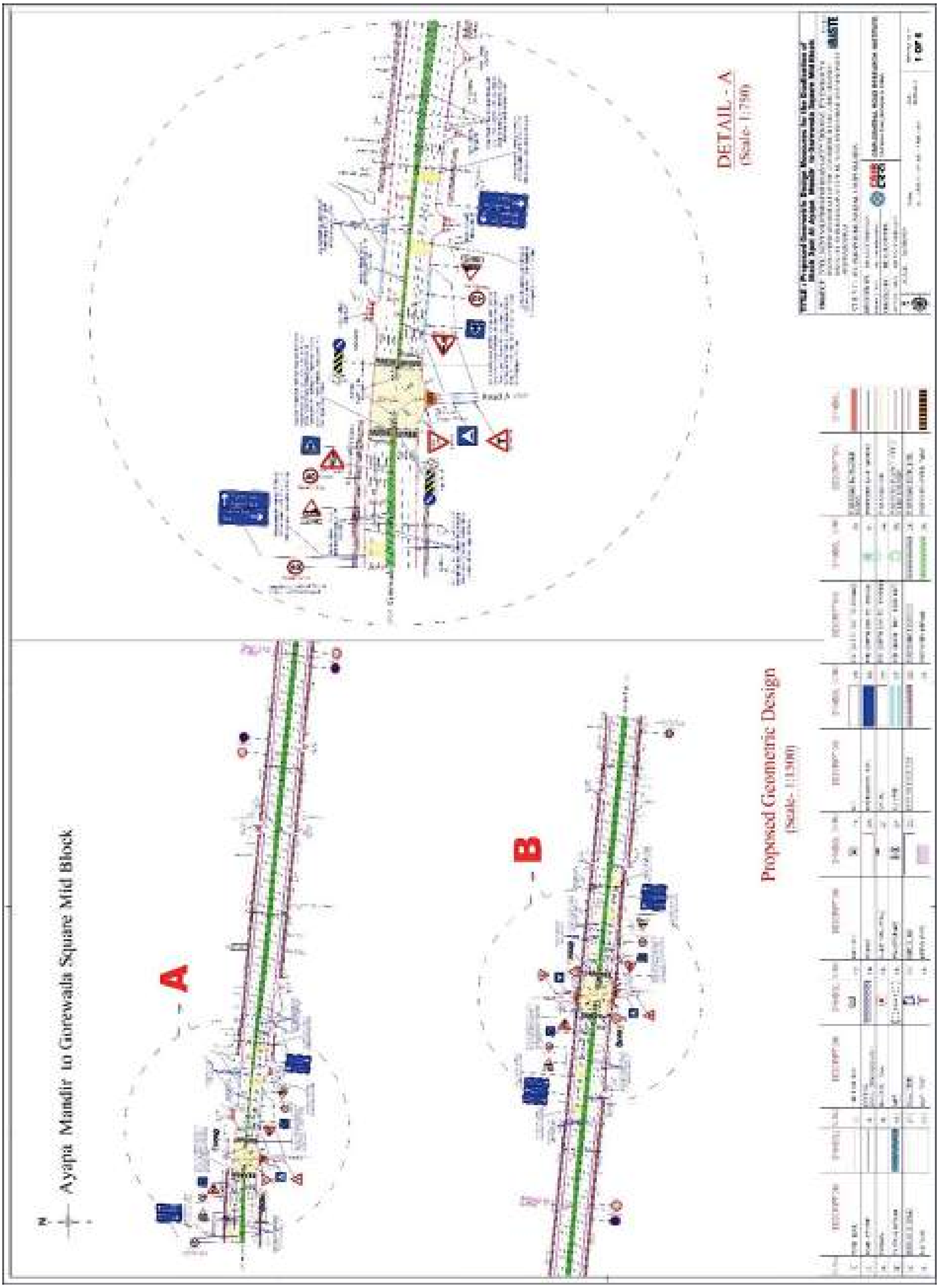


Figure 4.58 Detailed GDP for the Midblock stretch from Ayyappa Temple to Gorewada Square (View -1)

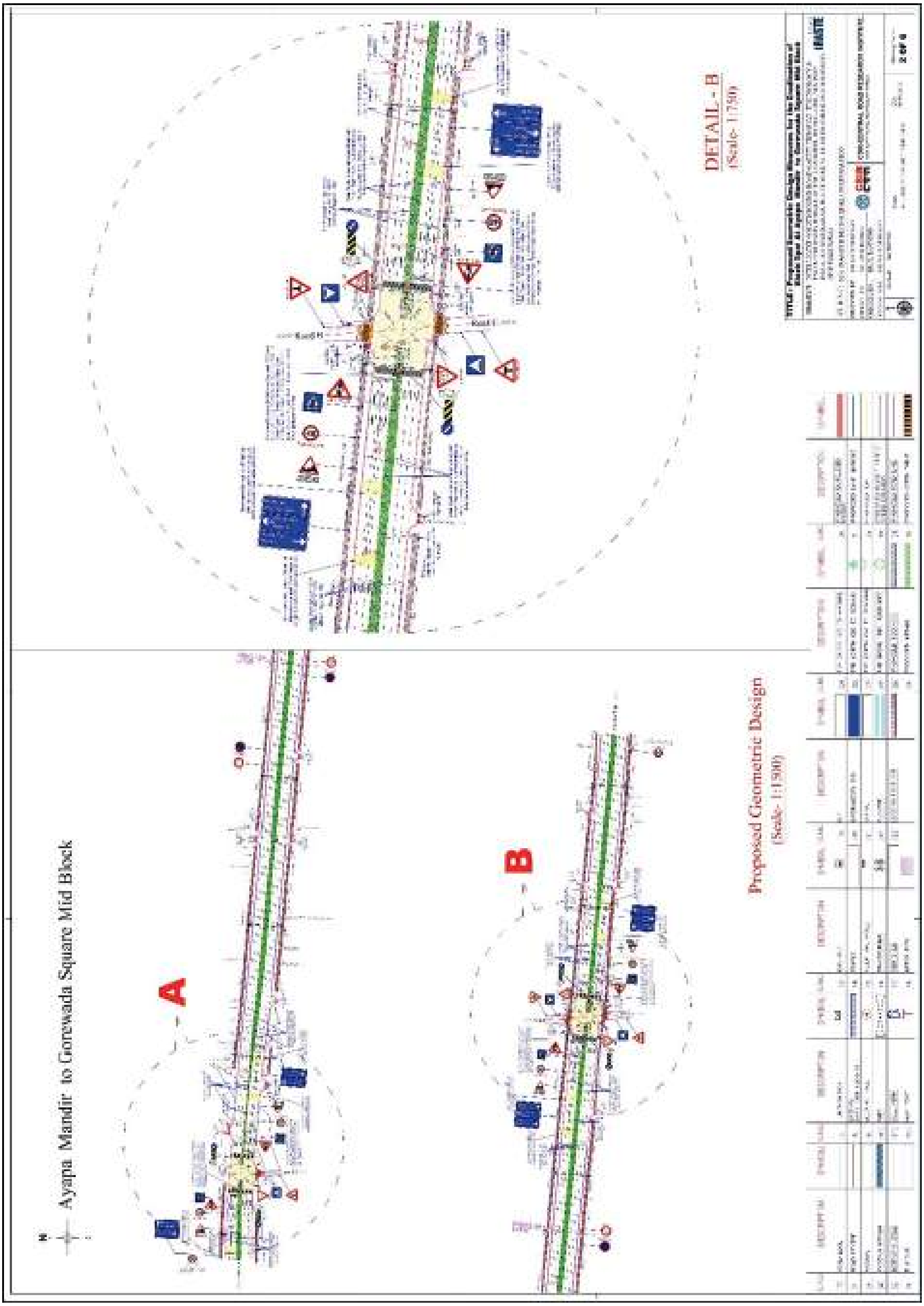


Figure 4.59 Detailed GDP for the Midblock stretch from Ayyappa Temple to Gorewada Square (View -2)

4.4.22 Police Talawe T Point: Base Plan and GDP

Figure 4.60 depicts the physical survey plan depicting the present conditions at Police Talawe T-Point whereas Figure 4.61 presents the detailed Geometric Design Plan (GDP) conceived for the T-Intersection spanning a length of 250 m on each of the approach arms of the blackspot

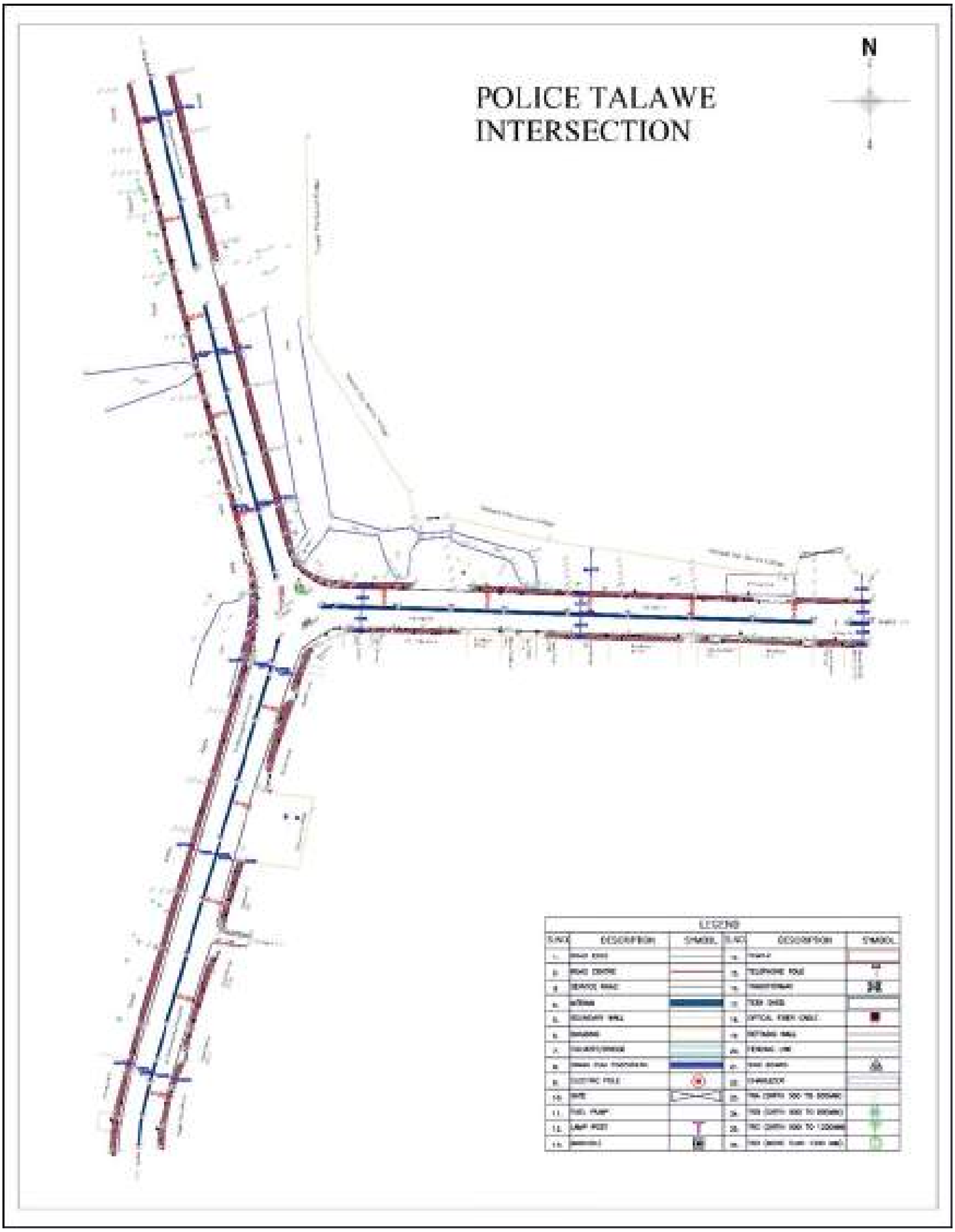


Figure 4.60 Physical Survey Plan of the Police Talawe T Point

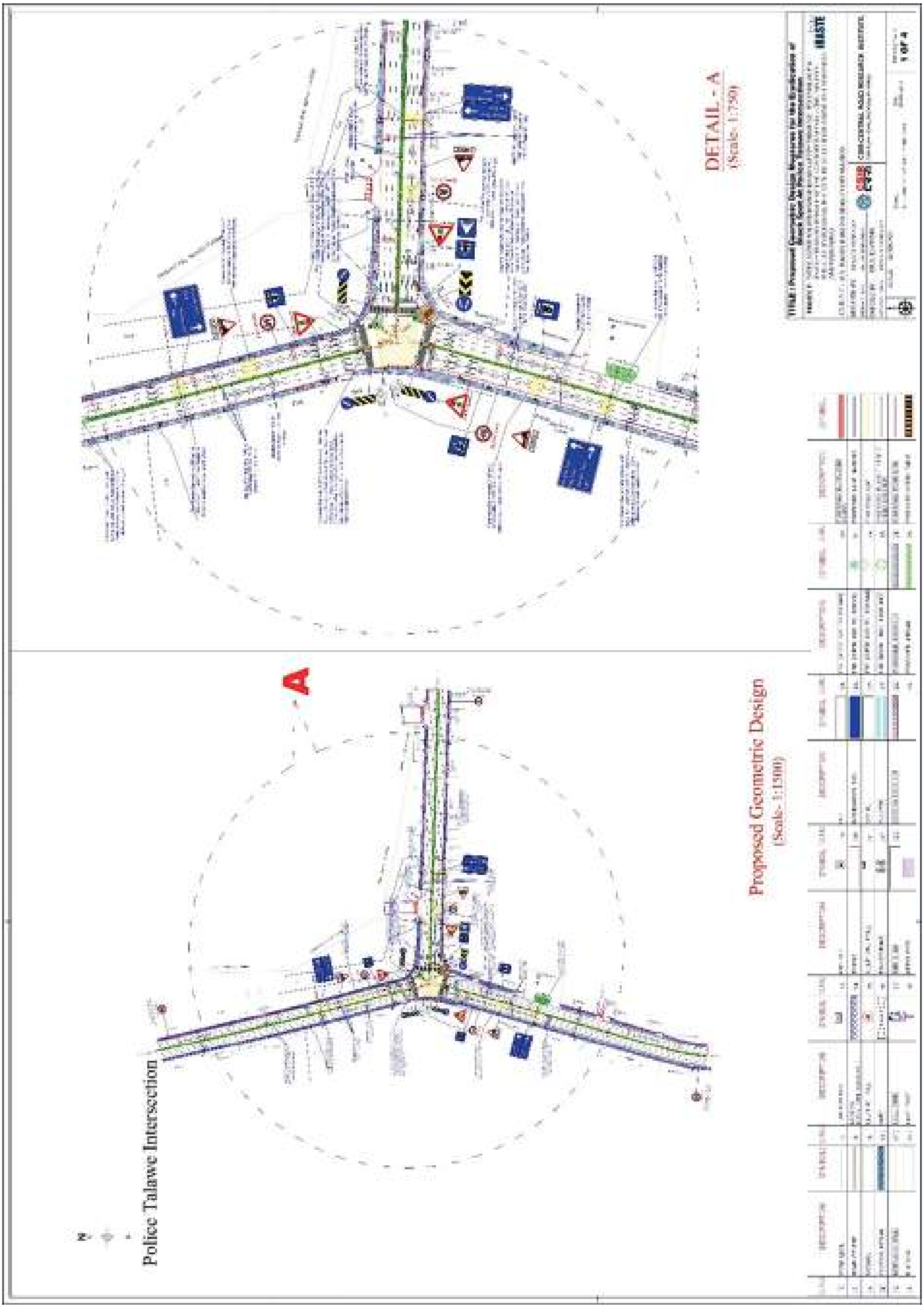


Figure 4.61 Detailed GDP for the Police Talawe T-point

4.4.23 Auto HUB to Toll Naka: Base Plan and GDP

Figure 4.62 depicts the physical survey plan depicting the present conditions whereas Figure 4.63 presents the detailed Geometric Design Plan (GDP) conceived for the Auto HUB to Toll Naka Intersection spanning a length of 250 m on each of the approach arms of the blackspot.

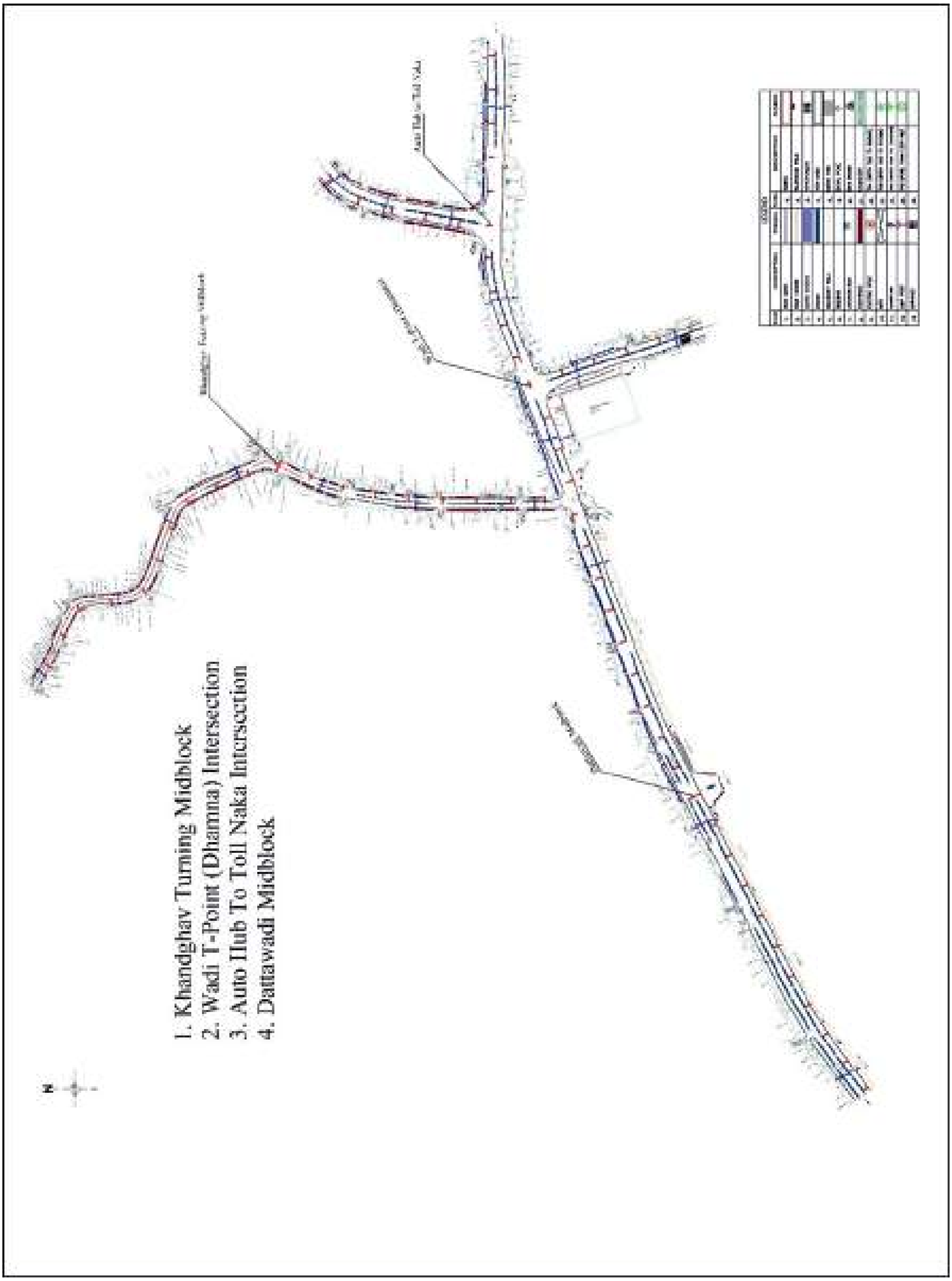


Figure 4.62 Physical Survey Plan of the Auto HUB to Toll Naka Intersection and Other Adjacent Intersection

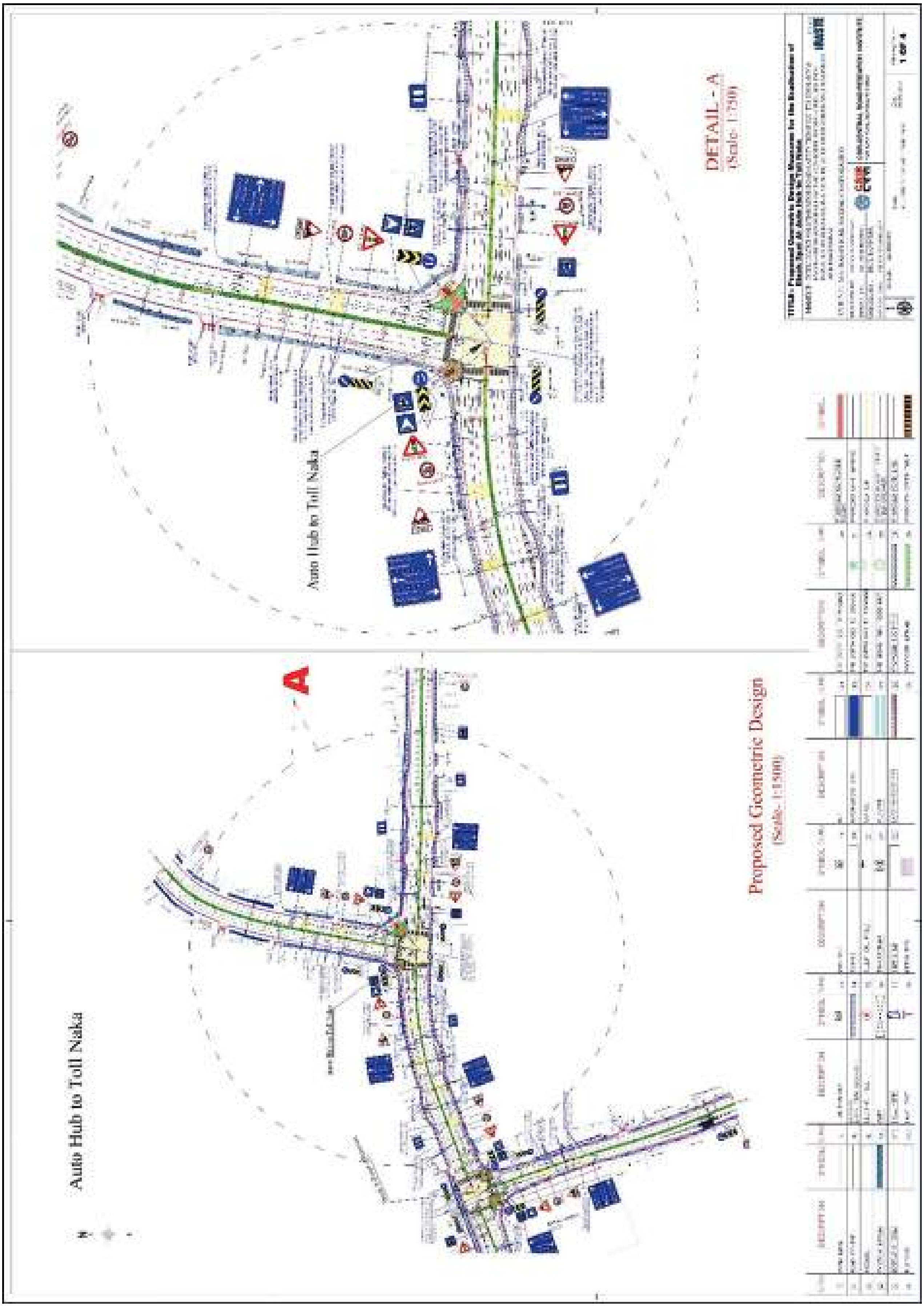


Figure 4.63 Detailed GDP for the Auto HUB to Toll Naka Intersection

4.4.24 Gittikhadan to Dinshaw: Base Plan and GDP

Figure 4.64 depicts the physical survey plan depicting the present conditions on the midblock stretch from Gittikhadan to Dinshaw Factory whereas Figure 4.65 & 4.66 presents the detailed Geometric Design Plan (GDP) conceived for the same spanning a length of 500 m on either side of the blackspot.

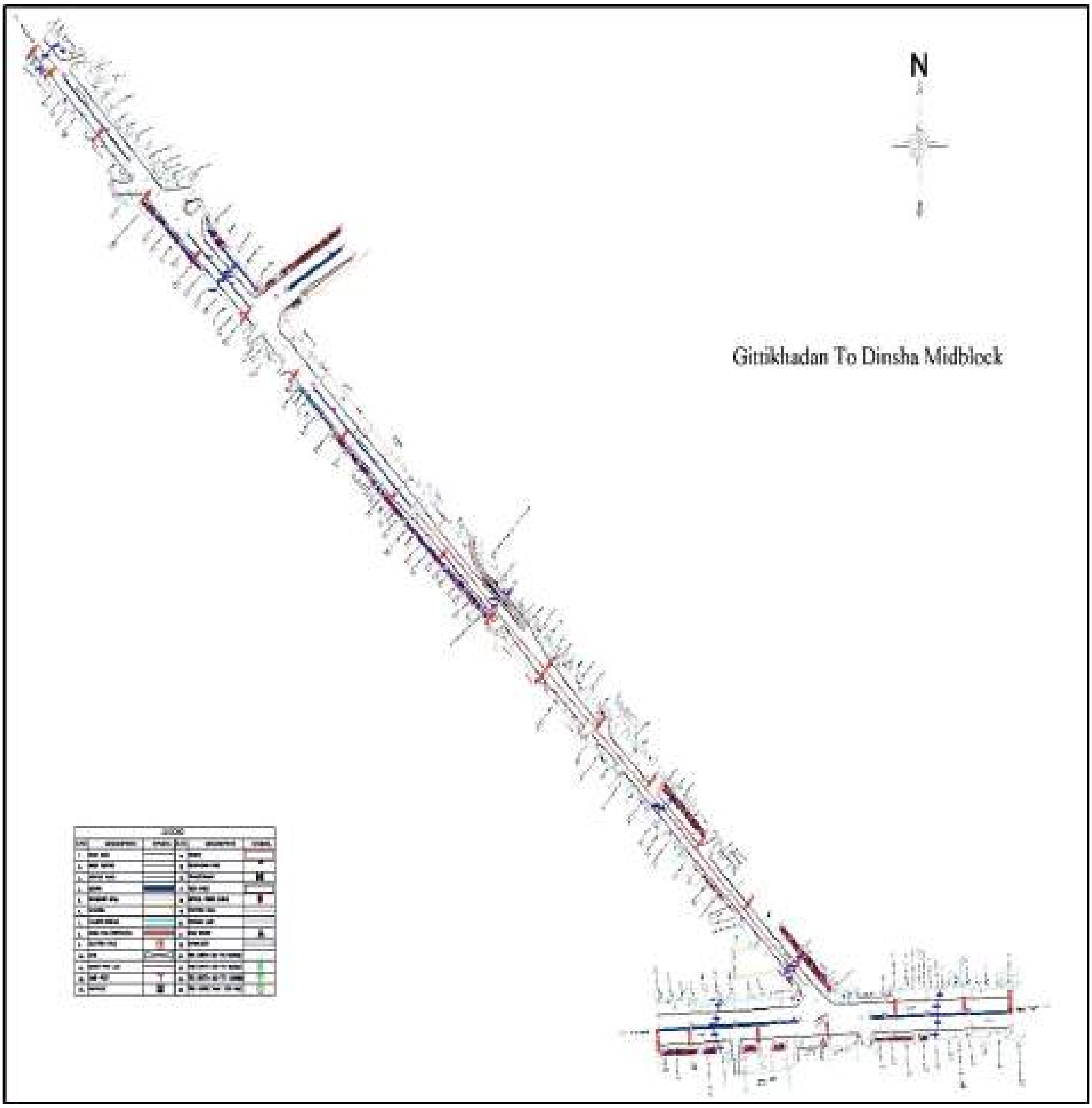


Figure 4.64 Physical Survey Plan of the Gittikhadan to Dinshaw Factory Road Stretch

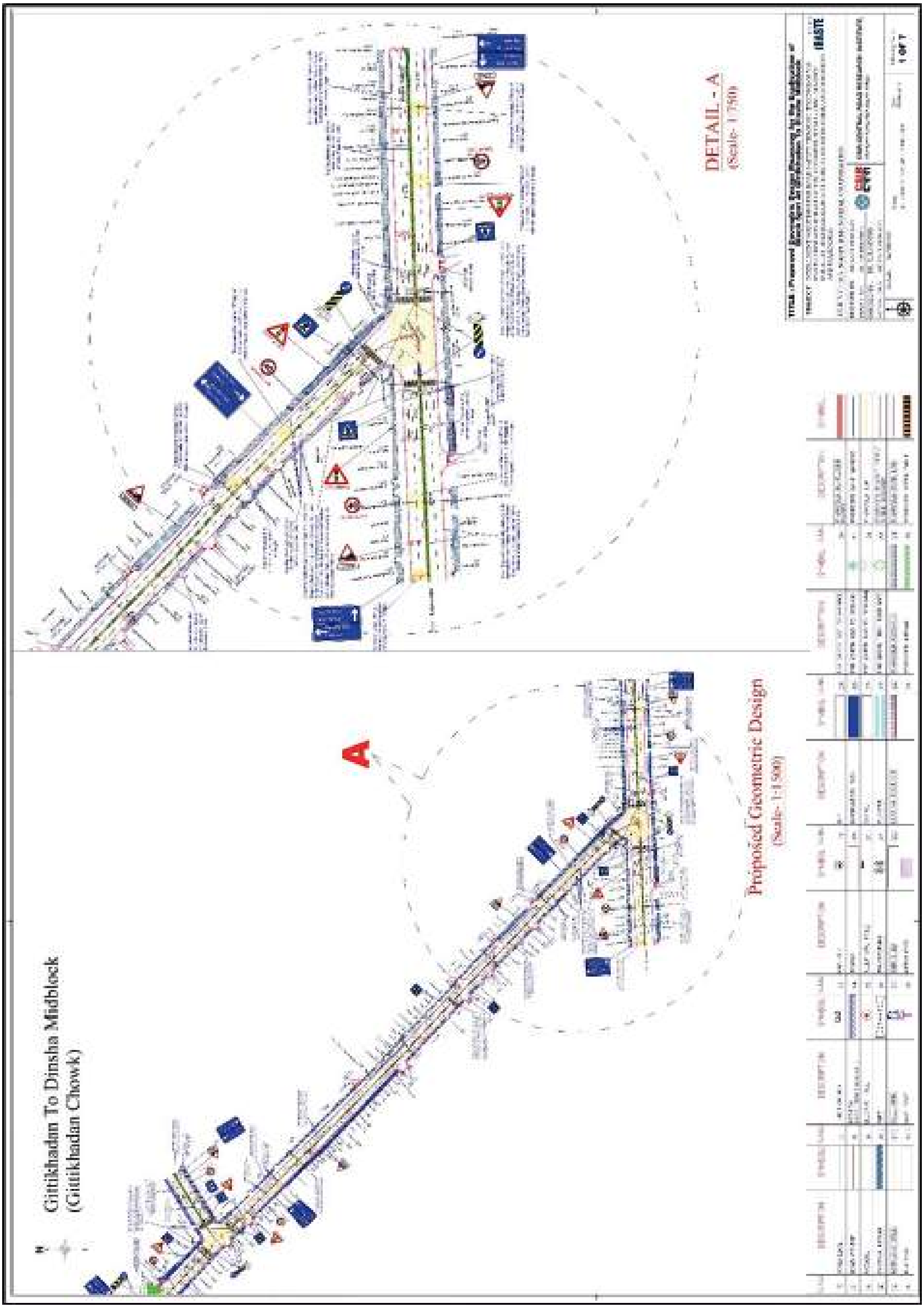


Figure 4.65 Detailed GDP for the Gittikhadan to Dinshaw Factory Road Stretch: View - 1

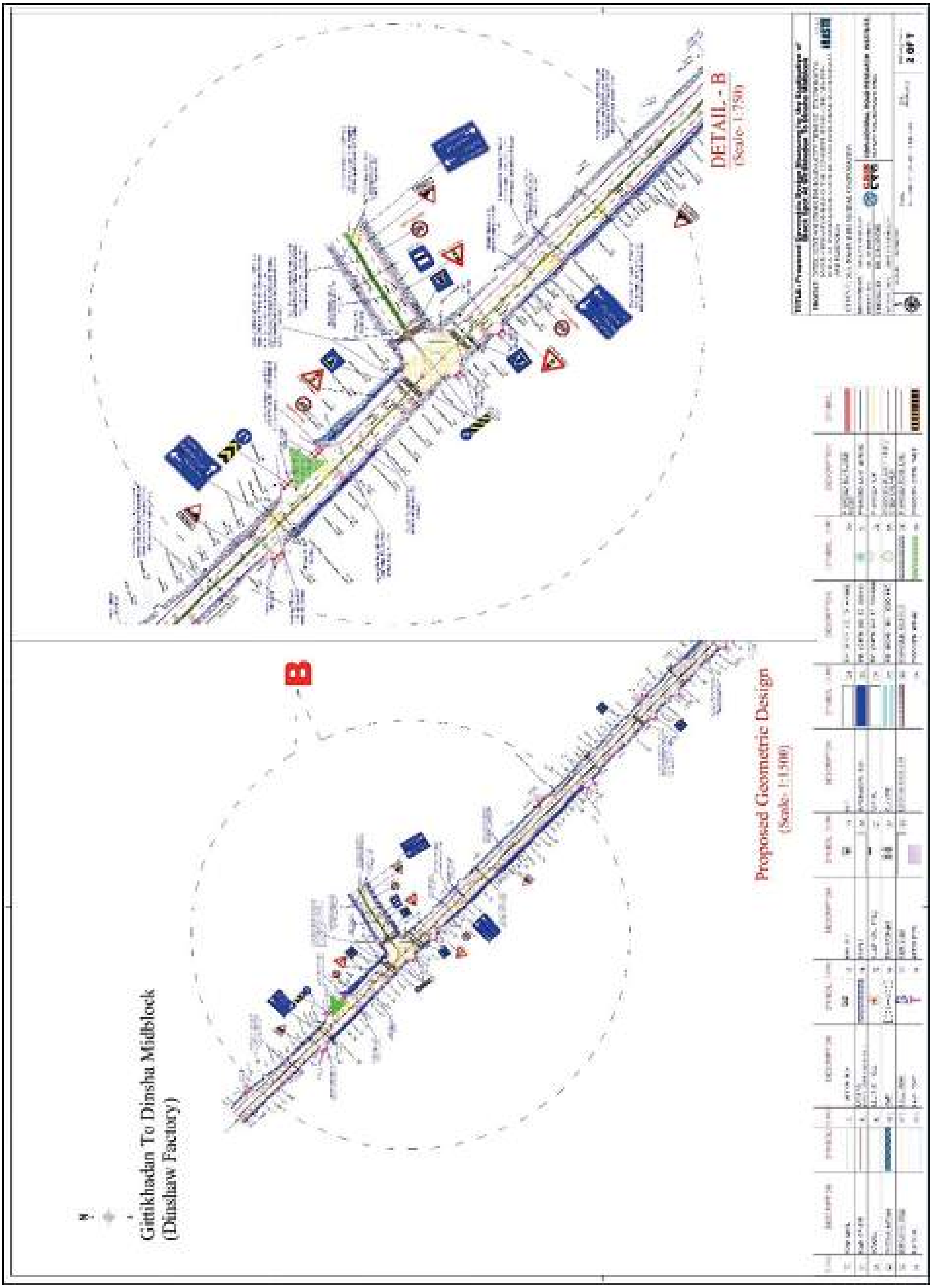


Figure 4.66 Detailed GDP for the Gittikhadan to Dinshaw Factory Road Stretch: View - 2

4.4.25 New Toll Naka to Toll Naka Intersection: Base Plan and GDP

Figure 4.67 depicts the physical survey plan depicting the present conditions whereas Figure 4.68 presents the detailed GDP conceived for the Auto HUB to Toll Naka Intersection spanning a length of 250 m on each of the approach arms of the blackspot.

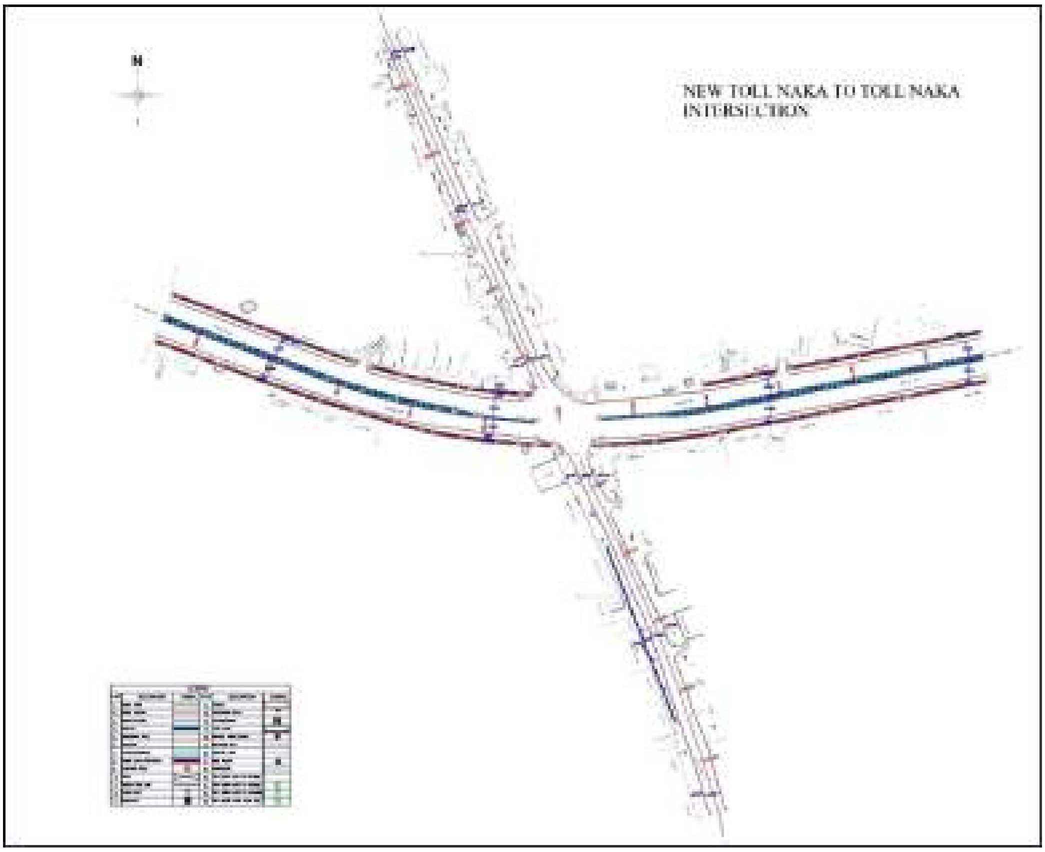


Figure 4.67 Physical Survey Plan of the New Toll Naka to Toll Naka Road Intersection

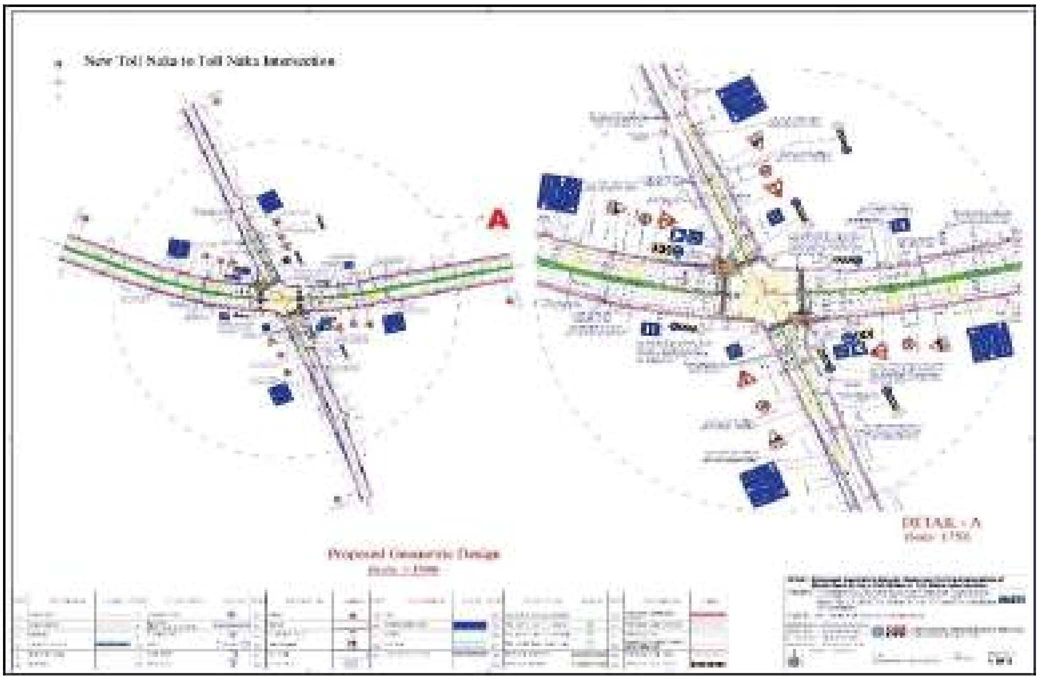


Figure 4.68 Detailed GDP for the New Toll Naka to Toll Naka Road Intersection

4.4.26 Gorewada to toll Naka intersection: Base plan and GDP

Figure 4.69 depicts the physical survey plan depicting the present conditions whereas Figure 4.70 presents the detailed GDP conceived for the Gorewada to Toll Naka Intersection spanning a length of 250 m on each of the approach arms of the blackspot.

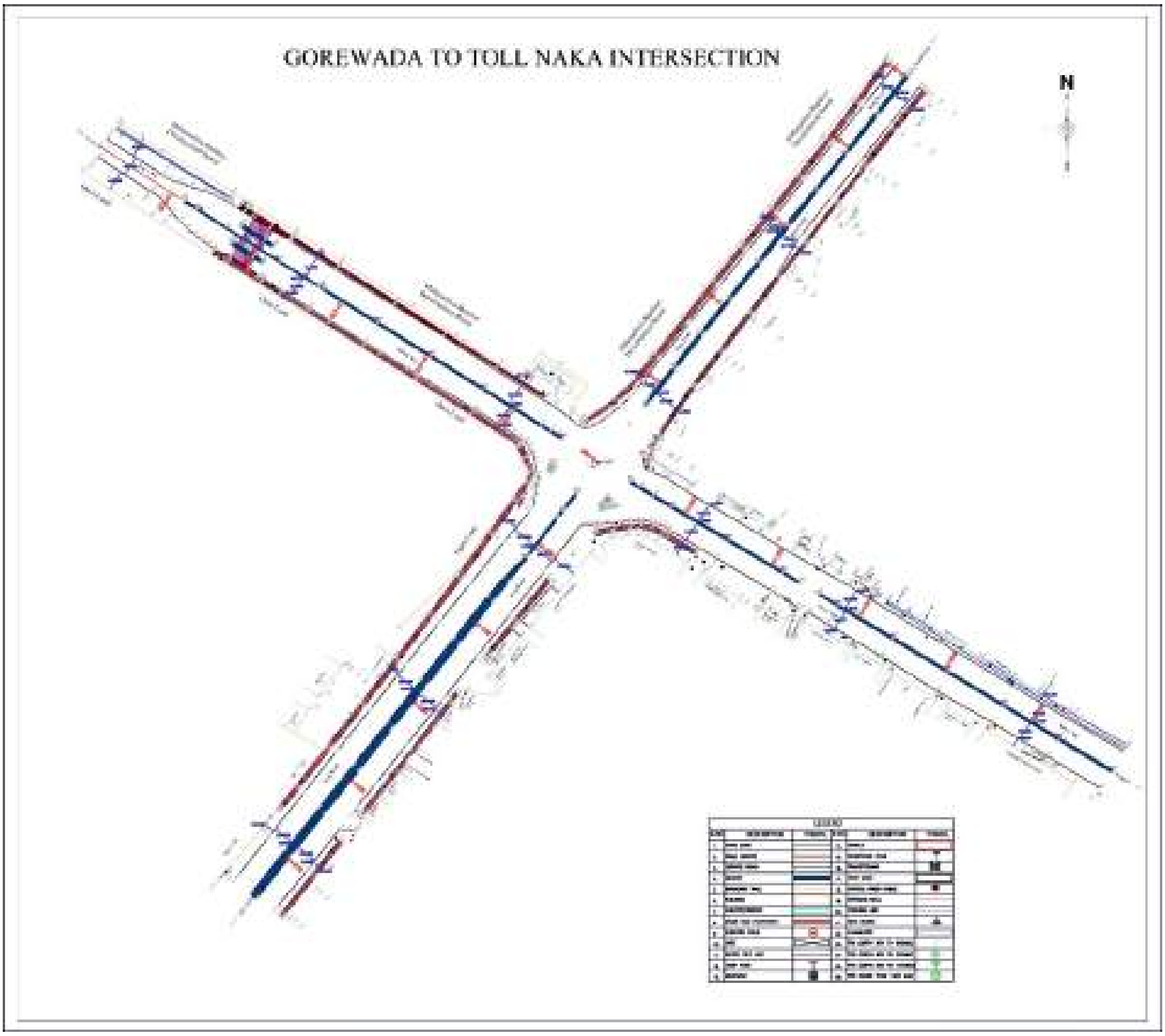


Figure 4.69 Physical Survey Plan of the Gorewada to Toll Naka Intersection

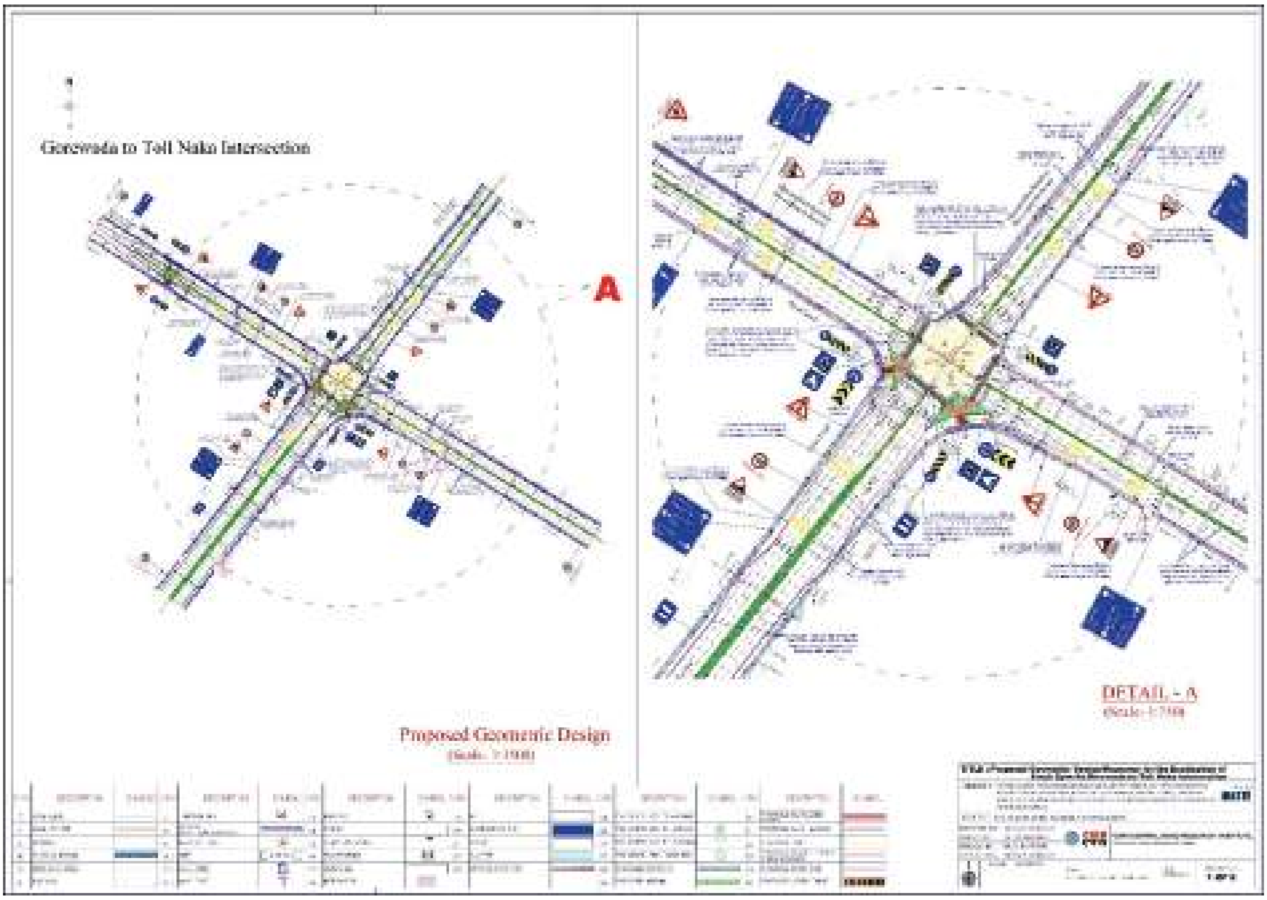


Figure 4.70 Detailed GDP for the Gorewada to Toll Naka Road Intersection

4.4.27 Mayo Square: Base Plan and GDP

Figure 4.71 depicts the physical survey plan depicting the present conditions whereas Figure 4.72 presents the detailed Geometric Design Plan (GDP) conceived for the Mayo Square spanning a length of 250 m on each of the approach arms of the blackspot.

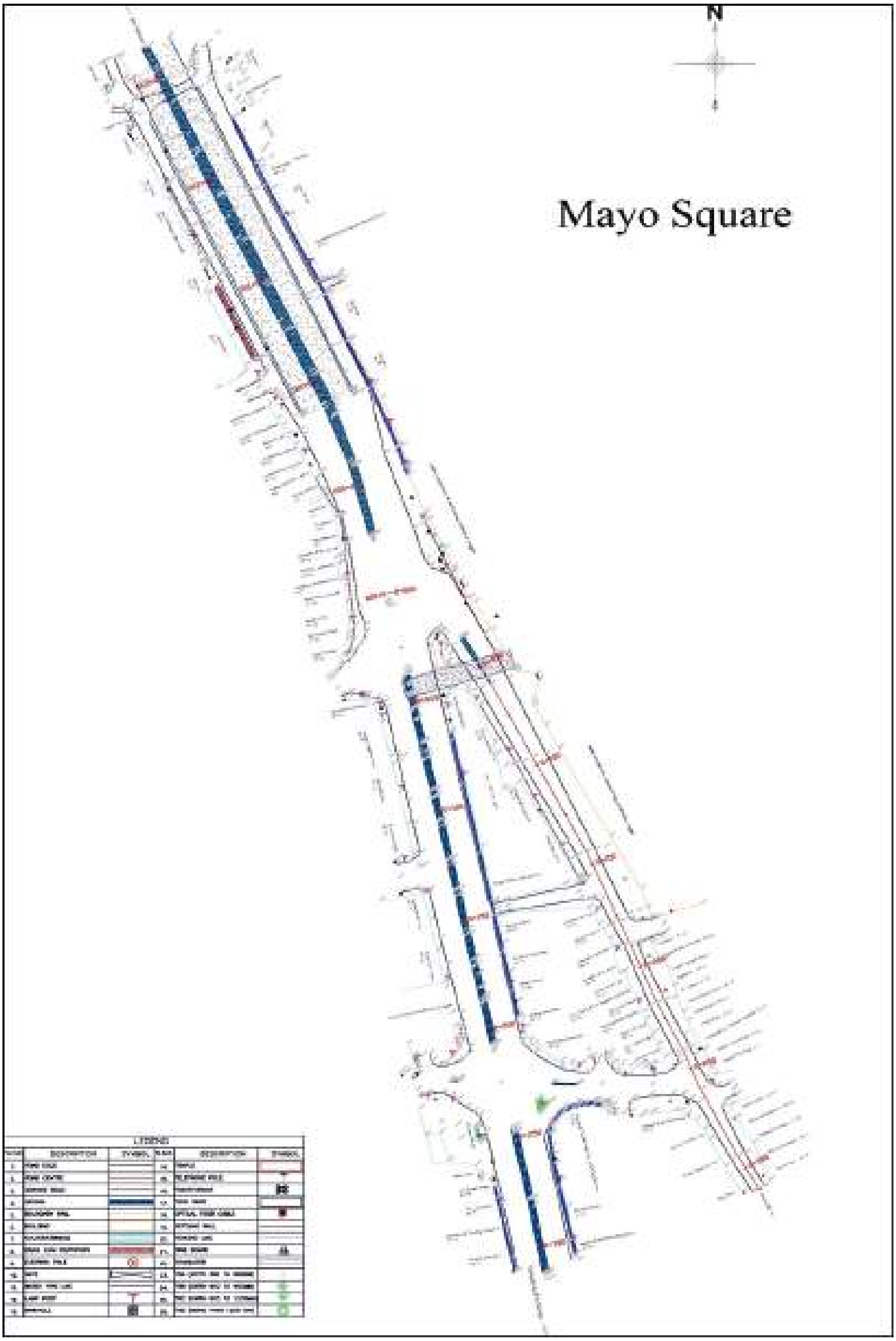


Figure 4.71 Physical Survey Plan of the Mayo Square

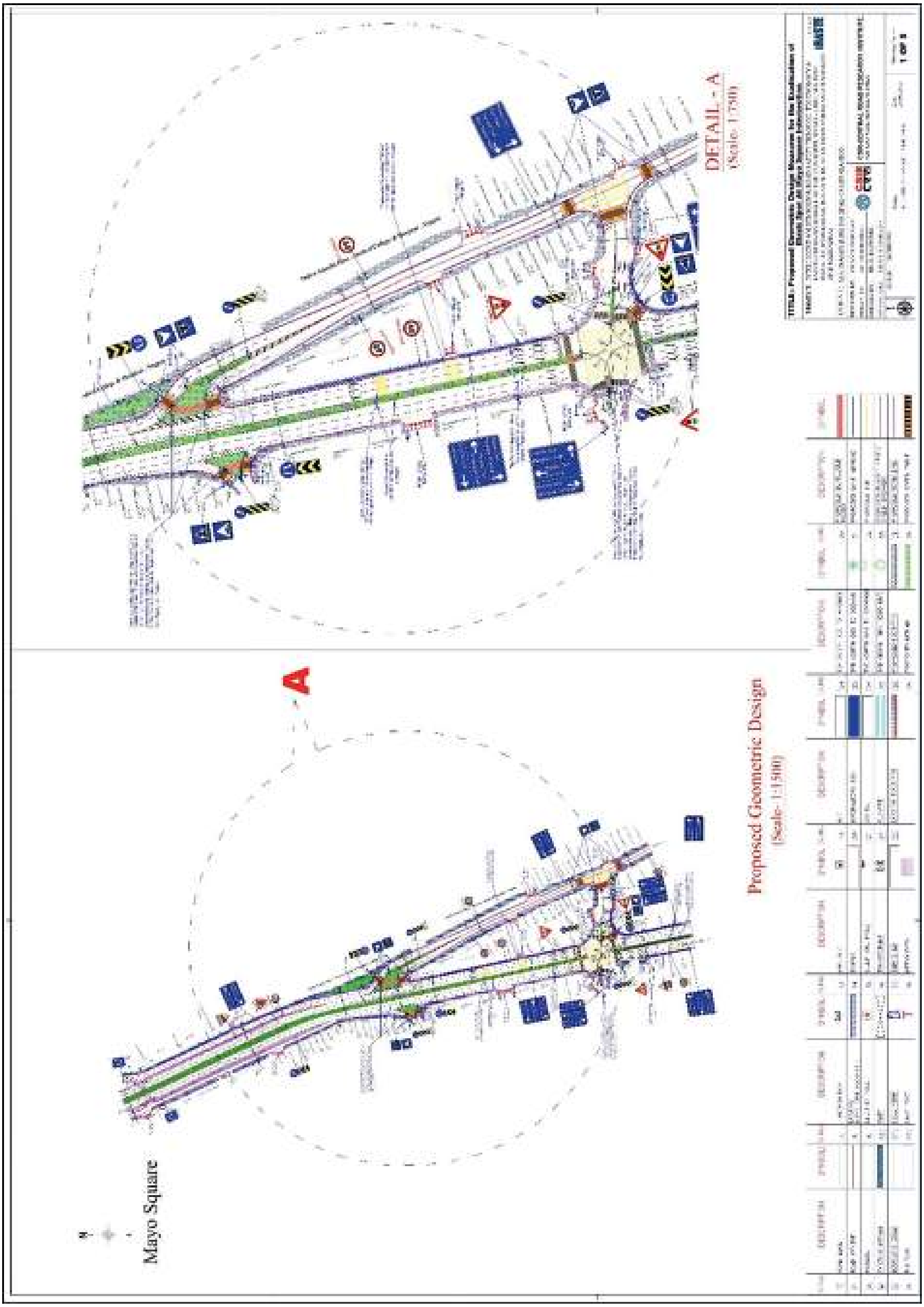


Figure 4.72 Detailed GDP for the Mayo Square

4.4.28 Veerghav Square (Omkar Nagar): Base Plan and GDP

Figure 4.73 depicts the physical survey plan depicting the present conditions whereas Figure 4.74 presents the detailed Geometric Design Plan (GDP) conceived for the Veerghav Square (Omkar Nagar) spanning a length of 250 m on each of the approach arms of the blackspot.

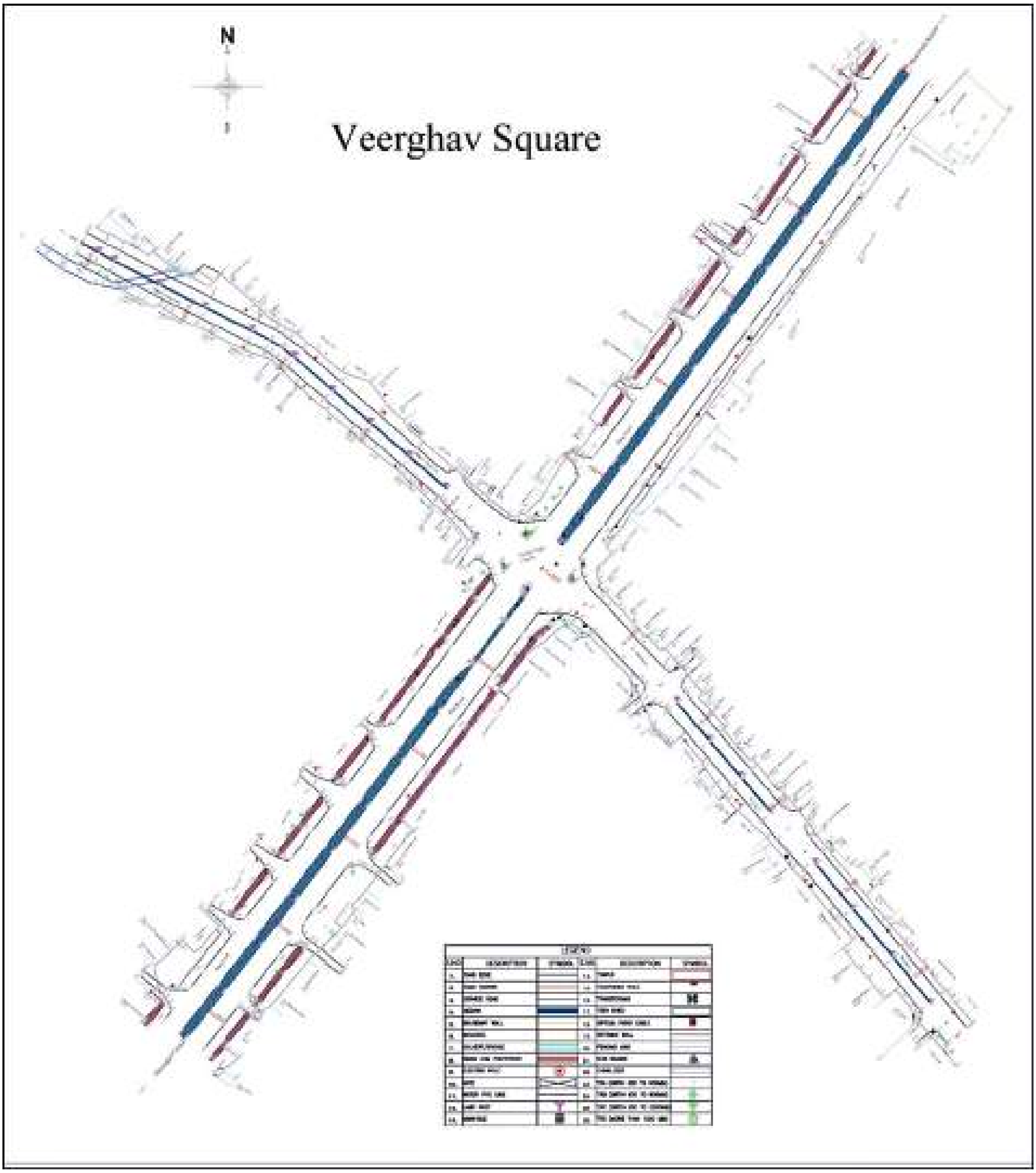


Figure 4.73 Physical Survey Plan of the Veerghav Square (Omkar Nagar)

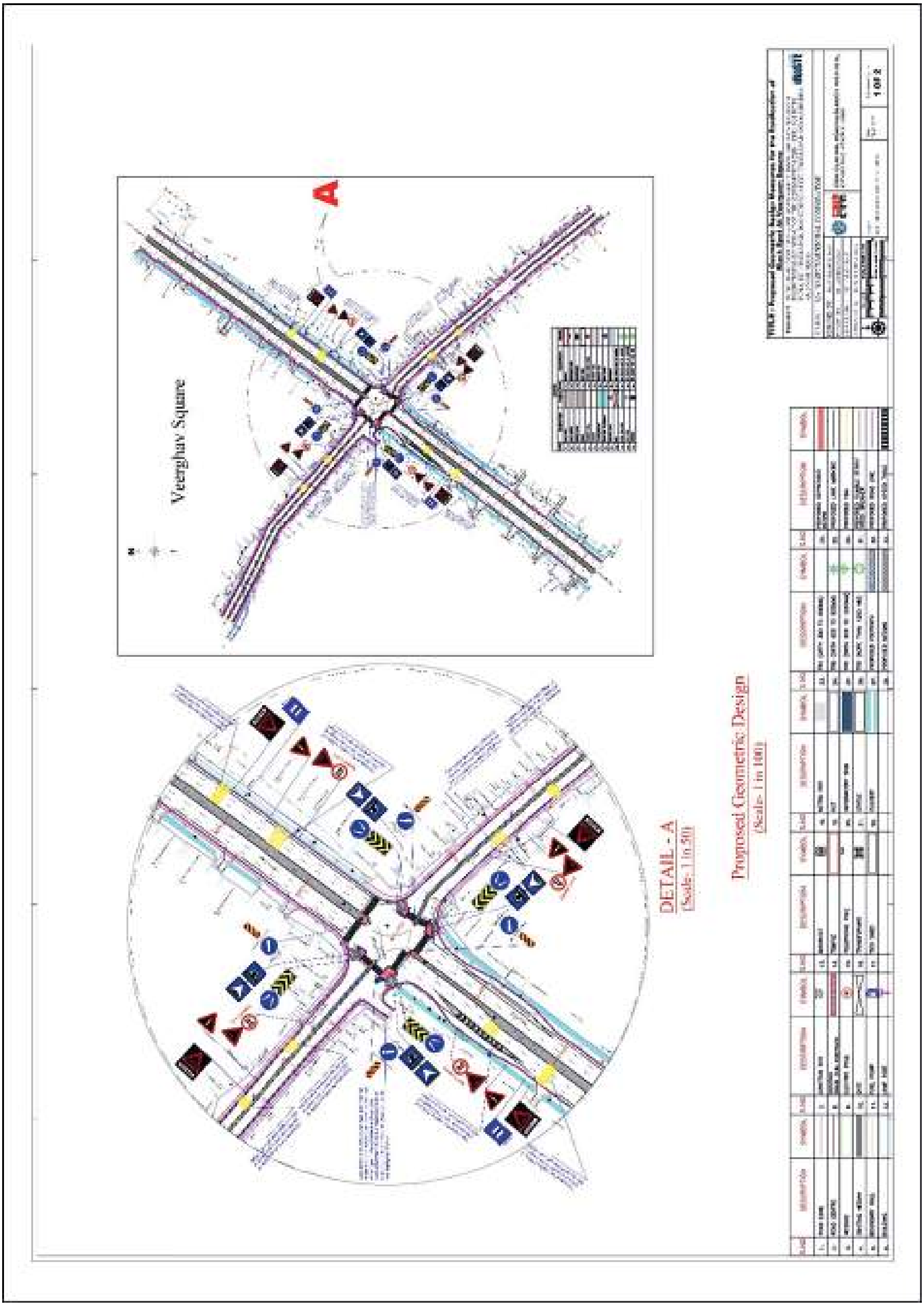


Figure 4.74 Detailed GDP for the Veerghav Square (Omkar Nagar)

4.4.29 Mhalgi Nagar Square: Base Plan and GDP

Figure 4.75 depicts the physical survey plan depicting the present conditions whereas Figure 4.76 presents the detailed Geometric Design Plan (GDP) conceived for Mhalgi Nagar Square spanning a length of 250 m on each of the approach arms of the intersection. It may be noted that openness in the intersection area available at present encourages the road users to make haphazardly in the wrong direction and at high speeds which is specifically addressed in the GDP.

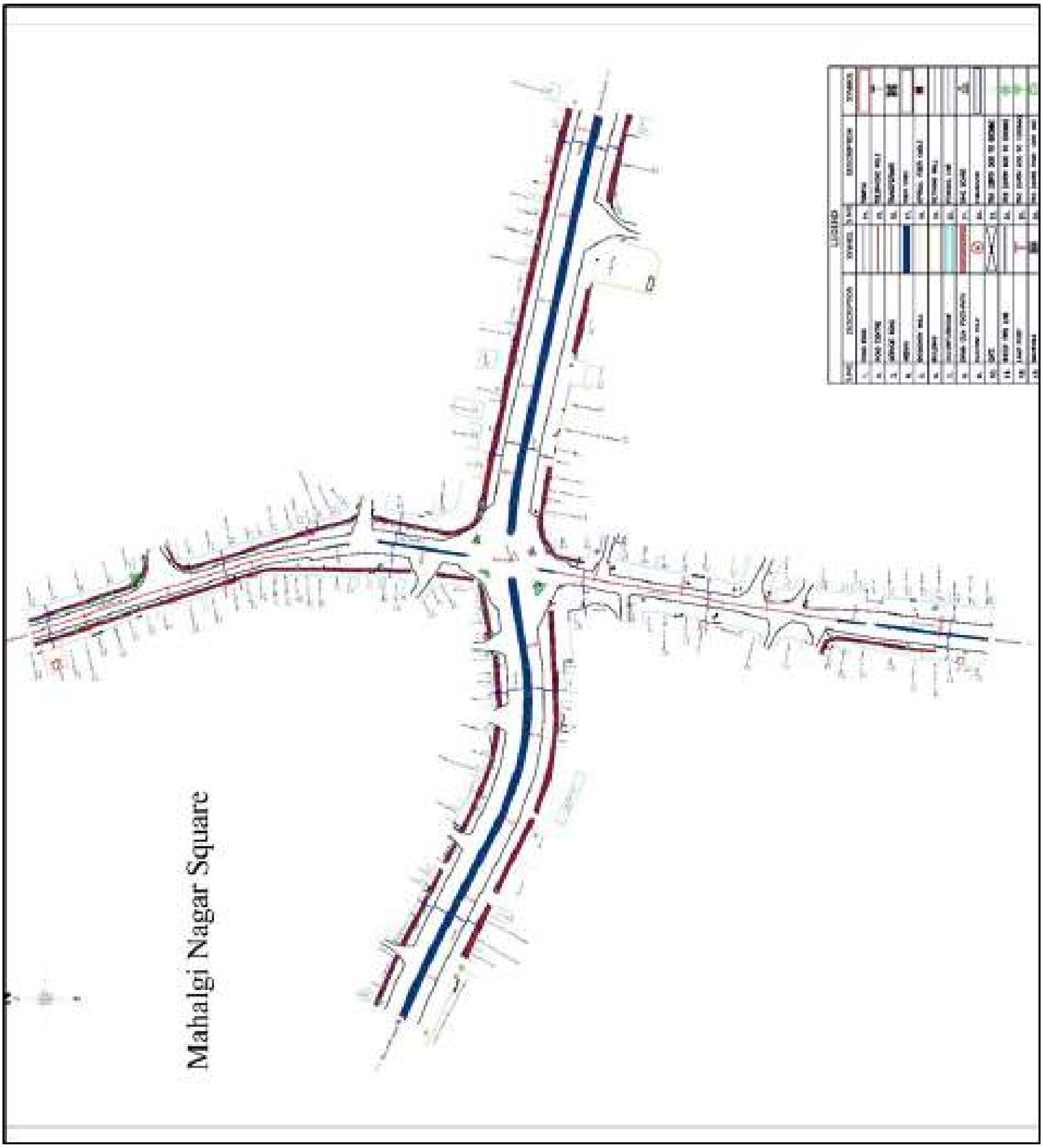


Figure 4.75 Physical Survey Plan of Mhalgi Nagar Square

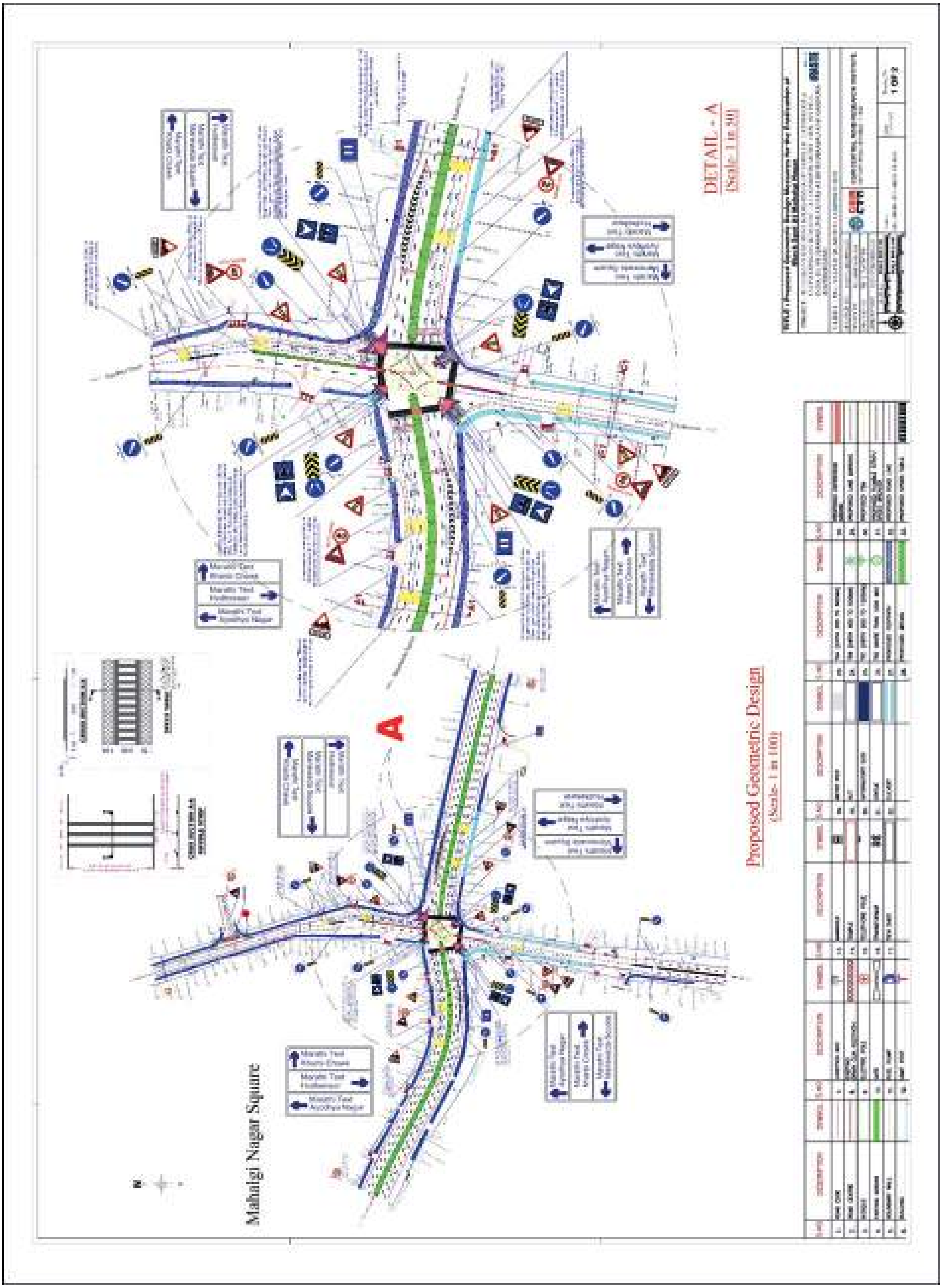


Figure 4.76 Proposed Detailed GDP for Mhalgi Nagar Squar

4.4.30 Manewada Square: Base Plan and GDP

Figure 4.77 depicts the physical survey plan depicting the present conditions whereas Figure 4.78 presents the detailed Geometric Design Plan (GDP) conceived for the Manewada Square spanning a length of 250 m on each of the approach arms of the blackspot.

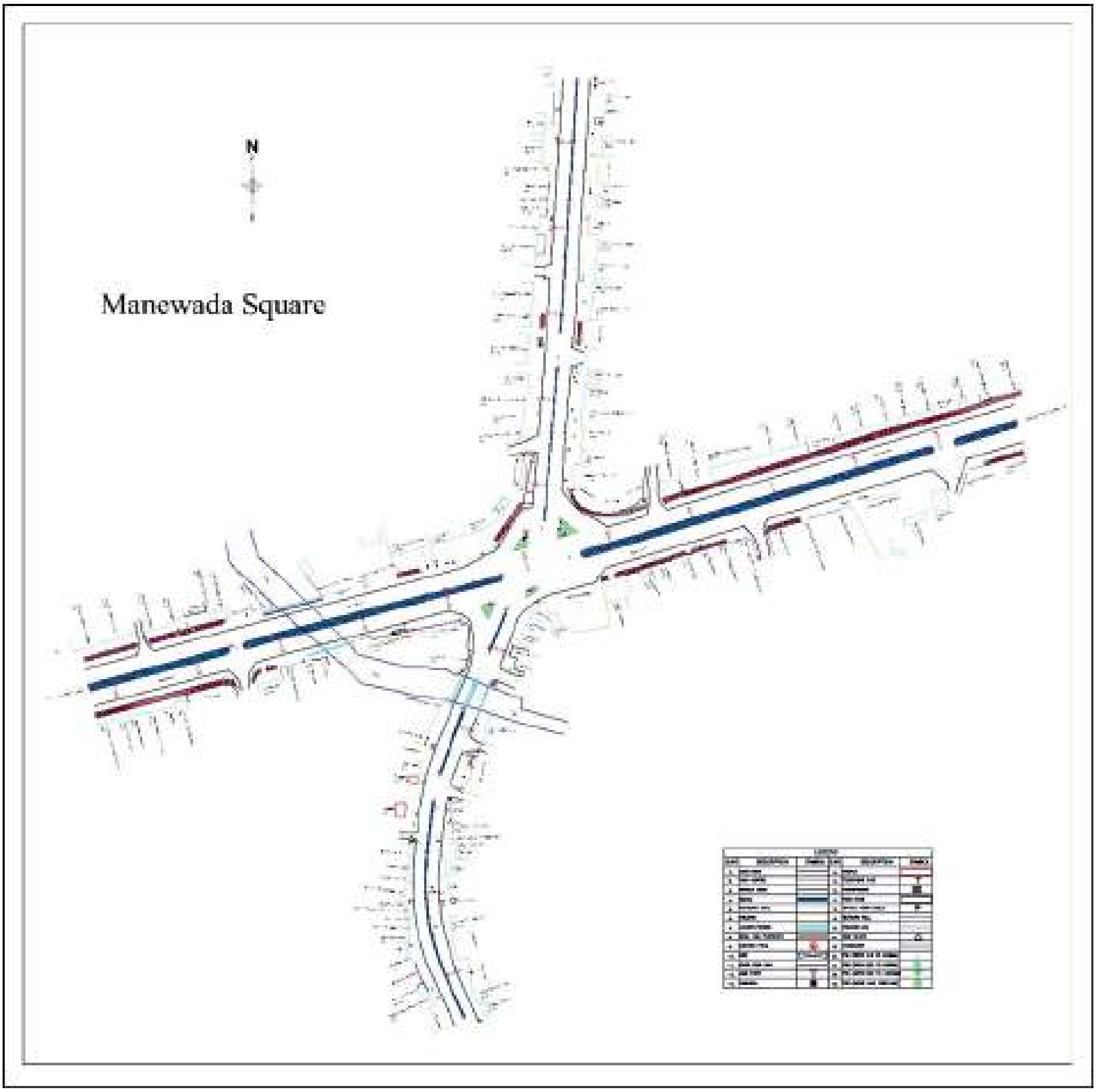


Figure 4.77 Physical Survey Plan of the Manewada Square

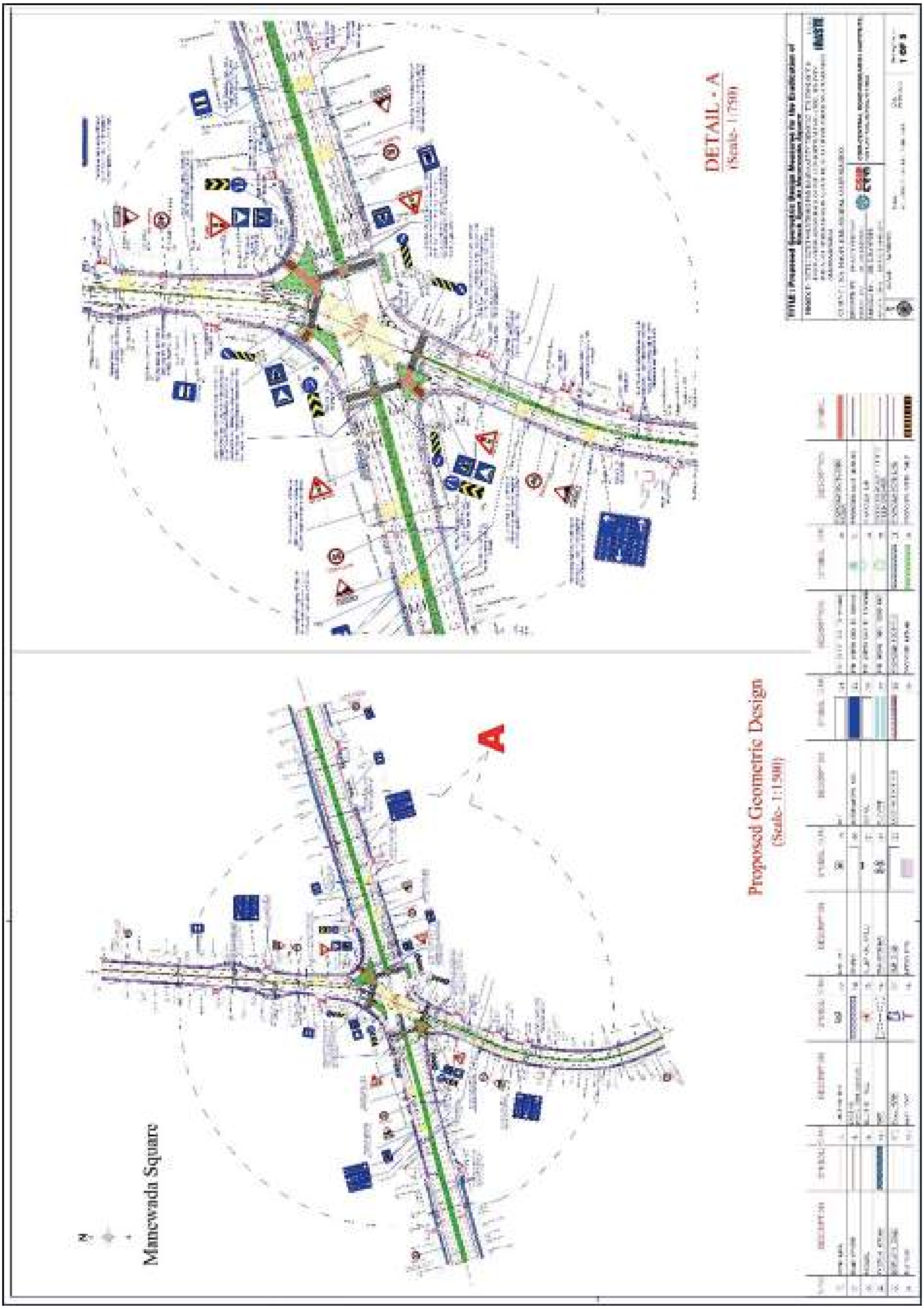


Figure 4.78 Detailed GDP for the Manewada Square Road stretch

4.4.31 Shrinagar Square: Base Plan and GDP

Figure 4.79 depicts the physical survey plan depicting the present conditions whereas Figure 4.80 presents the detailed Geometric Design Plan (GDP) conceived for Shrinagar Square spanning a length of 250 m on each of the approach arms of the blackspot.

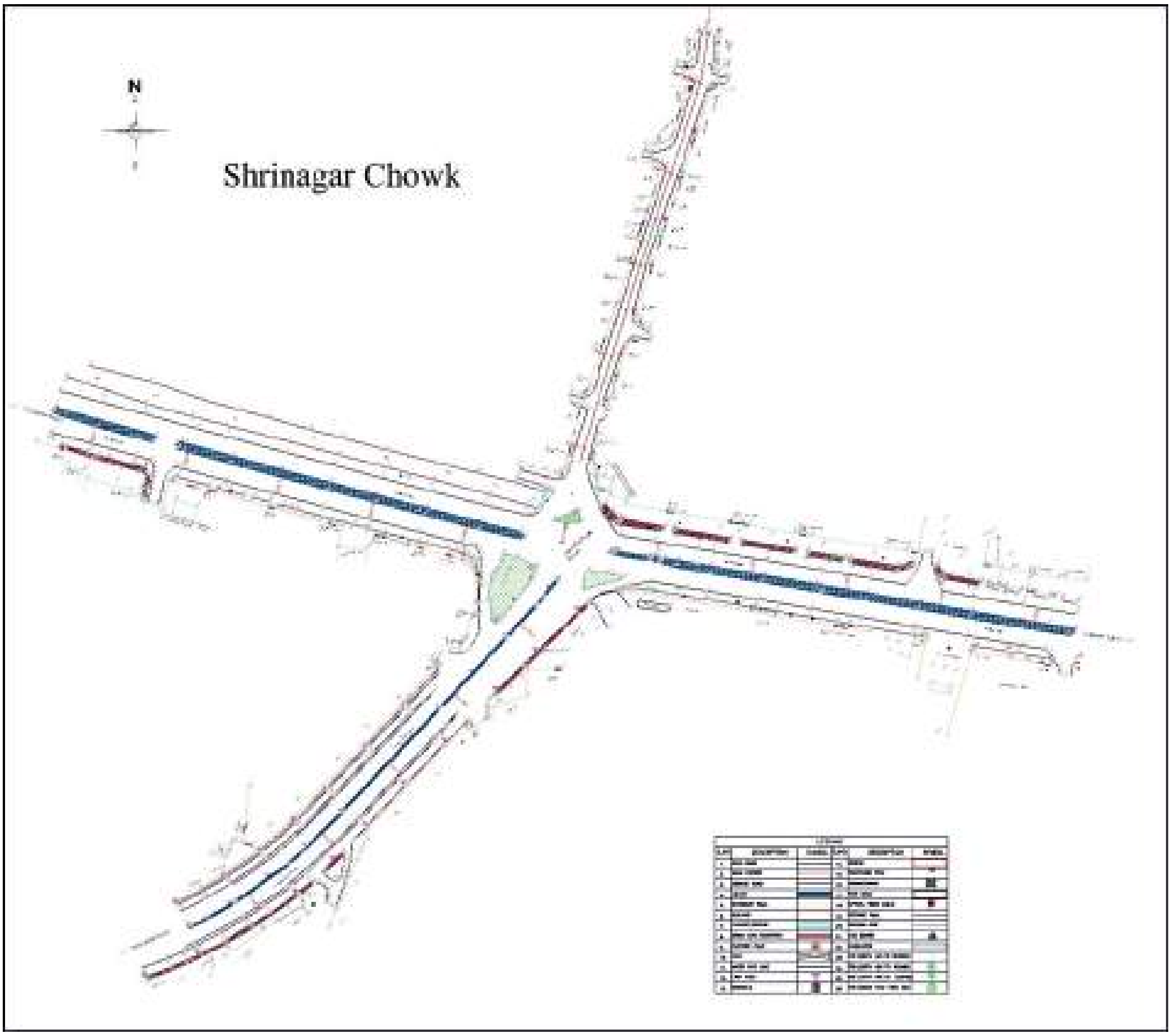


Figure 4.79 Physical Survey Plan of the Shrinagar Square

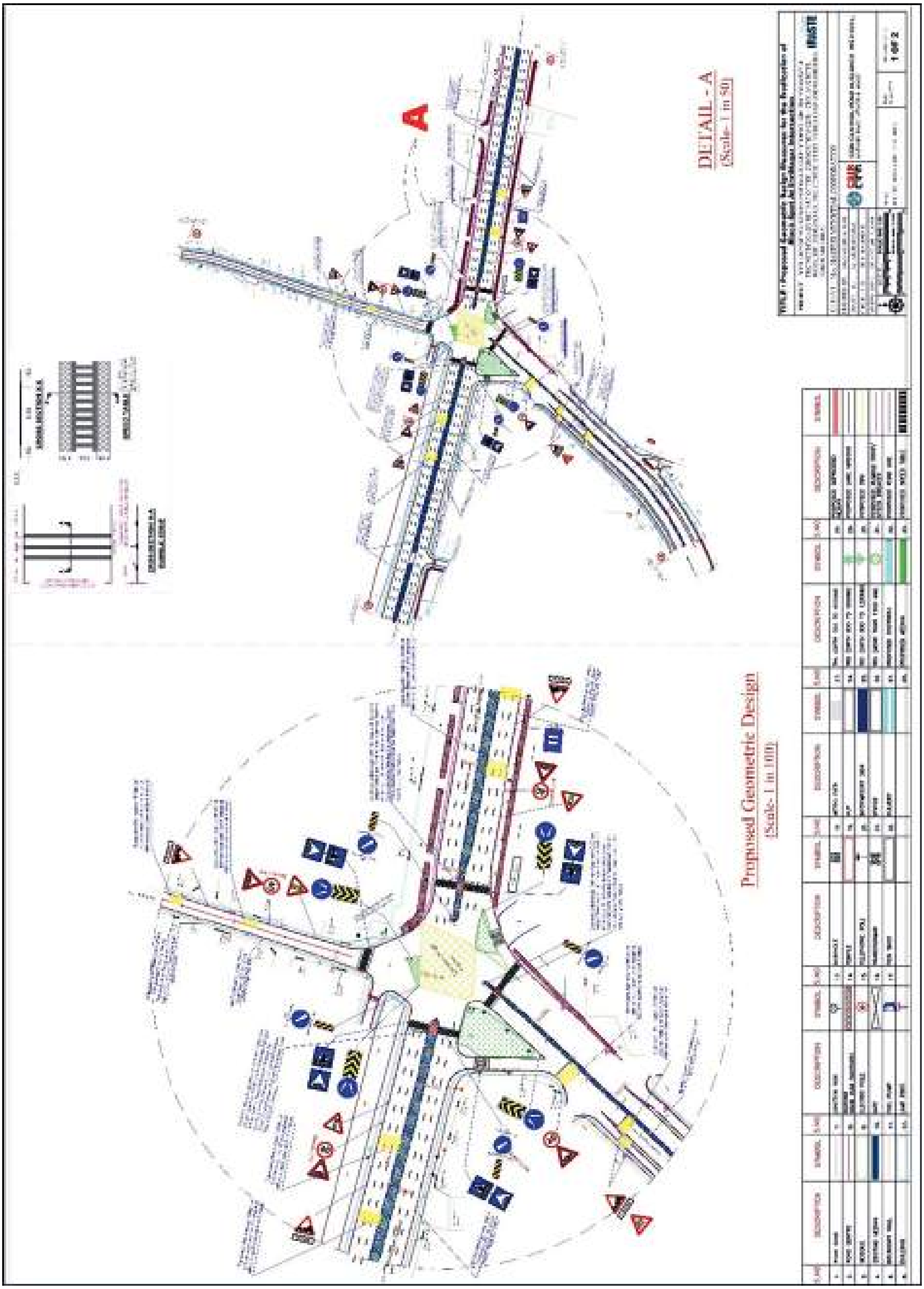


Figure 4.80 Detailed GDP for the Shrinagar Square Road stretch

4.4.32 Mahesh Dhaba: Base Plan and GDP

Figure 4.81 depicts the physical survey plan depicting the present conditions whereas Figure 4.82 presents the detailed Geometric Design Plan (GDP) conceived for the Mahesh Dhaba Intersection spanning a length of 250 m on either side of the blackspot.

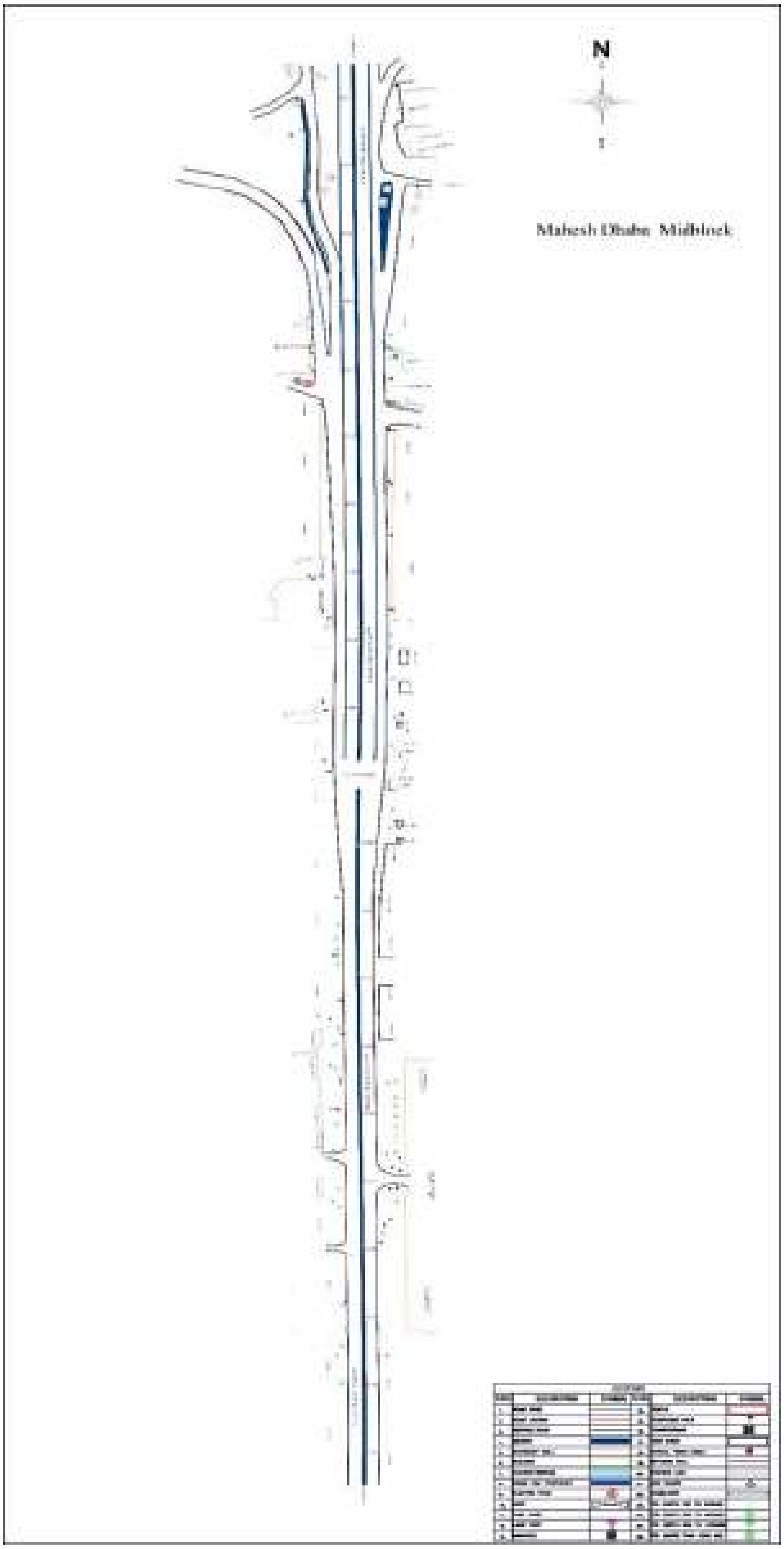


Figure 4.81 Physical Survey Plan of the Mahesh Dhaba

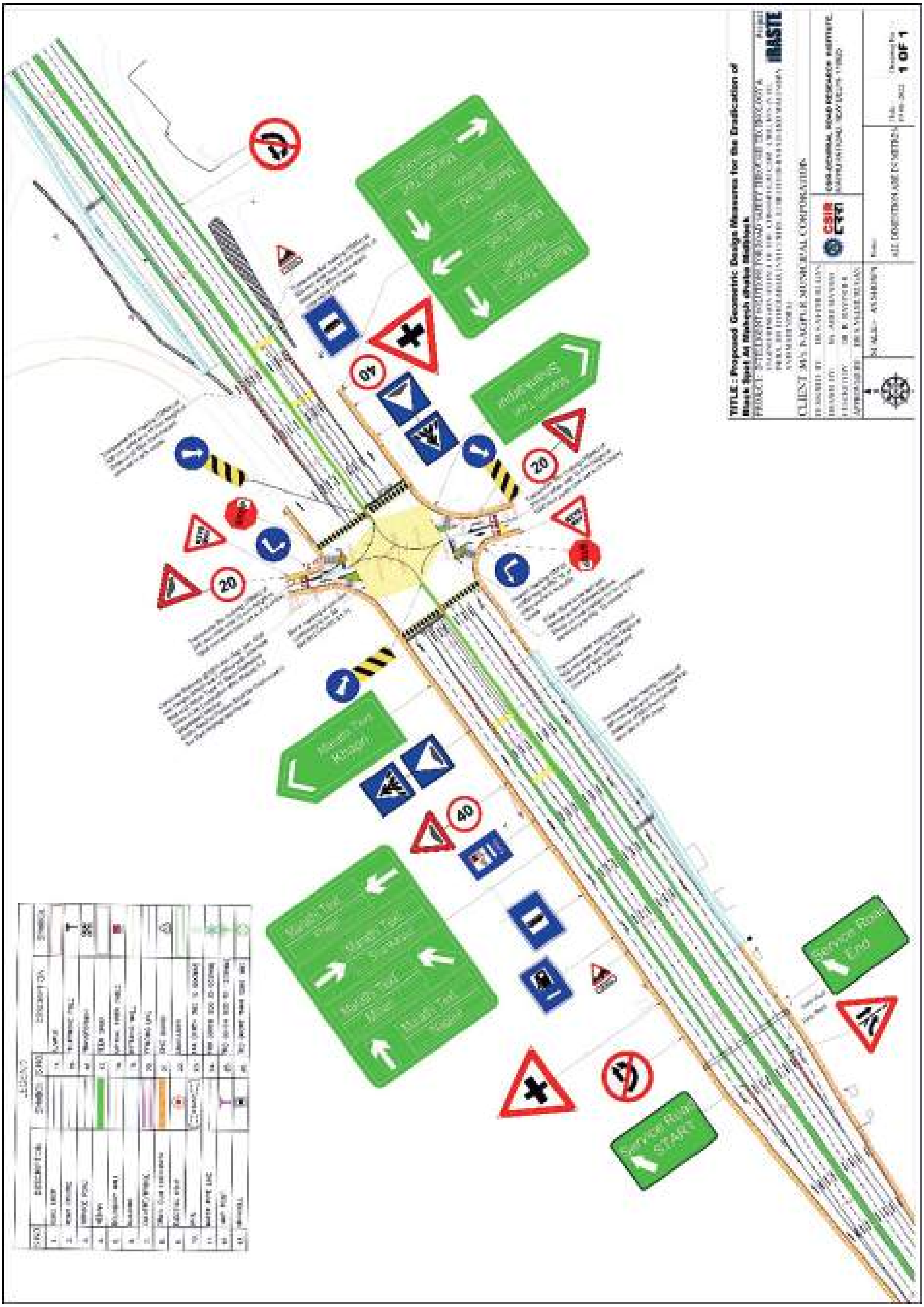


Figure 4.82 Detailed Geometric Design Plan (GDP) for the Mahesh Dhaba

4.4.33 Chinchbhavan Square: Base Plan and GDP

Figure 4.83 depicts the physical survey plan depicting the present conditions whereas Figure 4.84 presents the detailed Geometric Design Plan (GDP) conceived for the Chinchbhavan Square spanning a length of 250 m on each of the approach arms of the blackspot.

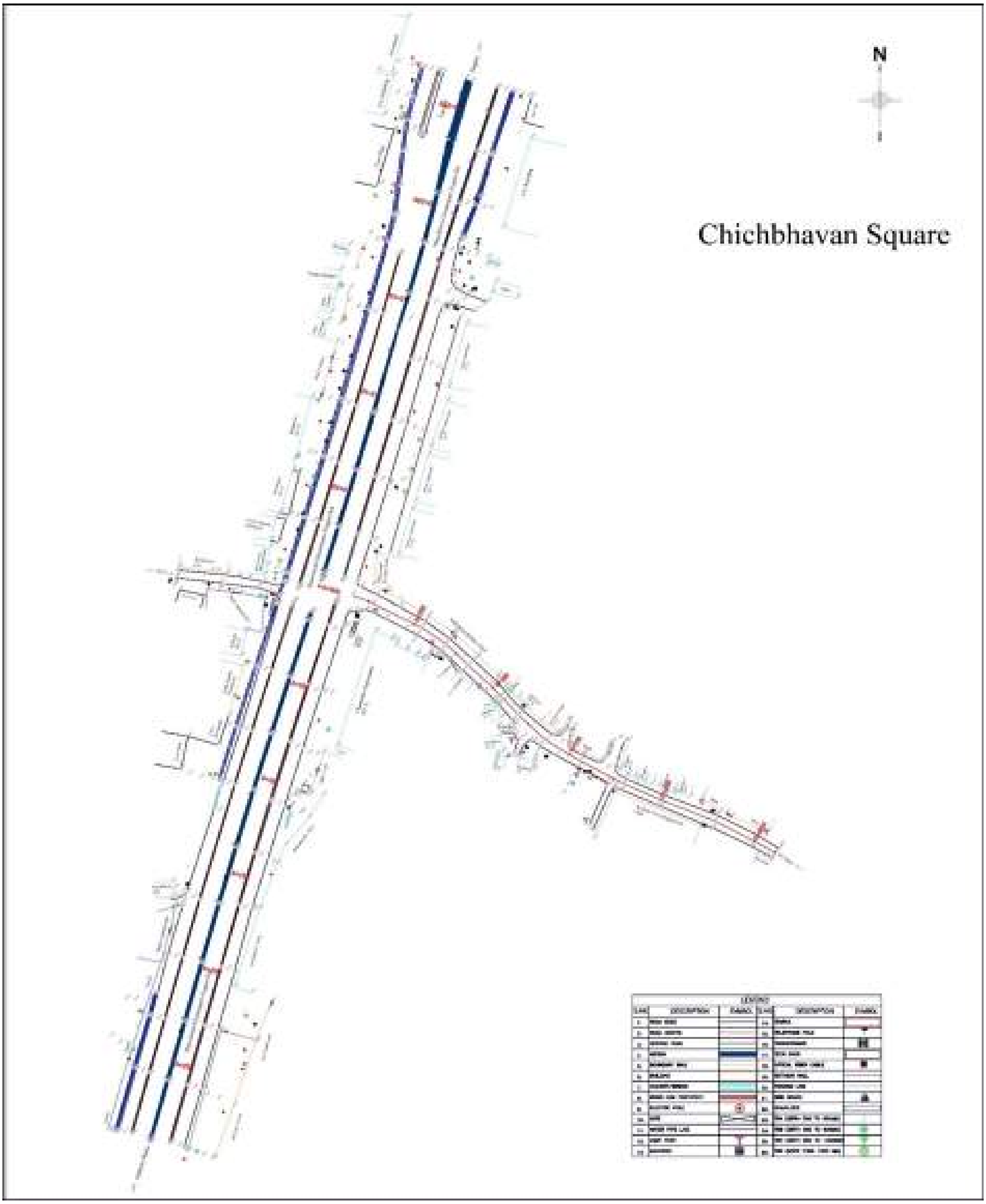


Figure 4.83 Physical Survey Plan of the Chinchbhavan Square

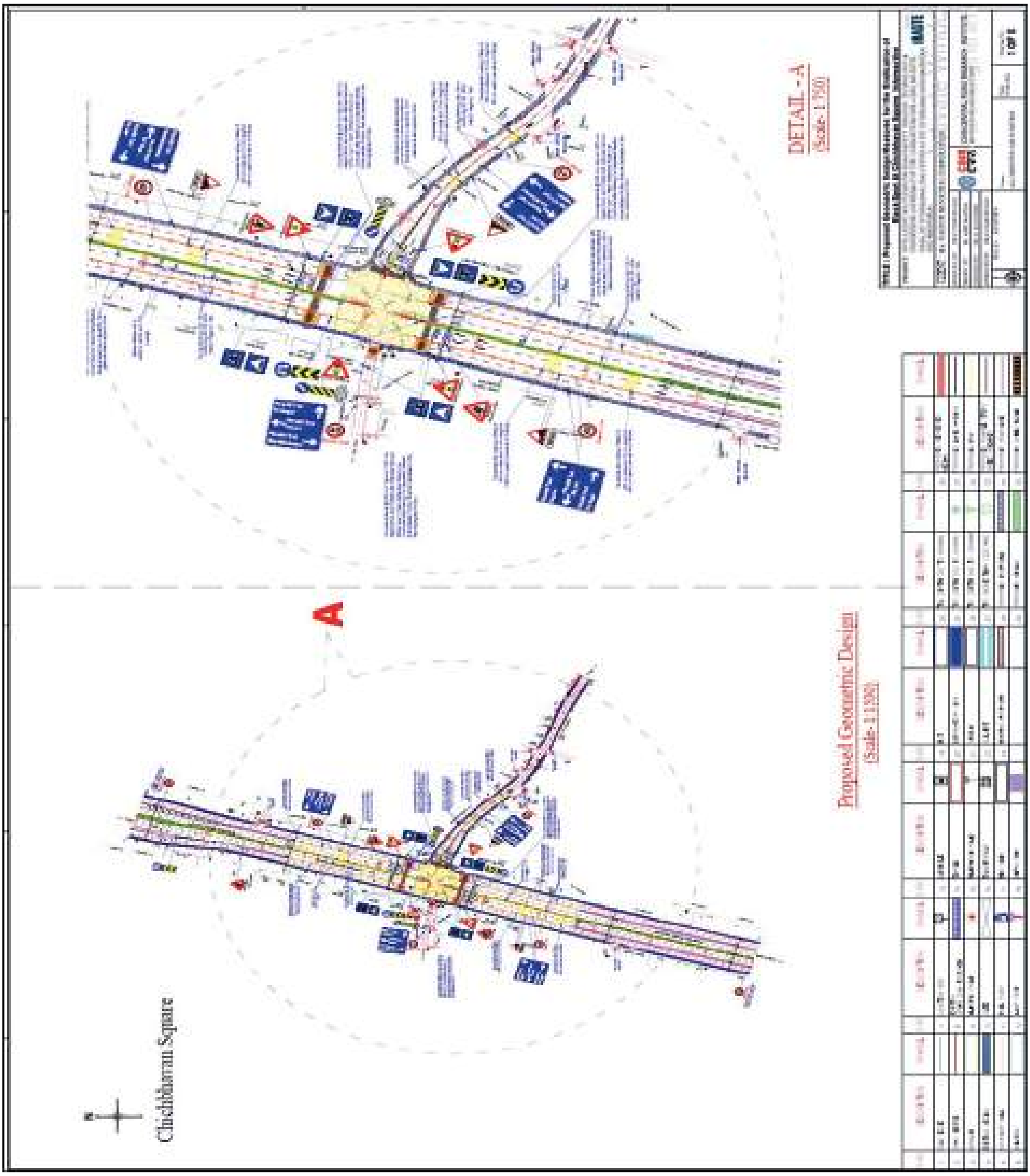


Figure 4.84 Detailed GDP for the Chinchbhavan Square

4.4.34 Kharbi Chowk: Base Plan and GDP

Figure 4.85 depicts the physical survey plan depicting the present conditions whereas Figure 4.86 presents the detailed Geometric Design Plan (GDP) conceived for the intersection of Kharbi chowk stretch spanning a length of 250 m on each of the approach arms of the blackspot.

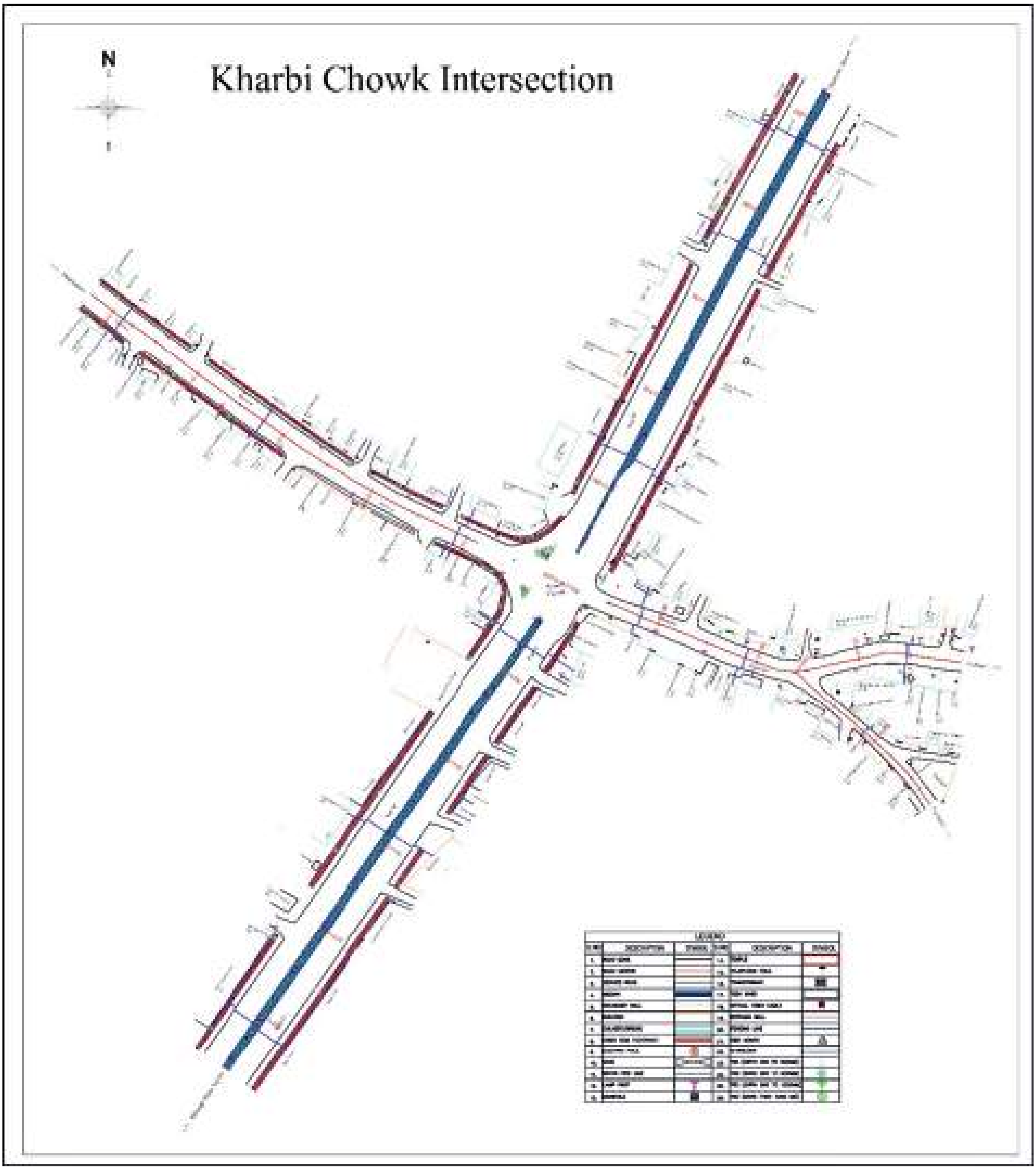


Figure 4.85 Physical Survey Plan of the Kharbi Square

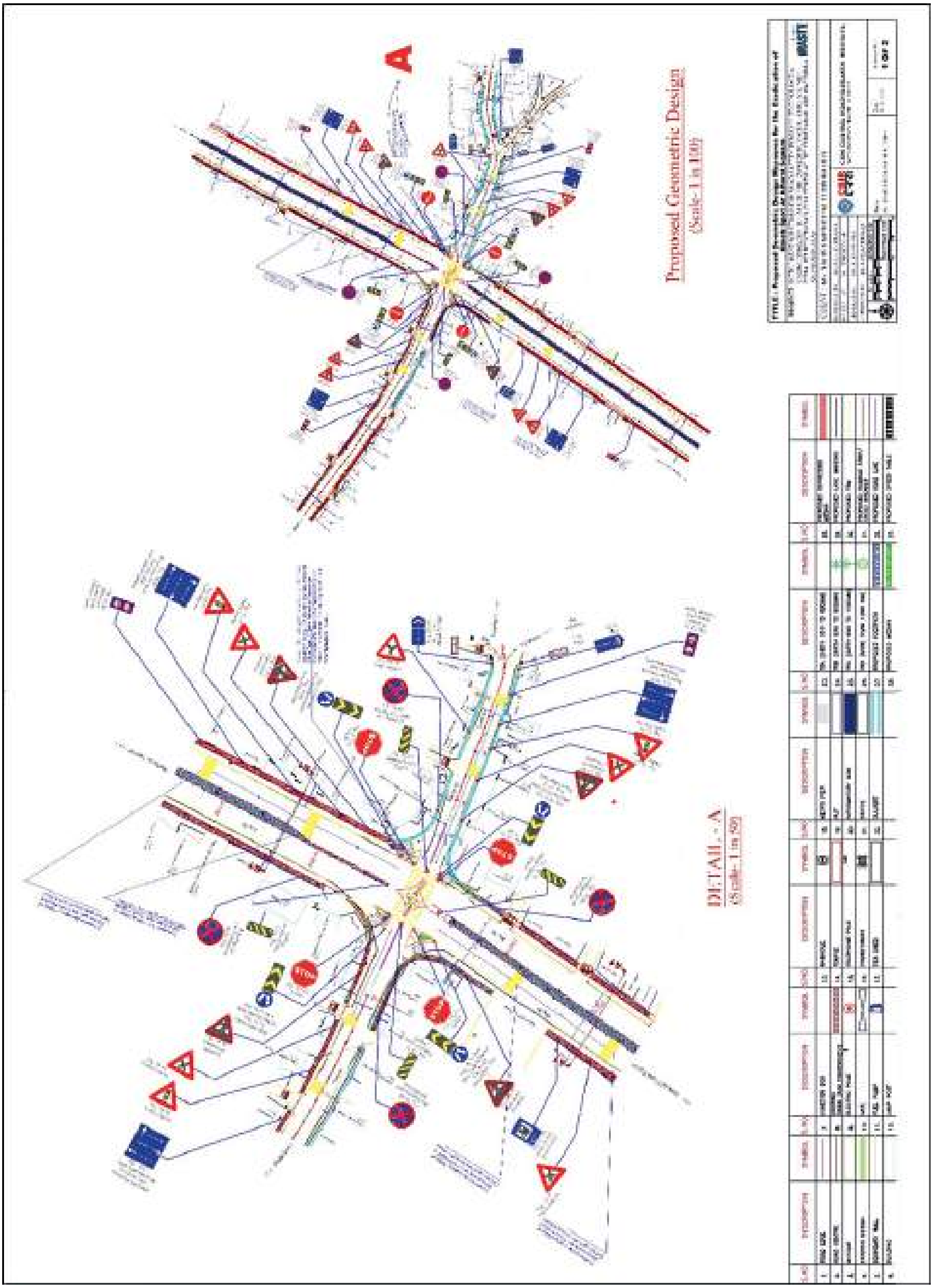


Figure 4.86 Detailed GDP for the Kharbi Square

4.4.35 Shitla Mata Square: Base Plan and GDP

Figure 4.87 depicts the physical survey plan depicting the present conditions whereas Figure 4.88 presents the detailed Geometric Design Plan (GDP) conceived for the Shitla Mata Square spanning a length of 250 m on each of the approach arms of the blackspot.

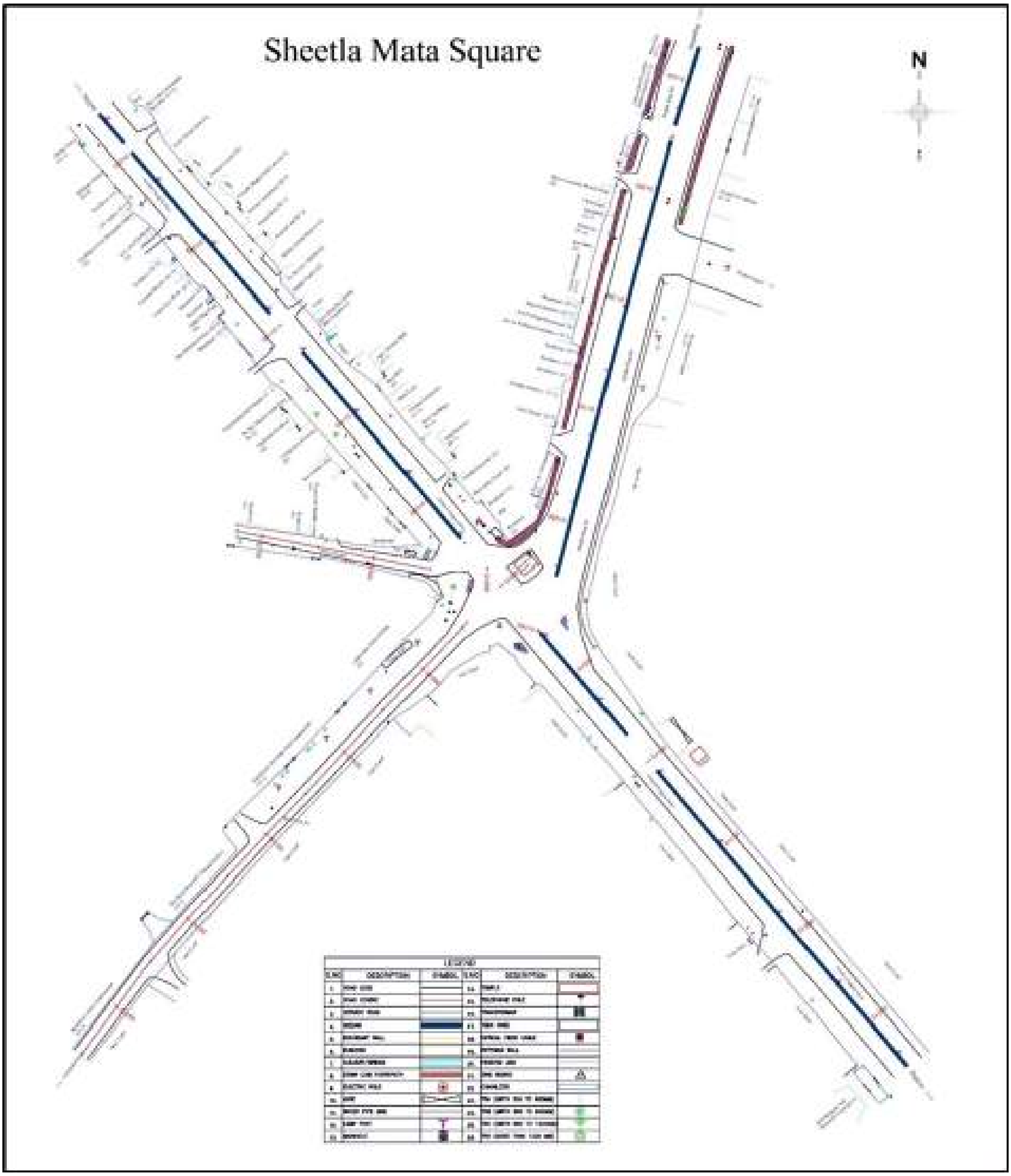


Figure 4.87 Physical Survey Plan of the Shitla Mata Square

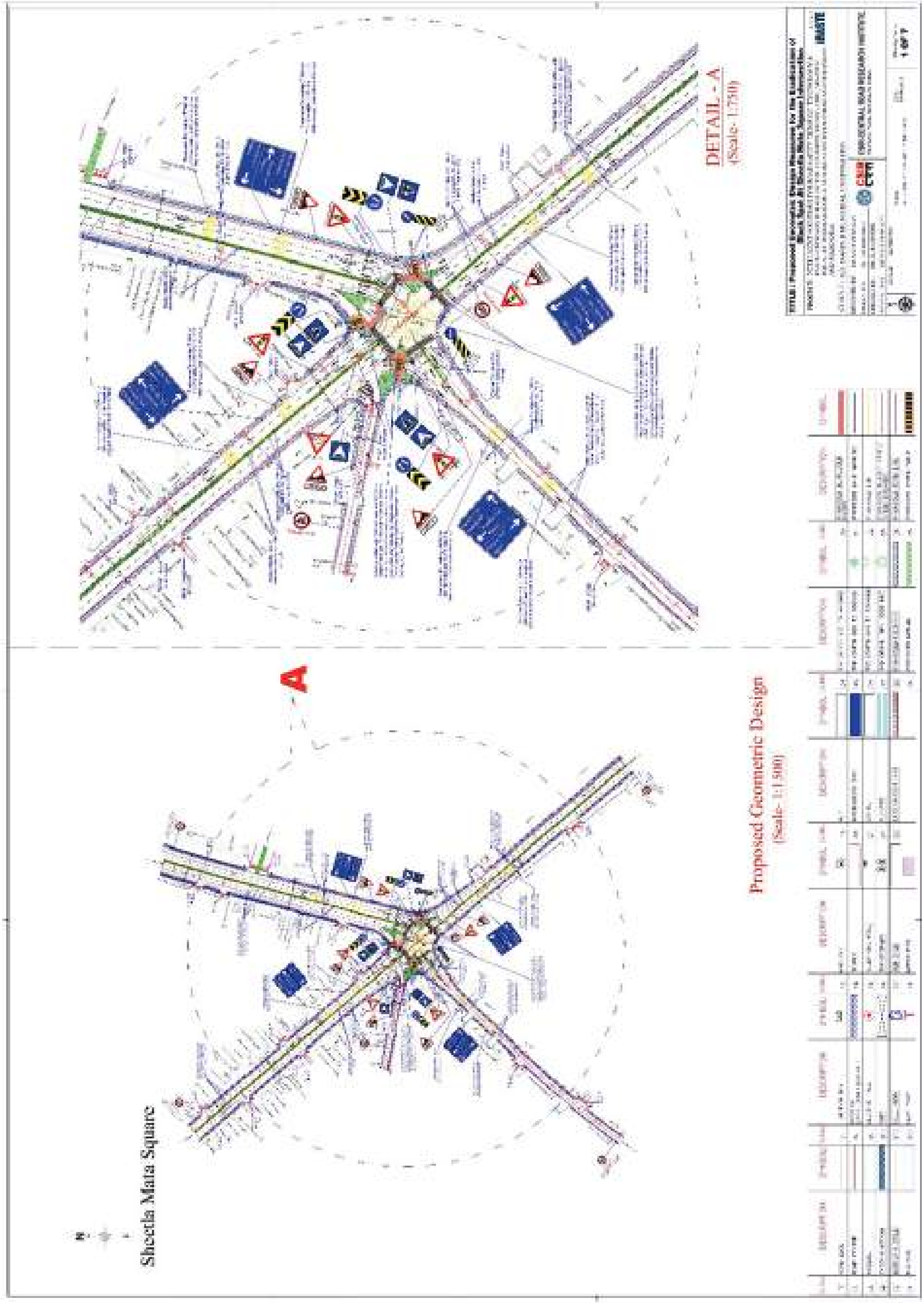


Figure 4.88 Detailed GDP for the Shitla Mata Square

4.4.36 Wathoda Square: Base Plan and GDP

Figure 4.89 depicts the physical survey plan depicting the present conditions whereas Figure 4.90 presents the detailed Geometric Design Plan (GDP) conceived for the Wathoda Square spanning a length of 250 m on each of the approach arms of the blackspot.

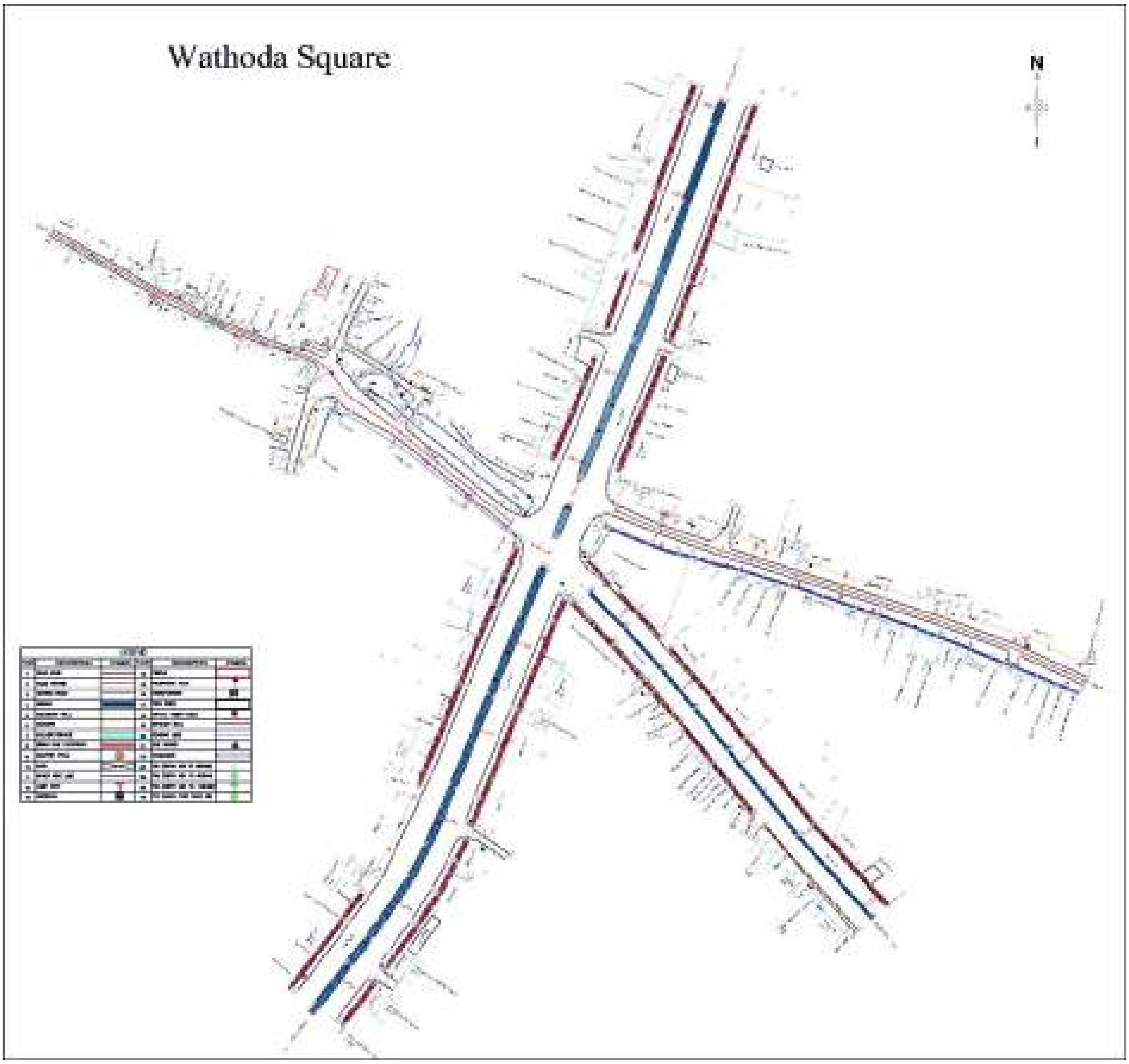


Figure 4.89 Physical Survey Plan of the Wathoda Square

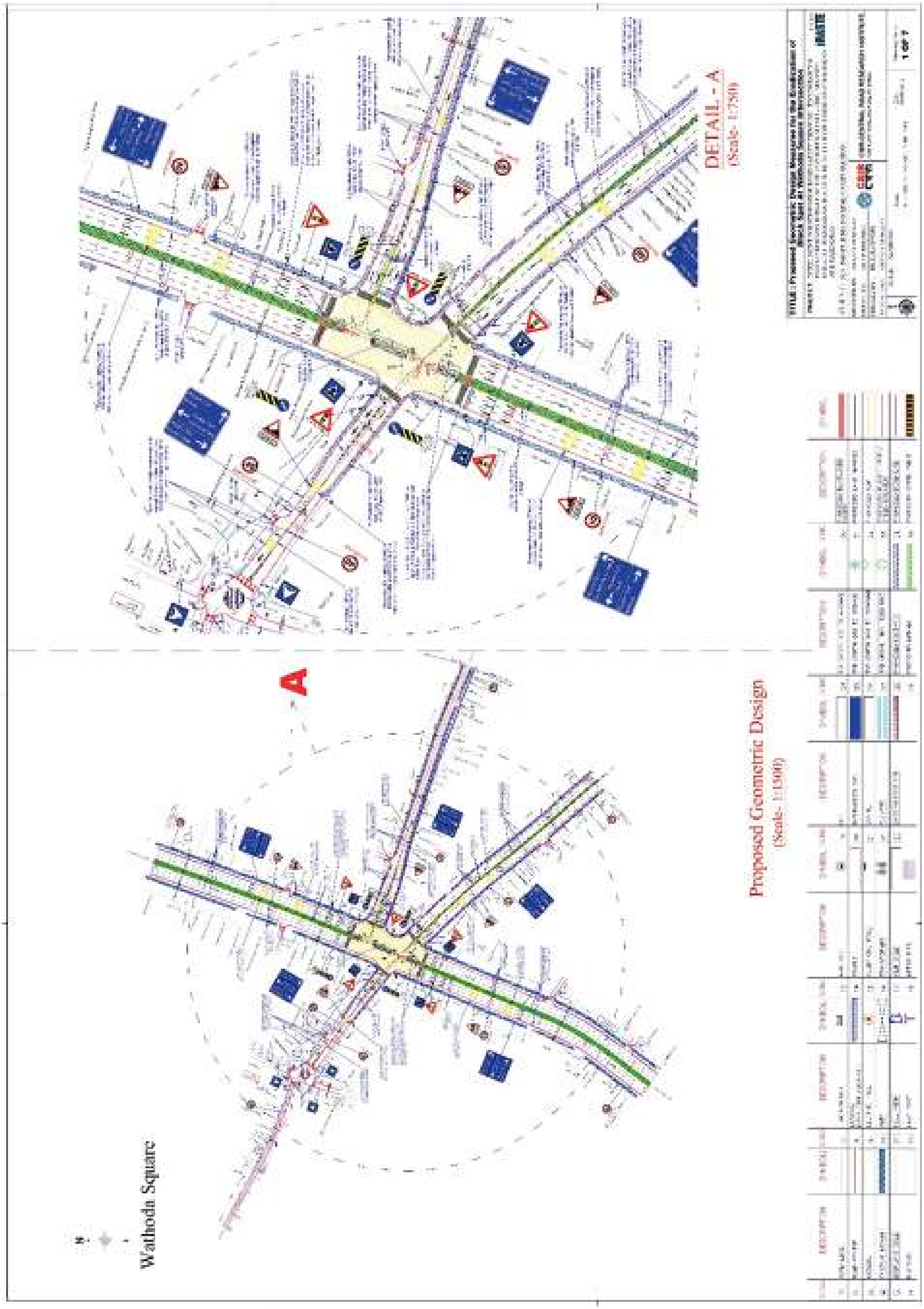


Figure 4.90 Detailed GDP for the Wathoda Square

4.4.37 Chikli Square: Base Plan and GDP

Figure 4.91 depicts the physical survey plan depicting the present conditions whereas Figure 4.92 *(Option 1)* and Figure 4.93 *(Option 2)* presents the detailed Geometric Design Plan *(GDP)* conceived for the Chikli Square spanning a length of 250 m on each of the approach arms of the intersection. It may be noted that openness in the intersection areas available at present encourages the road users to move haphazardly in the wrong direction and at high speeds. It is expected that the implementation of either one of the conceived design improvements at the above intersection spanning a length of 250 on each of the approach arms will help to eliminate the location from appearing in the list of blackspots and thus address the road safety issues. Out of the two GDP options conceived Chikli Square, Option 2 providing guided U – Turn on the major approach has the following advantages:

a)Reduction of conflicts from 24 to 8 nos.
b)Make use of availability of RoW to provide the guided U- Turns
c)Reduce the speeds by Streamlining the traffic at the intersection area.
d)Taking on board the % of right turning flows esp. during the peak hour flow and
e)Poor adherence to the existing traffic signals by all types of traffic which is noted during the CVC survey.

Considering the inherent advantages mentioned above, Option 2 can be considered by NMC for implementation

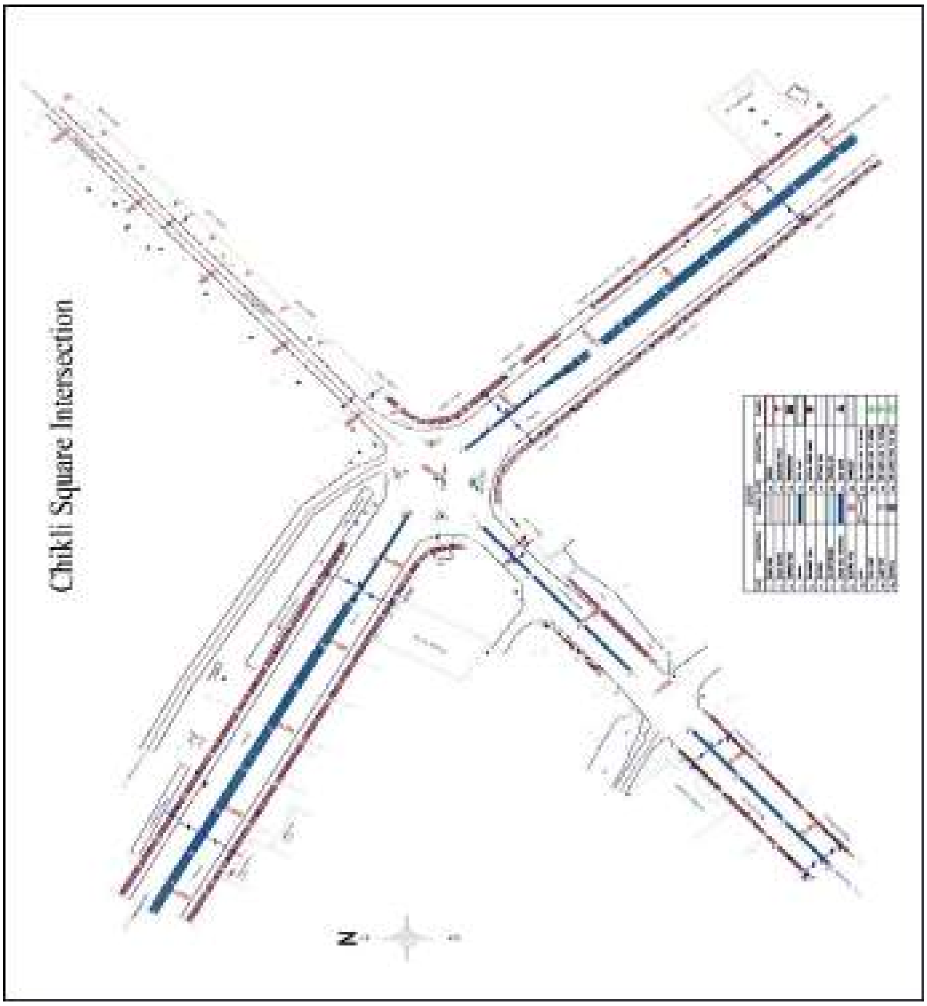


Figure 4.91 Physical Survey Plan of Chikli Square

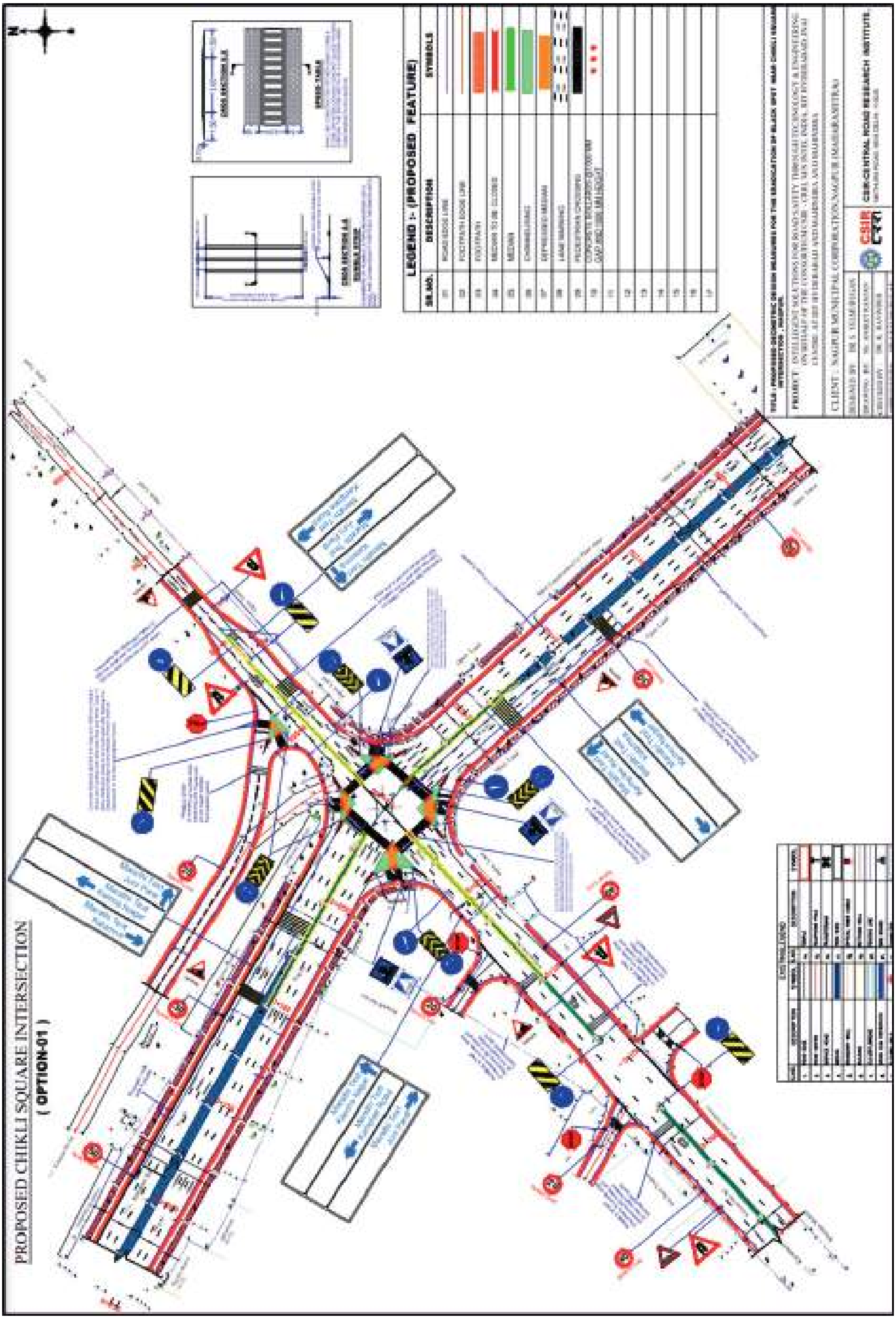


Figure 4.92 Detailed GDP for Chikli Square: Option 1

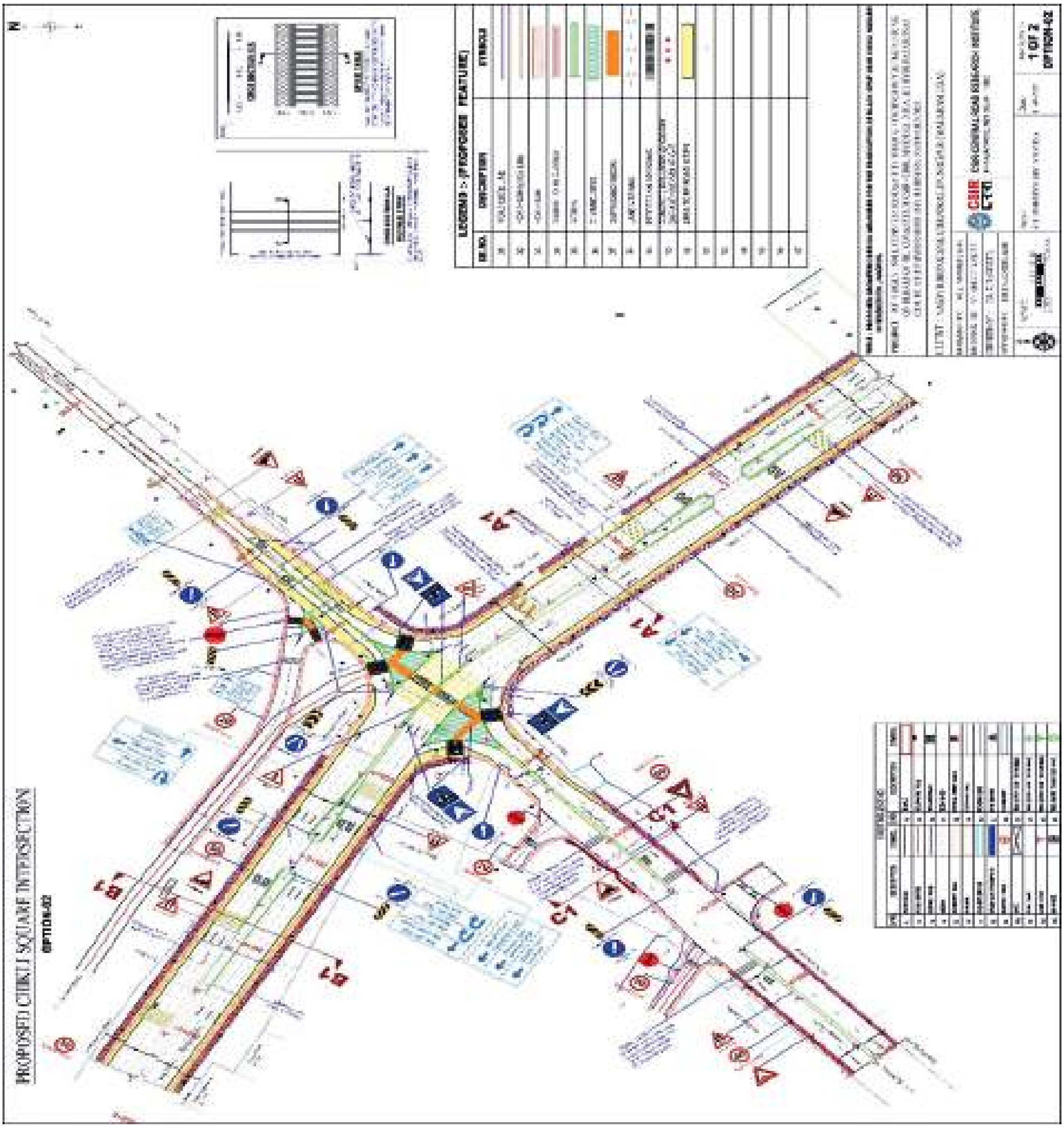


Figure 4.93 Detailed GDP for Chikli Square: Option 2

Figure 4.94 (a) and (b) presents graphical illustration of some of the GDP proposed for Chikli Square Intersection.

a. Proposed Junction Closure on the Major Approach

b. Proposed junction treatment for Pedestrian Crossing

Figure 4.94 Pictorial Illustration of Few of Geometric Design Plans proposed at Chikli Square for Option 2

4.4.38 Maruti Sewa Square, Amravati Road: Base Plan and GDP

Figure 4.95 depicts the physical survey plan depicting the present conditions whereas Figure 4.96 presents the detailed Geometric Design Plan (GDP) conceived for the Maruti Seva Square, Amravati Road spanning a length of 250 m on each of the approach arms of the blackspot.

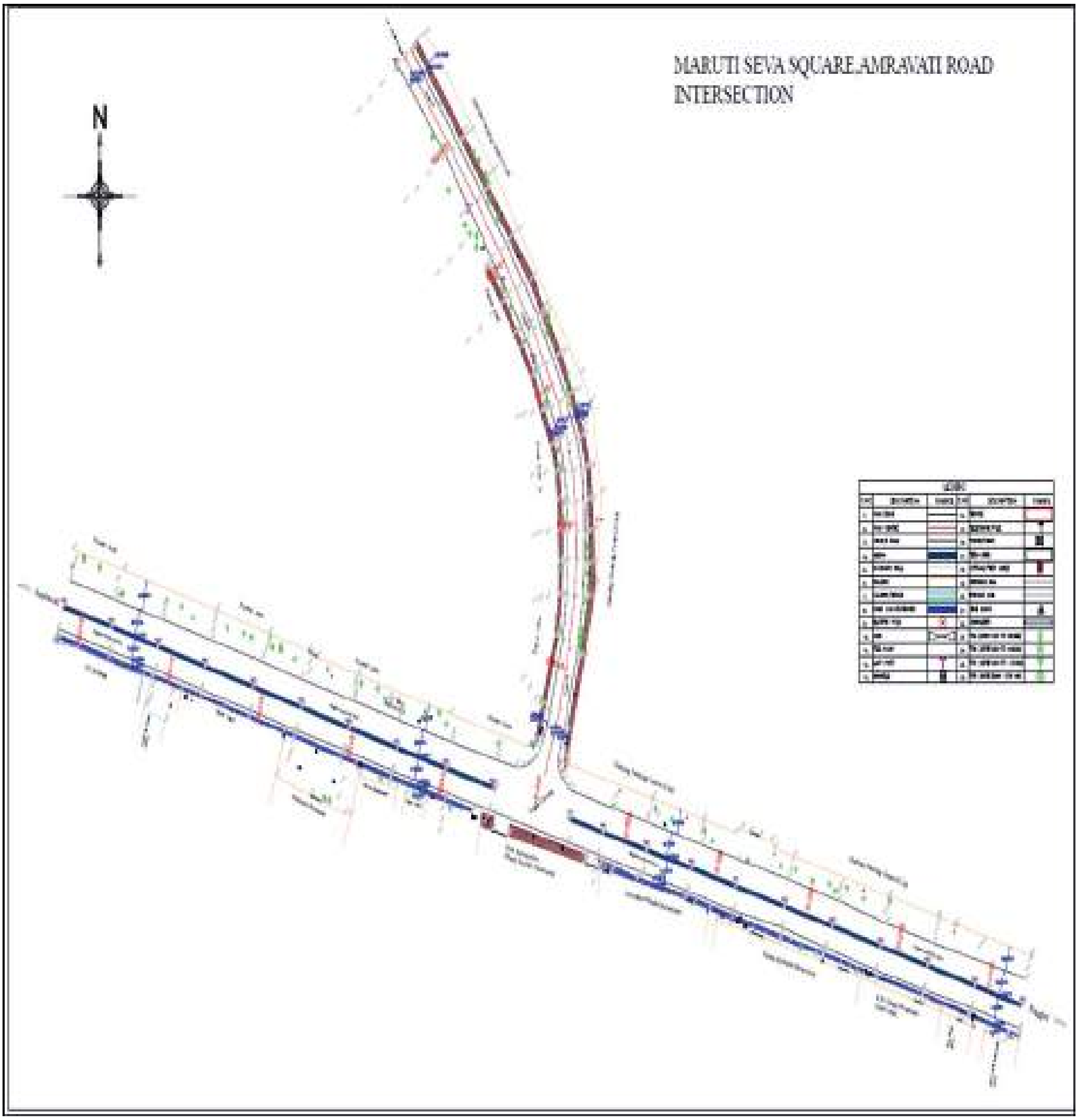


Figure 4.95 Physical Survey Plan of the Maruti Seva Square, Amravati Road

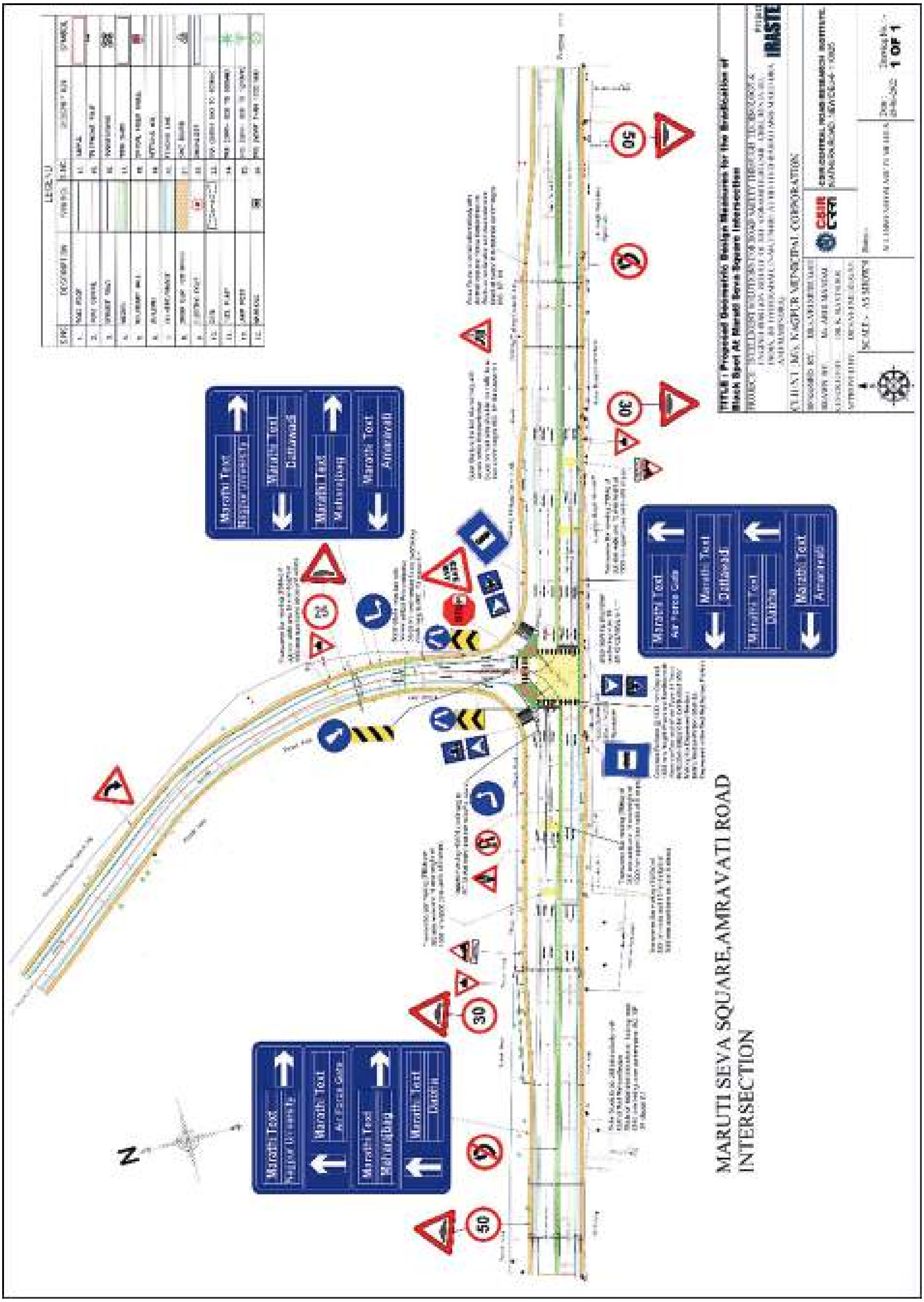


Figure 4.96 Detailed GDP for the Maruti Seva Square, Amravati Road

4.5 Economic Benefit Assessment of Blackspot Improvements

The crash statistics of Nagpur city shows that the number of road crash and fatality rates are on the higher side for a city which necessitates the need for devising appropriate engineering interventions and estimating its economic benefits. In the year 2020, out of the 774 crashes in rural Nagpur there were 382 fatal crasheswhereas in urbanNagpur the fatalities reduced to 210. Pedestrians, bicyclists, and two-wheelers account for 85 % and 59 % of all road crashesin urban and rural areas of the city respectively, which implies the fact that there is a lack of adequate infrastructure to ensure the safe commute for the above category of vulnerable road users in the city. Improvements in road geometrylike provision of a median,number of lanes and lane width mainly influence the behaviour of drivers. Hence, the blackspots must be treated to reduce the number of fatal crashesand grievous injuriesby devising countermeasures which would be forgiving in nature to address the human errors and their unpredictable behaviour into account.

Common types of crashescan be successfully reducedby specific engineering treatments known as countermeasures. In certain blackspots, where there is not a prevalent crash type, multiple interventions related to different types of scenarioshave been proposed.

4.5.1 Methodology

The study methodology has been devised and presented in Figure 4.97 wherein appropriate countermeasures are intendedto be formulated followed by the assessment of the economic benefits due to the same.

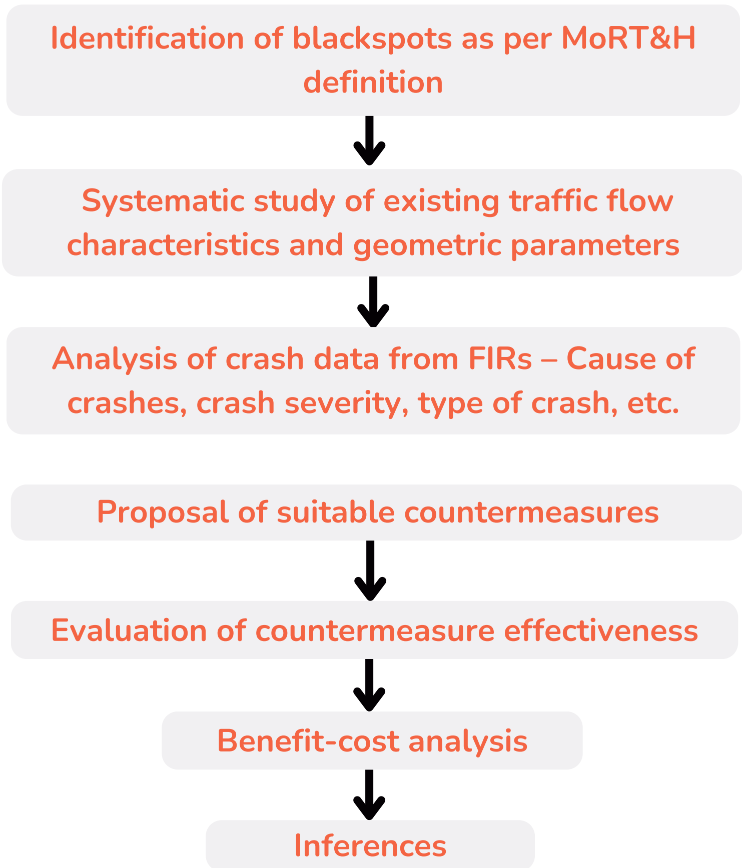


Figure 4.97 Study methodology

- As mentioned earlier, First Information Reports (FIRs) obtained from the Nagpur Police served as the baseline in identifying the Blackspots. The FIRs encompassing the road crash and fatality data from 1.1.2019 to 30.11.21 provided by the Nagpur Traffic Police (NTP) were analyzed in the study. The data consisted of the date and time of the crash, the latitude and longitude of the crash location, number and type of vehicles involved, type of crash, age of victim(s), number of fatalities, whether the victims have sustained grievous or minor injuries.

- To assess the existing traffic flow parameters at the identified blackspots, the following traffic studies were carried out at all the selected locations: Classified Traffic Volume Counts (CTVC), Spot Speed studies, Pedestrian Volume Counts (PVC) and Speed & Delay (S&D) studies were obtained. 12-hour CTVC & PVC studies were carried out to capture the number of vehicles and pedestrians using the road network and to estimate the intensity of traffic on the intersecting roads as well as on the midblock sections of the same. This survey was collected using videography on a typical working day from 8:00 am to 8:00 pm to cover the morning and evening peak flow along with off-peak flow.

- To understand the variation of speed profile, spot speed studies were conducted using Laser Speed Guns at vulnerable locations such as Blackspots of the road network covering both directions of travel. Direction wise sample data of spot speeds of different vehicles were analyzed to get various speed characteristics namely, minimum speed, maximum speed, average speed, and different percentile speeds such as 15th, 50th,85th and 95th in order to evolve appropriate speed control and safety measures.

- Topographic surveys by using Total Station system were conducted at each of the blackspots to assess the existing geometric features, which would help create the Base Plans. With the obtained base plan, Detailed Geometric Design Plan (GDP) was formulated by CSIR-CRRI in the form of Detailed Project Report (DPR).

- To evaluate the effectiveness of the proposed countermeasures, the construction and maintenance costs were calculated for a period of 5 years. The unit rates for each countermeasure were taken from Development of model road stretches by NHAI and appropriate inflation rates obtained from World Bank data were applied for a period of 5 years. The cumulative effectiveness values for each type of crash were calculated as outlined in section 4.5.3 and the reduction in crashes were computed for each blackspot are as follows.

*Crash Reduction = (cumulative effectiveness * number of crashes)* .... **Eq. 4.1**

Total Discounted Cost = Total discounted construction cost + Total discounted benefits.................. **Eq. 4.2**

*Benefit/Savings = (Reduced number of crashes/ Total number of crashes) * Average annualcrash cost*.... **Eq. 4.3**

The cost of construction, maintenance, and savings for the future year by considering the analysis period of 5 years and its discounted value have been determined by using the following equation.

*Future Value = Previous year value + (Previous year value * GDP growth % in the year considered)* ....**Eq. 4.4**

4.5.2 Counter Measures for 4 Typical Blackspots in Nagpur

Counter measures in the form of engineering interventions and other fiscal measures (if any) carried out for four blackspots have been considered in this study to showcase the effectiveness of this approach which encompasses two intersections and two midblock locations. The two intersections selected include Chikli square and Jhansi Rani square which are 4-arm and 5-arm intersections respectively whereas the midblock locations chosen are Prakash high school and Telephone exchange to C. A. Road. Common road safety issues observed at the blackspots include:

- Open areas lacking proper geometric design.
- Absence of road markings, delineation, road signs, etc.
- Absence of channelizing islands in the intersections leads to higher chances of conflicts between turning and through moving traffic.
- Improper pedestrian facilities such as lack of designated areas for crossing, absence of refuge areas, depressed median for at grade crossing.
- Obstructions in footpath by parked vehicles and vendors, absence of contiguous footpaths.

Obviously, many of the countermeasures suggested were common / generic in nature amongst the four blackspots which are as follows:

- Provision / Improvement of physical channelizing islands at intersections / diverging / merging locations, median refuge areas with concrete bollards to ensure safe crossing of pedestrians. Placement of speed table at the designated pedestrian crossing locations including the Free Left Turning approaches.
- Provision of Speed Breaker / Table / rumble strips / transverse bar markings (TBM) at the minor intersecting approaches and other applicable crash prone locations
- a)Provision of lane markings and edge markings using zigzag marking, median markers, solar road studs (for about 100 m) followed by conventional retro reflective road studs at 9 m center to center on the outer edge of the pavement / median / traffic lanes conforming to IRC:35(2015).
- Provision of Single and two-way Object Hazard Markers(OHM) ahead at all the diverging and merging sections conforming to IRC:35 (2015).
- Provision of various signages such as prohibitory / Regulatory Signs, Cautionary / Warning signs (especially Crash-Prone Sign), Informatory and Directional information / Facility Information signs wherever applicable, conforming to IRC:67 (2022).

The site-specific solutions developed for the four blackspot locations spanning a length of 500 m on either side of the road in the case of the midblock locations and 250 m from the center of the intersection in the case of the intersections are briefly discussed in the subsequent sections.

4.5.2.1 Prakash High School

This blackspot is encompassed by Asian Highway 46 in the east west direction. The road geometry present near Prakash High school is a mid-block section between two intersections. The totaltraffic volume handledat this midblock during the 12-hour survey period was observed to be 49283 PCUs (45748 Vehicles). The peak hour traffic flow was measuredto be 4418 PCUs/hour in the morning and 4478 PCUs/hour (passenger car unit) in the evening. This peak hour flow and the available Right of way was utilized to propose the necessary countermeasures. This stretch of the road consists of two minorroads merging with the Nationalhighway. The specific issues observed at this blackspot were improper merging of minor road traffic coupled with traffic calming measures on minor intersecting roads, absence of chevron signs and markings ahead of a sharp curve and absence of treatment at locations wherein minor construction works are in progress. Further, there are no forms of traffic calming measures deployed near the school zone to slow down the traffic speeds. Considering the above, the major site-specific countermeasures devised for 1 km stretch along the Prakash High School is presented:

- Improvement of geometrics / traffic calming measures on all the minor intersecting roads with the Project Corridor.
- Provision of speed table and Speed Limit Signs of 30 Kmph ahead of pedestrian crossing area before the school zone.
- Provision of Chevron signs on both sides of the carriageway to improve visibility in the curved section during night time.

The construction cost to carry out the proposed countermeasures was computed to be 28.25 lakh rupees. The estimated road crashes if the interventions are implemented is estimated to be 8 and thereby accounting for 60 % reduction from the 20 reported crashes in the vicinity of Prakash High School on the road corridor during the study period. Figures 4.98 and 4.99 provide a glimpse of the typical road conditions 'before' and 'after' geometric design plan conceived (typically depicted here only for about 100 m length only) near Prakash High School.

Figure 4.98 Road section 'before' implementation of the countermeasures near Prakash High School

Figure 4.99 Typical illustration of geometric design for the case of 'after' countermeasure implementation scenario

4.5.2.2 Chikli Square

This blackspot is formed at the intersection of National Highway NH 44 and the Major state highway of Maharashtra SH-09. The total traffic volume handled at this intersection during the 12-hour survey period was observed to be 50291 PCUs (61330 Vehicles). It can be noted that the Two wheelers (61.04 %) dominate the traffic composition followed by 3-wheeler & 4- wheeler goods vehicles (11.10%), Cars including (9.51 %), and slow-moving vehicles including Bicycle & cycle rickshaw(7.86 %). The proportion of Bus and Mini Bus observed to be only around 0.27 %. The main issues at this blackspot were found to be lack of road marking and signs, absence of channelizing islands as well as large open area of the intersection encouraging the road users, mainly motorcycles (61% of the total vehicle composition) to drive in the wrong direction at high speeds. To mitigate these issues, two alternative geometric designs were proposed: First one is a standard signalization of the four-arm intersection; second alternative is to provide a guided U-turn towards the major approach. This option reduces the number of conflict points from 24 to 8. Since this blackspot is situated in an open area, there is ready availability of ROW which facilitates widening of the carriageway. There is a possibility of further reduction in the road crashes and fatalities as largescale disobedience of traffic signals (rampant violation of Signal was observed during the surveys) is addressed in the second alternative through the provision of back-to-back U-Turn. Considering the above issues, the major site-specific countermeasures devised for the two options conceived for the Chikli Square is presented:

- ·Provision of channelizing islands and depressed medians with cement concrete bollards to facilitate safe pedestrian crossing.
- ·Pedestrian signal to be installed at a distance of 45 m from the zebra crossing; the signal will be open for pedestrians for 25 seconds during the 60 second signal time in the case of Option 2 implementation.
- ·Provision of speed table at free left turns onevery approach.
- ·Provision of back-to-back U-Turnsby flaring the road withinthe available RoW.

The construction cost in order to carry out the proposed countermeasures was computed to be 39.83 lakh rupees and 81.23 lakh rupees for Options 1 and 2 respectively. The increase in total cost in option 2 is attributed to the development of the road structure, lane widening withinthe available RoW and footpath construction costs to be incurred for the case of back-to-back U- Turn. The estimated road crashes if the countermeasures are implemented is estimated to be 13 and 11 for options 1 and 2 and thereby accounting for more than 60 % and 72 % reduction respectively from the 30 reportedcrashes at the Chikli Squareduring the studyperiod. Some of the existing safety-related issues observed at the Chikli Square and its vicinity are presented through a few snapshots in Figures 4.100 and 4.101 whereas Figure 4.102 provide a glimpse of the typicalroad conditions for the scenarioof ‘After’ geometric design plan implementation which is typically depicted here only for the Option 2 covering only the intersection portion of the Chikli Square.

Figure 4.100 Typical Illustration of Large Size Intersection with Open area without Road Marking and Signs and Absence of Speed Tables

Figure 4.101 Poor Upkeep of the Channelizers and Absence of Depressed Median to facilitate Pedestrian Crossing

Figure 4.102 Typical Illustration of Chikli Square Option 2 having Junction Closure on the Major Approach.

4.5.2.3 Telephone Exchangeto C. A. Road

This blackspot is encompassed by Asian Highway46 running in the east to west direction of the city. The road geometry present at this location is a typical mid-block section serving two major intersections coveringin excess of 1 km. The averagespeeds of the traffic flow were found to be 39.5 km/h and 34.75 km/h in the morning and evening peak hours respectively. 12-hour traffic count in both directions from Juni Pardi Naka to Mayo squarewas found to be 40,835 PCUs (50,557 vehicles). Out of which two-wheelers dominatedas the most preferred mode of transport accounting for 69 % of the total traffic volume. Passenger cars and Auto rickshaws comprised 15 % and 6 % of the total traffic volume. Considering the above issues, the major site-specific countermeasures devised for the midblock stretchbetween Telephone Exchange to C.A. Road is presented:

a) Provision of bus bay on both sides o after the intersection approach in Chappruchowk.
b) Provision of channelizing island with depressed medians to allow safe pedestrian crossing on all the Major / Minor intersecting roads at Chappru chowk and Dr. Rajendra Prasad chowk.
c) Provision of traffic calming measures ahead of the Telephone exchange metro station to reduce the traveling speeds where pedestrian volume is on the higher side.

The construction cost in order to carry out the proposedcountermeasures was computedto be Rs. 49.55 lakh. The estimated road crashes if the interventions are implemented is estimated to be 15 and therebyaccounting for 59 % reduction from the 37 reported crashes on the road stretch between Telephone Exchange to CA Road during the studyperiod.

4.5.2.4 Jhansi Rani Square - 1

Jhansi Rani Square - 1 is a 5-arm intersection wherein AH-46, SH-255 and SH-264 intersects along with the road leading to Nagpur Railway station also meet at this location. This blackspot also encompasses two 4-arm intersections in the south direction, namely Dattawadi intersection and Jhansi Rani Square 2. The average journey speeds of the traffic flow were found to be 31.9 km/h on the Chhatrapati to Jhansi Rani Square – 1 direction whereas 30.3 Kmph on the on the opposite direction during the morning and evening peak hours respectively. 12-hour traffic count in both directions from was found to be 55,774 PCUs (74,871 vehicles). Out of which two-wheelers dominate the flow accounting for 62 % of the total traffic volume. Passenger cars and Auto rickshaws comprised 14 % and 17 % of the total traffic volume respectively. Considering the above issues, the major countermeasures devised for this location will be similar to the ChikliSquare - Option 1 which is discussed in Section 4.5.2.2. The construction cost in orderto carry out the proposedcountermeasures was computed as 81.21 lakh rupees. The estimated road crashes if the countermeasures are implemented is estimated to be 11 and thereby accounting for more than 66 % from the 36 reported crashes at the Rani Jhansi Square 1 during the study period.

Further, it is noted that that at all four blackspot locations the proportion of public transport traffic is less than 1 % which indicates there is a reluctance from road users end to use public transport. This indicates that the Level of Service (LOS) provided by the public transport needs improvement which would result in less traffic volume thereby improving road safety and traffic congestion.

4.5.3 Effectiveness of countermeasures

The cumulative effectiveness was calculated since there are multiple interventions used in each scenario.

$$Cumulative\ effectiveness = [1 - [(1 - E1) * (1 - E2) * \ldots\ldots (1 - En)]] \quad \text{Eq. 4.5.}$$

where E1, E2 and En are the effectiveness of 1st, 2nd, and nth countermeasure respectively.

Since there are no indigenous manuals/ research studieswhich provide standardeffectiveness of interventions in India, the effectiveness scale data was taken from various sources such as World Bank, the handbook of road safety measures of UK, ITE of USA, andiMAAP software, etc. Addressing the various forms of appropriate road geometric improvement measures like the provision of channelizing Island, zebra crossing, and median refuge islands were found to be 70 % effective in terms of preventing pedestrian and bicycle fatalities / grievous- injury-type of road crashes. Similarly, the effectiveness of the various forms of traffic calming measures like the speed breakers / rumble strips / TBM are expected to reduce 50 % of the fatalities / serious injury type road crashes at intersections. Considering the above stated effectiveness scale, one can arrive at an estimate of reduction in fatalities / serious injury type road crashes for the above types of collisions which is presented in Table 4.11 The costs of the countermeasures provided were taken from NHAI report carried out in in 2020 which in turn has been updated to the present-day costs by applying the suitable cost escalation.

Table 4.11 Effectiveness of countermeasures

S. No.	Countermeasure and effectiveness	Cost of countermeasure provided (INR)	Source
1	Speed humps, TBMs and rumble strips – 35% reduction in injury crashes	TBM, rumble strips – 580 per sq. m	Elvik, Hoye, and Vaa 2009
2	Edge line, Centrelines markings, delineator posts and chevron signs – 45% reduction in crashes	Edge line and CL – 580 per sq. m Chevron signs, OHMs - 5155 per unit	Elvik, Hoye, and Vaa 2009
3	Provision of medians – 30-40% reduction in severe crashes	Earthwork – 666 per cum	Duduta et. al 2015
4	Channelizing island, median refuge islands – 70% decrease in fatal crashes	Construction of footpath – 769 per sq. m	FHWA Safety 2013
5	Design improvements in school zones – 39%	N/A	Sul 2014
6	Provision of Median U turns – 30% reduction in intersection injury related crashes	N/A	FHWA Safety 2013
7	Speed limit signs, warning signs – 10% reduction in overall crashes	Speed limit signs, warning signs –5155 per unit	World Resources Institute 2015

4.5.3 Effectiveness of countermeasures

Road crashes pose a social and economic cost due to sudden deaths, injuries, and loss of potential income. Depending on the severity of the injuries, road crashes have been further classified as fatal, grievous, and minor injury road crashes.MoRT&H uses Human Capital Approachwhile calculating the total road crash costs.The basis of Human CapitalApproach is the concept that the cumulative output through the life of an individual can be quantified and the cost of future lost output can be calculated based on duration of productive life. In this method, the cost of a road crash consistsof victim relatedcosts, property damage costs and administrative costs. The study has estimatedthat out of the total costs, 97.7 % are victim related and the rest 2.3 % are for the other two components. The overall total crash cost for the Indian roads for the year of 2018 was estimatedto be INR 5,96,829 croreswhich is equivalent to 3.14 % of the GDP of the country. The baseline used for calculating crash cost based on the type of severity of injury / fatality is as follows in table 4.12.

Table 4.12 Average unit costs of crashes for each crash severity

Type of severity	Average unit crash cost per victim (INR)
Fatality cost	91,16,363
Grievous injury cost	3,64,398
Minor Injury and property damage cost	83,201

It is clear that the cost of a fatality creates a huge loss in terms of a valuable life and also to the economy of a country. Hence there is a huge responsibility on the road authorities to reduce the fatalities as much as possible. A study undertaken by the World Bank revealed that by reducing the road mortality by 50 % and sustaining it for a period of 24 years could generate additional flow of incomewhich is equivalent to 14% of India's GDP.

4.5.5 Benefit-Cost analysis

To devise the appropriate cost-effective countermeasures, adequate analysis has to be conducted prior to implementation by understanding the ground conditions and referring to the associated literature. After deducingthe same, Benefit-Cost Analysis can be conducted. This is a method that determines the future risk reduction benefits of a hazard mitigation project and compares those benefits to its costs. In India, economic evaluations of road safety measures are rarely published in the scholarly literature. There is considerable uncertainty of forecasts beyond a certain reasonable period. Human behaviour may change, travel patterns may undergo a shift and technology may experience transformation. Thus,it is worthwhile limiting the analysis period to 5 years since the amount invested amount is relatively on the lower side in the case of blackspot treatment. The discount rate is taken as 12 % which is used by the planning commission and the referenceyear is taken as 2022. The maintenance cost of all countermeasures is taken as 5 % of the construction cost.A project is considered cost effective if the BenefitCost (B-C) Ratio is greater than 1. Other than B-C ratio, other methods like Net Present Value (NPV) method and EconomicInternal Rate of Return (EIRR)are also deployedand all the three methodsare based on the discounted cash flow (DCF) technique of discounting all future costs and benefits to a commonyear. The three methods used for economic evaluation are discussed below in brief.

4.5.5.1 Benefit-Cost (B-C) ratio method

There are a numberof variations of this method,but a simple procedure is to discountall costs and benefits to their present worth and calculate the ratio of the benefits to costs. Negative flows are considered as costs whereas positive flows as benefits.

$$Benefit - Cost\ ratio = \frac{Total\ benefits\ over\ the\ analysis\ years\ discounted\ to\ the\ refernce\ year}{Total\ cost\ over\ the\ analysis\ years\ discounted\ to\ the\ reference\ year} \ldots\ldots\ \mathbf{Eq.\ 4.6}$$

4.5.5.2 NetPresent Value (NPV) method

In this method, the stream of costs/benefits associated with the projectover an extendedperiod of time is calculated and is discounted at a selected discounted rate to give the present value. Benefits are treated as positive and costs as negative and the summation give the Net PresentValue (NPV).

$$NPV = (B_0 - C_0) + \frac{B_1 - C_1}{(i+1)^1} + \cdots + \frac{B_n - C_n}{(i+1)^n} \ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{Eq.\ 4.7}$$

4.5.5.3 Economic InternalRate of Return (EIRR)

Economic internal rate of return (EIRR) is the discount rate which makes the discounted future benefits equal to the initial outlay. In other words, it is the discount rate which makes the stream of cash-flow to zero. The solution to the equation given below can be done by trial and error. However, the task of computing EIRR is rendered very simple now-a-days due to the availability of this function as an inbuilt one in many software. If the EIRR calculated from the above formula is greater than the rate of interest obtainable by investing the capital in the open market, the scheme is considered acceptable. The summary of the deduced results for the 4 blackspots are presented in Table 4.13.

Table 4.13 Summary of Benefit-cost evaluation

Name of the blackspot	Benefit-Cost ratio	First year cost savings (INR)	First year rate of return (%)	Net present value	Economic Internal Rate of Return
Chikli square - Option 1	9.82	1,18,02,695	2.71	4,21,19,210	63.53
Chikli square - option 2	5.16	1,24,36,765	1.42	4,04,63,423	54.72
Prakash High school	10.01	85,32,006	2.76	3,05,13,013	63.71
Telephone Exchange to C. A. Road	6.22	92,96,482	1.72	3,09,96,116	57.89
Jhansi Rani Square	5.46	1,33,88,615	1.51	4,34,54,691	55.76

4.5.6 Conclusions

This study provided an overview towards understanding the effectiveness of blackspot treatment through countermeasures for 4 out of the 38 blackspots in the city of Nagpur. Some of the salient findings derivedare as follows:

a) The proposed countermeasures were found to be cost effective for the four blackspots conforming to IRC: 131 (2022).
b) It is estimated that about 60 to 66 percent reduction in the overall road crashes coupled with 40 % reduction in fatalities if the countermeasures are applied assuming a similar rate of road crashes in the next 5-year periodon the road network of Nagpur as blackspot improvements falls under cost effective improvements.
c) The total cost savingsfor each blackspot are summarized in Table 4.13.On average, there is a cost saving of INR 89,14,244 in the mid-block locations and INR 1,25,95,655 in the intersections after one year of proposed countermeasures.
d) The Economic Internal Rate of Return (EIRR)was found to be ranging between 54 % - 63 % through the analysis period of 5 years which can be considered to be a significant Return on Investment (ROI). Even the First Year Rate of Return (FYRR) was estimated to be rangingbetween 1.42 % - 2.76 %, which shows that there is bound to be an immediate ROI in all four blackspot locations.
e) At the same time, though the implementation of blackspot interventions is an effective tool in treating the affected road stretches / locations, it is to be borne in mind that it is one of the forms of interventions to address road safety in the road network of any city. This is because, simultaneous measures are needed in the form of periodical Road Safety Audits (RSA) as well as other non-engineering interventions such as enforcement, road safety campaigns (by involving the Non-Governmental Organizations) and post-crash care in the vicinity of the identified black spots including the grey spot proposed in this study.

4.5.7 Limitations & Future scope

The limitations and the future scopeof this study are as follows:

a) More robust form of data collection is necessary to account for unreported and minor injurycrashes.
b) The effectiveness of the countermeasures needs to be studied extensively in the Indian road conditions.
c) Countermeasures needs to be studied for their medium to long term effectiveness by using reliable projections of the traffic and crash data through studying the trends in roadcrashes.

4.6 Blackspot Remedial Measures: Outcomes

Team iRASTE has initially partnered with Nagpur City Transportation Consultant, **M/s. Kataline Infraproducts Private Limited** and done a pilot ground improvement work at Nagpur-Amravati highway in Nagpur city to evaluate the effectiveness of road safety measures, where two critical spots are selected, Spot-1 is a Wadhamna intersection along the highway that has been identified as blackspot, characterized by inadequate road markings and insufficient speed calming measures, and Spot-2 is the horizontal curve profile of the road stretch, which poses a higher risk with the geometry and insufficient road markings at this location.

The accompanying Figure 4.103 visually depict these specific locations along the highway, highlighting the concerned locations.

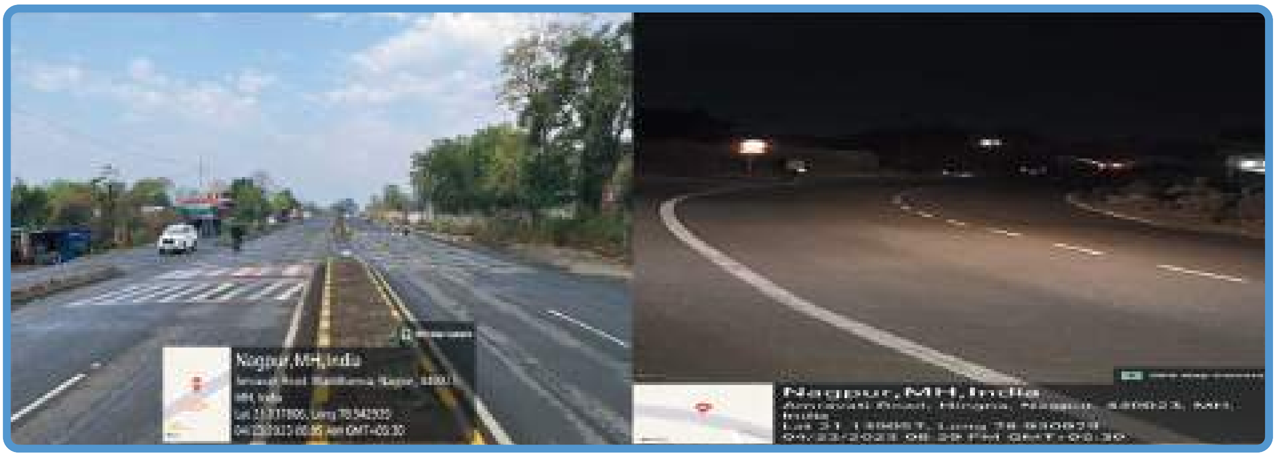


Figure 4.103 Ground Improvement Locations (Spot-1 and Spot-2)

In order to enhance safety during the night time, interventions such as Transverse Bar Markings (TBM), Augmented Wet Retro-Reflective Dot (AWRD) Markings, Zig-zag markings, and Coloured pedestrian markings, are implemented at these locations which are as follows-

A.Transverse Bar Markings (TBM)

At the Wadhamna intersection, the primary objective was to achieve gradual speed reduction, to accomplish this- a series of 2-component cold plastic TBM with varying thickness and configurations were installed. TBM with thickness of 5 mm, 10 mm, 15 mm, and 20 mm were utilized, with sets of six strips for 5 to 15 mm, and separate sets of six and nine strips for the 20 mm TBM. These interventions were implemented on one side of the road (left-hand side), specifically the direction towards Amravati, while the other direction remained unaltered due to a pilot implementation. The accompanying Figure 4.104 provide a visual implementation (i.e., bird-eye view) of the different TBM thickness, and arrangements employed in the project.

Figure 4.104 TBM installations over the Wadhamna intersection stretch. (Bird eye view)

Figure 4.105 to 4.109 offer a clear depiction of each TBM thickness employed over the Wadhamna intersection stretch as part of the interventions.

Figure 4.105. 5 mm thickness TBM

Figure 4.106. 10 mm thickness TBM

Figure 4.107.15 mm thickness TBM

Figure 4.108. 20 mm thickness TBM (six in numbers)

Figure 4.109. 20 mm thickness TBM (nine in numbers)

Apart from that, other interventions are also implemented, included delineation of the curve sections using the AWRD markings for hazardous locations as well as deployment of zig-zag markings, and zebra crossing using red and whitecolours at the identified crash prone locations confirming to IRC 35: 2015, which are discussed in succeeding sections

B. Augmented Wet Reflective Dot (AWRD) Markings

To enhance safety at the curve road stretch (Spot-2), raised pavement markings in a dot pattern were implemented as edge lines using a 2-compoment cold plastic material with high retroreflective drop on glass beads. The accompanying Figure 4.110 showcase the implementation of these raise pavements markings, highlighting their role in ensuring safer navigation along the curve road stretch.

Figure 4.110. Dot pattern road markings

C. Zig-zag markings

Yellow coloured zig-zag markings were installed using hot thermoplastic material as shown in Figure 4.111 & 4.112 (confirming to IRC 35: 2015), where it specifies motorists to slow down the vehicle and designed to indicate that overtaking is strictly not allowed.

Figure 4.111. Zig-zag marking at approaching intersection (1)

Figure 4.112. Zig-zag marking at approaching intersection (2)

D. Coloured Pedestrian Markings

The intersection itself was marked with check boxes, and coloured pedestrian red and white zebra crossing were installed to clearly delineate pedestrian crossing and prioritize pedestrian safety as shown in Figure 4.113. Additionally other markings and features such as ‘Speed Limit” road markings (as shown in Figure 4.114) contribute to creating a safer environment for both drivers and pedestrians at the intersection.

Figure 4.113. Coloured pedestrian marking at the intersection

Figure 4.114. Coloured horizontal signage between rumble strips

As a results of these above-mentioned safety interventions at Nagpur-Amravati Highway (Spot-1 & Spot-2), a spot speed analysis was conducted at these locations to compare the TBM of different thickness and its influence on change in speed for all categories of vehicle. The main focus was to observe- ***"Has the implementation of TBM resulted in a significant reduction in vehicle speed or not"***. For this the 85th percentile speeds of different categories of vehicles were analyzed and compared between pre and post scenarios for various thickness levels of TBM and found that the implementation of TBM resulted in a significant reduction in vehicle speed for all categories of vehicles as presented in Table 4.14.

This table presents the 85th percentile speeds of different categories of vehicles in Kilometer per Hour (Kmph) for both pre scenarios (without TBM) and post scenario (with TBM) at various thickness level of TBM (5mm, 10 mm, 15 mm, 20 mm with 6 strips, and 20 mm with 9 strips).

Table 4.14. Comparison of 85th percentile speed of vehicle speeds with and without TBM

Vehicle Type	85th %ile Speed (in Kmph)		Speed in Kmph (85th percentile)				
	Pre-Scenario: Towards Amaravati direction		Post Scenario -Towards Amaravati direction				
	Near median opening	100 m away from median opening	5mm TBM	10 mm TBM	15 mm TBM	20 mm TBM (6 strips)	20 mm TBM (9 strips)
2-Wheelers	58	55	45	37	33	38	27
% reduction	–	-	18.2	32.7	40	34.5	53.4
Small Cars	67	66	61	56	47	50	39
% reduction	-	-	7.6	15.2	28.8	25.4	41.8
Big Cars	62	67	60	56	40	55	47
% reduction	-	-	10.4	16.4	40.3	11.3	24.8
3-Wheelers	47	40	35	34	26	34	29
% reduction	–	-	12.5	15	35	27.7	38.3
*LCV	53	49	46	42	34	36	22
% reduction	-	-	6.1	14.3	30.6	32.1	38.5
**HCV	49	47	47	41	33	33	30
% reduction	-	-	0	12.8	29.8	32.7	38.8

From the above Table 4.14, it can be interpreted that:

a. The implementation of TBM has effectively reduced vehicle speeds across all vehicle categories. The highest speed reduction was observed for Two-wheelers (TW) and Small Cars (SC).

b. The greatest reduction in speed was observed with the installation of 20 mm TBM with 6 strips and 20 mm with 9 strips.

c. Remarkably, the average speed of vehicles remained at or below 30 Kmph for all vehicle categories when 20 mm TBM with 9 strips was used.

Furthermore, **Another Earthling (AE) Studio, Nagpur** to implement Blackspot Remedial Measures at other 7 blackspot locations. The team has worked on multiple blackspots across the city providing solutions through street geometry correction, proper signage, bold road markings, and planned & organized spaces on major streets. The following Blackspot locations have been identified for remedial measures as presented in Table 4.15: -

Table 4.15 Blackspots identified for remedial measures

S. No.	Blackspots	Latitude	Longitude
1	Ajni Square	21.119343	79.0725084
2	Chhatrapati Square	21.110772	79.0700259
3	Jaiprakash Nagar Square	21.104351	79.068361
4	Manewada Square	21.1053026	79.1024486
5	Omkar Nagar Square	21.105488	79.0944244
6	Chinchbhavan Square	21.0675	79.0583333
7	Mahesh Dhaba	21.040822	79.051996

4.6.1 Ajni Square

Ajni Square in Nagpur is an active junction that has been identified as a major blackspot, encountering heavy traffic flow from all four approach roads. A detailed analysis of the junction is conducted to identify issues, assess the existing scenario, and analyze the survey data obtained from observation survey and TVC survey. This analysis will serve as a foundation for developing junction improvement design proposals to enhance traffic flow, safety, and overall efficiency.

During the initial assessment of Ajni Square, several issues have been identified that require attention:

a) **Congestion and Traffic Delays:** The junction experiences significant congestion, especially during peak hours at conflict points, leading to traffic delays and reduced efficiency.
b) **Large Residual Spaces:** The skewed junction geometry permits more residual spaces at the junction increasing the pedestrian and vehicular crossing distance at the junction. Residual spaces refer to underutilized areas within the junction. These spaces not only create a visual and aesthetic concern but also pose potential safety risks and hinder the overall functionality of the junction.
c) **Pedestrians** face challenges while crossing the junction due to inadequate pedestrian facilities, insufficient crossing time, large crossing distances and no refuge spaces leading to conflicts with vehicular traffic.
d) **Public Transport:** Bus Stop to be shifted at the edge of the street to avoid parking in front of the bus stop and efficient use of the infrastructure by the public in waiting.
e) **Cyclist Accessibility:** There is a huge inflow of bicyclists observed at the junction at the peak hours. The junction lacks dedicated cycling infrastructure, making it challenging for cyclists to navigate through the junction safely.
f) **Signalized Junction:** The signalization at Ajni Junction requires assessment and potential improvements. Inefficient signal timing and coordination is leading to traffic congestion, delays, and conflicts between different traffic movements. Improper placement of signals promotes traffic violations as well.
g) **Lighting Conditions at Night:** Inadequate lighting conditions at Ajni Junction pose risks to road users, particularly during late night time when there is freight traffic crossing the junction. Insufficient street lighting can impair visibility, compromising safety for both drivers and pedestrians.
h) **Resting Spaces for Pedestrians:** During lean hours,the junction experiences high movement of four wheelers and two wheelers, and there is a lack of resting spaces for pedestrians. This leads to pedestrians being exposed to potential accidents and discomfort due to the absence of designated resting areas. The small channelizer further has all the infrastructures such as signals, electric poles, network towers installed in them so it cannot provide any space for pedestrian.

Figure 4.115 Existing Condition and Activity Mapping of Site

Figure 4.116 Existing condition of site

i) **Speed Calming Measures and Road Geometry:** The junction lacks adequate speed calming measures and road geometry improvements. The absence of traffic calming features such as speed breakers, roundabouts, rumble strips or traffic islands and channelizers can lead to excessive speeding, increasing the risk of accidents and compromising overallsafety.

j) **Provision of Road Signs and Road Markings:** The inadequacy of road signs and road markings contributes to confusion and potential conflicts among road users. Clear and visible signage, lane markings, and pavement markings are essential for guiding traffic and ensuring smooth and organized movement through the junction.

Dealing with the challenge of extensive commercial and residential spaces at Ajni Junction is essential to enhance its functionality, safety, traffic management, and aesthetic appeal. Implementing proposed improvements, such as landscaping, public spaces, functional use, seating, pedestrian infrastructure, parking, and an integrated design approach, can transform the junction into an organized and visually appealing space.

Black spot Mitigation Strategies:

- Geometry of the junction needs to be corrected.
- Refuge island for safer pedestrian crossing has to be provided by extension of the median.
- Bollards between the depressed median are the be placed for restricting vehicularmovement.
- Providing organized spaces for all the activities on the junction to reduce haphazard parking like designated informal vending zones, auto stands, bus stops, designated parking spaces, etc.
- Providing mandatory signage and road markings where necessary as per IRC: 67 and IRC: 35 (2022).

Proposed Design :

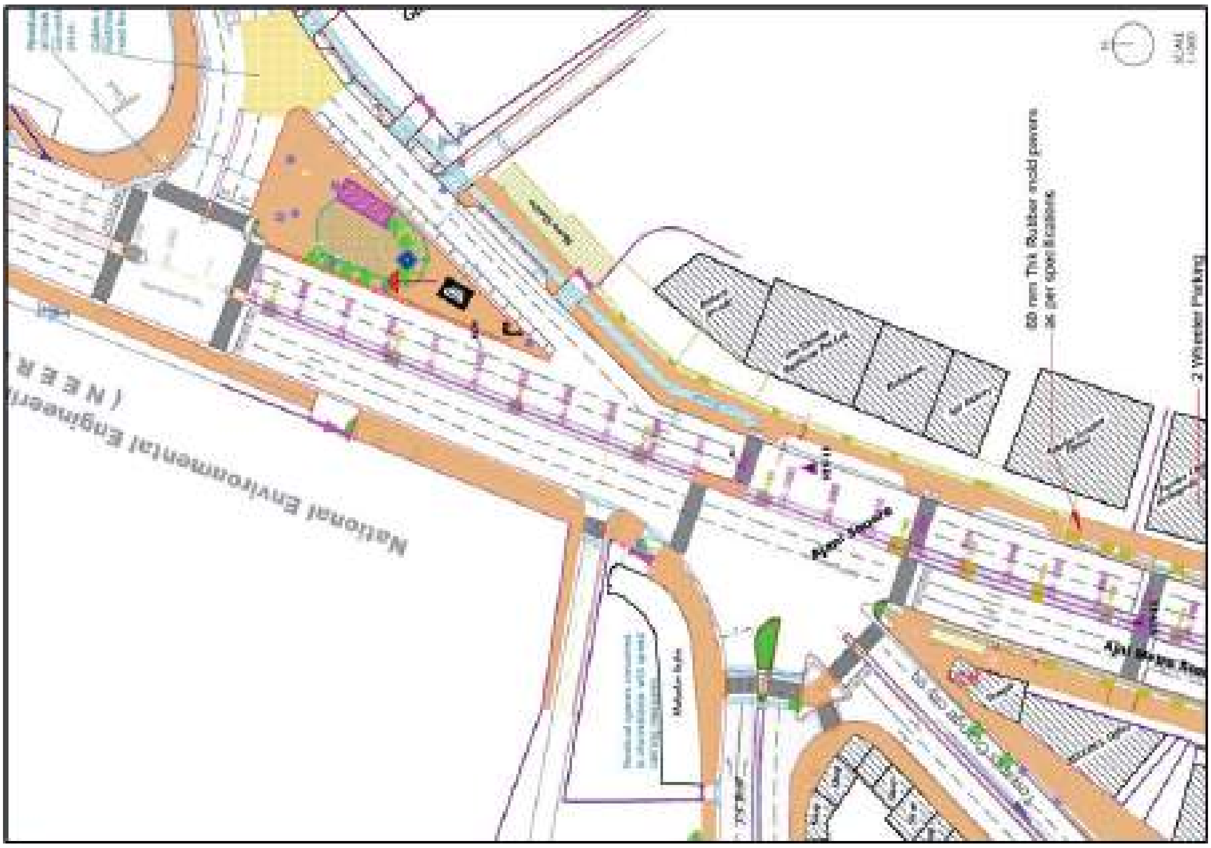


Figure 4.117 Proposed Plan of Ajni Square

As per the improved junction design,

- Able to reclaim the residual spaces and reduce the pedestrian crossingdistance and larger channelizers for vehicles.
- Introducing traffic islands for traffic controls.
- Introduced table top slip lanes for safer left turns and dividers for easier traffic movement at the junction.
- Reclaimed the extra spaces on the sides of the road and turned them into organized parking, cycle track,wider footpaths, green spaces, and public sitting spaces with proper lighting.

After Design :

In this section, below Figure 4.118 illustrates the glimpse of Ajni Square after the implementation of remedial works-

Figure 4.118 Completed improvement works at Ajni Square.

4.6.2 Chhatrapati Square

Chhatrapati Square of Nagpur city is a significant junction identified as a major blackspot, that experiences heavy traffic flow from all the four approach roads. The detailed analysis of the junction helps to identify issues, assess the existing scenario, and also serves as a foundation for developing junction improvement design proposals to enhance traffic flow, safety, and overall efficiency.

During the initial assessment of Chatrapati Square, several issues have been identified that require attention:

a. Congestion and Traffic Delays: The junction experiences significant congestion, especially during peak hours at conflict points, leading to traffic delays and reduced efficiency.

b. Large ResidualSpaces: Residual spaces refer to underutilized areas within the junction. These spaces not only create a visual and aesthetic concern but also pose potential safety risks and hinder the overall functionality of the junction.

c. Pedestrian Safety: Pedestrians face challenges while crossing the junction due to inadequate pedestrian facilities, insufficient crossing time, large crossing distances and no refuge spaces leading to conflicts with vehicular traffic.

d. Public Transport: Bus Stop to be shifted at the edge of the street to avoid parking in front of the bus stop and efficient use of the infrastructure by the public in waiting.

e. Cyclist Accessibility: There is a huge inflow of bicyclists observed at the junction at the peak hours. The junction lacks dedicated cycling infrastructure, making it challenging for cyclists to navigate through the junction safely.

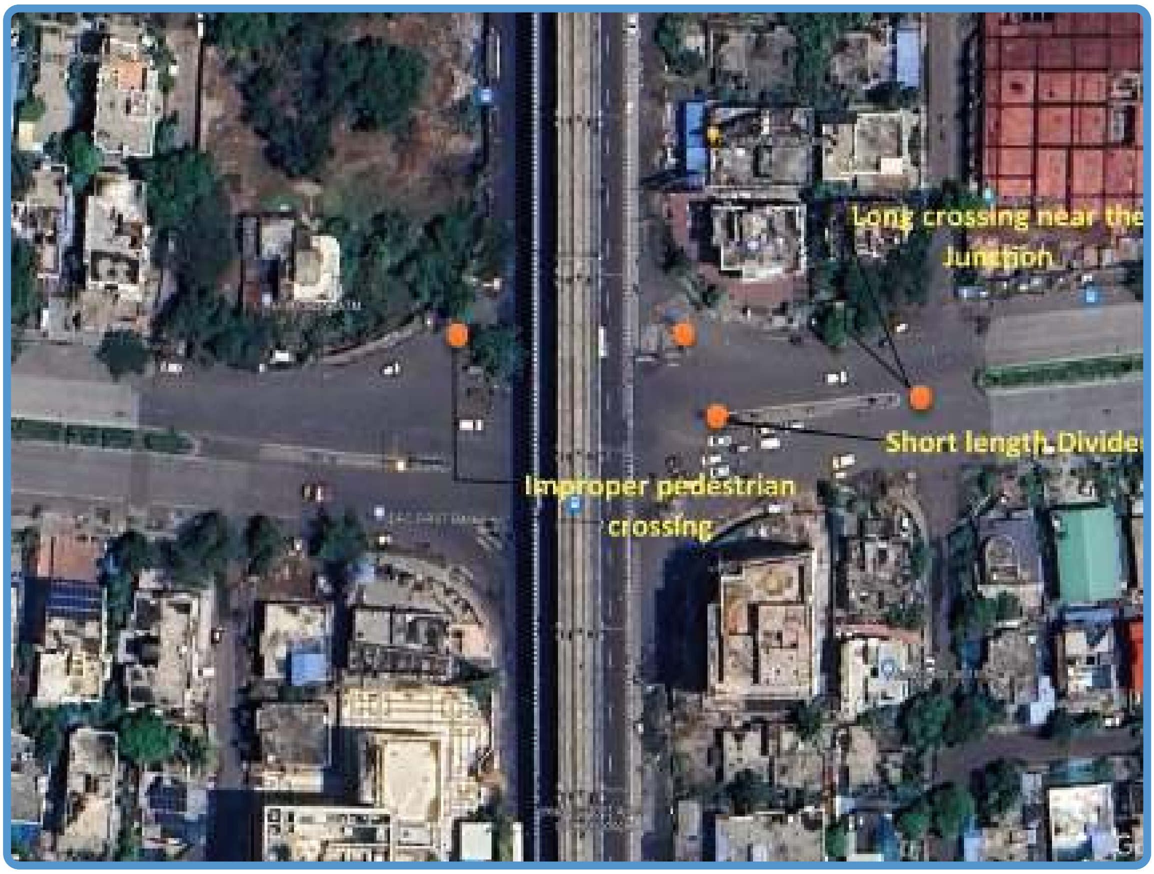


Figure 4.119 Existing condition and identified issues of site

f. Signalized Junction: The signalization at Chatrapati Junction requires assessment and potential improvements. Inefficient signal timing and coordination is leading to traffic congestion, delays, and conflicts between different traffic movements. Improper placement of signals promotes traffic violations as well.

g. Resting Spaces for Pedestrians: During clean hours, the junction experiences high movement of vehicles, and there is a lack of resting spaces for pedestrians. This leads to pedestrians being exposed to potential risk of accidents and discomfort due to the absence of designated resting areas. The small channelizer further has all the infrastructures such as signals, electric poles, and network towers installed in them so it cannot provide any space for pedestrians.

h. Speed Calming Measures and Road Geometry: The junction lacks adequate speed calming measures and road geometry improvements. The absence of traffic calming features such as speed breakers, roundabouts, rumble strips or traffic islands and channelizers can lead to excessive speeding, increasing the risk of accidents and compromising overall safety.

Figure 4.120 Existing condition of site

f. Provision of Road Signs and Road Markings: The inadequacy of road signs and road markings contributes to confusion and potential conflicts among road users. Clear and visible signage, lane markings, and pavement markings are essential for guiding traffic and ensuring smooth and organized movement through the junction.

Addressing the issue of huge commercial spaces at Chatrapati Junction is crucial for optimizing its functionality, safety, and aesthetic appeal. By implementing the proposed improvement measures, including landscaping, Elongated traffic islands, functional utilization, pedestrian infrastructure development, Road side Parking spaces and an integrated design approach, the junction can be transformed into a well- organized and visually pleasing space.

Black spot Mitigation Strategies:

- Geometry of the junction needs to be corrected also allow provide parking in a busy road side space.
- Refuge island for safer pedestrian crossing has to be provided by extension of the median.
- Channelizers to be reduced according to the pedestrian movement. Bollards between the depressed median are the be placed for restricting vehicular movement.
- Providing organized spaces for all the activities on the junction to reduce haphazard parking like designated informal vending zones, auto stands, bus stops, designated parking spaces, etc.
- Providing mandatory signage & road markings where necessary as per IRC:67 & IRC:35 (2022).

Proposed Design

Figure 4.121 Proposed plan of Chhatrapati Square

As per the improved junction design,

- Able to reclaim the residual spaces and reduce the pedestrian crossing distance and larger channelizers for vehicles also elongated traffic islands for traffic control.
- Introduced table top slip lanes for safer left turns.
- Extended the dividers for easier traffic movement at the junction.
- Reclaimed the extra spaces on the sides of the road and turned them into organized parking, cycle track, wider footpaths, and green spaces etc.

After Design

Figure 4.122 Ongoing construction photos at Chhatrapati Square

Figure 4.123 Elongated Islands for Traffic Control

Figure 4.124 Designed Islands and Pedestrian Crossings

Below Figure 4.125 illustrates the glimpse of Chhatrapati Square after the remedial works.

Figure 4.125 Completed improvement works at Chhatrapati Square.

4.6.3 Jaiprakash Nagar Square

Jaiprakash Nagar Square in Nagpur is a prominent intersection that has been classified as a blackspot due to the volume of traffic it receives from all four approach routes. In order to improve traffic flow, safety, and overall efficiency, design suggestions for junction improvements are developed on the basis of a thorough examination of the junction, which aids in problem identification and scenario assessment.

During the initial assessment of Jaiprakash Nagar Square, several issues have been identified that require attention:

a. Congestion and Traffic Delays: The junction experiences significant congestion, especially during peak hours at conflict points, leading to traffic delays and reduced efficiency.

b. Large ResidualSpaces: Residual spacesrefer to underutilized areas withinthe junction. These spaces not only create a visual and aesthetic concern but also pose potential safety risks and hinder the overall functionality of the junction.

c. Pedestrian Safety: Pedestrians face challenges while crossing the junction due to inadequate pedestrian facilities, insufficient crossing time, large crossing distances and no refuge spaces leading to conflicts with vehicular traffic.

d. Public Transport: Bus Stop to be shiftedat the edge of the street to avoid parkingin front of the bus stop and efficient use of the infrastructure by the public in waiting.

Figure 4.126 Existing condition and activity mapping of site

e. Cyclist Accessibility: There is a huge inflow of bicyclists observed at the junction at the peak hours. The junction lacks dedicated cycling infrastructure, making it challenging for cyclists to navigate through the junction safely.

g. Signalized Junction: The signalization at Chatrapati Junctionrequires assessment and potential improvements. Inefficient signal timing and coordination is leading to traffic congestion, delays, and conflicts between different traffic movements. Improper placement of signals promotes traffic violations as well.

h. Resting Spaces for Pedestrians: During clean hours, the junction experiences high movement of vehicles, and there is a lack of resting spaces for pedestrians. This leads to pedestrians being exposed to potential risk of accidents and discomfort due to the absence of designated resting areas. The small channelizer further has all the infrastructures such as signals, electric poles, and network towers installed in them so it cannot provide any space for pedestrians.

i. Speed Calming Measures and Road Geometry: The junction lacks adequate speed calming measures and road geometry improvements. The absence of traffic calming features such as speed breakers, roundabouts, rumble strips or traffic islands and channelizers can lead to excessive speeding, increasing the risk of accidents and compromising overall safety.

f. Provision of Road Signs and Road Markings: The inadequacy of road signs and road markings contributes to confusion and potential conflicts among road users. Clear and visible signage, lane markings, and pavement markings are essential for guiding traffic and ensuring smooth and organized movement through the junction.

Jaiprakash Nagar Junction's heavy traffic and commercial areas must be addressed if its usability, security, and visual appeal are to be maximized. The junction can be made into a well-organized and aesthetically pleasing area by putting the suggested improvement measures into practice, such as landscaping, extended traffic islands for traffic control, functional utilization and public spaces design, pedestrian infrastructure development, parking spaces, and an integrated design approach.

Black spot Mitigation Strategies:

- Geometry of the junction needs to be corrected.
- Refuge island for safer pedestrian crossing has to be provided by extension of the median.
- Bollards between the depressed median are the be placed for restricting vehicular movement.
- Providing organized spaces for all the activities on the junction to reduce haphazard parking like designated informal vending zones, auto stands, bus stops, designated parking spaces, etc.
- Providing mandatory signage and road markings where necessary as per IRC: 67 and IRC: 35 (2022).

Proposed Design

As per the improved junction design,

- We have been able to reclaim the residual spaces reduce the pedestrian crossing distance and larger channels for vehicles.
- Provide speed-calming premises and road signs and manuals.
- We have introduced tabletop slip lanes for safer left turns. Re-oriented the dividers for easier traffic movement at the junction.
- We reclaimed the extra spaces on the sides of the road and turned them into organized parking, cycle track, wider footpaths, and green spaces etc.
- Provide proper lighting and recreate public spaces.

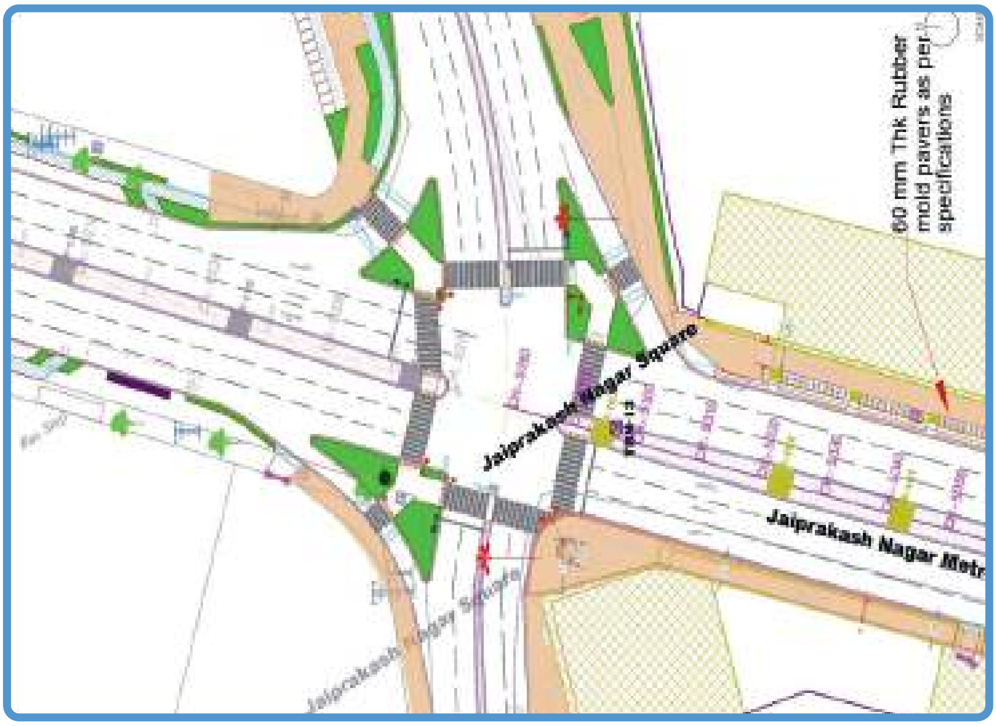
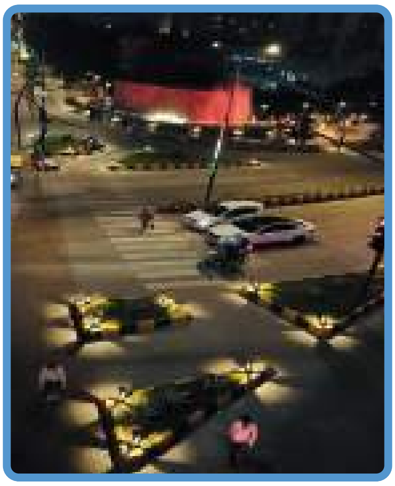


Figure 4.128 Proposed Plan of Jaiprakash Nagar Square

After Design

(a)



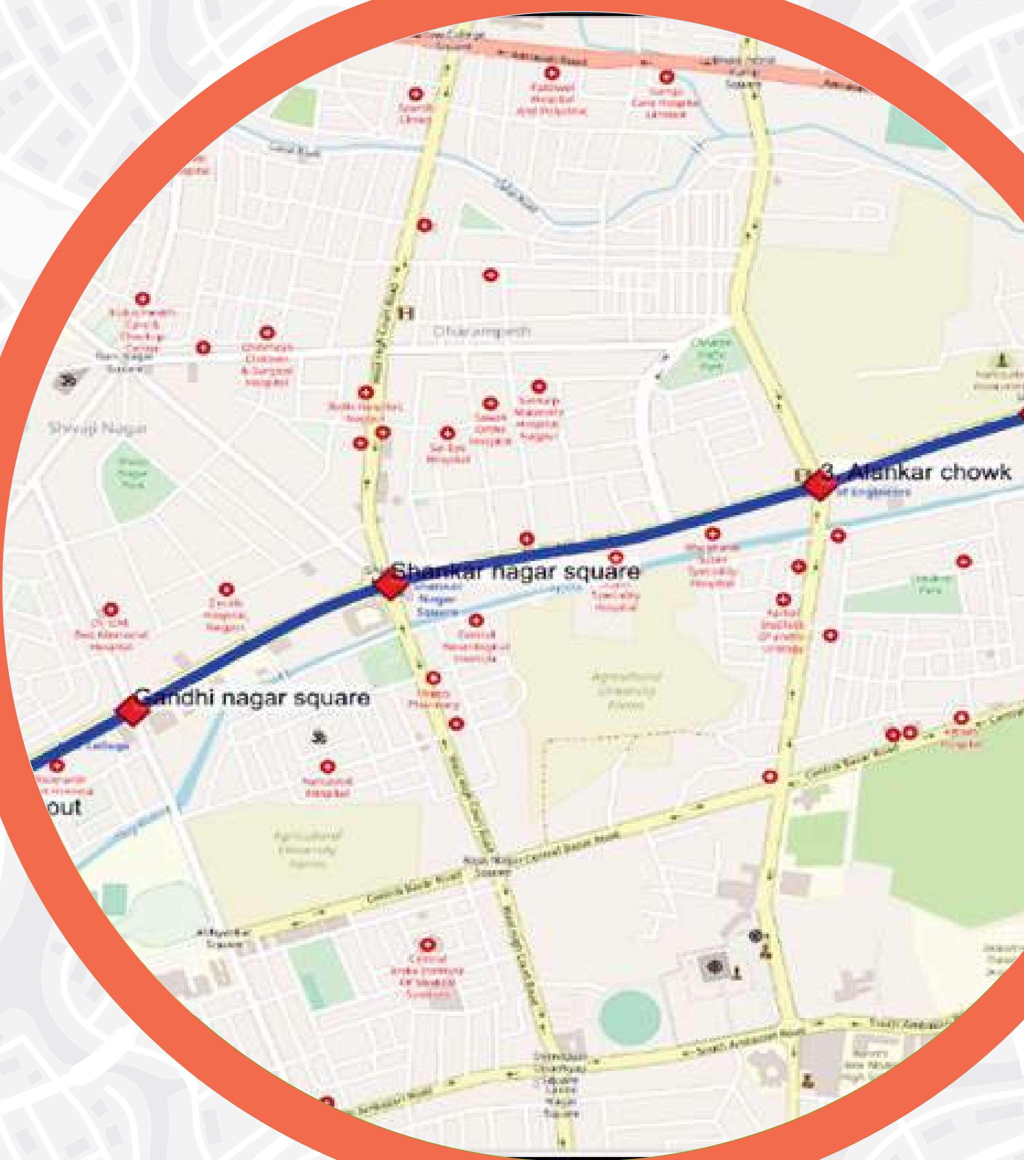
(b)

Figure 4.129 (a) Proper Designed Pedestrian Crossing, (b) Traffic Islands Elongated Islands for Traffic Control

4.6.4 Planning in Under Progress

The planning process is currently underway at Mahesh Dhaba, Chinchbhavan intersection, Omkar Nagar Square, Manewada Square. In the areas of Omkar Nagar Square and Manewada Square, the Total Vehicle Count (TVC) survey and report have been successfully completed, and the design & drawing file have received approval from CSIR - CRRI. As of now, for Mahesh Dhaba and Chinchbhavan intersection, the final report proposal have been completed, and the design & drawings have been submitted to the concerned road-owning agency.

QUICK ASSESSMENT OF ROAD INFRASTRUCTURE ASSETS THROUGH DIGITAL MAPPING



5

5. Quick Assessment of Road Infrastructure Assets through Digital Mapping

Presently urban roads in India are evaluated using conventional methods such as road tour assessment, field assessment, road safety audits, expert evaluation, and so on. These methods are inefficient and time-consuming in today's traffic conditions. In this digital age, the evaluation of urban roads requires more efficient and less time-consuming methods. These methods can utilize technologies like Artificial Intelligence (AI) to address assessment of road quality and safety, and hence assist in road maintenance, systematic evaluation of road safety assets, and lead to improvement in vehicle and road user safety. Therefore, these new methods can directly contribute to a decrease in road crashes and eventually help achieve the nation's target of 50% reduction in road crashes by year 2024.

iRASTE Team proposed and designed a new method for road quality assessment using data from AI devices in our project. This Road Quality Index (RQI) can be used as an evaluation metric. We demonstrated our proposed method with a calculation of RQI metric for a small road corridor in our project. Road-owning agencies can also calculate RQI using any similar data collected and use the metric for road maintenance work.

5.1 Data Collection

Artificial Intelligence based system was utilized to identify road infrastructure assets in the project. We evaluated the system for a pilot corridor in our project and found that this camera-based AI system to be many times faster and more efficient than the traditional, time-consuming, detailed, manual assessment process. Figure 5.1 shows a sample result of infrastructure detection with AI-based system on the pilot corridor – type of asset, its geographical position, and additional meta-data. The road assets detected are major and minor potholes, road distresses, crosswalks, various road signs (traffic, warning, mandatory and information), and power poles. This approach can be easily extended to any large area, zone, city or beyond.

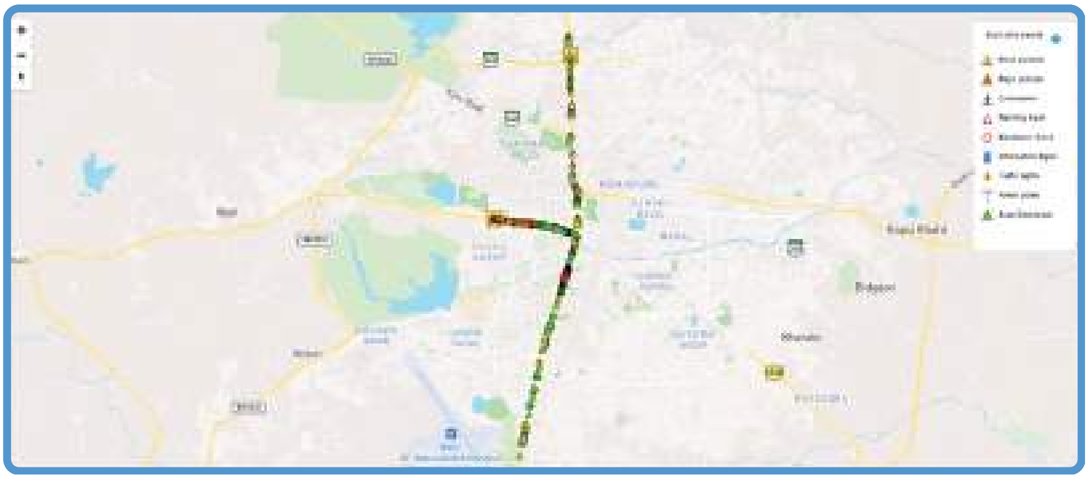


Figure 5.1 Digital mapping of road safety assets.

The data collected for the study corridor collected are classified into two types of parameters as shown in Table 5.1. The road safety assets include primary data such as traffic signs, traffic lights, lane markings, road edges, crosswalks, stop lines, power poles, and lane width are considered primary data, and some secondary data such as pavement distresses - rutting, raveling, potholes, cracking, and waterlogging are collected from a field visit.

Table 5.1 Details of Primary and Secondary Data

Primary data		Inventory data
AI-based road safety assets		
Asset	Type	Pavement distress (m2)
Traffic Signs (TS) (count)	Regulatory	Rutting
	Warning	
	Informatory	Raveling
Traffic Lights (TL) (count)	3 vertical traffic light	
	4 vertical traffic light	Potholes
	Pedestrian light	
Lane Markings (LM) (m)	Median Side Edge Line (MSEL)	
	Lane Line (LL)	
	Shoulder Side Edge Line (SSEL)	Cracking
Road Edges (RE) (m)	Length	
	Gap	
Crosswalks (CW) (count)	Zebra crossing	
Stop Lines (SL) (count)	Solid line	Waterlogging
Power Poles (PP) (count)	Electric pole	
Lane Width (LW) (m)	Carriageway width	

5.2 Study Area

The road corridor selected for this study on RQI is an urban road of Nagpur City from Jhansi Rani Square (JH) to Ambazari T-intersection (AMB). The total length of road section is 3.75 Km, which is further divided in to six segments of different lengths, that are visually represented in Figure 5.2, and details are given in Table 5.2.

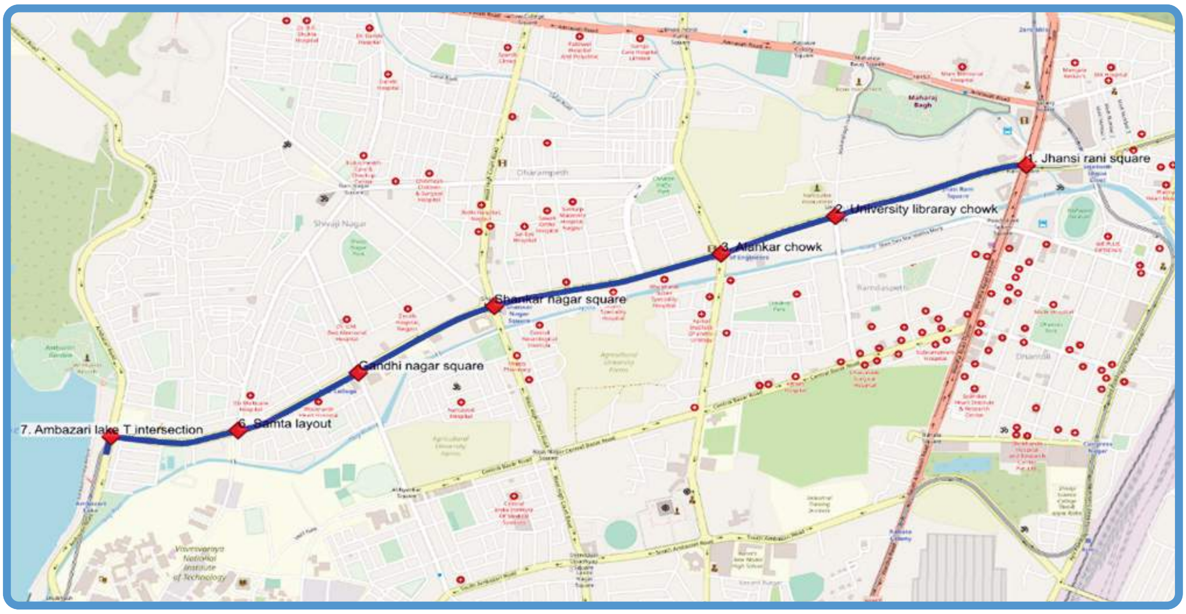


Figure 5.2 Study area corridor and segments.

Table 5.2 Details of segments in pilot corridor.

Segment ID	Segment		Length of segment (m)
	From	End	
1	Jhansi rani square (JH)	University library square	765.613
2	University library square	Alankar square	474.68
3	Alankar Square	Shankar Nagar square	898.3
4	Shankar Nagar square	Gandhi Nagar square	590.09
5	Gandhi Nagar square	Samta layout	522.18
6	Samta layout	Ambazari T-intersection (AMB)	498.73

The data collected from the AI-based system with geo-coordinates is analyzed further with the help of GIS software. Table 5.3 and Table 5.4 presents the road assets and operating conditions on both directions of the study corridor.

Table 5.3 Road inventory and condition data - from Jhansi Rani Square (JH) to Ambazari T-Intersection (AMB).

Segment	Traffic Signs	Traffic Lights	Stop lines	Crosswalks	Power Poles	Median Side Edge Line	Lane Line	Shoulder Side Edge Line	Ravelling (m^2)	Cracking (m^2)	Rutting (m^2)	Potholes (m^2)	Waterlogging (m^2)
JH-AMB 1	16	1	0	1	1	610.579	654.03	652.12	6.75	0.25	24	0.25	90.5
JH-AMB 2	7	2	1	2	1	417.01	412.2	434.48	0	0	24	0.25	4
JH-AMB 3	18	3	2	3	20	892.755	812.22	843.604	0.25	0	1	30.95	9
JH-AMB 4	15	1	2	5	10	592.629	494.23	480.652	1	0	0	0.25	0
JH-AMB 5	6	0	1	2	6	419.669	450.72	438.862	8.75	0	0.49	0	7.5
JH-AMB 6	3	0	2	3	2	451.472	433.14	340.336	0	0	0	0	10.85

Table 5.4 Road inventory and condition data - from Ambazari T-Intersection (AMB) to Jhansi Rani Square (JH).

Section ID	Traffic Signs	Traffic Lights	Crosswalks	Power Poles	Median Side Edge Line	Lane Line	Shoulder Side Edge Line	Ravelling (m2)	Cracking (m2)	Rutting (m2)	Potholes (m2)	Waterlogging (m2)
AMB-JH-S6	10	0	2	11	498.73	498.73	498.73	0	0	3.5	0	2.5
AMB-JH-S5	16	3	3	23	488.18	488.18	522.18	0	0	1	1.25	9.5
AMB-JH-S4	13	10	3	18	523.09	523.09	555.09	0.75	0	0	1	11
AMB-JH-S3	23	9	2	32	859.3	859.3	888.3	0	0	0	0.5	30
AMB-JH-S2	14	18	4	11	443.68	443.68	468.68	2.25	0	0	0	50
AMB-JH-S1	20	11	2	23	732.613	732.613	765.613	0	1	0	0	40

Using the above collected data, stakeholders and road-owning agencies can calculate Road Quality Index (RQI) or it is useful in the maintenance work of roads. A methodology to develop RQI is presented below.

5.3 Road Quality Index (RQI) - Methodology

The methodology we proposed for development of Road Quality Index (RQI) is developed by identifying the influencing parameters and their thresholds values as per the prevailing guidelines/standards and the scores (S) for each parameter below are calculated. The influencing parameters and methodology used are also described below.

a. Road Traffic Signs (S1)

- All the traffic signs which were collected by ADAS and after field validation the asset is evaluated.
- The operating speed of the study corridor is typically 50kmph. As per clause 4.8 of IRC: 67-2022, the minimum spacing between two consecutive traffic signs should be at a distance of 0.6*V (V is operating speed). The availability of spacing for different types of signs are evaluated.
- The number of sign scores has been calculated on the basis of their density i.e., the density of sign board in each segment and assigned weightages 50%, 25% and 25% for mandatory, warning, and informative sign respectively.

b. Traffic Signals (S2)

- The requirement traffic light has been calculated on the basis of each type of junction on study corridor as per the IRC: 93-1985, there are three types of traffic lights: Primary light, secondary light, and pedestrian light.
- The scoring has been assigned according to their presence/absence. The scores values have been assigned as 0, 0.5, 0.75 and 1 for the primary and secondary light as well as for pedestrian traffic light. 1 is for presence of all the traffic lights required ideally and 0 for absence of all the traffic lights, for primary and secondary as well as pedestrian traffic lights.

c. Pedestrians Crosswalks/Zebra Crossings (S3)

- ·The cross walk and zebra crossing has been calculated based on the density of crossing at every 500m on each segment. The score is assigned as per the density of cross walk/zebra crossing. The scores value has been assigned as 0.5 and 1. For more than 500m the score is 1 and 0.5 for less than per 500m.

d. Electric Power Poles (S4)

- The density of power pole has been calculated for each segment and compared with the IRC standards the scoring has been assigned accordingly. The scores values are 0.5 and 1. 1 has been assigned to ideal condition and 0.5 for deficient in electric poles availability

e. Road Markings (S5)

- The lane marking on selected road stretch has been calculated for median side edge line, lane line and shoulder side edge line. The density of each types of marking line has been calculated by the marking line divided by its segment length. The availability of road marking is evaluated with respect to IRC 35-2015. The scoring value has been assigned as per its density. The score value is one, if the lane marking is equal to its segment length and linearly reduced for their non-availability.

f. Road Distresses (S6)

- ·The distress such as patched area, cracked area, ravelling and potholes are collected and Pavement Condition Index (PCI) has been calculated according to percentage of each road distresses and the proportion of each distresses in their respective segment. The PCI index has been calculated as per the equation given below.

$$PCI = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 \quad \text{(Eq. 4.1)}$$

where, a1, a2,..., a5 are weightages for distresses type, and The final **Road Quality Index (RQI)** is defined for each section as

$$RQI = \sum_{i=1}^{6} S_i$$

where, S1, S2, S3, ... S6 are scored value of each asset.

5.4 Results and Discussions

The scores for each parameter are calculated for the study corridor on both directions of traffic. Figure 5.3 shows the scores of individual parameters on both directions of the traffic i.e., Jhansi Rani to Ambazari T-intersection and Ambazari T-intersection to Jhansi Rani Square.

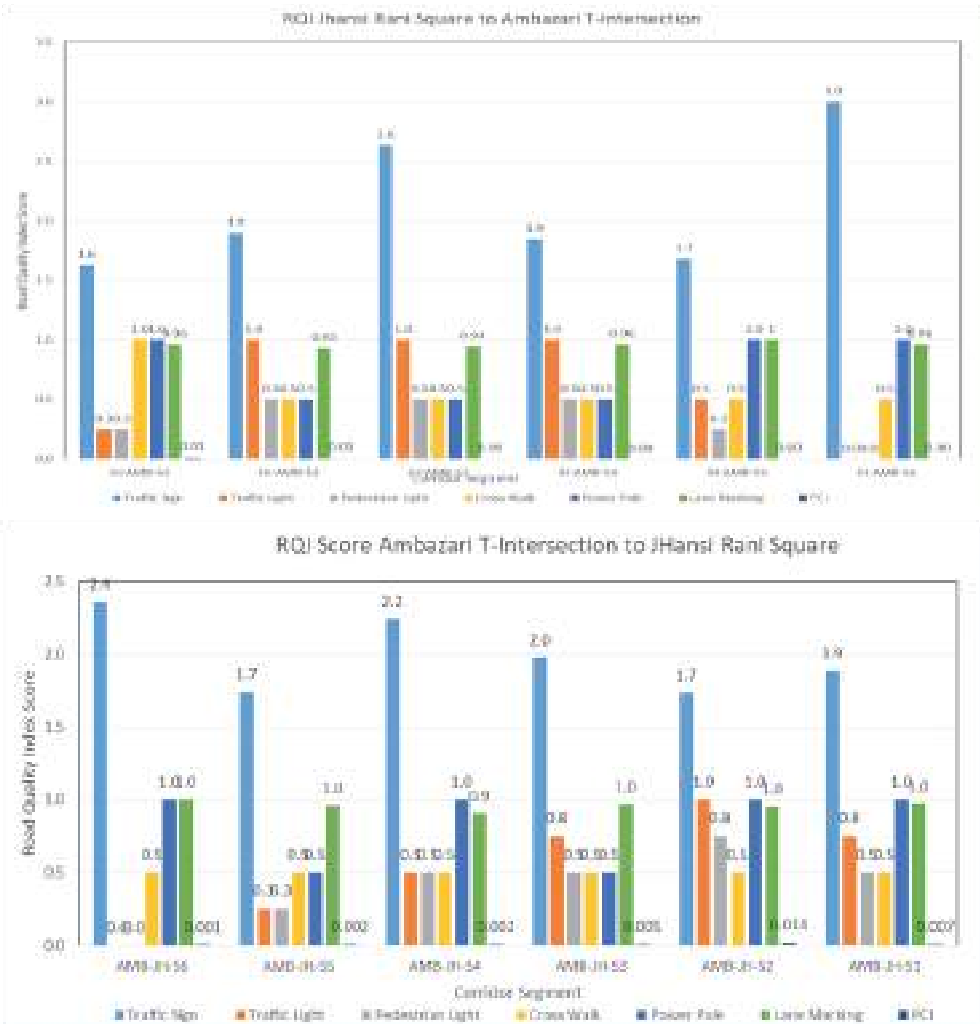
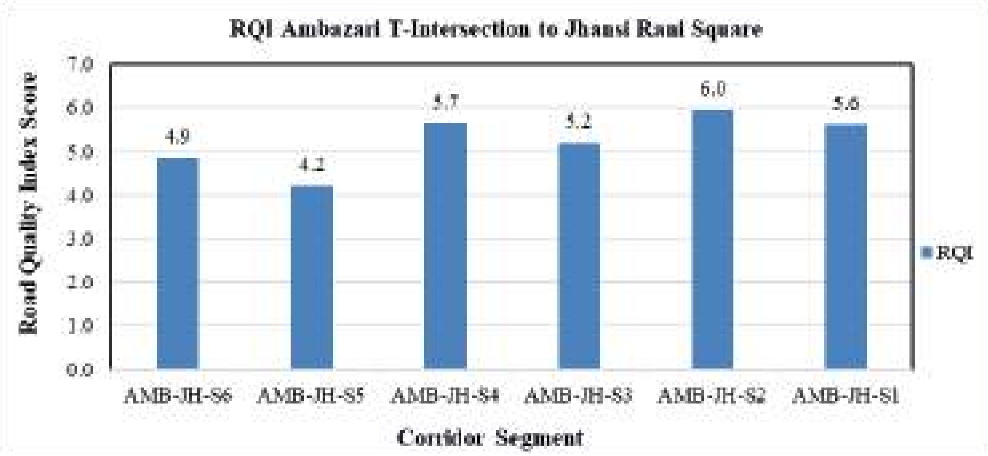


Figure 5.3 Individual parameter scores on the study corridor

From Figure 5.3 it can be observed that traffic signs, road markings and traffic signals are more influencing the Road Quality Index values. The pavement condition index has less influence because the overlay was done in recent years. The segment wise values of RQI are given in Figure 5.4.



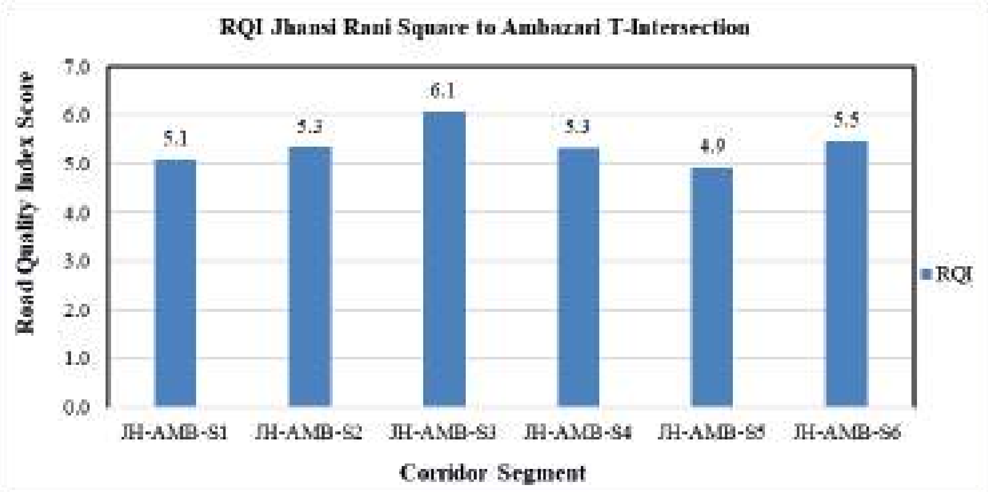


Figure 5.4 Road Quality Index (RQI) values for all the segments of study corridor

From Figure 5.4, it can be observed that the section number 3 and section number 6 are having lower RQI values in the Jhansi Rani to Ambazari T-Intersection direction and the sections number 2 sections number 4 having lower RQI values in the Ambazari T-Intersection to Jhansi Rani direction, hence these sections possibly require interventions to assure good quality of road.

5.5 Limitations & Future Work

The system of using a Camera-based Artificial Intelligence (AI) system to address assessment of road quality and safety has some known issues and limitations – it cannot accurately estimate the road distresses or faded road markings. These issues can be augmented with other sensory data in future.

DRIVER EDUCATION & TRAINING

6

6. Driver Education and Training

To create a path to sustained improvements in road safety, Project iRASTE is undertaking training, education and awareness initiatives targeting commercial vehicle drivers as well as the general public.

6.1 Driver's Education and Training program

Through the above innovative and holistic road safety framework, the project focuses on three crucial areas: vehicle safety, mobility safety and road infrastructure safety. As Driver Education, Training, and Awareness, is a very important part of the vehicle safety vector, the above consortium partners of **Project: iRASTE** in partnership with Nagpur Municipal Corporation (NMC) conducted four numbers of training programs spread two and half year period since February 2022 titled, **"Defensive Driving and Driver Assistance through Artificial Intelligence"**, specifically addressing the needs of Commercial Vehicles (i.e. Bus and taxi) drivers to promote Defensive Driving Practices amongst the drivers. Through the above programs, total 1337 drivers were trained.

One of the important aspects dealt with within Project iRASTE focused on imparting Safe Drivers Training Program. This provided a platform for interaction among the end users of the AI-based Advanced Driver Assistance Systems (ADAS). Apart from these, various activity-based sessions including **Eye Check-up and Skit programs on Road Safety** were conducted during the above training programs to reinforce the understanding related to road safety.

In this regard, CSIR – CRRI, New Delhi designed 4-part training program to benefit commercial vehicle drivers over a period of 2 years and 6 months. The first of this customized training program was conducted by one of the consortium partner, i.e., CSIR - CRRI, New Delhi over the project tenure *(Refer typical photos in Figure 6.1 & 6.4)*.

6.1.1 Program Highlights

a. Total number of drivers trained during the Training Program of iRASTE: 1337 number of drivers benefited from the initiative during the four Drivers Training Programs (DTP) on Defensive Driving Practices as well as the efficacy of the ADAS installed in 200 NMC buses and 50 school buses in Nagpur.

- 1st DTP: 340 drivers trained during 21st -26th Feb 2022
- 2nd DTP: 371 drivers during 12th -17th September 2022
- 3rd DTP: 300 drivers 13th to 17th March 2023
- 4th DTP: 326 drivers, 29th Feb – 2nd March 2024

b. Course Coordinators: Dr. Mukti Advani (1st to 3rd DTP), and Dr. Vinod Karar (4th DTP), CSIR – CRRI.

c. Topics covered

- ·Road safety, Defensive driving practices,
- ·First-aid, Health tips.
- ·Upskilling on technology enabled safe driving by using ADAS

d. Recognitions:

- 250 drivers awarded recognizing their compliance to ADAS and clocking 1,00,00 kms of Road Crash Free driving since the installation of ADAS

e. Additional services:

- Eye checkup for all participants during DTP-2 of the Training Program in September 2022.

f. Venues at Nagpur city:

- RTO Hall, CSIR - NEERI Auditorium, Mor Bhawan Depot

g. Training partners::

- a. Ashok Leyland Institute for Driver Training & Research (ALIDTR) and M/s ROADMARC Foundation, Nagpur.

Figure 6.1 Glimpse of Trainings & Recognition programs critical to maintaining safety behaviour (DTP -1).

Figure 6.2 Glimpse of Driver's Education specific to ADAS and maintaining safety behaviour (DTP-2).

Figure 6.3 Glimpse of Drivers Training through Street Show and Propagating Road Safety Awareness (DTP-3).

Figure 6.4 Driver Education & Trainings with Advanced Simulation Techniques (DTP – 4).

The most recent Training Program on Defensive Training was held from 29th February to 2nd March 2024 at CSIR - NEERI Auditorium by the team of CSIR - CRRI (Dr. S. Velmurugan, Project Investigator: iRASTE, Dr. Vinod Karar, Smt. Kamini Gupta, Sh. Mohd. Akil, and Sh. Mukesh Kumar) and Ashok Leyland Institute for Drive Training and Research (*ALIDTR*).

On the first day, **Prof. Manoranjan Parida, Director CSIR - CRRI was the Chief Guest** who appreciated the use of technology in improving safety and asked the drivers not to create unsafe zones and advised them from refraining to adopting risky driving practices. Based on his interaction with the Drivers of the buses running under Nagpur Municipal Corporation (NMC), he was pleased to know that the ADAS (Advanced Driver Assistance System) installed in their buses are serving as useful tool in this regard

On the second day of this program, Ms. Anchal Sood Goyal, IAS, Additional Commissioner, NMC graced the occasion as Chief Guest. She appreciated the research initiative undertaken by the consortium to improve road safety on the road network of Nagpur and he extended his wishes for its success. Dr. Atul Vaidya, Director CSIR - NEERI graced the program as Chief Guest on the third day. He appreciated the use of technology in improving safety. Closing ceremony of Day-5 i.e. 2.2.2024. was graced by **Prof. Udit Jain, Member of District Road Safety Committee**, Transportation Engineering Division, Department of Civil Engineering, VNIT Nagpur. Prof. Jain lauded the efforts of the consortium and asked the drivers to be vigilant during driving and also to obey the CAS alerts generated by the ADAS which can help to enhance road safety on the roads of Nagpur.

The expert lectures delivered by **Dr. Vinod Karar, Mr. Pathe, and Ms. Kamini Gupta**, insightful contributions made by **Shri Neelmani Gupta, GM of RK Travel Nagpur; and Shri Sunil Deshpande, Head of ALIDTR, Chindwara** is greatly appreciated.

Group photo with NMC Bus Fleet Drivers-

6.2 Assessment of Driver Alertness through Vienna System

One of the basic capabilities required for safe driving is the need to have proper reaction time exhibited by the drivers while encountering various situation(s) on the roads. To address the above, evaluation of the above trait has been attempted through the VIENNA TEST. This test system is performed through computerized psychological assessments for the subjects / drivers and provides automatic and comprehensive scoring as it captures the reaction time systematically. The Hardware part of Vienna test system includes three parts: (1) Display Screen, (2) Response Panel and (3) Foot pedals. As shown in Figure 6.5, these are connected through proper wirings. In the Vienna Test structure, the respondent's task is to react as quickly as possible to optical and acoustic stimuli that are displayed (on a computer screen) sequentially. Such reactions are made by pressing the corresponding buttons on the response panel or by pressing the foot pedals. More details on Vienna Test system and its design are provided in APPENDIX A.

Figure 6.5 Vienna Test System

6.3 Data Collection, Analysis, and Results

All data for this study were obtained between the 21st of Feb'22 to 26th Feb'22. This comprises 151 drivers taking the Vienna test. The Vienna test was carried out with CSIR-CRRI team at RTO, Nagpur, where drivers from all bus operators (three) used to come after their morning shift duties. Before beginning the exam, all drivers were given written and spoken instructions of the Vienna Test System's test procedure. This was followed by 15-minutes intervals testing for each driver in which 540 signs/signals were conveyed to the driver in 15-minutes at various speeds, intervals, and combinations. of testing. Figure 6.6 illustrates a sample of test setup and administration.

Figure 6.6 Vienna test setup & administration

These transmitted signals and associated reactions were exported in a matrix format at the end of the test time, as illustrated in Table 6.1.

Table 6.1 Vienna output matrix

Driver Name	A1								
Reactions (requested)	White	Yellow	Red	Green	Blue	Right foot	Left foot	High tone	Low tone
White answers	18								
Yellow answers		18							
Red answers			18						
Green answers				17					
Blue answers					18			1	
Right foot answers			1			13			
Left foot answers	1		1			3	3		
High tone answer								13	
Low tone answers								1	17
Omitted	1	1	1	2		6	16	5	1
Sum of wrong answers	1		2		1	3		2	
complete correct	17	18	16	17	18	10	3	11	17
omitted	1	1	1	2	0	6	16	5	1
wrong	1	0	2	0	1	3	0	3	1
total	19	19	19	19	19	19	19	19	19

Table 6.1 presents a typical output which is in form of a matrix. All the communicated signals and their responses have been presented through a matrix. This includes the information regarding

- Number of correct responses
- Number of wrong responses
- Number of omitted signals (i.e., driver could not respond at all)
- Delayed responses (correct responses but delayed)

Similarly, additional drivers were tested in similar manner, and so was collected the output matrix for all of them (drivers) like this.

It can be understood from Table 6.1, the responses are related to two kinds of signals (s), Audio & Visual, and these are randomly given to the drivers. Various lights are included in the visual signals of different colors (White, Red, Yellow, Green & Blue), as well as visual signals of Left and Right leg movement. And there are two types of audio signals present: High Tone and Low Tone. According to (Pain & Hibbs, 2007) research, basic Average Reaction Time (ART) had the Quickest Reaction Time (RT) for any given signals. *(Thompson, et al., 1992)* conducted a study, the typical RT to detect visual signal is roughly 180-200 milli-seconds (ms), whereas the RT to detect sound is approximately 140-160 ms. According to *(Kemp, 1973)*, an auditory signal takes just 8-10 ms to reach the brain, but a visual signal takes 20-40 ms. Also, there is a confusion occurs between the pitch of high tone and low tone signals. As a result, because auditory signal reaches the brain slightly faster than visual signal, Audio Reaction Time is faster than the Visual Reaction Time. As per a study done by *Mohammadi, Zokaei, & Sandrock, 2015*, exposure to road traffic noise increases the reaction time in introverts and extroverts, as well as in males and females. According to all of these studies and the matrix table, incorrect responses occur more frequently in audio signals than visual signals. As per this matrix Table 6.1, when left and right leg motions happened visually, the Complex Reaction Time for eye to foot movement came longer than eye to hand movement. As a result, foot movements become increasingly incorrect. With this test, the various reactions/responses of the drivers can be seen, so that the driver's behaviour while driving can be estimated approximately.

Table 6.2 also explains the relationship between the Vienna test and the ADAS device. To begin with, both audio and visual alerts are generated from the two, illustrating the various responses of the driver while driving, and both considered eye to hand movement, eye to foot movement, ear to hand and ear to foot movement, which validates their relationship practically

Table 6.2 Relation between ADAS and Vienna Test System

Movements	Vienna Test	Collision Alert System
Eye to Hand	✓	✓
Eye to Foot	✓	✓
Ear to Hand	✓	✓
Ear to Foot	✓	✓

In addition, during the Vienna test, a Detailed Questionnaire Survey (DQS) was completed with the consent of each driver, which provided different driving attributes of drivers. Table A.2 described the Questionnaire survey format, using this the drivers were asked about their name, age, experience, educational background, any past assistantship work during their beginning stage, previous involvement in road crashes, any eye diseases, wearing glasses, and so on. Only reliable and significant information that would be useful in driver assessment and developing an index were considered, such as age and driving experience, other past assistantship job, other eye illnesses, and wearing glasses or not.

After systematically reviewing the questionnaire survey data, relevant data was extracted that could be utilized in further research, such as age, driving experience, assistantship work in the early stages of their driving field, and any eye issue, which can be understood through the creation of a graphs.

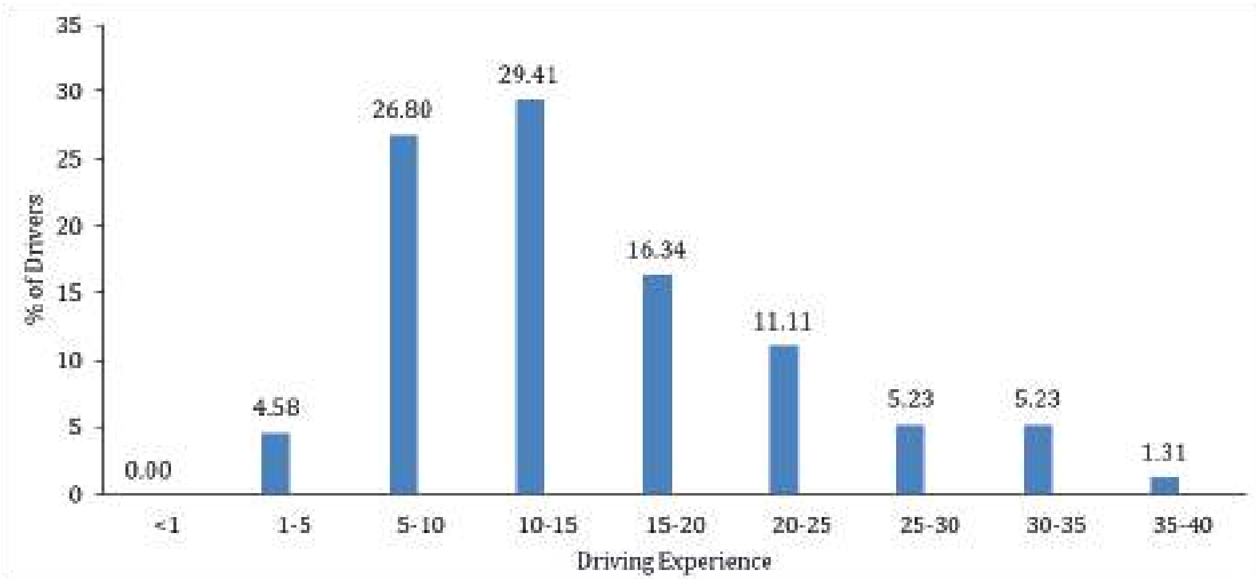


Figure 6.7 Categorizing % of drivers based on their experience

Figure 6.7 shows that drivers with less than a year of experience account for 0%, while drivers with 1 to 5 years of experience account for 5%, and drivers with 5-10 and 10-15 years of experience account for 27% and 30%, respectively. In addition, 16% of drivers have 15 to 20 years of experience, 11% have 20 to 25 years of experience, and 5% have 25 to 30 years of experience or more.

Figure 6.8 depicts the percentage of drivers who have previously worked as a driver's assistant (Like conductor or helper). Figure 6.9 is about driver's eye illness, and it shows how many percentages of drivers have it.

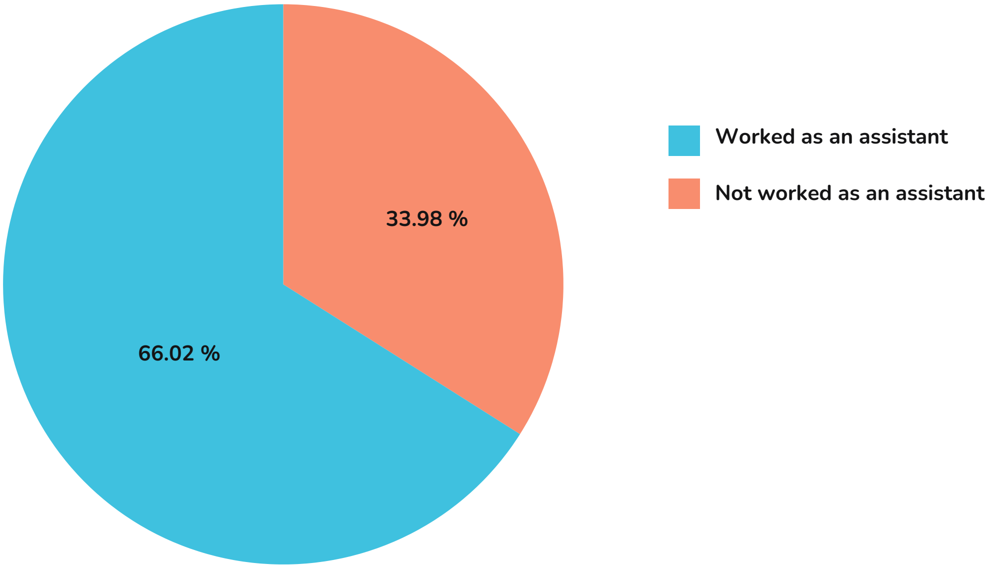


Figure 6.8 Categorizing % of drivers according to their assistantship work

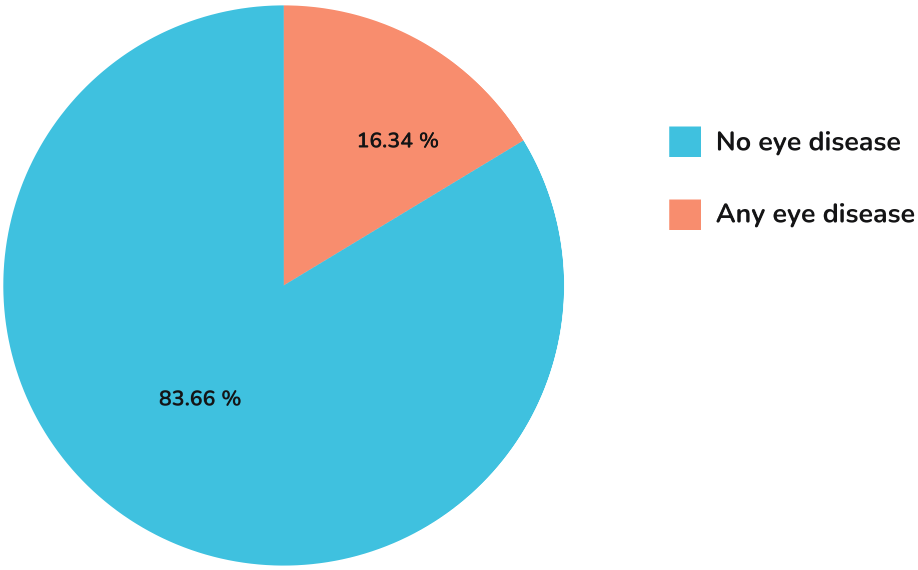


Figure 6.9 Categorizing % of drivers based on any eye disease

According to the study of this data, 16 % of the 153 drivers had eye issues and 66 % of these drivers had previously worked as a driver's assistant, but as a result of these factors there were no significant changes in ADAS alerts generation. When the alert generation was examined in relation to the driver's driving experience, it was shown that even experienced drivers generate more alerts, with the exception of young age drivers with who have driving experience of 5 years or less.

In this, the analysis of driver assessment is divided into two parts: first, the outputs of the Vienna test of drivers are analyzed, and then the correlation analysis between the relevant DQS data, Vienna scores, and ADAS alerts is examined. After that, developed a linear regression model using above data and from which an Index will be developed for the evaluation of drivers. The equation derived from this model can be used to analyze the driver, and based on this data, the function can be applied throughout India.

Following the Vienna test, data were evaluated in terms of responses classified as correct, incorrect, delayed, or omitted. A report for each driver is prepared based on its output answer matrix (refer Table 6.1), which is then computed individually for its overall correct responses and individual correct responses towards visual and audio signals. Five categories have been defined for drivers on the basis of correct responses towards total Vienna alerts and individual visual and audio alerts as shown in Table 6.3.

Table 6.3 Driver category based on Vienna score values

Total Correct Vienna Responses	Correct Visual Responses	Correct Audio Responses	Driver's Category
-	<50%	<50%	Weak
(50-75) %	>50%	>50%	Average
(75-85) %	>50%	>50%	Good
(85-95) %	>50%	>50%	Very good
>95 %	>50%	>50%	Excellent

Table 6.4 shows that when a driver responds less than 50% correct responses towards visual and audio signals of Vienna test individually, then the driver falls into the 'WEAK' category. And when the criteria of percentage correct response in individual visual and audio signals is greater than 50% is fixed but the percentage total correct response is between (50-75) %, the driver is in the 'AVERAGE' category; and in case when percentage total correct response is between (75-85) %, the driver is in the 'GOOD' category; if the driver is between (85-95) %, the driver is in the 'very good' category; and 'EXCELLENT' if percentage total correct responses (>95 %). This allows categorization of drivers that falls into which previously described driver category based on their percentage correct response towards total and individual Vienna signals (Visual/Audio).

After that, the data from the Vienna test was evaluated, this indicated how the driver reacts to the arrival of any visual/ audio signals in terms of their response time and describes the driver's attentiveness towards various signals/alerts. Following the analysis, the different outputs are generated, as illustrated in Figure 6.10, 6.11, and 6.12 below.

It is evident from Figure 6.10, that amongst the 153 subjects (Drivers) studied, 24 % drivers fall under the 'VERY GOOD' category, 31 % of the drivers having scores in the range of 'GOOD' category, 9 % falls the 'AVERAGE' category and 36 % of drivers have their Vienna score in the range of 'WEAK' category.

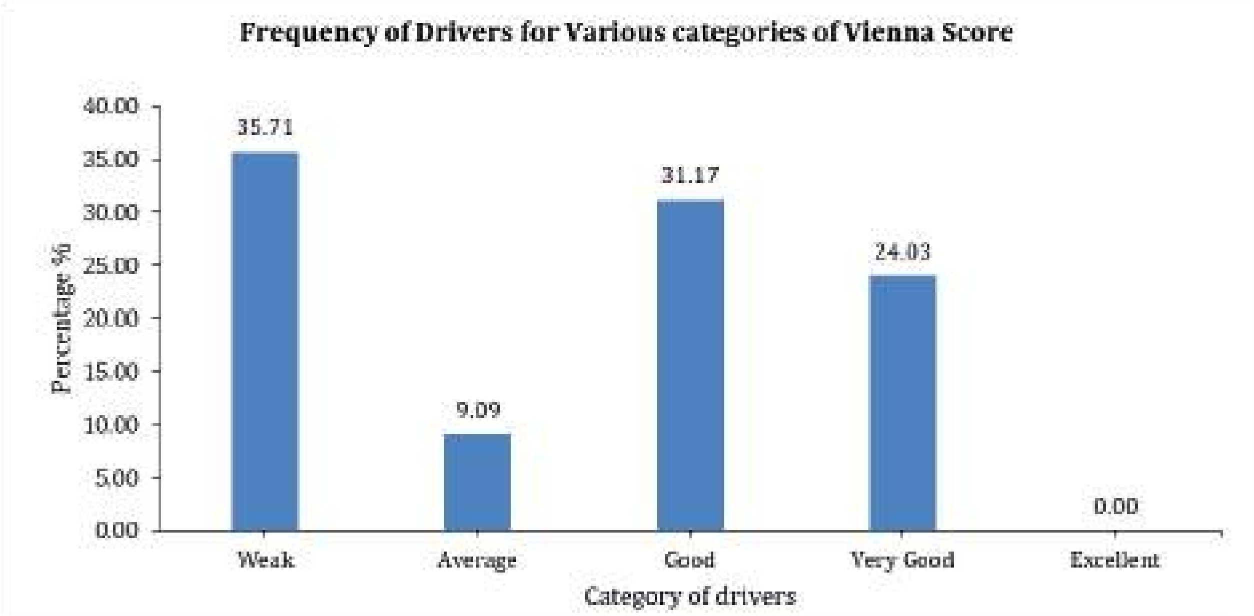


Figure 6.10 Categorizing Drivers based on Vienna Test Responses

Further analysis was done to understand drivers' response to visual and audio alerts separately. Figure 6.11 summarizes response to visual alerts. None of the drivers fall in the category of 0-20 range, 0.65 % drivers falls in the range of 20-40, 2 % drivers in the range of 40-60, 15.58 % drivers falls in the range of 60-80 and maximum 82 % drivers falls in the 80-100 range.

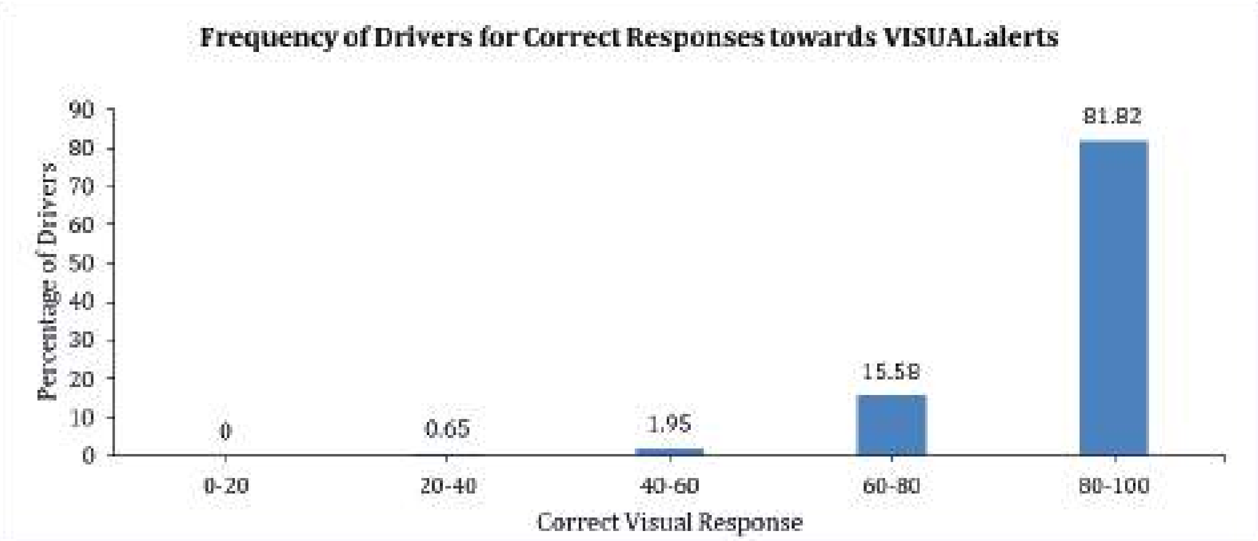


Figure 6.11 Categorizing Drivers based on Responses towards Visual signals of Vienna Test

Figure 6.12 summarizes response to audio alerts. It is noted that 12 % of the drivers fall into 0-20 range, 14 % being observed falling in the range of 20-40, 25 % in the 40-60, 34 % falls in the range of 60-80 and the remaining 15 % are observed to be falling in the range of 80-100.

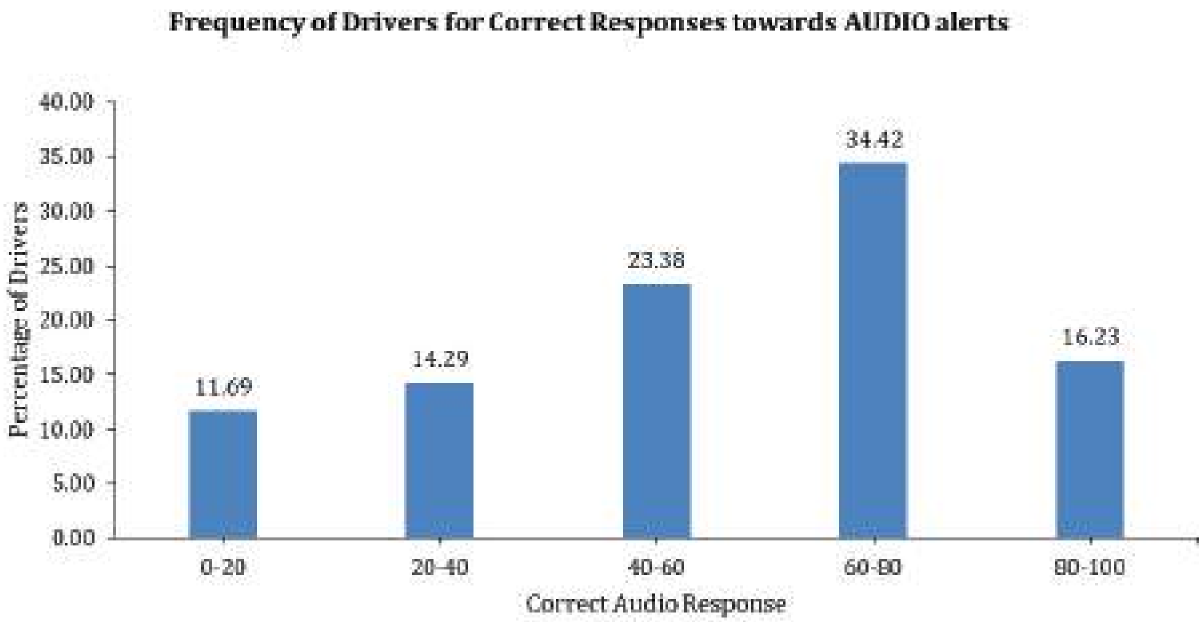


Figure 6.12 Categorizing Subjects based on Responses towards Audio signals of Vienna Test

6.4 Summary

It was inferred that the visual alerts are getting better responses compared to the audio alerts. Considering the above, one of the important take ways is that the subjects respond better to the visual alerts generated out of the ADAS system installed in the NMC fleet.

AWARENESS & EMERGENCY CARE

A. AWARENESS CAMPAIGNS AT BLACKSPOTS AND GREYSPOTS

B. INSTALLATION OF TRYSTANDER CELLS

7

7. Awareness Campaigns and Emergency Care

Beyond the technology, engineering and driver training vectors, Project iRASTE spent significant effort on awareness programs at a city scale both to affect general behavioural change as well as equip citizens (especially around blackspots and greyspots) with first-aid knowledge to help save crash victims. **RoadMarc Foundation**, (Road Accident Disaster Management and Research Centre) led by **Mr. Raju Wagh**, is the on-ground implementation partner. Three key programs were initiated as part of this effort which are as follows:

a) Avagatkara
b) City Wide Good Samaritan Event
c) Blackspot Responder Cell

7.1 Avagatkara

In Blackspot / Greyspot locations, Project iRASTE team in collaboration with RoadMarc Foundation, organized events with the primary objective of creating awareness to educate residents to follow 100% traffic rules and avoid human errors that cause road crashes.

To start with, a pilot was conducted with the support of 75 families in the area, to identify what percentage of them follow the traffic rules. Their driving skills and behaviour were studied based on 20 questions. After analysing the answers submitted by the participants, an improvement in behaviour pattern was needed to reduce the safety hazards they are exposed to on the roads. Posters and door stickers were also stuck at a number of houses and establishments. At every entry point in the lanes of the locality, boards were erected, displaying traffic norms to be regularly followed by the people. Banners were set up on the roads for public awareness. The aim was to give constant reminders to the people as scrupulously following the traffic rules will result in lesser and lesser crashes. Each participant was also educated about fatal road crashes, the problems that lead to road crashes, the social, educational, psychological, and economic losses due to road crashes, and the mountain of grief that falls on the family due to an accident, so that the family members do not fall prey to fatal road crashes due to human errors/faults.

Booklets were distributed so that vehicle users can record their individual day to day experience after following traffic rules and their behaviour pattern before this, for a continuous period of 21 days. It was also experienced that when people take an oath every day, or whenever they can, they are reminded of the behaviour pattern they have to stick to and become more serious about the issue. People were also very enthusiastic about sending us their photographs and videos while taking the oath.

The next stage of the project began with the inauguration of the 'Learn the Art of Living Road Accident Free' initiative. More than 50 families took part in the project. The program conducted an awareness campaign which included 9 days of survey followed by 21 days of discussion with all the members of their families including parents, father, uncle, son, daughter, etc. The 30-day public awareness program culminated in each participant taking an oath to follow the traffic rules every day, to try to correct human errors for 21 days so as not to repeat it. The inauguration of this program was held on 26th May in the evening at Bandu Soni layout and DCP Traffic Mr. Sarang Awad inaugurated the program. He was very encouraging about the outcome of the project and promised the traffic department's help.

Some youth coming to gymnasiums or classes in the locality were also enthusiastic about this initiative and participated in the program. The team also visited Startups in the locality, discussed with them about our objective, and thereafter they also became part of the initiative.

This event spread awareness that following Traffic Rules can potentially reduce road crashes. 40% of the 500 participants (including 75+ families, 25 start-up businesses, 2 gymnasiums and local shopkeepers) admitted their mistakes and this awareness program made positive changes to improve their driving behaviour. 35% of citizens were committing mistakes unknowingly, and they expressed faith that they will rectify the mistakes/errors. All participants took a pledge to abide by Traffic Rules.

Figure 7.1 Avgatkara Team- Mr. Raju Wagh with INAI CEO Mr. Varma Konala (extreme left) and Mr. Manoj Murkute (Right)

Figure 7.2 Family members taking Oath to follow Traffic Rules.

Figure 7.3 Youth at a Gym being educated to follow Traffic Rules.

Outcome of Avagatkara:

- Dispel the citizen's perception that only carrying 100% vehicle documents means following all traffic rules.
- Spread awareness that using mobile phone while driving, skipping signals, speeding, overtaking without reason or without noticing the vehicle in front, avoiding using a helmet, not fastening the seat belt, driving while listening to loud music with headphones, etc. are the reasons that cause road crashes. 40% of the participants admitted their mistakes and this awareness program has made positive changes to improve their driving behaviour.
- 35% of citizens were committing mistakes to the extent of 90 to 100 %, as they were unknowingly making some mistakes, and they expressed faith that they will rectify the mistakes/errors. While 10% of citizens said that the initiative is good and co-operated, they were indifferent to following the traffic rules. There was no response from 5% of the citizens who seemingly were not afraid of crashes.

Some interesting observations:

- Some people blamed the administration and the government for road crashes and not without reason. They showed that even after repeated reminders the greyspots remained unattended. The traffic lights remained off at any hour of day or night causing chaos. When a traffic cop appears from nowhere, all of a sudden, to catch a rule breaker the people get confused and try to speed away, causing crashes. Stray cattle and stray dogs also roam around in abundant bliss.
- Many believed that a Mass Movement or a People's Movement is a need of the hour so that the violators who do not follow traffic rules will feel ashamed, and gradually a whole generation will emerge which follows traffic rules scrupulously, which in turn will drastically reduce the road crashes.
- People in general were totally unaware about greyspots & blackspots and the caution meant to be exercised while crossing these dangerous spots.

- ·Many a time people do not know which authority they should contact for rectification of these spots.

The concepts of Grey Spot and Black Spot were highlighted in this pilot. The Grey Spots, Black Spots, their technical nuances, and the dangers to which people were exposed while traversing these spots were also highlighted by Project iRASTE team.

7.2 City-wide Good Samaritan Event

In order to create a mechanism to help accident victims in the country through people's participation and to save the lives of thousands of injured people, Project iRASTE and RoadMarc Foundation have made an effort to start a people's movement in the country called **"Get First Aid Training, Become an Accident Defender".**

The goal of this program is to train up to 1 lakh people in the city of Nagpur with the basic first-aid techniques that can be used during the golden hour of a road accident to save lives. RoadMarc conducted programs at various police stations as well as a mega event with 2000+ people that were drawn from all segments of society in Nagpur.

RoadMarc conducted the following 8 training programs near Traffic Police stations. Each training event was conducted with the support of Traffic Police and attended by 50-60 people from neighboring localities. The program trained the participants on how to provide First Aid and educated them on following traffic rules to avoid crashes.

Table 7.1 List of Traffic police stations

Date	Location
17/5/2023	M.I.D.C POLICE STATION
20/5/2023	SONEGAON POLICE STATION
22/5/2023	MAHINDRA & MAHINDRA
24/5/2023	KAMTHI POLICE STATION
25/5/2023	AJNI POLICE STATION
25/5/2023	BALTARODI POLICE STATION
28/5/2023	JANKI NAGAR MAHILA MANDAL

Figure 7.4 First Training Program near MIDC Police Station

After a series of individual Training events, on June 10, 2023, a first aid training (refer Figure 7.4 and 7.5) was conducted in at Suresh Bhat Auditorium in Nagpur. The program was inaugurated by Hon'ble Mr. Nitin ji Gadkari, Minister of Road, Transport and Highways. More than 2000 attendees congregated from various schools, colleges, social organizations, etc., such as Mr. Shrimant Mudhoji Raje Bhosale, Ms. Chetna Tidke (Deputy Commissioner of Traffic Police), Dr. Vandana Kate (IMA Nagpur President), Mr. Rajesh Loya & Mr. Varma Konala (CEO of INAI) were present as chief guests for the event.

The audience in this program was given detailed training through expert doctors on how to give first aid to an accident victim in case of an accident. Information was given on how to handle the accident victim, how to give first aid and how to get him to the hospital as soon as possible.

Figure 7.4. First Aid Live Training at Good Samaritan Event, Nagpur

A street play was performed to raise public awareness. All the attendees also took an oath to follow road safety rules as well.

Figure 7.5 Audience taking an Oath to Follow Traffic Rule (1), INAI CEO Mr. Varma Konala Speaking at the Event (2).

Speaking at the event (refer Figure 7.6), the Union Minister of Transport and Highways gave a reward of Rs 5 lakh to the organization for such an initiative to become a public movement and appealed to the attendees to provide financial support for this innovative initiative.

Figure 7.6 Hon'ble minister Shri Nitin Ji Gadkari speaking at the event.

7.3 Blackspot Trystander Cell

The objective of the 'Blackspot Trystander Cell' is to act quickly in the first one hour (Golden Hour) of any accident near the Blackspot location. Whenever there is an accident, the first people who go there or help are usually tea shopkeepers, car mechanics, hotel vendors, fruit sellers, vegetable vendors, and local shopkeepers who live there.

Project iRASTE has partnered with Nagpur NGO RoadMarc to install Trystander Cells at 8 locations. RoadMarc Team worked on the ground to register and screen all the people and shopkeepers in both directions of the movement of the area, within a radius of 2 kilometers of each Blackspot. After registration, they become part of a committee and the board of the committee is put up at the local disaster management center, with a name and mobile number in it, the hospitals nearby, police stations, department of transport of the nearest area will also have the phone numbers of these units on that bord so that people can call.

The list of Trystander Cells set up in Nagpur city are shown below:

Table 7.2 Trystander cells implemented in Nagpur

S. No.	Location Name	Inauguration date
1	Mahesh Dhaba Square	22/7/2023
2	Chinchbhavan Square	10/8/2023
3	Chhatrapati Square	28/8/2023
4	Narendra Nagar /Shrinagar Square	28/11/2023
5	Omkar Nagar Square	10/11/2023
6	Manewada Square	24/11/2023
7	Mhalgi Nagar Square	10/11/2023
8	Wathoda Square	5/11/2023

In each cell a process of registration and screening was undertaken to form a committee of volunteers as outlined below:

Registration:

The main purpose of registration is to form the committee of members who are registered by Roadmarc Foundation. We have registered people around the Blackspot area, including small shopkeepers, hotels, tea-pan shops, auto drivers, puncture repairers, shoemakers, auto garages, small vendors, and some social foundations. In one Disaster Management Center, we have registered approximately 280 people. We have collected their names, mobile numbers, occupations, and addresses

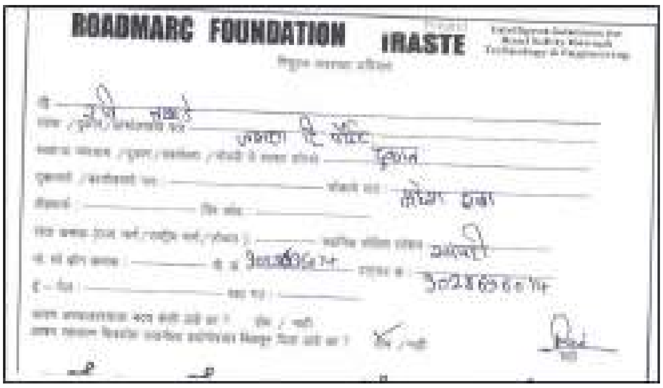


Figure 7.7 Registration Slip

Figure 7.8 Registration Process of Trystander

7.3.1 Mahesh Dhaba

Survey over Black Spot Area

Conducted a survey in the blackspot area, focusing on construction and human mistakes with reference to the respected authorities such as PWD, NHAI, Traffic Police, NMC, and the local public. During the survey, we identified various problems, documented them, and engaged in discussions on how to address and solve these issues. Additionally, we deliberated on strategies to raise public awareness regarding road safety and related concerns

Figure 7.9 Conducted a survey at Mahesh Dhaba Blackspot

Figure 7.10 Noting issues at Mahesh Dhaba Blackspot

1. The concerned department will solve the problems as follows:

- Proper Blinkers in between (both sides).
- Accident Prone Board (Both Sides)
- Speed Limit Board (Both Sides)
- Prohibition of going in the opposite direction (01 board)
- ·Zebra Crossing
- Warning symbol

2. Human Mistakes:

- Local citizens cross the square or take a U-turn sitting on triple, quadruple seats
- Impatient drivers violate red signal.
- Improper judgment while crossing the square.
- In which lane should a bike ride on the road in the Chowk area? 90 % have no knowledge about it
- Speedily leaves by removing the vehicle from as much space as can be found in two large vehicles.
- Drink and drive fast on the road at late night.
- Cross the road by jumping over the divider instead of going through the square area.
- Over speeding in square area.
- The driver does not use the indicator while turning.
- They are not using Helmet while riding bike.

3. Letter to Corresponding Department:

Given the letter to the concerned road authority regarding the issues present in the particular location and also suggested remedial measures required at Blackspot.

Figure 7.11 Intimation Letter to Concerned Road authority (PWD)

4. Awareness Campaign at Nearby Area:

The people of Khapri village in the Mahesh Dhaba area are making human mistakes that lead to fatal road accidents. We have discussed avoiding these mistakes and assured the people of Khapri village that we will explain the problems causing accidents on Wardha Road NH No. 7 and plan a solution for them.

Process of Selecting Volunteers

Formed a group of people, registered them, and created a WhatsApp group comprising all the registered members. After the registration process, we identified active individuals who are willing to assist others and contribute to disaster management. The Road Accident Disaster Management Centre is a committee consisting of 15 active citizens, selected from a pool of approximately 285 citizens within a 2 to 3 km area. We have documented the names of these Good Samaritans, who, despite being victims of accidents, engage in small businesses in the black spot area. They have been provided with mobile numbers displayed on boards. The primary objective is to facilitate their assistance to other citizens when needed.

Type of Training Provided

The training was conducted by expert doctors who instructed local citizens on how to use the tools available in a first aid box, how to access emergency services, how to admit the injured to the nearest hospital during the golden hour, and how to administer first aid to save lives. It is emphasized as a national duty to help the injured in an accident without expecting thanks, viewing it as a divine task, and approaching assistance with a humane perspective. A first aid box is installed below the disaster management board, and a stretcher and first aid kit are kept inside it. The first aid box is locked, and 15 to 20 keys have been made. These keys have been distributed to each member of the Disaster Management Committee.

Country's first road accident disaster management centre starts in district

Raju Wagh, Manjiri Javadekar, Naresh Borkar, Senior PI Vaijayanti Mandawdhare, Santosh Atram and others at the inauguration of road accident disaster management centre on Wardha Road.

■ Staff Reporter

ROADMARC Foundation, in collaboration with Intelligent Solutions for Road Safety through Technology and Engineering (Project IRASTE), has started what could be country's first road accident disaster management centre with people's participation. The centre was inaugurated on Saturday near Mahesh Dhaba at Khapri Pardi on Wardha Road.

The centre has been named after late Mohan Javadekar, who was killed in a road accident on Wardha Road in 2011. The location of the centre has been finalised considering that it is a 'black spot' (accident prone). Manjiri Mohan Javadekar; Naresh Borkar, Executive Engineer of Public Works Department; Senior PI Vaijayanti Mandawdhare of Beltarodi Police Station; and Raju Wagh, Chairman of Roadmarc Foundation and non-official member of National Road Safety Council; Santosh Atram; Dr Mercy Kharat, Raju Khandelwal, Sheshrao Charde, Shankar Junde and Swami Vivekananda Hospital officials were present on the occasion.

At the outset, Raju Wagh made introductory remarks and shed light on the concept of the centre. Baburao Wankhede conducted the proceedings and proposed a vote of thanks. Wagh said that the programme was organised to mark the birthday of Devendra Fadnavis, Deputy Chief Minister. He also administered oath to everyone to follow traffic rules and also help the accident victims.

According to Wagh, Roadmarc Foundation and IRASTE Project have set up country's first road accident disaster management centre with public participation. In case of a road accident, the first responders are usually the people running or working at small businesses in the area viz. hotel, tea-stall, fruit, flower and vegetable vends, two-wheeler/four-wheeler garages, puncture repair shops, shoemakers, grocery shops, dhaba. A road accident disaster management committee of 15 active citizens out of population of 385 area has been formed. Their names with contact numbers have been displayed on a board installed at the centre. Below the board, a locked first-aid box has been installed with a stretcher and first-aid kit inside. As many as 15-20 keys to the box have been made. One key each is kept with each member of the committee and also at Mahesh Dhaba, to facilitate immediate help to the accident victims. The local citizens have been trained on how to use the first-aid kit, how to help accident victims, and how to make safe use of the road.

Borkar assured that his department would help in addressing the factors causing road accidents in the area. Mandawdhare assured police support in the endeavour. Manjiri Javadekar also spoke on the occasion.

Pramod Madavi, Anil Godghate, Amol Misal, Sachin Naidu, Satyajit Waghade, Yogesh Sonkusare, Suraj Dharve, Nitesh Barahate, Gajanan Raut, Sagar Korde, Avinash Ilme, Anil Wagh, Ravi Tayde, Sushant Godghate, Amol Meshram, Amol Khapekar, Kapil Dongre, Prajwal Dighekar and Sahil Wankhede worked hard to make the programme successful.

Figure 7.12 Paper cutting of the Inauguration program

Figure 7.13 Road Accident Disaster Management Centre

Figure 7.14 Road Accident Disaster Management Centre at black spot area. Name of Good Samaritan and First aid box.

Figure 7.15 Dignitaries inaugurating the Disaster Management Centre. PWD, NHAI, Police, Nursing College Hospital.

Figure 7.16 Board with name and phone number of Samaritan

7.3.2 Chinchbhavan Square

A Road Accident Disaster Management Committee comprising 15 active citizens has been established from a pool of approximately 200 residents in the area. The names of these Good Samaritan accident responders, who are engaged in small businesses at Chinchbhavan Chowk, are displayed on a mobile number board. In the event of a road accident, immediate assistance can be sought from these committee members. Each of the 15 individuals is committed to providing aid to the injured, collaborating with others to help save lives.

Figure 7.17 First Aid Box and Stretcher

Figure 7.18 First aid box and board with names of Samaritan and their phone number

Figure 7.19 Awareness Board

7.3.3 Chhatrapati Square

A Road Accident Disaster Management Committee comprising 17 active citizens has been formed out of approximately 385 citizens in the area.

Figure 7.20 Road Accident Disaster Management Center with Samaritan name and their phone numbers

Figure 7.21 Survey work over Chhatrapati Square Blackspot

Figure 7.22 First Aid Training

Figure 7.23 List of Good Samaritan Committee

7.3.4 Shrinagar Square / Narendra Nagar Square

A road accident disastermanagement committee of 14 activecitizens has been formed out of about 180 citizens in the area and the names of these Good Samaritan accident victims who are doing small business at Shrinagar square / Narendra nagar square have been given on the mobile number on board.

Figure 7.24 Awareness Campaign at Shrinagar square / Narendra nagar square

7.3.5 Veerghav Square / Omkar Nagar Square

A road accident disaster management committee, consisting of 15 active citizens out of approximately 280 residents in the area, has been established. The names of these Good Samaritan citizens, who are engaged in small businesses at Omkar Nagar Chowk, have been provided on the board along with their mobile numbers. In the event of a road accident, immediate assistance can be sought from these committee members.

At least one of the 15 designated individuals is available to aid the injured with the support of others, contributing to life-saving efforts. A first aid box is affixed below the disaster management board, containing a stretcher and a first aid kit, securely locked. Fifteen to twenty keys have been produced, with each key distributed to a member of the Disaster Management Committee. Additionally, keys have been provided at Omkar Nagar Chowk, ensuring accessibility to the box for utilizing its contents in administering first aid to accident victims.

Figure 7.25 Dignitaries Inaugurating the Road Accident Disaster Management Centre at Veerghav Square / Omkar Nagar Square

Figure 7.26 Road accident disaster management center with board having Samaritan name and phone number.

Figure 7.27 First Aid Training

Figure 7.28 All Good Samaritans and Dignitaries

7.3.6 Manewada Square

To facilitate rapid response, a road accident disaster management committee comprising 14 active citizens has been formed from a pool of approximately 280 residents in the area. The names of these Good Samaritans, engaged in small businesses around Manewada Chowk, have been shared on a mobile board. In case of a road accident, immediate assistance can be sought from these committee members, ensuring that at least one of the 17 designated individuals will provide aid, mobilizing additional help if need to save lives.

Local citizens underwent training on disaster tool usage, accessing emergency services, admitting the injured to the nearest hospital within the golden hour, and administering effective first aid. Dr. Bhagyashree Guadhe conducted the first aid training sessions. Public awareness campaigns have been implemented to highlight the potential for human error.

Figure 7.29 RADMC with board having Samaritan name and phone number

Figure 7.30 Special guest Addressing the Disaster management Centre

7.3.7 Mhalgi Nagar Square

A road accident disastermanagement committee of 17 active citizens has been formed out of about 250 citizens in the area and the names of these Good Samaritan accidentvictims who are doing small business in Mhalgi NagarChowk have been given on the mobile number on board. First Aid training is provided by Dr. Bhagyashree Guadhe. Public awareness has been raised concerning human errors while traveling from the village (black spot) to the accident-prone area.

Figure 7.31 RADMC with board having Samaritan name and phone number

Figure 7.32 President of Roadmarc Foundation were addressing about Disaster management center

7.3.8 Wathoda Square

A committee comprising 15 active citizens has been formed out of approximately 180 residents in the area. The names of these Good Samaritans, who are also small business owners in Wathoda Nagar Chowk, have been provided on the mobile number displayed on the board. In the event of a road accident, immediate assistance can be sought from these members, ensuring prompt aid. At least one of the 15 individuals will assist the injured with the support of others, contributing to saving lives.

Local citizens underwent training on how to utilize the tools available in a disaster, access emergency services, admit the injured to the nearest hospital during the golden hour, administer first aid to the injured, and recognize it as a national duty to assist those injured in accidents

Figure 7.33 Station with board having name and phone number of people

Figure 7.34 First Aid Training

Figure 7.35 All good Samaritan and dignitaries while taking photos after the inauguration of the Road Accident Disaster Management center

Figure 7.36 First Aid Training

7.4 Outcome of Trystander cells at Blackspots

The proposed outcome of the Trystander cells is outlined below:

- Reduced Fatality Rates: Trystander cell contribute significantly to decreasing fatality rates in road accidents by ensuring prompt and effective first aid is administered.
- Empowered Communities: The initiative empowers communities by equipping individuals with first aid skills, transforming them into capable responders during emergencies.
- Swift Emergency Response: Trained Trystander enable a quicker emergency response, especially during the critical golden hour, improving the chances of saving lives.
- National Duty and Humanitarian Perspective: The emphasis on helping the injured without expecting thanks instills a sense of national duty and fosters a humanitarian perspective within society.
- Strategic First Aid Placement: The placement of first aid boxes, stretchers, and kits in accessible locations enhances the strategic distribution of life-saving resources.
- Community Resilience: Trystander cells contribute to building community resilience by creating a network of individuals capable of providing immediate assistance in times of need.

Within a few weeks of Trystander cell Installation, good progress has been seen at many locations. The volunteers have helped out accident victims by either providing immediate First Aid and/or taking them to nearby Hospital as presented in Table 7.3.

Table 7.3 Details of Trystander cells and their outcomes

S. No.	Blackspot Location	Date of Inauguration	No. of people attended inauguration	No. of people registered for screening	No. of Good Samaritans who are selected	No. of accident victims helped	Type of help provided
1	Mahesh Dhaba	22/7/2023	62	206	13	12	Major accident, provided First Aid & admitted to hospital
2	Chinchbhavan	10/8/2023	77	152	15	5	Major accident, provided First Aid & admitted to hospital
3	Chatrapati Square	28/8/2023	55	272	17	6	Minor accidents, provided First Aid only.
4	Shrinagar Square	28/11/2023	58	280	14	6	3 Minor accidents and 3 major accidents, victims were admitted to hospital
5	Omkar Nagar	10/11/2023	73	230	15	0	No accident happened
6	Manewada Square	24/11/2023	78	280	14	2	1 major and 1 minor accident happened
7	Mhalgi Nagar Square	10/11/2023	82	250	17	1	1 minor accident happened
8	Wathoda Square	5/11/2023	68	180	13	4	Minor accidents, provided First Aid, and one was admitted to hospital

Below Figure 7.37 illustrates the graphical presentation of outcome of trystander cells at various blackspots, and it shows that in these 8 blackspots, life of 36 road crash victims were saved due to all these emergency care interventions.

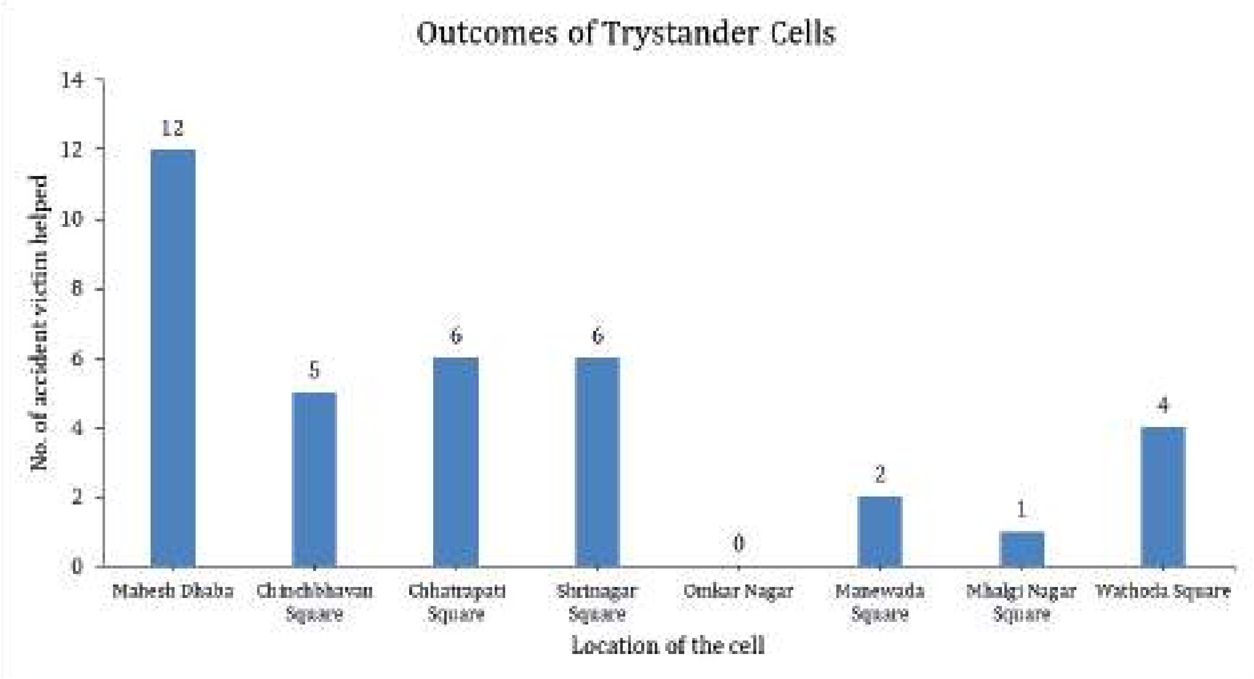


Figure 7.37 Lives saved through Trystander cell (as of April 22, 2024)

INTRODUCING THE 5TH “E“ OF ROAD SAFETY

8

8. Introducing the 5th 'E' of Road Safety

Project iRASTE extended its efforts by introducing 5th 'E' of Road safety i.e., **Encouragement**, by piloting a new sensor-based technology developed by **TrafficRewards** (our project partner) in Nagpur city. Promoting road safety through encouragement involves motivating vehicle drivers to adopt responsible behaviours. Initiatives like this may include incentivizing adherence to traffic rules, maintaining safe driving practices, and fostering a commitment to road safety. Such encouragement not only enhances driver awareness but also contributes to creating a safer and more responsible road environment. Technology developed by TrafficRewards provides the nudge to the Nagpur Municipal Corporation (NMC) bus drivers based on the principle of "Positive Reinforcement." Radio Frequency Identification (RFID) scanners placed at ten intersections across the city on the traffic signals, identifies the buses with the tags once they halt seeing the red signal.

Figure 8.1 RFID scanners installed on Traffic Signal.

Each time the driver adheres to the traffic rules, will receive a set number of points as rewards on their app profile in real-time, which could be redeemed and utilised to avail benefits from 100+ merchant establishments

As of January 2024, 438 NMC buses have been tagged with TrafficRewards RFID, and drivers have embraced this technology and demonstrated 24 % improvement in traffic signal adherence across all the vehicles with the TrafficRewards tag.

CONCLUSION AND RECOMMENDATIONS

9

9. Conclusion and Recommendations

The goal of Project iRASTE is to leverage Artificial Intelligence & Road Safety expertise to create a meaningful impact to achieving road safety goals. This was accomplished by executing along 4 vectors (Vehicle Safety, Mobility Safety, Infrastructure Safety and Education, Awareness & Emergency Care) aligned with the 4E framework for road safety: Engineering, Education, Enforcement & Emergency Care.

9.1 Vehicle Safety

The results deduced from the vehicle safety vector are highly encouraging with 41% reduction in road crash risk of Advanced Driver Assistance System (ADAS) fitted buses. ADAS-based Cabin training approach also represented a major upgrade in enhancing the driver skills with 7 out of 10 drivers reporting above-average risk scores after 12 observation periods. Driver risk score, based on median of overall ADAS alerts per 100 km distance travelled showed 30% reduction at the end of these observation periods. ADAS-fitted school bus fleet reported 13% overall reduction in risk scores.

Improvements in defensive driving practices like safe driving distance and alertness to Vulnerable Road Users (VRUs) are noteworthy. Periodic reinforcement of safe driving behaviours among drivers via trainings and digital campaigns is absolutely essential to sustain this improvement. This requires fleet operators to periodically track and incentivize safety performance of drivers of ADAS-enabled fleet who exhibit better compliance of road safety.

9.2 Mobility Safety

The novel technique of Greyspot (potential Blackspot) prediction and modelling is the first instance of the application on urban roads in India. Dynamic ADAS data has been fused with the static data like the road parameters to develop the Greyspot models. Separate Greyspot models are developed for intersections and midblock sections. The Greyspot approach developed in this study is more accurate and scalable than one-time manual surveys. Once Blackspots and Greyspots are identified accurately, road geometry improvements by road owning agencies and proactive enforcement by Traffic department at these locations can significantly lower road risk.

9.3 Infrastructure Safety

The objective of infrastructure safety vector is to develop remedial measures i.e., countermeasures for the identified blackspots in Nagpur city. Accordingly, 38 locations(consisting of 30 intersections & 8 Midblock) were identified based on the analysis of First Information Report (FIRs) obtained from the Nagpur Traffic Police (NTP). The detailed project report (DPR) in the form of black spot rectification strategy (ies) showcasing the feasible and cost-effective engineering treatment are conceived for each of the blackspots. Further, the study also provided an insight towards understanding the effectiveness of blackspot treatment through countermeasures by performing economic benefits assessment for 4 out of the 38 blackspots in the city of Nagpur. Some of the salient findings derived from the economic analysis are as follows:

- Assessment concluded about 60-66% reduction in the overall road crashes coupled with 40% reduction in fatalities, assuming the current rate of road crashes in the next 5 -year period.
- On average, there is a cost saving of INR 89,14,244 in the mid-block locations and INR 1,25,95,655 in the intersections after one year of proposed countermeasures.
- The Economic Internal Rate of Return(EIRR) was found to be ranging between 54% - 63% through the analysis period of 5 years which can be considered to be a significant Return on Investment (ROI).

Geometrical remedial interventions were implemented in 3 blackspots (Ajni Square, Chhatrapati Square, and Jaiprakash Nagar Square) and complete traffic delineation and pedestrian safety interventions were implemented in 1 blackspot (Wadhamna intersection) which is helpful to road users for safer driving that ultimately reduces the road crash risk. Along with these, simultaneous measures are needed in the form of periodical Road Safety Audits (RSA) as well as other non-engineering interventions such as enforcement and road safety campaigns. Further, Camera-based mapping techniques using Artificial Intelligence (AI) have been deployed to extract road infrastructure assets which offer a cost-effective mechanism to periodically collect road data that is digital, up-to-date, and accurate. Such data can inform stakeholders of critical issues of road safety, road maintenance, planning of existing and new roads etc.

9.4 Education, Awareness & Emergency Care

Project iRASTE has also spent significant effort on awareness programs (Avagatkara, City-wide good Samaritan program) at a city scale both to affect general behavioural change as well as equip citizens (especially around blackspots) with first-aid knowledge to help save crash victims. Additionally, installed Trystander cells at 8 blackspot locations that contains equipment like stretchers, first-aid kit, etc., that provide aid to road crash victims. Through these interventions, life of **36 road crash victims were saved** in these blackspots (refer Figure 7.37). In this regard, parallel and central to the above three vectors is the concerted efforts put forth towards imparting drivers' training, education, and awareness towards achieve enhancing road safety, and trained total 1337 commercial vehicle drivers i.e., NMC bus drivers.

9.5 Road Safety 5th E - Encouragement

Project iRASTE in Nagpur introduced the 5th 'E' – Encouragement – to enhance road safety, employing sensor-based technology developed by trafficrewards. Through Positive Reinforcement, NMC bus drivers earn rewards for adhering to traffic rules via RFID scanners at intersections. This approach has yielded a significant 24% improvement in signal adherence across all the vehicles with traffic rewards tags. Such technological interventions not only boost driver compliance but also foster a safer road culture for all.

9.6 Way Forward

Project iRASTE Nagpur was the first initiative in India to integrate AI into the 4E framework for road safety and was the largest and longest-running study of ADAS for commercial vehicles. This iRASTE model has led to faster and more precise implementations with promising results: a 41% reduction in accidents in the NMC ADAS enabled bus fleet and a reduction in driver risk scores by 30%. A novel technique for Greyspot prediction and modelling was developed. We have gained experience in executing a multi-vector strategy to address the urgent challenge of road safety.

Moving forward, our plan is to replicate this model in other cities and metropolitan regions in India and engage with the Union Ministry of Road Transport and Highways (MoRTH) to institutionalize the components that have yielded consistent results.

Appendix

Appendix A: Vienna Test

One of the basic capabilities required for safe driving is the need to have proper reaction time exhibited by the drivers while encountering various situation(s) on the roads. To address the above, evaluation of the above trait has been attempted through the Vienna Test.

This test system is performed through computerized psychological assessments for the subjects / drivers and provides automatic and comprehensive scoring as it captures the reaction time systematically. The Hardware part of Vienna test system includes three parts: (1) Display Screen, (2) Response Panel and (3) Foot pedals.

As shown in Figure A.1, these are connected through proper wiring. In the Vienna Test structure, the respondent's task is to react as quickly as possible to optical and acoustic stimuli that are displayed (on a computer screen) sequentially. Such reactions are made by pressing the corresponding buttons on the response panel or by pressing the foot pedals. Respondents have to react as quickly as they can to optical or acoustic signals. This involves pressing or releasing a button as quickly as possible when a simple light signal (yellow or red light), a tone or a combination of two stimuli (yellow and tone or yellow and red) is presented. The optical stimuli include five colors (white, yellow, red, green, and blue) which are presented in a 2x5 matrix of gray circles. Each color can occur in two different locations. The reaction buttons assigned to these five colors are arranged on the response panel in such a way that the respondent can use both hands. There are two additional visual stimuli, in the form of white, rectangular, visually distinct fields that appear in the bottom left- and right-hand corners of the screen, to which the respondent must react by pressing the corresponding (left or right) foot pedal. Two acoustic stimuli (high and low tone) are assigned to the two sound buttons in the middle of the panel. The lower, rectangular black button is pressed for a low tone and the upper rectangular gray button for a high tone.

Figure A.1: Vienna Test System

Table A.1 summarizes the stimulus reaction assignment.

Table A.1: Stimulus reaction assignment

S. No.	Stimulus	Presentation	Required reaction
1	Colour	White	Round white button
		Yellow	Round yellow button
		Red	Round red button
		Green	Round green button
		Blue	Round blue button
2	Tone	Low (250 Hz)	Rectangular black button
		High (1.000 Hz)	Rectangular grey button
3	Pedal	Left	Left pedal
		Right	Right pedal

Vienna tests were conducted covering 155 NMC drivers in February, 2022 month. These tests were carried out at RTO, Civil Lines, Nagpur wherein drivers of all the three bus operators operating under the umbrella of NMC used to come after the completion of their morning shift duty. Two Vienna systems were set up to cover maximum drivers. Table A.2 presents the questionnaire designed to solicit personal information of the subjects in terms of their socio-economic characteristics, driving experience and education level and associated details including the consent form signed by the subject.

Table A.2: Questionnaire for Driver's Personal Interviews

<table>
<tr><td>1</td><td colspan="6">Name/ नाम:</td></tr>
<tr><td>2</td><td>Age/उम्र:</td><td>3. Gender/लिंग</td><td>Male/ पुरुष</td><td colspan="2">Female/ स्त्री</td><td>Other/ अन्य</td></tr>
<tr><td rowspan="2">4</td><td colspan="6">Educational Qualification/ शैक्षणिक योग्यता</td></tr>
<tr><td>Uneducated/ निरक्षर</td><td>Primary/ प्राथमिक</td><td>High School/ उच्चविद्यालय</td><td>Graduate/ स्नातक</td><td colspan="2">Others (Specify)/ अन्य (विवरण)</td></tr>
<tr><td>5</td><td colspan="6">Driving Experience/ड्राइविंग अनुभव (Years/ वर्ष):</td></tr>
<tr><td rowspan="2">6</td><td colspan="2" rowspan="2">Type of Vehicle Driven/ चालित वाहन का प्रकार</td><td colspan="2">Car/ कार</td><td colspan="2">Bus/ बस</td></tr>
<tr><td colspan="2">Truck/ ट्रक</td><td colspan="2">Other/ अन्य</td></tr>
<tr><td>7</td><td colspan="2">Exposure of Driving/ड्राइविंग संसर्ग</td><td>Hills/ पहाड़</td><td>Plains/ मैदान</td><td>Urban/ शहर</td><td>Rural/ ग्रामीण</td></tr>
<tr><td rowspan="3">8</td><td colspan="2" rowspan="3">Driving Learned from? आपने किससे ड्राइविंग सीखी?</td><td colspan="4">By Own/ स्वयं</td></tr>
<tr><td colspan="4">Friends or Relatives/ मित्र या रिश्तेदार</td></tr>
<tr><td colspan="4">Driving School/ ड्राइविंग स्कूल</td></tr>
<tr><td rowspan="2">9</td><td colspan="2">Have you involved in any Crash/ Accident while driving?</td><td colspan="3">Yes (No. of Crash)/ हां</td><td rowspan="2">No/ नहीं</td></tr>
<tr><td colspan="2">क्या आपके साथ कभी गाड़ी चलाने के दौरान दुर्घटना हुई है?</td><td colspan="3">(दुर्घटनाओं की संख्या)</td></tr>
<tr><td rowspan="3">10</td><td colspan="2" rowspan="3">Have you worked as an assistant to Driver? /क्या आपने कभी ड्राईवर के सहायक के रूप में कार्य किया है?</td><td colspan="3">Yes (Years)/</td><td rowspan="3">No/ नहीं</td></tr>
<tr><td colspan="3">हां (वर्ष)</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Appendix B: Classified Traffic Volumes

Table B.1: Hourly Classified Traffic Volume Count at Prakash High School Data Collected on 13th December 2021

LOCATION NAME	TIME PERIOD OF SURVEY	MODE OF VEHICLES						PEDESTRIANS
		HEAVY VEHICLES	BUSES	CARS	LCV	AUTO RICKSHAW	MOTORISED TWO-WHEELER	
Prakash High School	0800 - 0900	64	65	471	232	143	2003	316
	0900 - 1000	60	66	682	275	205	3027	542
	1000 - 1100	57	56	683	374	184	2680	573
	1100 - 1200	68	40	819	426	133	2578	634
	1200 - 1300	149	120	729	439	178	2351	0
	1300 - 1400	181	60	687	461	159	2027	0
	1400 - 1500	191	36	658	452	125	1754	0
	1500 - 1600	168	59	690	431	139	1644	0
	1600 - 1700	106	57	735	445	162	1455	367
	1700 - 1800	64	40	753	412	179	2625	403
	1800 - 1900	56	65	866	354	177	2507	228
	1900 - 2000	80	52	793	336	126	1685	23

Table B.2: Hourly Classified Traffic Volume Count Chikli Square Data Collected on 23rd December 2021

LOCATION NAME	TIME PERIOD OF SURVEY	MODE OF VEHICLES						PEDESTRIANS
		HEAVY VEHICLES	BUSES	CARS	LCV	AUTO RICKSHAW	MOTORISED TWO-WHEELER	
Chikli Square Intersection	0800 - 0900	60	12	185	485	233	1797	297
	0900 - 1000	97	10	387	717	338	4010	537
	1000 - 1100	51	7	511	779	357	4621	571
	1100 - 1200	80	5	519	844	373	3529	497
	1200 - 1300	242	10	584	749	327	3014	0
	1300 - 1400	199	9	495	767	315	2719	0
	1400 - 1500	197	14	481	752	295	2811	0
	1500 - 1600	170	6	497	729	268	2609	0
	1600 - 1700	97	20	513	672	296	2585	377
	1700 - 1800	59	36	507	621	311	2911	479
	1800 - 1900	54	3	630	565	288	3928	365
	1900 - 2000	50	13	523	460	206	2900	243

Table B.3: Hourly Classified Traffic Volume Count Mhalgi Nagar Data Collected on 23rd December 2021

LOCATION NAME	TIME PERIOD OF SURVEY	MODE OF VEHICLES						PEDESTRIANS
		HEAVY VEHICLES	BUSES	CARS	LCV	AUTO RICKSHAW	MOTORISED TWO-WHEELER	
Mhalgi Nagar Square	0800 - 0900	28	61	593	180	259	3644	1075
	0900 - 1000	10	64	785	180	379	5010	1216
	1000 - 1100	9	51	913	249	447	5631	1242
	1100 - 1200	35	48	993	303	442	5020	1158
	1200 - 1300	64	39	934	311	553	4890	0
	1300 - 1400	82	58	913	347	545	4978	0
	1400 - 1500	42	40	899	295	457	4551	0
	1500 - 1600	27	38	914	345	430	4846	0
	1600 - 1700	40	53	929	369	449	4574	1046
	1700 - 1800	36	40	971	285	395	5057	1268
	1800 - 1900	32	31	1075	278	380	5643	1121
	1900 - 2000	25	40	896	244	349	5062	1223

Appendix C: Pedestrian Volumes

Table C.1: Hourly Pedestrian Traffic Volume Count at Chhatrapati Square Data Collected on 14th December 2021

Time	DIRECTION FROM												Total Across	Total Along	Total Across + Along
	Jhansi Rani Chowk			Narendar Nagar			Wardha			Partap Nagar					
	Across	Along Left	Along Right	Across	Along Left	Along Right	Across	Along Left	Along Right	Across	Along Left	Along Right			
0800 - 0815	25	23	16	14	16	16	14	29	11	5	7	12	58	130	188
0815 - 0830	20	7	15	8	25	6	9	31	7	20	20	6	57	117	174
0830 - 0845	25	8	4	5	23	20	31	36	12	30	10	15	91	128	219
0845 - 0900	25	8	12	17	30	11	30	53	9	26	5	25	98	153	251
0900 - 0915	25	9	12	11	26	25	37	38	17	45	20	18	118	165	283
0915 - 0930	32	15	7	10	30	8	28	30	20	20	6	12	90	128	218
0930 - 0945	35	15	5	12	24	7	29	41	23	12	3	5	88	123	211
0945 - 1000	37	17	12	22	8	15	32	65	12	16	7	5	107	141	248

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