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A Comprehensive Analysis of Bajrang Intersection (NH-46 and NH-146), India: A Proposal to Enhance Intersection Efficiency

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Abstract: Intersection development involves planning and design to ensure safe and efficient traffic flow while enhancing safety and considering environmental and community factors. This research proposes the improvement of the existing Bajrang intersection located at the junction of Bhopal Bypass (NH-46) and Bhopal-Raisen Road (NH-146) in the Kokta area of Madhya Pradesh, India. The Bajrang intersection is a designated black spot notorious for its unsafe conditions for crossing and driving, resulting in accidents and subsequent human and financial losses. Therefore, it is imperative to enhance and redesign it to facilitate safe and easy crossing and manoeuvres. Options for improvement have been proposed. Heavy commercial traffic utilizes NH-46, while NH-146 caters to a large number of private vehicles, with the area also surrounded by numerous educational institutions generating significant college bus traffic. The proposed methodology is based on an inventory (preliminary) survey and adheres to IRC codes. The inventory survey collected data on the existing road, and the best suitable options per IRC recommendations have been proposed accordingly. The outcomes of this research indicate that the newly proposed grade-separated intersections will reduce accidents, increase capacity, accommodate future demands, and enhance the Level of Service (LOS). The improved proposal ensures greater safety compared to the existing intersection, with the design speed of vehicles increasing from 20-30 Km/h to 60-80 Km/h. These improvements, such as Vehicle Operation Cost (VOC), will reduce human and financial losses.

Keywords: Intersection, Accident, Congestion, At-grade, Grade separated, Design Speed

1. INTRODUCTION

A well-planned road network is crucial for the balanced development of any country. In India, recent economic growth highlights the vital role transportation plays. A robust road network is a backbone for steady growth for developing nations, requiring good links between villages and market centres. Economic prosperity is not accurately reflected by urban areas alone. Sufficient transport facilities between villages, district headquarters, and commercial centres are necessary for economic progress. Expressways are essential to support fast vehicle movement along arterial roads. Developing countries must enhance the length and quality of their transportation systems to meet growing demands. Present highways in India, initially upgraded from pre-automobile local roads, lack geometric design elements suitable for modern automobile traffic. Many national highways face single-lane carriageways, narrow bridges, sharp curves, zig-zags, steep gradients, and inadequate

sight distances. Urgent rectification is required, especially for important roads like National and State Highways. Liberal values of geometric design parameters should be considered where favourable conditions and reasonable costs permit.

2. SELECTION OF STUDY AREA

Bhopal, the capital of Madhya Pradesh, is renowned as the City of Lakes and among India's greenest cities. With a robust economy driven by large and medium industries, it holds a significant position in Madhya Pradesh's financial landscape. Bhopal was selected for development under PM Narendra Modi's Smart Cities Mission. The proposed research focuses on the "Bajrang Chouraha" intersection, situated at the crossing of Bhopal-Raisen Road (NH-46) and Bhopal Ring Road (NH-146). This area, marked by colleges, RTO (Bhopal), residential societies, and catering to heavy commercial vehicles, faces traffic challenges. The study identifies issues and suggests a grade-separated option to replace the existing at-grade intersection.

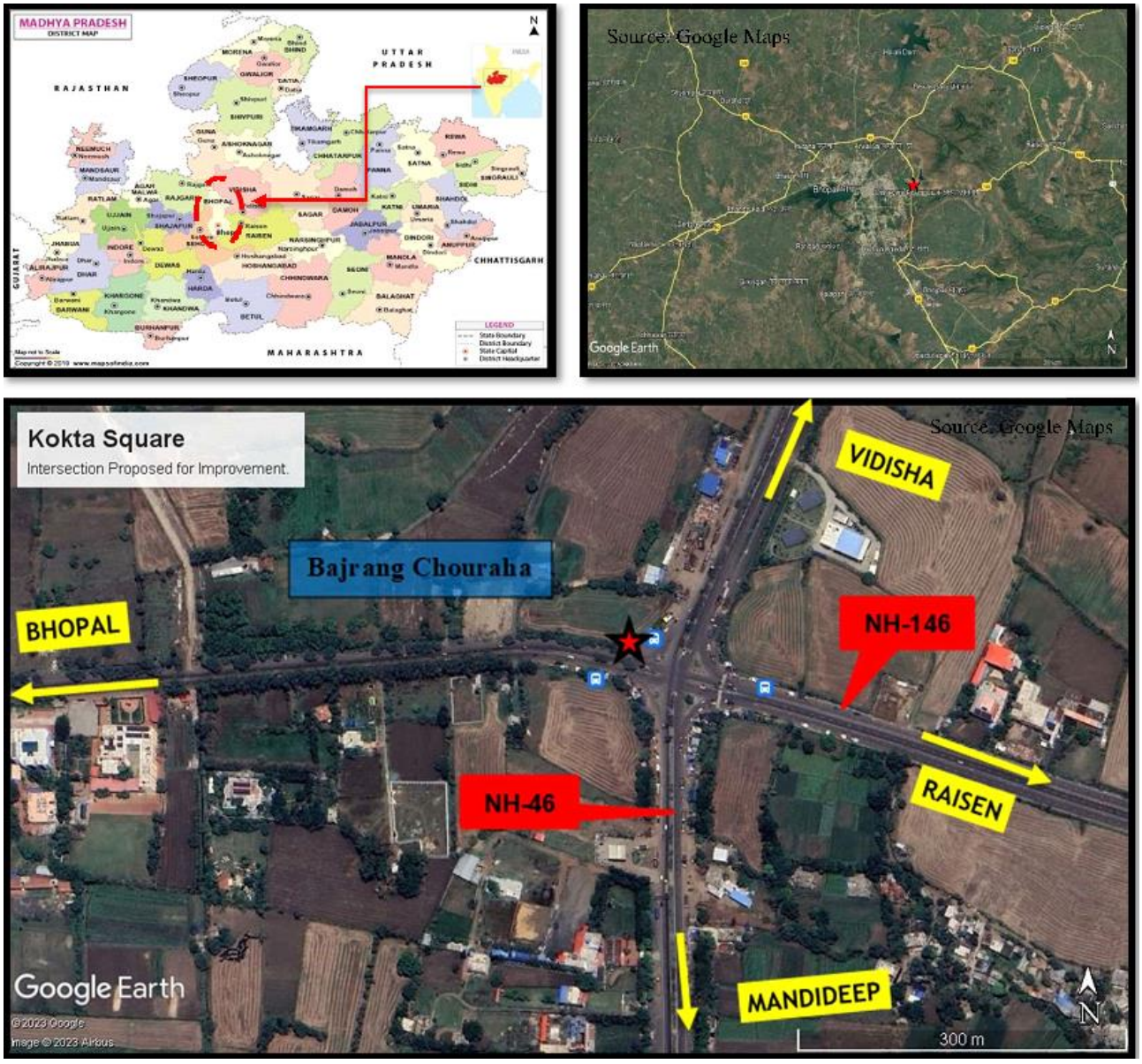

Figure 1. Map showing Project Area

3. IDENTIFIED PROBLEMS IN THE PROJECT AREA

An at-grade road intersection, where multiple roads meet at the same level, poses various challenges for road users. The Bajrang Square in Kokta, currently an at-grade intersection, faces issues identified through roadside interviews and accident records from the local police station. The geometry of the intersection is inadequate for the present traffic volume and does not align with IRC recommendations. Problem identification methods include roadside interviews and analysis of accident records. Based on the interviews and literature surveys, two problems have been identified at the project intersection: accidents and congestion. Accident records obtained from Bilkhiriya Police Station reveal that the project area experienced 84 reported accidents, primarily attributed to the high movement of college/school buses and the proximity of the RTO office. Notably, 22 fatalities occurred, constituting 26% of the total accidents. The at-grade intersection in question has 32 conflict points.

Bilkhiriya Police Station Accident Record for the year 2023

Month	Type of Accidents					Number of persons involved			
	Fatal	GI	MI	NI	Total	Fatal	Grieyous Injured	Minor Injured	Total
January	2	1	2	2	7	2	1	2	5
February	1	5	1	1	8	1	5	1	7
March	1	1	3	1	6	1	1	3	5
April	1	0	1	0	2	1	0	1	2
May	3	0	8	1	12	3	0	8	11
June	5	0	7	3	15	5	0	7	12
July	3	0	5	2	10	3	0	5	8
August	1	1	2	0	4	1	1	2	4
September	2	0	2	1	5	2	0	2	4
October	0	3	1	1	5	0	3	1	4
November	1	2	3	0	6	1	2	3	6
December	2	0	2	0	4	2	0	2	4
TOTAL	22	13	37	12	84	22	13	37	72

Figure 2. Accidental Data obtained from Bilkhiriya Police Station

Figure 3. Depiction of 32 Conflict Points on the Project Intersection

Another significant issue observed is congestion caused by a substantial number of commercial vehicles passing through the project intersection, leading to a complete traffic standstill. According to IRC: SP:84-2014, the Level of Service (LOS) for Plain and Rolling terrain for a 4-lane highway is specified as 40,000-60,000 vehicles per day.

Table 1. LOS as per Design Service Volume in PCU per Day (IRC: SP:84-2014)

Terrain	Design Service Volume in PCU Per Day	
	Level of Service 'B'	Level of Service 'C'
Plain and Rolling	40,000	60,000
Mountainous and Steep	20,000	30,000

Figure 4. Congestion on the project area

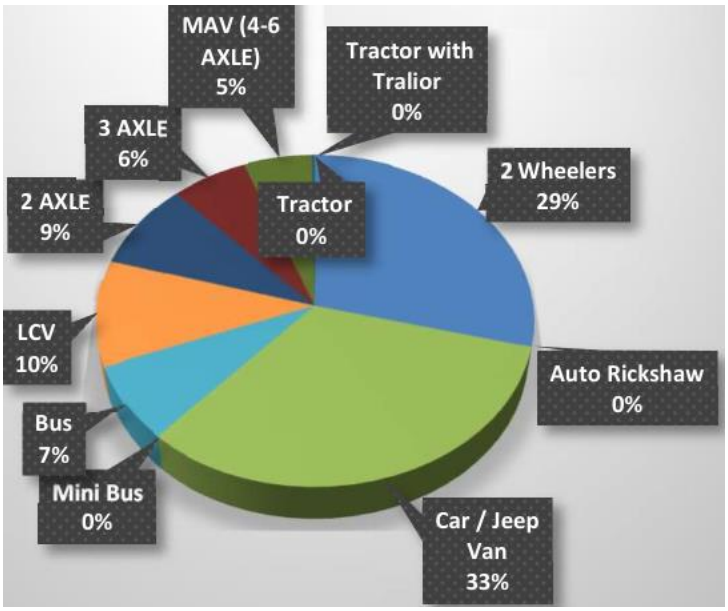

Figure 5. Vehicle Classification Based on Category

Table 2. Turning Movement Count for Morning and Evening Peak Hours

Type of Vehicle	TMC (Morning Peak Hour)		TMC (Evening Peak Hour)	
	Number	PCU	Number	PCU
2 Wheelers	1001	501	851	426
Auto Rickshaw	0	0	0	0
Car / Jeep / Van	1130	1130	966	966
Mini Bus	0	0	0	0
Bus	259	777	222	666
LCV	357	536	302	453
2 Axle	296	888	241	723
3 Axle	213	639	175	525
MAV (4-6 Axle)	190	855	160	720
Tractor with Trailer	3	14	0	0
Tractor	6	9	5	8
Total Fast Moving	3455	5348	2922	4486
Cycle	0	0	0	0
Cycle Rickshaw	0	0	0	0
Bullock Cart	0	0	0	0
Horse-drawn	0	0	0	0
Hand Cart	0	0	0	0
Other	2	6	3	9
Total Slow Moving	2	6	3	9
Total ADT	3457	5354	2925	4495

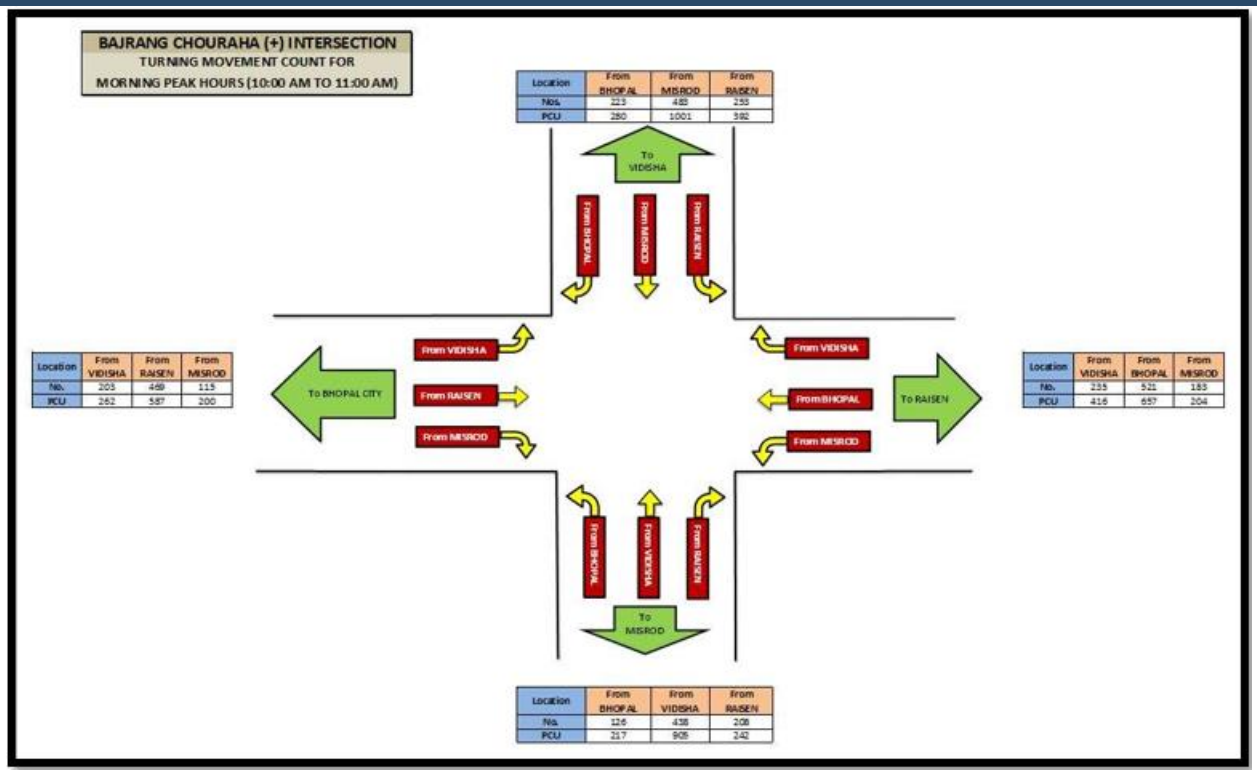

Figure 6. Turning Movement Count at Bajrang intersection for Morning Peak Hours

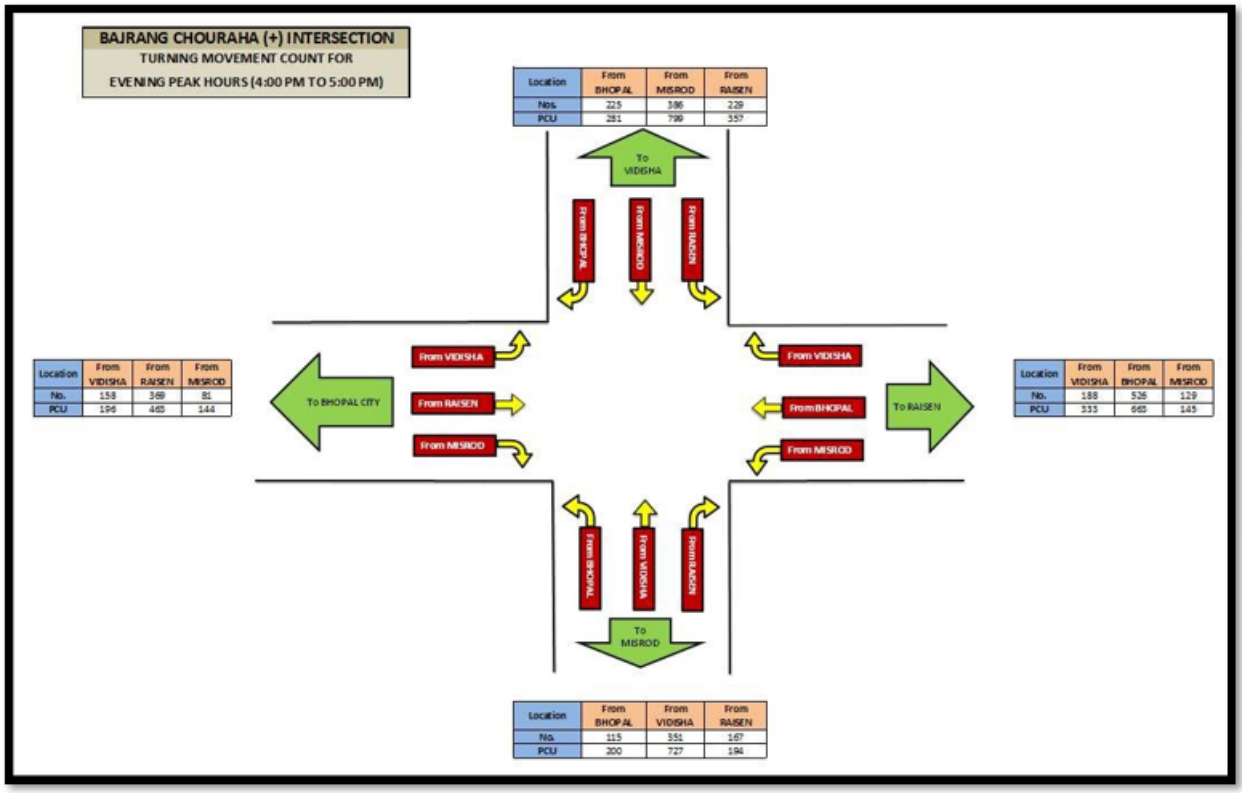

Figure 7. Turning Movement Count at Bajrang intersection for Evening Peak Hours

Table 3. Percentage of Directional Distribution for Morning and Evening Peak Hours

Origion and Destination	Movement Percentage
Bhopal to Raisen	16%
Raisen to Bhopal	13%
Bhopal to Vidisha	7%
Vidisha to Bhopal	6%
Bhopal to Misrod	4%
Misrod to Bhopal	3%
Vidisha to Raisen	7%
Raisen to Vidisha	8%
Vidisha to Misrod	12%
Misrod to Vidisha	14%
Raisen to Misrod	6%
Misrod to Raisen	5%

Origion and Destination	Movement Percentage
Bhopal to Raisen	18%
Raisen to Bhopal	13%
Bhopal to Vidisha	8%
Vidisha to Bhopal	5%
Bhopal to Misrod	4%
Misrod to Bhopal	3%
Vidisha to Raisen	6%
Raisen to Vidisha	8%
Vidisha to Misrod	12%
Misrod to Vidisha	13%
Raisen to Misrod	6%
Misrod to Raisen	4%

Table 4. Traffic Projection for 20 Years Design Life

S. No.	YEAR	Total in Vehicles/Hr	Total in PCU/Hr	Total in PCU/Day	LOS Category	Remark
1	2023	3457	5354	53535	B	Construction Period
2	2024	3629	5621	56210	B	
3	2025	3810	5902	59020	B	
4	2026	4000	6197	61970	C	
5	2027	4200	6506	65060	C	(Open for Traffic) 1
6	2028	4410	6831	68310	C	2
7	2029	4630	7172	71720	C	3
8	2030	4861	7530	75300	C	4
9	2031	5104	7906	79060	C	5
10	2032	5359	8301	83010	D	6
11	2033	5626	8716	87160	D	7
12	2034	5907	9151	91510	D	8
13	2035	6202	9608	96080	D	9
14	2036	6512	10088	100880	E	10
15	2037	6837	10592	105920	E	11
16	2038	7178	11121	111210	E	12
17	2039	7536	11677	116770	E	13
18	2040	7912	12260	122600	E	14
19	2041	8307	12873	128730	E	15
20	2042	8722	13516	135160	F	16
21	2043	9158	14191	141910	F	17
22	2044	9615	14900	149000	F	18
23	2045	10095	15645	156450	F	19
24	2046	10599	16427	164270	F	20

The current Level of Service (LOS) of the Bajrang Intersection road is 'B'. Considering future traffic growth projected for 2046 (following a 20-year design period as per IRC 84:2014), it is anticipated that the LOS may deteriorate to 'F'.

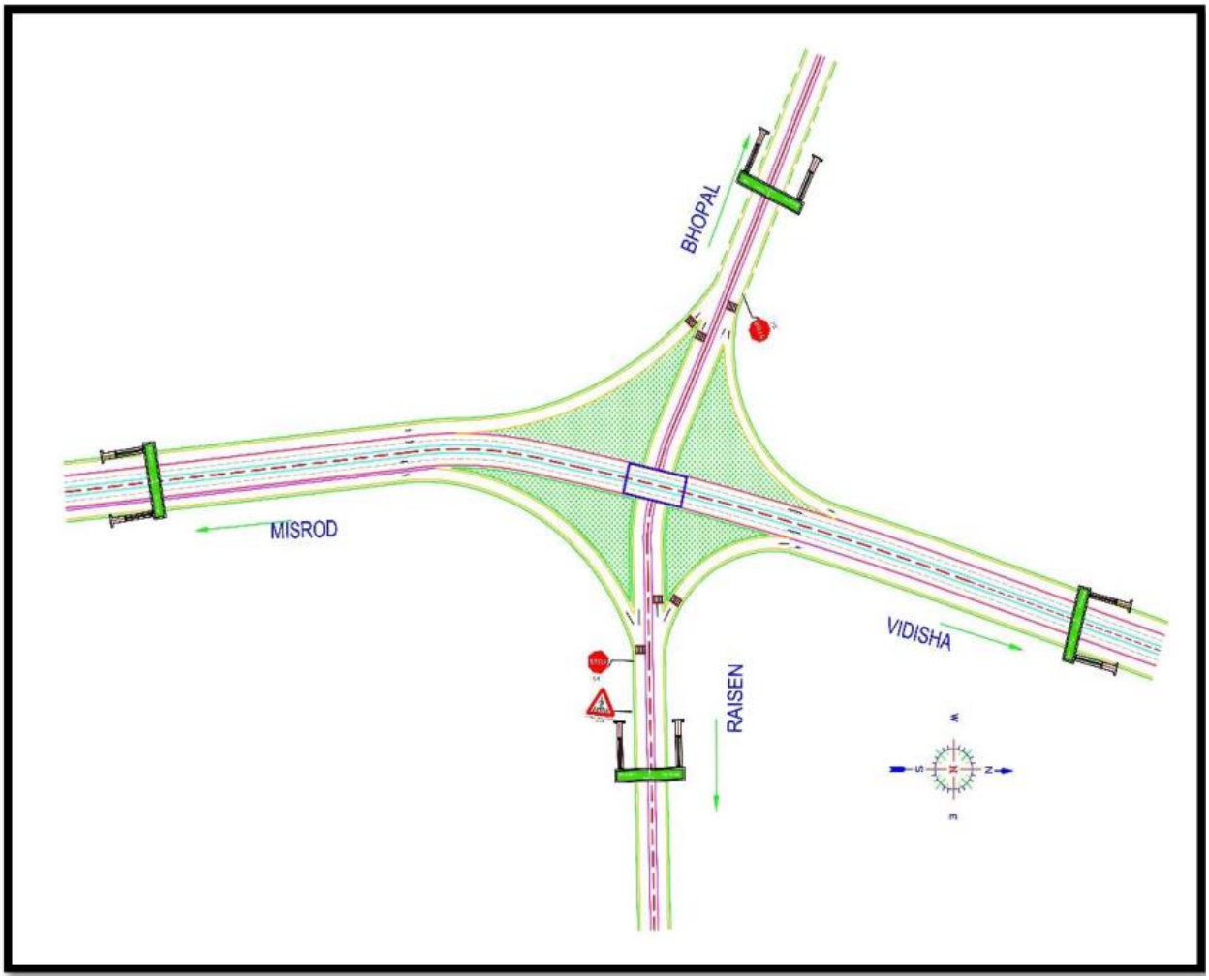

Figure 8. Proposed Plan for Vehicle Underpass

4. SUGGESTED IMPROVEMENT

After analyzing the survey data, it is recommended that the most suitable and cost-effective solution for enhancing the Bajrang intersection is to implement grade separation by constructing a Vehicle Underpass. The design specifications for the Vehicle Underpass are outlined as follows:

1. As per IRC:84-2014 "Guidelines for the Design of Interchanges in Urban Areas," the design specifications for the vehicle underpass have been established.
2. NH-146 is designated as the priority road within the interchange.
3. All left turns at the intersection are unrestricted.
4. Ramps are provided to facilitate right turns for vehicles.
5. The design speed for the Major highway is set at 80 km/h, with a reduction to 40-60 km/h due to Entry and Exit on Approaches.
6. The Stopping Sight Distance is established at 45 meters.

7. The Vertical Clearance of the Underpass is specified as 5.5 meters.

Figure 9. Modelling and Simulation of the proposed options have been done with the help of SketchUp software for better understanding and visualization.

5. IMPROVEMENT ANALYSIS

The Improvement Analysis for the Bajrang Intersection, outlined in Table 5, reveals significant enhancements anticipated following the proposed improvements. Firstly, transitioning from the existing four lanes with paved shoulders to a more optimized setup promises to streamline traffic flow and enhance efficiency. Adjusting the lane width to 8.5 meters ensures better vehicle accommodation, facilitating smoother movement within the intersection. A notable reduction in conflict points, from 32 to just 8, is expected to enhance safety significantly, minimizing the risk of accidents and improving overall traffic management. Moreover, with a remarkable increase in design speed from 20-30 Km/h to a more efficient range of 60-80 Km/h, the intersection is poised to facilitate faster and more seamless vehicle transit. Anticipated improvements from Level D to Level B-C signify a substantial upgrade in the intersection's performance and operational efficiency. Transitioning from poor road geometry to good geometry ensures smoother traffic flow, reducing the likelihood of bottlenecks and congestion. Introducing 900 meters of approaches enhances accessibility and manoeuvrability, further optimizing traffic movement within the intersection. Two ramps provide better vehicle access and egress, improving traffic flow and safety. The proposed elimination of head-on collisions is expected to significantly reduce

accident severity, ensuring minor incidents instead of fatal ones, thereby enhancing overall safety. While the current capacity reaches its limit during peak hours, the proposed improvements are projected to delay congestion, with the onset expected five years after the opening for traffic, allowing for sustained operational efficiency. Although large trailers may still cause congestion when making right turns onto the Vehicle Underpass (VUP), overall congestion is anticipated to be mitigated significantly through the proposed enhancements. Ensuring a right of way of 60 meters provides sufficient space for safe and efficient traffic movement within the intersection. Additionally, a vertical clearance of 5.5 meters accommodates taller vehicles, ensuring unimpeded passage and minimizing disruptions. With a minimum turning radius of less than 20 meters, the intersection can accommodate vehicles of varying sizes and facilitate smoother turns, enhancing overall traffic flow.

Table 5: Improvement Analysis for Bajrang Intersection

S. No.	Description	Before Improvement	After Improvement
1	Lane Configuration		Four lanes with Paved Shoulder
2	Lane Width		8.5 + 5 + 8.5
3	Conflict Points	32	8
4	Design Speed	20-30 Km/h	60-80 Km/h
5	Level of Service	D	B-C
6	Road Geometry	Poor	Good
7	Length of Approaches	-	900 m
8	No. of Ramps	-	2
9	Severity of Accidents	Fatal due to head-on collisions	Minor, as the chance of head-on collisions will be eliminated
10	Capacity	Reaches its capacity during the Peak Hours	Congestion will start after five years of opening for traffic
11	Traffic Congestion	Yes	Large trailers can cause congestion when taking a right turn to get onto the VUP.
12	Right of Way (R.O.W.)		60 m
13	Vertical Clearance		5.5 m
14	Min. Turning Radius		<20 m

6. COST ESTIMATION

The necessity for grade separation has been identified in the Cost Estimation for enhancing the existing Bajrang Intersection, situated in plain terrain. We adhere to the guidelines in the Ministry of Road Transport and Highways (MoRTH) Letter no. RW/NH-24036/27/2010-PPP, dated 25/04/2018, with a specific focus on flexible pavement, a normative cost analysis for the improved alignment has been conducted. The breakdown of the cost analysis for the enhanced alignment is based on Table 6. The Vehicular Underpass project, covering a span of 0.900 km for the main carriageway, is estimated to cost 7.00 Cr. The necessary approaches and retaining wall installation, spanning 0.900 km, incur an estimated cost of 10.00 Cr.

Furthermore, the construction of the service road, extending over 1.720 km, requires an allocation of 4.90 Cr. While the installation of ramps is not applicable, the structure, comprising two 20-meter spans, necessitates an estimated investment of 5.90 Cr. Additionally, the construction of drains, spanning 6.9 km, amounts to 6.7 Cr. An allocation of 5.175 Cr. has been set aside for miscellaneous works, including safety measures and aesthetic enhancements. The total civil cost is estimated at 39.675 Cr., with pre-construction activities requiring an investment of 3.97 Cr. Consequently, the Total Cost for the proposed enhancement stands at 43.645 Cr.

Table 6. Proposed Preliminary Cost for Vehicle Underpass

S. No.	Description	Unit	Vehicular Underpass	Amount in Cr
1	Length of Main Carriageway	km	0.900	7.00 Cr
2	Length of Approaches with RE Wall	km	0.900	10.00 Cr
3	Length of Service Road	km	1.720	4.90 Cr
4	Length of Ramps	km	-	-
5	Length of Structure	km	2x20m span	5.90 Cr
6	Length of Metal Beam Crash Barrier	Km	-	-
7	Length of Drains	km	6.9	6.7 Cr
8	Misc. Work (Safety Works, Paintworks, etc.)	Cr	-	5.175 Cr
9	Civil Cost	Cr	-	39.675
10	Pre-Construction Cost	Cr	-	3.97
Total Cost		Cr	-	43.645

7. BENEFITS AFTER IMPROVEMENT

The benefits anticipated after the improvement of the Bajrang Intersection, as outlined in this research study, are as follows:

1. Increased Design Speed: The upgraded intersection will facilitate a design speed exceeding 60 kmph, enabling smoother and faster traffic flow for road users.
2. Enhanced Safety: With the implementation of improvements, the intersection will become safer for all road users, significantly reducing the likelihood of accidents and improving overall safety conditions.
3. Reduced Delay Time: The time delays caused by the slow speed of commercial vehicles at the intersection will be minimized, leading to improved efficiency and reduced congestion for motorists.
4. Elimination of Accident-Prone Area: Addressing existing deficiencies and upgrading safety measures will eliminate the intersection's status as an accident-prone area, resulting in fewer accidents and enhanced road safety.

5. Improved Level of Service (LOS): The Level of Service (LOS) at the intersection will be upgraded to B-C, indicating a significant enhancement in operational efficiency and traffic flow, providing a better experience for road users.

8. CONCLUSION

In conclusion, the research study, titled "A Comprehensive Analysis of Bajrang Intersection (NH-46 & NH-146), India: A Proposal to Enhance Intersection Efficiency," meticulously follows the guidelines and recommendations established by the Indian Roads Congress (IRC). The proposed solution aims to enhance the intersection's efficiency by introducing a Vehicle Underpass to segregate traffic flow across all four legs, focusing on addressing NH-46 (Bhopal Bypass Road). The horizontal alignment and vertical profile design have been considered crucial factors. All proposed improvements adhere strictly to IRC recommendations, ensuring compliance with industry standards. The design incorporates desirable minimum radii for a Full Cloverleaf interchange, enhancing safety and efficiency, while ruling gradient values have been meticulously applied to optimize road usability. Careful formulation of design speeds accommodates a ruling Design Speed of 60 kmph, ensuring smooth traffic flow. The proposed alignments are geared towards reducing accident rates, minimizing delay times, and enhancing the safe design speed for road users. Anticipated enhancements to the existing alignment are poised to result in notable reductions in both human and economic losses associated with accidents.

Moreover, a reduced travel time at the intersection is projected, alongside decreased Vehicle Operating Costs (VOC) for motorists, enhancing overall efficiency. Improved infrastructure will facilitate easier and faster goods transport, contributing to enhanced efficiency within product supply chains. The proposed Vehicle Underpass, estimated at Rs. 43.645 Cr, has been meticulously planned following the research study and is designed to cater to future traffic demands while remaining economically viable for a 20-year design life.

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