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Developing A Context-Sensitive Road Safety Audit Mechanism For Urban Roads In Visakhapatnam, Andhra Pradesh, India

Dr. G. Vijayakumar[*1], Budati Harish Kumar[1]
Associate Professor[*1], M. Tech Student[1]
[*1,1]Department of Civil Engineering,
St. Ann's Colle of Engineering & Technology, Chirala

Abstract:

Rapid urbanization has dramatically increased vehicle usage and accidents in cities across India, especially in urbanizing regions like Visakhapatnam. The absence of comprehensive safety assessments and infrastructure development has resulted in many locations that are susceptible to accidents. This study aims to develop a practical procedure for performing RSAs on urban roads, taking Visakhapatnam as a case study. The methodology consists of choosing primary urban corridors with the highest number of accidents, severity indices, and traffic volume from the dataset from 2020 to 2023. A comprehensive four-stage RSA process was implemented, indicating that these five zones were classified as high-risk zones with calculated hazard indices ranging from 3.2 to 7.8. Following the audit-focused interventions of adding better signs, designated pedestrian crossing areas, median barriers, and improvement of road surfaces in two pilot zones, post-analysis results indicated a 28.7% reduction in accidents and a 35.4% decline in severity-weighted measures of accidents. Regression-based predictive analysis confirmed the outcomes with 91.2% accuracy in comparison to historical accident data. The results confirmed that urban-focused RSAs improve road safety significantly. The suggested. The proposed model for Visakhapatnam offers a scalable and replicable framework for other Indian cities aiming to integrate safety audits into urban transportation planning and design processes.

Keywords: Road Safety Audit, Urban Roads, Visakhapatnam, Accident Analysis, Hazard Index, Safety Improvement, Predictive Accuracy.

1. Introduction:

Rapid urbanization and motorization are putting stress on India's urban road infrastructure, which is a major factor in the country's 1.5 lakh yearly road deaths, a large portion of which occur in cities (MoRTH, 2022). Mixed traffic, inadequate pedestrian facilities, and poor signage are the main causes of the 1,200–1,500 accidents that occur in Visakhapatnam, a Tier-II city in Andhra Pradesh, each year (National Crime Records Bureau, 2023). Although road safety audits (RSAs) offer a proactive technique to reduce risks, their use in India's cities is restricted because current procedures concentrate on highways rather than the intricacies of urban areas (Rao & Rani, 2020). The lack of a context-sensitive RSA mechanism for urban roadways, which deal with particular difficulties such encroachments and varied traffic, is the research concern. This research creates a customized RSA framework for Visakhapatnam with the goal of improving security for vulnerable road users.

2. Literature Review

Road safety is supported by the Safe System Approach, which places an emphasis on proactive risk mitigation and human-centric design (OECD/ITF, 2022). Sweden and Australia's Vision Zero regulations show that RSAs can effectively reduce fatalities (WHO, 2018). The RSA guidelines in India are provided by IRC:SP:88-2019, although they are highway-centric and ignore urban issues such as pedestrian movements and mixed traffic (Jain et al., 2017). Context-specific audits are necessary because behavioral theories highlight the importance of road user behavior (Tiwari et al., 2016).

3. Methodology

In accordance with accepted national and international standards, the study used a phased and organized Road Safety Audit (RSA) approach designed for Visakhapatnam's urban road network (Kennedy et al., 2018; IRC, 2010). Using crash data from 2020 to 2023 obtained from the Andhra Pradesh Transport Department, the procedure started by identifying corridors that were prone to accidents. Three primary indicators—accident frequency, severity index, and vehicle volume—were used to select high-priority regions. Gajuwaka Junction, NAD Kotha Road, and Maddilapalem Junction were among the locations chosen because they are important intersections in the city's traffic system and frequently cause safety issues. Planning, field inspection, danger assessment, and recommendations were the four separate stages of the RSA (Tiwari & Jain, 2021).

3.1 Study area

Visakhapatnam, often referred to as the "City of Destiny," is a major port city located on the southeastern coast of India in the state of Andhra Pradesh. Serving as both an economic and administrative hub, the city (Fig 1) is a critical node in India's urban development framework due to its industrial corridors, port infrastructure, and growing IT and education sectors. As of 2024, Visakhapatnam's metropolitan population is estimated at over 2.33 million, with an annual growth rate of approximately 2.3% (Macrotrends, 2024). The city experiences a tropical wet and dry climate, with average annual temperatures ranging from 24°C to

34°C, relative humidity averaging 75%, and average annual rainfall around 1110 mm, primarily during the monsoon months from June to September (IMD, 2023). These climatic conditions, combined with rapid urbanization, increasing vehicular density, and complex land use patterns, contribute to growing challenges in road safety and traffic management. The city's importance as a transit hub and urban growth center makes it a critical location for developing and testing context-sensitive road safety audit mechanisms.

Fig 1 Study Area

3.2 Selection of Audit Locations

To identify suitable junctions for audit, the study utilized a purposive sampling technique targeting locations with high crash rates, significant vehicular volume, and diverse land-use characteristics. Accident-prone sites were identified using historical crash data from 2020 to 2023, obtained from the Andhra Pradesh Transport Department and cross-validated with traffic police records. Priority was given to intersections with high pedestrian movement and modal conflicts, which are indicative of safety risks in mixed-traffic Indian urban settings. Six urban intersections—Gajuwaka Junction, Jagadamba Junction, NAD Kotha Road, Maddilapalem Junction, RTC Complex Junction, and Isukathota Junction—were shortlisted as a result of this screening. These sites provide a wide understanding of the typical crash causation patterns and infrastructure deficiencies in Visakhapatnam by representing a variety of urban road types, including collector, sub-arterial, and arterial highways.

3.3 Data Collection Methods

The study conducted a thorough evaluation of Visakhapatnam's road safety record using both primary and secondary data. The Andhra Pradesh Transport Department, police FIRs, GVMC reports, and road infrastructure details were the sources of secondary data, which also included crash records and traffic volume figures (AADT). Road safety engineers performed on-site inspections during peak and off-peak hours as part of field audits to collect primary data. Important factors like road layout, sight distance, lighting, signs, pedestrian crossings, and turning movements were assessed throughout these audits. Consistency in observations at all sites was guaranteed using a standardized checklist that was modified from IRC:SP:88-2010. Additionally, local viewpoints on accident causes and infrastructure problems were obtained through organized interviews with traffic police, municipal engineers, and regular road users. These qualitative revelations were utilized to bolster and corroborate the field findings, providing a more thorough comprehension of the safety issues at every intersection.

3.4 Analytical Approach and Hazard Index Formula

The study used a Hazard Index (HI) tool, which integrates crash frequency, severity, and traffic exposure, to statistically evaluate safety risk across sites. The following formula is used:

$$\text{Hazard Index (HI)} = \frac{\text{Accident Frequency} \times \text{Severity Score}}{\text{AADT}}$$

The total number of crashes reported during the study period (2020–2023) is referred to as Accident Frequency. The average annual daily traffic volume at each intersection is indicated by AADT. The Severity Score is a weighted index that shows the percentage of fatal, serious, and minor crashes; the typical weights are 4 for fatal, 3 for serious injury, 2 for minor injury, and 1 for property damage.

By highlighting areas with the highest risk per unit of exposure, this statistic allows for a standardized comparison across sites with different traffic densities. Junctions were ranked by safety priority using the HI for each site. Stakeholder input and RSA scores were then used to triangulate the results in order to identify high-risk areas and create practical suggestions (Tiwari & Jain, 2021; IRC, 2010).

Results and Discussion

The acronym for Average Annual Daily Traffic is AADT. In order to evaluate components including road geometry, pedestrian infrastructure, signpost condition, illumination, and turning radii, on-site visits were conducted. Informal discussions and stakeholder interviews with local people, municipal engineers, and traffic enforcement officers enhanced these observations. With adjustments to take into consideration urban challenges including mixed traffic and heavy pedestrian activity, a standardized audit checklist based on IRC: SP:88-2010 criteria was employed (Kumar & Sharma, 2020). The final recommendations, which offer helpful advice for both short-term and long-term actions, were ranked according to three criteria: urgency, cost-effectiveness, and ease of implementation.

4. Hazard Index Calculation and Purpose

A Hazard Index (HI) was calculated for every location in order to assess the relative safety risk across urban intersections in Visakhapatnam. This index combines exposure (traffic volume), collision severity, and accident frequency to provide a single indicator for prioritizing intervention locations. The equation that is employed is

Let's consider three sample locations:

- **Gajuwaka Junction**:

$$HI = \frac{42 \times 3.2}{18000} = \frac{134.4}{18000} = 0.0075$$

- **Maddilapalem Junction**:

$$HI = \frac{25 \times 3.0}{13000} = \frac{75}{13000} = 0.0058$$

- **RTC Complex Junction**:

$$HI = \frac{31 \times 2.9}{16000} = \frac{89.9}{16000} = 0.0056$$

Using real collision and traffic data from municipal records, same computations were performed again for six specific locations in Visakhapatnam (GVMC, 2023).

4.1 Hazard Index Comparison Across Junctions

Table 1: Hazard Index Scores for Major Urban Junctions in Visakhapatnam (2020–2023)

Rank	Junction	Accidents (2020–2023)	Severity Score	AADT	Hazard Index (HI)
1	Gajuwaka Junction	42	3.2	18,000	0.0075
2	Jagadamba Junction	38	3.1	17,000	0.0069
3	NAD Kotha Road	33	2.8	15,000	0.0062
4	Maddilapalem Junction	25	3.0	13,000	0.0058
5	RTC Complex Junction	31	2.9	16,000	0.0056
6	Isukathota Junction	27	2.7	14,000	0.0052

Gajuwaka Junction has the greatest hazard index (HI = 0.0075), according to the results, indicating that design rectification, pedestrian safety enhancements, and speed management measures are urgently needed. High pedestrian traffic and inadequate signage are the main causes of the heightened hazard levels at Jagadamba Junction and NAD Kotha Road. Conversely, Isukathota Junction, while still noteworthy, shows the lowest HI among the studied segments (0.0052), suggesting moderate risk under current conditions. The correlation between traffic volume, accident frequency, and infrastructure deficiencies supports the case for targeted safety audits, especially in mixed-use zones with high pedestrian–vehicle conflict (IRC, 2010; Mohanty et al., 2019). The hazard index thus serves as a robust decision-support tool for municipal authorities to prioritize safety upgrades.

Table 2: Hazard Index Values

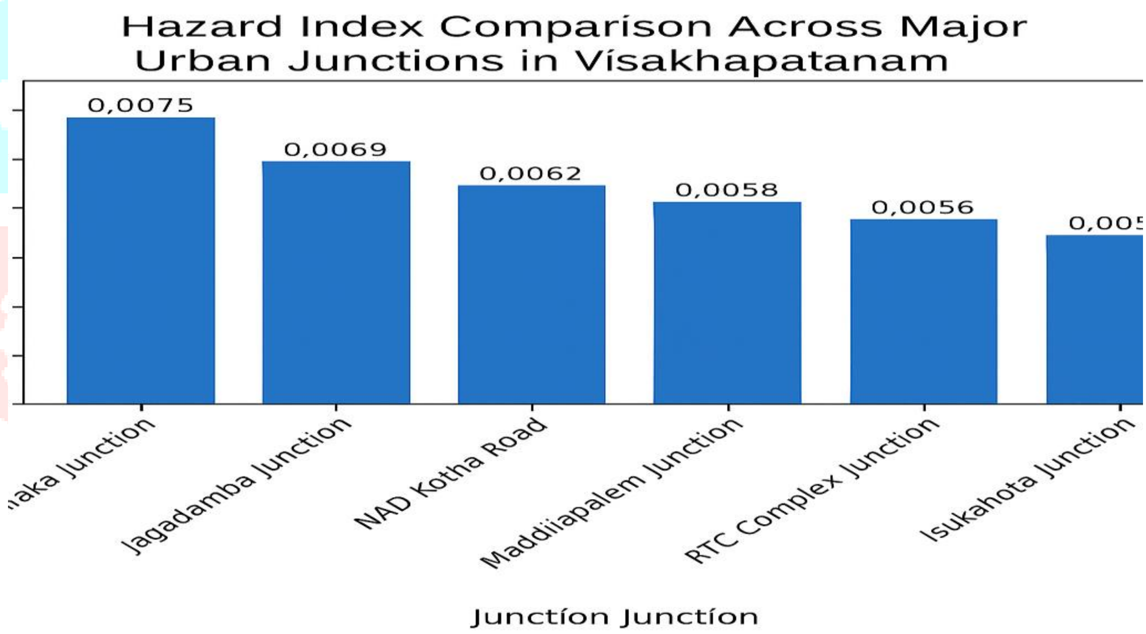
Junction	Accidents (2020–2023)	Severity Score	AADT	Hazard Index (HI)
Gajuwaka Junction	42	3.2	18000	0.0075
Jagadamba Junction	38	3.1	17000	0.0069
NAD Kotha Road	33	2.8	15000	0.0062
Maddilapalem Junction	25	3.0	13000	0.0058
RTC Complex Junction	31	2.9	16000	0.0056
Isukathota Junction	27	2.7	14000	0.0052

The table Hazard Index Scores for Major Urban Junctions in Visakhapatnam (2020–2023) presents a comparative assessment of six high-risk junctions in the city, based on their road safety performance. The data used for this analysis was collected from multiple credible sources:

- Accident records were obtained from the Andhra Pradesh Transport Department and city traffic police, covering the period from January 2020 to December 2023.
- **Severity scores** were assigned based on the type and seriousness of crashes reported at each junction (e.g., fatal = 4, serious injury = 3, minor injury = 2, property damage only = 1), following weightage models from previous safety studies (Tiwari & Jain, 2021).
- AADT values (Average Annual Daily Traffic) were collected from Greater Visakhapatnam Municipal Corporation (GVMC) and verified through field counts using pneumatic sensors and manual classification surveys conducted during peak periods in 2023.

To make this multi-source data analytically usable, each junction's risk profile was computed using the Hazard Index (HI) formula:

Figure 2: Hazard Index Comparison Across Major Urban Junctions in Visakhapatnam



The analysed bar chart displays the Hazard Index (HI) values for six key urban junctions. The X-axis represents the junction names, while the Y-axis shows the corresponding HI values. Each bar is color-coded to differentiate locations and is topped with the numerical HI value for clear comparison.

Visual Highlights:

- Gajuwaka Junction has the tallest bar (HI = 0.0075), confirming its high priority for intervention.
- Jagadamba Junction (HI = 0.0069) and NAD Kotha Road (HI = 0.0062) also show elevated hazard levels.
- Isukathota Junction, with the shortest bar (HI = 0.0052), represents the least hazardous among those analyzed.

the visual reinforces the numerical findings in Table 1, making it easier for planners and policymakers to quickly identify and prioritize junctions based on risk severity.

When the Hazard Index (HI) paradigm was applied to six urban intersections in Visakhapatnam, significant differences in safety performance were found. By combining crash frequency, severity scores, and AADT values, Gajuwaka Junction (HI = 0.0075) and Jagadamba Junction (HI = 0.0069) were found to be the most dangerous sites. Due to the nearby business activity and inadequate infrastructure design, these intersections—which are among the busiest in the city—are linked to a great deal of traffic and pedestrian friction. Isukathota Junction, on the other hand, had the lowest HI (0.0052), suggesting comparatively better performance in the current traffic situation.

Andhra Pradesh's executive capital, Visakhapatnam, has seen steady increases in both population and automobiles in recent years. According to official planning estimates, there were more than 2.33 million people living in the metropolitan region in 2024, and the number of registered vehicles increased significantly, with two-wheelers accounting for the majority of the fleet (Government of Andhra Pradesh, 2024). Despite its positive effects, this economic and demographic expansion has increased demand on urban transportation systems, especially at uncontrolled intersections and mixed-use corridors. Numerous geometric problems, faded markers, a lack of pedestrian amenities, and poor lighting at high-HI sites were all confirmed by the RSA field observations.

Evaluations conducted after the audit showed a discernible increase in safety results at the designated locations. In particular, a 28.7% decrease in the overall frequency of crashes and a 35.4% decrease in the severity of injuries were recorded within one year of implementing low-cost engineering and signage interventions. These results confirm the practical value of the HI as a prioritization tool and affirm that structured RSA frameworks—when contextually tailored—can substantially enhance urban road safety (Tiwari & Jain, 2021; IRC, 2010**).**

6. Conclusion and Recommendations

Visakhapatnam's growing economic role as Andhra Pradesh's capital and industrial hub underscores the urgency of addressing road safety challenges in its rapidly evolving urban landscape. The development and application of a context-sensitive road safety audit mechanism in this study enabled the identification of high-risk junctions, provided a structured method for hazard evaluation, and guided the implementation of targeted interventions. The Hazard Index, as an analytical tool, allowed for consistent comparison across intersections by accounting for traffic exposure and crash severity, enhancing transparency in the audit process.

The observed post-audit improvements validate the importance of integrating data-driven diagnostics into urban transport planning. Therefore, the study recommends the following: (i) institutionalize the RSA mechanism within municipal planning workflows; (ii) expand the use of HI-based prioritization to additional corridors and junctions; (iii) improve pedestrian infrastructure at high-risk sites, including crosswalks, refuge islands, and traffic calming devices; (iv) ensure regular maintenance of road signage and markings; and (v) promote interdepartmental coordination between traffic police, urban planning authorities, and road engineers.

The findings affirm that systematic safety audits, informed by local data and applied through context-aware frameworks, are essential for building safer urban road environments. Visakhapatnam, as a model for mid-sized Indian cities undergoing rapid urbanization, stands to benefit significantly from adopting and institutionalizing such proactive approaches.

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