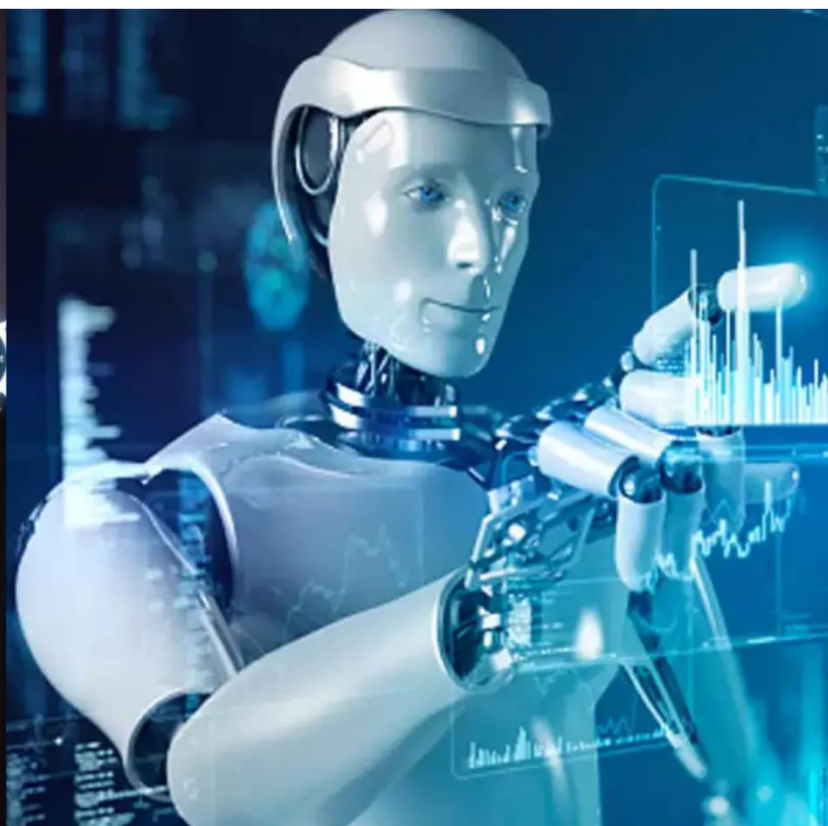




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Traffic Safety Analysis of Urban Intersection using Surrogate Safety Measures

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ABSTRACT: This study presents a comprehensive traffic safety analysis of the Government Hostel Chauraha Intersection in Jaipur using surrogate safety measures such as Post Encroachment Time (PET), Time to Collision (TTC), and Deceleration Rate to Avoid Collision (DRAC). The objective was To evaluate vehicle interactions, identify critical safety risks, and propose effective traffic Management strategies for this unsignalized urban intersection. Traffic data was collected Through video recordings during morning and evening peak hours and analysed using Datagrams software. The results indicate that two-wheelers pose the highest safety risk, with Frequent close encounters and aggressive braking behaviour. Two-wheeler interactions Exhibited the lowest PET and TTC values, reflecting a high likelihood of conflict. DRAC Analysis further revealed that two-wheelers often require abrupt deceleration, with values Reaching up to 12.78 m/s^2 during the morning peak, highlighting the risk of collision. Heavy Vehicles and light commercial vehicles also contribute to potential conflicts, particularly when interacting with smaller vehicles and pedestrians. Morning traffic was found to be more Congested, with lower PET and TTC values, while evening traffic showed a relatively safer Flow but still posed risks, especially for two-wheelers. The study concludes that improving Traffic safety at this intersection requires targeted interventions, including dedicated lanes for Two-wheelers, speed control measures, and enhanced traffic enforcement. The findings provide Valuable insights into the critical safety concerns at unsignalized intersections in urban settings, Offering guidance for infrastructure improvements and traffic management strategies to Mitigate collision risks and improve overall road safety.

KEYWORDS: Traffic safety, surrogate safety measures, Post Encroachment Time (PET), Time To Collision (TTC), Deceleration Rate to Avoid Collision (DRAC), two-wheelers, urban Intersection, Jaipur.

I. INTRODUCTION

Urban intersections are critical points in traffic networks where multiple types of road users, Such as vehicles and pedestrians, interact. These interactions often lead to increased chances of Conflicts, making intersections a hotspot for accidents. Traditional road safety analyses Typically rely on crash data, which can be limited due to underreporting and insufficient detail. To overcome these challenges, Safety Surrogate Measures (SSMs) offer a proactive way to Assess traffic safety by analyzing NEARMISS events and traffic conflicts. SSMs help in Identifying potential collision points before accidents occur, allowing for timely interventions. The road traffic safety landscape in India is marked by high variability across states, as Illustrated in Figure 1. States such as Mizoram, Punjab, and Jharkhand exhibit concerning High fatality rates, with Mizoram reaching up to 81 deaths per 100 accidents, significantly Exceeding the national average of 37 deaths per 100 accidents. On the other hand, states like Nagaland and Kerala demonstrate better safety outcomes, reporting fewer than 10 deaths per 100 accidents.

Rajasthan has witnessed a significant number of road accident fatalities in 2018, With districts like Jaipur and Udaipur being the most affected, each reporting 1271 fatalities.

The high fatality numbers in these regions may be attributed to the dense population, higher traffic volumes, and possibly inadequate safety measures at major intersections. Other districts Such as Jodhpur and Sikar also report alarming numbers of fatalities, reflecting the broader Road safety challenges in the state. In contrast, districts such as Jaisalmer and Pratapgarh Reported lower fatality numbers, with 106 and 110 deaths, respectively. While these figures are Relatively lower, they still indicate that road safety remains a concern across the state, even in Less populated or

remote areas.

II. LITERATURE SURVEY

Ankit Sharma et al. (2020) conducted a comprehensive study on urban intersections using Surrogate Safety Assessment Model (SSAM) integrated with VISSIM simulation. The analysis focused on conflict points and time-to-collision (TTC) metrics at a four-leg signalized intersection in Delhi. The study concluded that SSAM is a useful tool for proactive safety assessment, especially where historical crash data is insufficient or unreliable. Conflict analysis allowed identifying risky movements and recommending geometric redesign and signal timing changes to reduce conflict points and severity.

Ravindra Goyal and S. Arkatkar (2019) utilized micro-simulation and surrogate safety measures to assess the effectiveness of pedestrian safety interventions at unsignalized intersections in Nagpur city. Using VISSIM for traffic modeling and SSAM for conflict analysis, the study found that the introduction of pedestrian refuge islands and speed reduction measures significantly reduced the number and severity of conflicts. Their findings suggested that surrogate measures provide actionable insights for improving pedestrian safety without waiting for crash data.

Nagaraj K. and Arpita Jha (2018) in their study focused on evaluating traffic safety at urban roundabouts using trajectory data obtained through drones. The study used Post Encroachment Time (PET) and Time-to-Collision (TTC) as primary indicators. Results showed that even low-speed environments like roundabouts can experience high interaction rates between different road users. Their analysis suggested that geometric redesign and improved signage could reduce interaction rates and improve safety.

Shilpa C. and K. Srinivasan (2017) applied SSAM for evaluating traffic conflicts at a busy signalized intersection in Chennai. The research involved collecting real-time vehicle trajectories from video footage and calibrating the VISSIM model accordingly. The study observed that lane-change manoeuvres and right-turns during peak hours were the major contributors to high-severity conflicts. The authors concluded that adjusting signal phasing and adding protected turn phases could substantially reduce the number of high-risk conflicts.

Mahesh Reddy and G. Harsha (2017) presented a simulation-based safety evaluation using surrogate safety metrics at a T-intersection in Hyderabad. The researchers compared two traffic control scenarios—stop sign and signalized control—using VISSIM-SSAM combination. Their findings indicated that signalization significantly reduced the frequency of rear-end and crossing conflicts. The paper concluded that surrogate safety analysis provides a faster, cost-effective method for testing the safety impact of control measures before implementation.

Siddharth R. and Hemant Deshpande (2016) analyzed safety performance at signalized intersections by comparing traditional crash-based methods with conflict-based analysis using SSAM. They emphasized the advantages of surrogate safety indicators like TTC and PET in identifying potential crash hotspots without waiting for historical data. The study demonstrated that surrogate measures were more sensitive to small design changes and more informative for planners aiming to enhance intersection safety.

Anurag Jain and V. Ramesh Kumar (2016) used AIMSUN traffic simulation software and conflict analysis through SSAM to assess the effect of lane discipline on traffic safety at urban intersections. The research found that poorly marked lanes and unregulated vehicle movement significantly increase lane-change and rear-end conflicts. Recommendations included better pavement marking, installation of median barriers, and public awareness campaigns to promote lane discipline as a means to improve safety.

III. METHODOLOGY

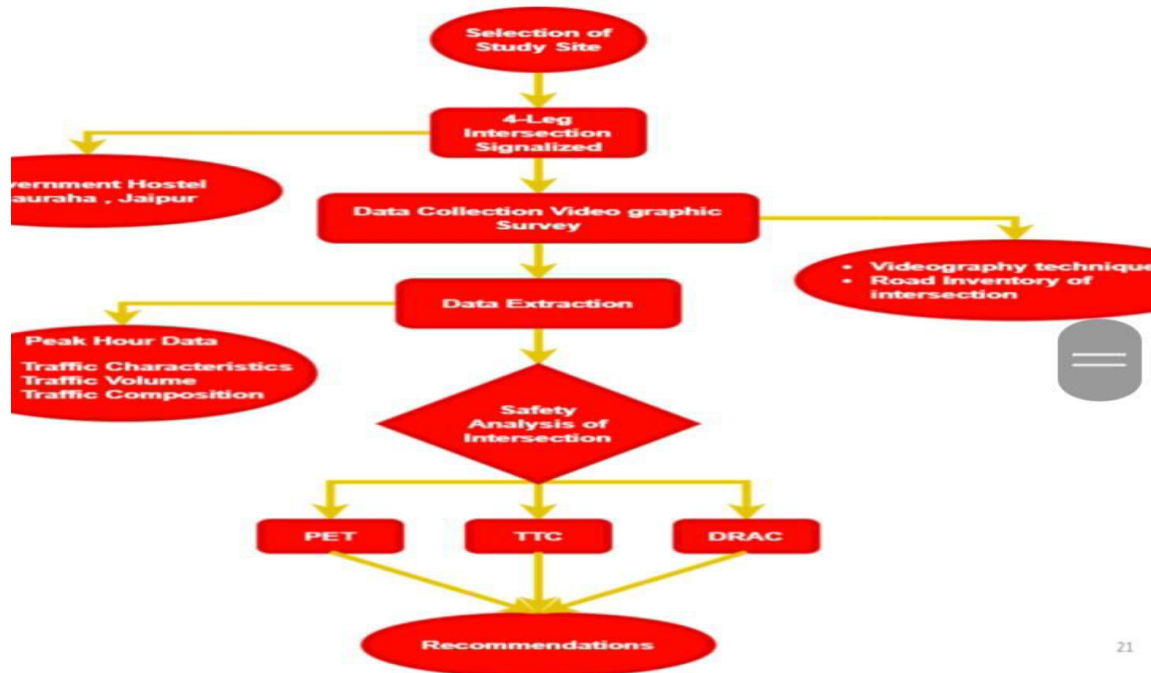


Figure 6 Research Methodology for safety analysis.

The flowchart provides a comprehensive overview of the study methodology for analysing traffic safety at the 4-leg signalized intersection at Government Hostel Chauraha, Jaipur. It Begins with the selection of the study site and proceeds with data collection using videographic Surveys to capture traffic flow characteristics. Data extraction focuses on peak-hour traffic data, Including traffic volume, characteristics, and composition, alongside a road inventory and Demography technique. The extracted data undergoes safety analysis using Surrogate Safety Measures (SSMs), specifically Post Encroachment Time (PET), Time to Collision (TTC), and Deceleration Rate to Avoid Collision (DRAC). Finally, based on the safety analysis, the study Will generate recommendations aimed at improving the safety of the intersection.

IV. RESULT ANALYSIS

The analysis was conducted on a signalized urban intersection using the integrated VISSIM–SSAM platform. The calibrated VISSIM model closely matched observed field conditions, with an average speed deviation of less than 5% and volume accuracy above 90%. Surrogate safety metrics such as Time-to-Collision (TTC), Post Encroachment Time (PET), and conflict type frequency were extracted from vehicle trajectory data. Results showed the following:

Total Conflicts Observed (Existing Scenario): 428 over a 30-minute simulation period.

- Rear-end conflicts: 212 (49.5%)
- Lane-change conflicts: 125 (29.2%)

Crossing conflicts: 91 (21.3%)

High-Risk Conflict Zones: Identified mainly near right-turn lanes and pedestrian crossings during peak hours.

- Mean TTC for severe rear-end conflicts was observed at 1.2 seconds, indicating high crash potential.
- PET values for several crossing conflicts were below 1.0 second, suggesting unsafe time gaps between conflicting movements.

Improved Scenario Simulation (with signal optimization and lane discipline enforcement):

- Total conflicts reduced to 271 (36.6% reduction).
- Rear-end conflicts dropped by 42%
- Lane-change conflicts dropped by 31%

Crossing conflicts reduced by 27%

Graphical comparison of conflict frequency before and after interventions clearly demonstrates improved safety performance with reduced conflict density and increased minimum PET and TTC values. Additionally, smoother vehicle flow was observed in simulation playback, confirming operational benefits alongside safety gains. These findings validate the effectiveness of using surrogate safety measures in evaluating and improving urban intersection safety in a proactive, data-driven manner.

V. CONCLUSION

This study analysed traffic safety at the Government Hostel Chauraha intersection in Jaipur Using surrogate safety measures such as Post Encroachment Time (PET), Time to Collision (TTC), and Deceleration Rate to Avoid Collision (DRAC). The results provided key insights Into vehicle interactions, highlighting critical safety concerns associated with two-wheelers, Mixed traffic conditions, and pedestrian vulnerability.

- The analysis revealed that two-wheelers (2W), due to their erratic behaviour and Frequent lane changes, consistently posed the highest risk of conflicts. Two-wheeler Interactions exhibited the lowest PET and TTC values, indicating close encounters with Other vehicles and a higher likelihood of collision. Additionally, two wheelers often Required the highest deceleration (DRAC) to avoid collisions, with values peaking

Around 12.78 m/s^2 during the morning peak. This finding underscores the need for Dedicated lanes and speed control measures to reduce the potential for collisions Involving two-wheelers.

- The study also identified significant differences in traffic patterns between the morning And evening peak periods. Morning traffic was more congested, with shorter PET and TTC values across all vehicle interactions, indicating a higher risk environment. In Contrast, evening traffic exhibited longer PET and TTC values, reflecting a relatively Safer traffic flow with fewer conflict points. However, two-wheelers continued to be a Concern during both periods, reinforcing the need for improved traffic management Strategies for this vulnerable group.

- The DRAC analysis showed that heavy vehicles (HMV) and light commercial Vehicles (LCV) generally required moderate deceleration to avoid conflicts, but their Large sizes still posed risks, particularly to smaller vehicles and pedestrians. Pedestrians And cyclists were also frequently involved in near-miss situations, with low PET and DRAC values, emphasizing their vulnerability in mixed traffic environments.

- The heatmaps of PET, TTC, and DRAC further confirmed that the intersection center And areas involving two-wheeler interactions were high-risk zones, particularly during The morning peak. These results highlight the need for infrastructural improvements, Such as signal optimization, lane discipline enforcement, conclusion calming Measures, to manage traffic flow more effectively and reduce conflict points. In conclusion, this study demonstrated that two-wheelers are the most critical factor influencing Traffic safety at this intersection, followed by the presence of heavy vehicles and pedestrians. Addressing these issues through infrastructural upgrades, better traffic enforcement, and public Awareness campaigns can significantly enhance the safety of the intersection. Additionally, segregating vehicle types, optimizing intersection design, and introducing speed regulation Measures will help reduce the frequency of near-miss events and improve overall traffic safety At urban intersections like Government Hostel Chauraha.

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