Road Safety Risk Assessment in Highway Work Zones under Mixed Traffic Conditions

Sanjeev Sharma[1] Dinesh Kumar[2] Sambhangi Ram Babu[3] Vummadi Kanaka Durga Rao[4]
[1,2,3,4]Department of Civil Engineering
[1,2,3,4]LNM Infra Projects Pvt. Ltd., India

Abstract — Highway work zones require safety assessments that remain useful as construction stages, traffic composition and temporary alignments change. A checklist can document installed controls, but it cannot by itself establish how road users respond to those controls. This focused narrative review examines selected research and official guidance on work zone traffic behaviour, surrogate safety measures and transportation management. The evidence is synthesised into a proposed assessment framework for Indian mixed traffic. The framework separates infrastructure deficiencies, observed operational conflicts and exposure, and applies a critical-hazard override before any aggregate ranking. A prospective validation design is developed using repeated site observations, vehicle trajectories, worker exposure records and independent field ratings. The paper argues that traffic conflict indicators should complement physical inspections, while pedestrian, two-wheeler and worker risks require explicit observation beyond conventional automobile conflict analysis. Its contribution is an auditable connection between site conditions, measurable outcomes and corrective decisions. No primary observations, crash reductions, calibrated weights or model-performance results are reported. The framework remains a research proposition requiring local validation before operational thresholds are adopted.

Keywords: Highway Work Zones; Mixed Traffic; Road Safety; Traffic Conflicts; Risk Assessment; Construction Supervision

I. Introduction

Temporary road layouts change the environment in which drivers choose speed, negotiate gaps and interact with construction activity. The assessment problem is therefore temporal as well as spatial: a satisfactory arrangement observed during one shift may not represent a different construction stage. For an Indian highway study, the appropriate question is how physical provisions and traffic behaviour should be observed together without treating every vehicle or every work zone as equivalent.

Research by More, Therattil and Bharadwaj [1] demonstrates the relevance of trajectory-based analysis at merging work zones in Guwahati and Pune. Official guidance also treats transportation management as a process requiring monitoring and revision [4]. These perspectives motivate a framework in which inspection records identify deficiencies and operational observations test whether the traffic arrangement functions as intended. Neither perspective alone provides a complete account of exposure to harm.

This paper addresses three questions. Which kinds of evidence can support a work zone risk assessment? How can an assessment preserve serious hazards that might disappear within an average score? What validation design could determine whether the proposed indicators predict independent safety outcomes? The intended application is highway construction supervision, but the paper does not prescribe contractual responsibilities or site-specific traffic-control dimensions.

II. Review Method and Scope

A focused narrative search was undertaken on 1 November 2026 using web-indexed publisher pages and official highway research resources. Search phrases included “work zone safety mixed traffic India crash research study”, “work zone safety transportation management plans surrogate safety assessment model” and the title of the mixed-traffic trajectory study. Sources were selected for direct relevance to traffic behaviour, conflict measurement or the management process. Six sources are cited; the selection is purposive, not an exhaustive database review.

The accessible publisher abstract of [1], indexed publisher summary of [2], and official technical or guidance webpages [3]–[6] form the evidence base. Full journal texts were not available for appraisal. Study-level numerical effects were therefore not extracted, and no pooled effect estimate or formal risk-of-bias score was produced. The synthesis distinguishes an empirical study, a methodological tool and management guidance because they answer different questions. International guidance is used as comparative technical material rather than as an Indian compliance standard.

III. Literature Synthesis

A. Behaviour within mixed traffic

More et al. [1] analysed video-derived trajectories at two Indian work zones and used minimum time-to-collision values within an extreme-value framework to estimate merging-related rear-end risk. The accessible abstract describes a Gumbel distribution approach. It supports the feasibility of collecting trajectories where reliable crash histories are limited; it does not establish a universal threshold or a transferable prediction equation. The present review does not reproduce coefficients or claim predictive accuracy from an abstract.

The publisher summary of the study on work zone traffic-stream parameters [2] describes comparisons between road sections with and without construction, including lateral driving behaviour under heterogeneous traffic. This adds an important measurement dimension: a work zone assessment should not be reduced to longitudinal following alone. However, the restricted source access prevents detailed evaluation of sample selection and model assumptions. Its contribution here is the explicit inclusion of lateral behaviour, not an asserted magnitude of risk increase.

B. Surrogate safety measures

The FHWA Surrogate Safety Assessment Model technical brief [3] describes conflict identification using simulated vehicle trajectories and measures such as time to collision,

All rights reserved by www.ijsrd.com

post-encroachment time, deceleration and speed difference. Such measures provide operational information without waiting for a long crash series. They remain surrogate measures, and their interpretation depends on trajectory accuracy and the assumptions of the traffic model.

The official SSAM overview [6] identifies its principal orientation toward conventional automobile conflicts. That qualification is material to a mixed-traffic application. A system that captures car-following interactions does not automatically measure the risks faced by pedestrians crossing a diversion or workers near moving plant. Separate event definitions and validation samples are needed for those interactions.

C. Management and feedback

FHWA guidance [4] links monitoring of queues, delay, incidents and other performance measures to revision of the transportation management plan. This provides a practical feedback structure: observed performance informs changes in staging or management. The sample-plan guide [5] also recognises that the detail of a plan should vary with the expected impact of the project. These are management principles rather than quantified demonstrations of crash reduction.

Taken together, the selected sources support a combined inspection and observation approach. They do not prove that the specific index proposed below is superior to existing procedures. The research opportunity is to test whether a transparent combination adds predictive or decision value under Indian conditions, especially after vehicle class, work stage and exposure have been considered.

Evidence	Contribution to this review	Limit on interpretation
Indian trajectory study [1]	Rear-end risk assessment at work zone merges	Two reported sites; abstract-level appraisal
Mixed-traffic study [2]	Lateral behaviour and section comparisons	Indexed summary only; no effect extraction
SSAM resources [3, 6]	Conflict indicators and tool scope	Simulation and automobile emphasis
Management guidance [4, 5]	Monitoring and revision process	Guidance does not establish local effectiveness

Table 1: summarises the evidence and its transfer limits.

IV. Proposed Assessment Framework

A. Observation Unit and Indicator Structure

The proposed unit is a work zone segment observed during a defined time interval and construction stage. Its identifier should combine chainage, direction, stage, date and shift. The observation record should preserve the traffic layout actually in service, including any changes during the observation window. Joining all stages under one site identifier would conceal exposure changes.

The proposed framework contains three separate records. The first describes physical deficiencies against the applicable approved plan and requirements. The second describes observed operations, including speed distributions, queues and classified conflicts. The third measures exposure, such as traffic passing the site, pedestrian crossings and worker-hours near traffic. These records should be linked but not merged indiscriminately. In particular, worker-hours and vehicle counts are different denominators.

Domain	Proposed variables	Reason for collection
Layout and visibility	Usable width, sight restrictions, delineation condition	Describe the arrangement encountered
Vehicle operations	Classified volume, speed spread, queue extent	Interpret demand and instability
Conflict events	Rear-end, lateral and crossing interactions	Distinguish mechanisms of near collision
Worker and pedestrian exposure	Crossings, work location, exposure duration	Retain users missed by vehicle-only analysis
Stage and environment	Stage changes, lighting, rainfall, surface state	Account for changing observation conditions

B. Ranking without Concealing Critical Hazards

For research screening, let d(ij) be the assessed deficiency for indicator j at observation i on an anchored scale from 0 to 1. A candidate index is $S(i) = 100 \times \text{sum}[w(j) \times d(ij)]$, where weights are non-negative and sum to one. The anchors and weights are proposed parameters, not calibrated findings. Equal weights provide a transparent baseline; expert-derived alternatives should be reported alongside sensitivity tests.

A separate critical-hazard flag is necessary because an arithmetic mean can compensate a serious deficiency with several satisfactory items. Before field use, competent project personnel should define the conditions triggering immediate escalation under the applicable safety arrangements. The index must never authorise continued exposure to an identified imminent hazard. The research record should preserve the flag, the action and the reason independently of the numerical score.

Missing information is not a zero deficiency. Each record should show completeness and whether its observations were sufficient for ranking. Where an indicator cannot be assessed, the analyst should publish both the omission and its possible influence. Renormalising weights across whatever data happen to be available can make unlike sites appear comparable; this should be avoided unless a predeclared rule and sensitivity analysis justify it.

V. Proposed Empirical Validation

A. Sampling and measurement

A prospective study should sample several independent projects and contrasting work zone arrangements, with repeated observations across shifts and stages. Site selection should capture variation in vehicle composition, roadside access, terrain and pedestrian activity. Sample size should

All rights reserved by www.ijsrd.com

follow a pilot assessment of outcome frequency, between-site variation and the minimum effect of interest, rather than an arbitrary target number of videos.

Calibrated cameras may provide trajectories where placement and permissions permit. A manual audit of sampled tracks should estimate position error, lost tracks and classification errors. Occlusion rates should be reported by vehicle class. Observers should independently code a subset of physical deficiencies; agreement should be assessed using an appropriate statistic for the scale, with disagreement reviewed before the main survey.

Time to collision requires an explicit motion model and should not be computed as a finite value for non-closing pairs under a simple constant-speed following model. Post-encroachment time concerns successive occupancy of a defined conflict space. Thresholds, event-merging rules and trajectory smoothing should be set before testing associations. The same sustained interaction should not be counted repeatedly as numerous independent conflicts.

B. Analysis and validation outcomes

One candidate outcome is a class-specific conflict count per observation interval. A count model could specify log(mu_it) = log(E_it) + beta_0 + beta_1 S_it + beta_2 X_it + u_i, where E_it is a positive, appropriately defined exposure, X_it contains preselected contextual variables and u_i represents site-level variation. A negative-binomial form is a candidate if overdispersion warrants it. Zero-exposure intervals require separate treatment and cannot enter a logarithmic offset.

Physical-deficiency scores should predict independently observed outcomes. Including conflict counts within the score and then validating that score against the same conflicts would be circular. Model development and testing should therefore be separated by project or by a later time period. Evaluation should report calibration, uncertainty and performance across vehicle classes, rather than only an overall discrimination measure.

For interventions, a controlled before-and-after design is preferable to a simple comparison of two short observation windows. Controls should have similar traffic and seasonal conditions, and analysis should account for stage changes and other concurrent measures. If crash outcomes are sufficiently available, regression to the mean and exposure changes must be addressed. Any estimated improvement should include an uncertainty interval and the observation period.

VI. Discussion and Practical Implications

The proposed framework's potential value lies in making decisions traceable: a deficiency is linked to an observation, an assigned response and a subsequent check. It also makes disagreements visible. A site might satisfy documented provisions while displaying adverse operational behaviour, or present a severe physical hazard before enough conflicts have been observed. These cases require different responses and should not be forced into a single interpretation of a score.

Implementation can begin with structured manual records rather than advanced automation. Automated video analysis becomes useful only if its errors are measured and its outputs remain understandable to the field team. A future study should compare the additional cost and decision value of trajectory analysis against an inspection-only baseline. The framework should be retained only if that comparison demonstrates worthwhile improvement.

VII. Limitations

This paper uses a small, purposively selected evidence base, including two journal sources with restricted access. It is not a systematic review and cannot establish completeness or publication-bias estimates. The proposed indicators, weights and validation model have not been tested. Differences between urban and highway work zones, climate, vehicle behaviour and construction practice limit transfer. No Indian code compliance finding is made, and implementation requires checking the actual project documents and applicable standards.

VIII. Conclusion

A defensible work zone assessment should preserve physical conditions, operational behaviour and exposure as distinguishable evidence. The selected literature motivates their joint use but does not validate a universal risk score. This paper proposes a transparent screening index, a separate critical-hazard override and a prospective validation design. The next empirical contribution should test predictive value across independent Indian projects and determine whether the method improves corrective decisions beyond existing inspection practice.

IX. Declarations

Data availability: No primary dataset was collected or analysed. All evidence comes from the cited publicly accessible material. Research status: The scoring framework and validation design are proposals; no statistical results are claimed. Author affiliations, funding and competing-interest statements should be completed by the submitting authors after review.

References

[1] P. A. More, J. T. Therattil and N. Bharadwaj, "Work-Zone Safety Analysis: Evaluating Rear-End Crash Risk with Extreme Value Theory," Transportation Research Record, vol. 2679, no. 2, 2025; first published online 2 August 2024. https://doi.org/10.1177/03611981241263820. Publisher abstract consulted.

[2] "Effect of Construction Work Zone on Traffic Stream Parameters Using Vehicular Trajectory Data under Mixed Traffic Conditions," Journal of Transportation Engineering, Part A: Systems, vol. 146, no. 6, 2020. https://doi.org/10.1061/JTEPBS.0000353. Indexed publisher summary consulted; title-led citation used pending full-text bibliographic verification.

[3] Federal Highway Administration, Surrogate Safety Assessment Model, FHWA-HRT-10-020, October 2009. https://www.fhwa.dot.gov/publications/research/safety/10020/

All rights reserved by www.ijsrd.com

[4] Federal Highway Administration, Developing and Implementing Transportation Management Plans for Work Zones, section 2, "Process for TMP Development, Implementation, and Assessment." https://ops-dr.fhwa.dot.gov/wz/resources/publications/trans_mgmt_plans/sec2.htm
[5] Federal Highway Administration, Sample Transportation Management Plans and Templates, section A, "How to Use the Guide." https://ops.fhwa.dot.gov/wz/resources/final_rule/tmp_examples/sample_tmps/sec_a.htm
[6] Federal Highway Administration, Surrogate Safety Assessment Model Overview. https://highways.dot.gov/turner-fairbank-highway-research-center/software/ssam

All rights reserved by *www.ijsrd.com*