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A review of conflict-based road safety application in Low- and Middle-Income Countries

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Introduction

Road safety analysis has historically relied on crash data, which faces limitations like prolonged observation periods, data unavailability, underreporting, and a reactive nature, raising ethical concerns. An alternative approach has been introduced, consisting in analysing safety using non-crash event know as traffic conflicts.

This approach, widely used in High Income Countries (HIC), shows promise for Low- and Middle-Income Countries (LMICs) due to poorer crash data quality and under-reporting. However, its application in LMIC is recent and have often been overlooked (or partly addressed) in review studies, despite the unique challenges posed by LMICs' traffic environments (less organized, heterogenous, non-lane based, etc.).

The paper aims to comprehensively review the application of conflict-based safety analysis in LMICs, focusing on conflict indicators, observation methods, road user and facility types, study purposes, modeling approaches, and safety result validity, but also seeks to offer insights into challenges and future research avenues in conflict-based safety analysis in LMICs.

Research methodology

This research adheres to the PRISMA guidelines to systematically review literature from the past fourteen years using databases like Scopus and Web of Science. Synonyms for traffic conflict (e.g., surrogate safety measures, near misses, safety critical events) and terms relevant to LMICs (e.g., developing countries, heterogenous traffic) guided the search. The goal was to focus on studies most relevant to the central themes, rather than to compile an exhaustive list. The initial search yielded 1132 peer-reviewed articles, narrowed down to 845 after removing duplicates and non-English papers. Screening for relevance to traffic conflict-based safety analysis in LMICs further reduced the pool to 195. After assessing clarity in conflict measures and data collection methods, 115 studies were selected for review.

Results

The following provide a glimpse of some of the findings.

- **Conflict indicator**. Approximately 60% of the reviewed studies utilized kinematic-based measures or mixed measures like speed, deceleration, safety critical events or near crashes, while the remaining studies mainly relied on temporal proximity (e.g., time to collision-TTC, post encroachment time-PET). Temporal proximity measures tend to identify conflicts as values decrease. However, in LMICs with their heterogeneous and non-lane-based traffic, vehicles often travel closely, making it challenging to determine if a low temporal proximity instance implies actual conflict situation. Thus, requiring additional evidence or indicators to separate conflict from non-conflict events.

- **Observation methods**. Around 75% of the studies used manual field investigations (sometimes aided by video) with traditional methods like the Swedish Traffic Conflict Technique (STCT), or the Dutch technique (DOCTOR), which further explain the predominance of kinematic and mixed measures as these methods easily capture instances like deceleration, near crashes, and evasive actions through human observation. Other studies employed semi-automatic video analysis using tools like T-Analyst. While advances in computer vision have enabled fully automatic conflict detection in HICs, there were not common in the studies reviewed (< 15%) certainly due to financial and technical constraints. The reliance on manual observation raises concerns about the reliability of safety results, as this approach is often criticized for the subjectivity and variability among observers.

- **Road user**. All road user types were observed, with a notable emphasis (>80%) on conflicts involving motorized vehicles and vulnerable road users, particularly vehicle-pedestrian interactions. This focus aligns with the prevalent mixed traffic environments in LMICs and the suitability of traditional traffic conflict methods, employed through manual field observation, for observing these interactions.

- **Road facility**. Most studies (>75%) focused on urban road facilities such as junctions, segments, crosswalks, and midblock crossings, where infrastructure is generally more developed than in rural areas. Among junctions, three and four-leg unsignalized intersections were more commonly studied than signalized ones, due to the higher resources required for installing and maintaining signalized intersections.

- **Study purpose**. The predominant application (>70%) of these studies was site safety assessment, focusing on observing specific conflicts at particular road facilities over set periods to evaluate intersection safety. Studies involving before-and-after analyses of safety treatments were limited due to the significant financial and technical resources required, either for implementing safety measures in field studies or for calibrating and validating simulation models. These resources are often scarce in LMICs.

- **Modelling approaches.** Most studies (>80%) used predefined thresholds from literature to distinguish conflicts from non-conflicts. However, these thresholds tended to be smaller (indicating more severe conflicts) compared to those used in HICs, likely due to the closer navigation of vehicles in LMICs' heterogeneous, non-lane-based traffic, coupled with riskier driving behaviours. Consequently, situations considered severe conflicts in HICs might be less severe in LMICs. Most studies (70%) analysed data using traditional general/generalized linear/nonlinear regression model, while a small proportion (10%) attempted advanced models like extreme value theory.

- **Validity of safety results**. Less than 10% of the studies effectively validated their safety results, typically using linear correlation between observed conflicts and historical crashes or comparing historical crash data with predictions from conflict models based on extreme value theory. The main issue in validating conflict studies was the absence of crash data.

Discussion and conclusions

The paper offers a comprehensive overview of conflict-based safety analysis in LMICs, highlighting the differences in application compared to HICs due to factors such as mixed traffic, limited infrastructure development, and resource constraints. Key areas for further research and discussion include:

- Validation of conflict indicators developed for HICs in LMIC contexts.
- Customization of conflict measures tailored to LMICs.
- Exploration of new methods (e.g., computer vision, extreme value theorem) in LMIC traffic environments to validate indicators and establish crash-conflict relationships.
- Development of microsimulation models specifically utilizing traffic safety indicators for LMICs, considering the limitations of existing models (SSAM) designed for HICs.
- Development of practical frameworks for proactive assessment applicable to LMICs, considering resources constraints.
- Development of conflict validation method in situation of unavailable crash data.