Analyzing traffic conflict scenarios and safety assessment in the context of intelligent vehicles: A research review

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Abstract The several internal disputes and various types of traffic accidents at an urban crossroads make for a complex traffic scenario. Because accident data and crash-based methodologies are limited, researchers are now examining other safety measures, including traffic conflicts that do not depend on crashes. To better assess road safety in the decades to come new real-time data is essential. The automobile industry is heading toward intelligent cars with the goal of enhancing road safety. Although there is a common failure mechanism between accidents and traffic conflicts during driving, which makes it possible to apply crash frequency and severity estimates to traffic conflict frequency and severity models, predicting traffic conflicts presents distinct difficulties. This study discusses conceptual and methodological concerns while reviewing research papers on traffic disputes as safety measures. It offers a thorough synopsis of previous research from the viewpoint of intelligent vehicles. It explains that there are three primary categories into which the perception technology of intelligent cars may be separated: perception technology, communication technology, and the combination of perception and communication technologies. The paper emphasizes the need of harmonizing international safety standards as well as the role that governments and regulatory agencies play in guaranteeing the security of intelligent vehicles. It highlights the need for additional research on transport conflict modeling techniques and offers practical recommendations for future study.

Keywords: Road Safety, Traffic Conflict, Intelligent Vehicles, V2X Communications, Environment Perception

1. Introduction

The modeling of potential traffic conflicts and the safety evaluation form the basis of contemporary transportation studies and planning. This in-depth investigation examines the possibility of future conflicts as well as the effectiveness of safety measures for passengers as well as motorists (Arun et al. 2021). Traffic conflict incidents are potentially dangerous situations involving cars and pedestrians. A thorough understanding and assessment of these situations are required to improve safety proactively (Katrakazas et al. 2019). Assessing the stability of transportation networks requires measuring safety. Risk management is the process of recognizing danger, assessing it, and taking steps to mitigate its impacts. Experts may gain deeper insight into the underlying causes of traffic issues and the efficacy of preventative actions by looking at hypothetical situations involving these conflicts (Virdi et al. 2019). The area of study has the potential to significantly contribute to reducing traffic conflicts and raising road safety. Data analysis and simulation assist in identifying potential danger regions, which facilitates the construction of countermeasures (Li et al. 2020). In conclusion, we must design transportation networks that are safer and more efficient for every user. Risk assessments and accident investigation become more important in the age of intelligent cars (Xing et al. 2019). Intelligent automobiles that make advantage of developments like sensors, AI (AI), and vehicle-to-vehicle (V2V) communications could increase road safety. However, when they communicate with ordinary cars and pedestrians, they can cause additional issues that need for a safety assessment (Severino et al. 2021). Interactions between these new cars and traditional drivers may result in situations involving intelligent vehicles and traffic conflicts, which could be dangerous. Understanding and evaluating these prospects is crucial before we include intelligent automobiles into our transportation networks (Zheng et al. 2021). The number of road casualties and traffic congestion may be directly correlated with the expansion of intersections. In crowded metropolitan regions, recent developments in artificial intelligence, the development of smart vehicle technology, and the spread of upscale smart transportation systems have showed significant
promise for reducing traffic and boosting safety (Zhu and Tasic, 2021). The outcomes of transport conflict analyses are used to evaluate traffic safety, making these analyses vital and significant. By observing the possible driving conflicts and developing with alternate driving methods to alleviate these conflicts, it promotes safer and more efficient traffic management and ultimately improves the quality of life on the road and the efficiency of travels (Zhang et al 2020). The global toll of traffic-related deaths and injuries has dropped precipitously in recent decades, particularly in advanced nations (Hang et al 2022). Road safety has come a long way, but there are issues to be resolved. Significant advancements have been achieved in the study of road safety over the years, particularly in the refinement of statistical tools for modeling the association between accident frequency severity and the variables that contribute to them. This study has cleared the path for the development of efficient safety rules and countermeasures by shedding light on the underlying processes of accidents (Esenturk et al 2022). Though these advancements have helped with the transition toward safety’s express priority in the design and planning of roads, there are difficulties that must be solve to give even more substantial safety advantages. Analysis of accident statistics is the bulk of current road safety research (Guériau and Dusparic 2020). Consideration should be given to the possibility that the drivers identified in accident data may not reflect the diversity prevalent among motorists. This is because those who are more prone to engaging in risky driving behaviors may skew the statistics of accidents, making it harder to estimate parameters. As an illustration of the problem make the scenario described in which a model built from real-world collision data concludes that precipitation makes motorbike accidents more dangerous (Scanlon et al 2021). There are two possible explanations for the trend toward more severe injuries during wet weather. As a first possible cause, wet roads reduce traction and visibility, increasing the danger of collisions. Alternatively, it might be linked to the personalities of bikers who choose to hit the road when it’s wet out. These individuals could be a self-selected sample of risk-takers (Shetty et al 2021). In conventional crash-data based analysis, it is challenging to disentangle the impact of these two alternatives to arrive at appropriate safety measures. Using impact data for road safety analysis is ethically problematic, since it requires deaths and injuries to accumulate over extended time periods before dangerous areas can be identified (Rasouli and Tsotsos 2019). This one is concerned with the modeling of traffic disputes and crashes, including their frequency, severity, and root causes. Intersections have a different kind of traffic, including cars, bikes, and pedestrians. For example, Pedestrians may find it difficult to cross the street (Erdoğan et al 2021). Conflicts associated with city traffic include in addition to cars and other vehicles but also pedestrians and other pedestrians. Figure 1 depicts the congestion caused by the intersection’s traffic lights.

Figure 1 A demonstration of environmental perception systems in intelligent vehicles.

2. Traffic Conflicts in Road Safety Analysis

When diverse road users, such as cars, pedestrians, and bicyclists have their paths to meet or overlap in a manner that increases the danger of an accident or harmful contact, this is called a traffic conflict (Astarita and Giofré 2019). In road safety evaluations, these kinds of events are helpful indicators because they can be signs of more major incidents. An analysis of the causes and consequences of traffic disputes can teach academics and transportation specialists a lot for the dynamics of roadway safety and possible danger zones. A variety of techniques are employed to collect data for traffic conflicts analysis, such as personal observation, video recordings, and sophisticated sensor systems (Fancello et al 2019). Researchers examine the data to identify and categorize various types of disputes, taking into consideration factors such as vehicle speed, traveling distances between vehicles, and the actions of other road users. This analysis clarifies the reasons behind conflicts, which will help to better secure people’s safety. In analyzing these kinds of occurrences, we may find problem areas and take proactive steps to make our roads safer. Authorities and engineers on the roads may make improvements to safety and efficiency by anticipating and eliminating risks that might cause accidents. Figure 2 provides an overview of the representation of Traffic Conflict.

2.1. Applying traffic conflicts as a metric for assessing safety

There is an increased chance of an accident, whenever one driver passes another on the road. Distracted driving, other
user-related issues, and inattentive driving contribute to this danger. While the specific process that puts all road users at
danger of a collision is not immediately visible, it can be deduced from empirical realizations like as actual crashes,
disagreements, and other traffic occurrences (Formosa et al 2020). When two or more vehicles on the road are headed in
opposite directions and likely to collide unless one or both of them makes a course correction, this is called a traffic conflict.
This definition is consistent with the people think about the situations. According to this definition, a traffic conflict
encompasses an extensive variety for protection metrics, including close calls among other incidents and evasive maneuvers.
Disputes between drivers have been shown to be a plausible cause of accidents, both theoretically and empirically (Chaudhari
et al 2021). All possible traffic scenarios, from calm, uncomplicated journeys to chaotic collisions are mapped out in this model.
According to this concept, both traffic disputes and crashes can be explained by the same mechanism in a hypothetical
situation. An accident would happen if the behaviors of the various road users involved had not altered. In situations when
there is a persistent risk of collision, these instances are referred as near-miss incidents or, more generally, as traffic conflicts
(Guo et al 2019). This commonsense justification is applicable across many fields since minor injuries and mishaps serve as
indicators of serious ones. Empirical evidence suggests that traffic disputes can be a prelude to collisions, and this finding
supports the hypothesis that conflicts are common. Previous research using correlation analysis has identified several
substantial associations between traffic disputes and impacts (Nadimi et al 2020). There are a number of causes for the low
rates of interaction. The correlation between traffic disputes and impacts were the subject of some statistical modeling. These
algorithms provide accident predictions that are possible by using data from observed traffic conflicts (Yang et al 2023).
Other empirical research has investigated whether or not there is a correlation between traffic disputes and crash rates, ranked
dangerous areas, and assessed the efficacy of interventions meant to improve safety (Abdel-Basset et al 2021).

\[\text{Figure 2 Overview of traffic conflict.}\]

2.2. Procedures of traffic conflicts

When vehicles are closer in time and space to colliding, and more drastic measures must be taken to prevent a collision,
the resulting traffic conflict is more intense. Multiple indications of closeness to a possible collision have been developed, those
are post-encroachment time (PET) and time to collision (TTC) (Kovačić et al 2022). The duration till an Accident Occurs (TTC) is
the duration, which no accident happens when the cars involved and maintain their current directions as well as speeds. Similar
indications include the encroachment time, gap time, and headway, which measure the amount of time that passes between
one vehicle leaving the location of probable accident and the arrival of the second vehicle at the same place (Sinha et al 2020).
While both TTC and PET assess how close two objects are in time, they do it in distinct ways and hence reflect various types
of impacts. The TTC is a metric that indicates whether or not a collision trajectory exists between two moving objects on a road.
The deceleration rate to prevent an impact is the most used indication of deceleration, however the deceleration to safety
time and the profile are also useful (Song and Li 2021). In less-regulated traffic situations, spin rate, which measures the speed
at a vehicle is spinning, and is more useful than proximity indicators for determining the severity of confrontations involving
motorcycles, bicycles, and pedestrians (Rhim et al 2021). It might be hard to tell the difference between an individual’s evasive
maneuvers and the natural variations in their position and speed as they move through traffic. Despite those mentioned factual
measures, there are subjective ways to evaluate traffic jams. In this setup, observers are educated on the topic and then sent
out into the field to witness accidents (Lyu et al 2021).

2.3. Utilizations of traffic conflict scenarios

Safety analyses may include both collisions and traffic conflicts. They have been utilized as a standalone safety measure
in certain cases, and they have the potential to be used to anticipate accidents. Traffic conflict data has negligible social cost

https://www.malque.pub/ojs/index.php/mr
and is widely accessible, making it ideal for these applications (Markkula et al. 2020).

2.3.1. Analyzing critical behavior and assessing safety

Frequency or intensity of traffic disputes can be used as measures of the security of both researched activities and road items, since they are used to study how drivers respond in dangerous circumstances. These programs are common and useful for a broad variety of drivers, driving styles, and road-related entities. The large number of information included in vehicle trajectories allows for a precise and comprehensive safety analysis is possible with typical accident data. The primary difficulty in doing an exhaustive risk assessment is amassing a sufficient quantity of data on vehicle trajectories.

2.3.2. Safety analysis prior to and after

The goal of a prior to and after security analysis is to assess the treatment’s impact on treated areas in terms of safety. Typically, the treatment effects are evaluated in before-and-after studies involving traffic conflicts by comparing the frequencies of conflicts in the “after” period to those in the before period. Studies that compare outcomes before and after a therapy are implemented are preferable in the case of traffic disputes because they allow for rapid assessment of treatment efficacy and provide insight into the causes of accidents. We can learn more about the program’s effects and its potential to reduce accidents if we use this methodical approach. The potential investigation of the treatment’s impacts is enhanced by using an extreme value theory method, which allows for the inclusion of conflicts of varying severities. Recent advancements have shown substantial improvement in this area.

2.3.3. Predicting safety in real time

Proactive road security management systems rely on real-time safety prediction approaches that monitor traffic in real-time, look for dangerous patterns in the flow of vehicles, and take corrective measures as needed. The research predicted current traffic conflicts on road segments and found a direct link between them and the current conditions of moving cars. While there hasn’t been a ton of research done on using traffic conflicts to forecast safety in real time, there has been shows a number of benefits over studies that have relied on accident precursors or collision-prone traffic circumstances. Most signs of traffic conflicts are gleaned from vehicle trips, which make it possible to implement real-time collision prediction that takes driver and passenger behavior into account. Crash prediction studies exclude such behavioral elements since they depend on data from circuit detectors.

3. Investigating Traffic Conflict using Advanced Vehicle Communication Technology

As a result of advancements in networking and communication technologies, automobiles, roads, pedestrians, and other actors in the traffic system are transformed into interconnected data nodes. When comparing communication technology to perceptual technology, the former represents a significant advancement in time and space, which is particularly useful when trying to make sense of one’s immediate surroundings (Rezaei and Azarmi 2020). Over time, V2X communication enables smart cars to obtain real-time road data, such as the current location and status of adjacent vehicles, the timing of traffic signals, and projections of future road conditions, such as weather patterns and the likelihood of traffic congestion. All of this data contributes to complete understanding of the traffic condition by the vehicle (Chen et al. 2019). Key transportation nodes, or V2X components, include automobiles and other vehicles, road infrastructure, non-motorized vehicles, and humans. Figure 3 depicts one form of V2X communication, which includes the V2V and V2I technologies, among others.

![Figure 3 Communication type for V2X.](https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRDGLn4QhElCoS5UXZb9TLB0qweQ_bGkrMlnA&usqp=CAU)
4. Investigating Traffic Conflict Analysis Utilizing V2V Communication

Vehicle-to-vehicle communication allows cars to share data about their driving and the road ahead, leading to improved safety and productivity in fully automated driving. Vehicle-to-vehicle communication has the benefit of spreading essential information, such as road closures, accidents, and emergencies. Network connection technologies enable the sharing of data between vehicles, which is essential for the forecast of traffic problems made possible by V2V communication. Both the vehicle internet and the vehicle cloud network factor in the autonomous nature of cars and their predictive motion patterns when assessing the likelihood of a conflict occurring (Jiang et al. 2020). Typical applications of vehicle-to-vehicle communication technology include providing early warnings of impending collisions to help drivers avoid them. Developed an enhanced algorithm for detecting collisions at road intersections, developed a method for calculating the likelihood of vehicle-vehicle collisions, and devised a plan for disseminating warnings to drivers to prevent accidents. Preventing accidents data collection poses a barrier to full control of a single vehicle. Zhou and Lei (2020) employ Using vehicle-to-vehicle communication technology, updates on each car’s state can be sent in real time, giving drivers more information which to fine-tune their routes and prevent accidents. With V2V communication, automobiles may exchange information with one another. It’s superior to the on-board sensors since it provides more data about the road conditions. Through the use of inter-vehicle communication; we have developed a technique that allows for totally automated lane changes (Patriarca et al. 2019). In order for vehicles in close proximity to engage with one another, its communication system use wireless communication to relay data about their locations and speeds. When used in conjunction with standard vehicle sensors, it may enhance their perception capabilities, allowing for more accurate risk prediction and the timely resolution of disputes.

5. Integrating Intelligent Vehicle Perception and Communication Technologies for Traffic Conflict Analysis

Intelligent vehicles will coexist alongside conventional automobiles and other road users throughout the testing and prototyping phases of this technology. Studying traffic disputes using perception and communication technologies has its benefits and drawbacks. Therefore, a secure option is the combination of these two methods. High-precision, real-time awareness of the road traffic environment is made possible by cutting-edge vehicle and road sensor technology like radar and video. Vehicles will be able to communicate each other, the road, people, and road infrastructure to a standardized communication protocol and data interaction standard. V2V/V2I communication aims to enhance information sharing and detection between moving vehicles by connecting them to one another and to stationary infrastructure. Liu and Jaekel (2019) presented a V2I-based approach to urban driving environment collection, which combines data from RSU cameras and in-car GPS systems. Through V2I connection, cars and trucks relay their GPS coordinates to the rescue service unit (RSU). Simultaneously, the RSU camera is used to extract and gather data on passing cars, lanes, and vehicle locations, making it possible to eliminate traffic jams. For the purpose of intersection (Ma et al. 2021) suggested a radar-based V2I/P2I collaborative perception communication system.

6. Traffic environment

In our quantitative synthesis of 240 studies, 62% were conducted in countries with well-established traffic systems, while the rest focused on regions with less structured traffic systems, such as India. Figure 4 and Table 1 illustrates that more than 75% of research in controlled traffic conditions employs temporal proximity measurements like gap, modified The duration until a collision occurs, as well as time after invasion. In contrast, studies in less structured traffic conditions use mixed measures, including near-crash rates (10%), along with kinematic measurements such as longitudinal diminution (7%) and essential speed (4%). The rationale for this difference lies in controlled traffic settings, where vehicles maintain safe distances, making abnormal encounters readily observable. In less structured traffic environments, vehicles share the road simultaneously, making it challenging to detect conflicts through proximity data.

7. All-Conflict–All-Collision Safety Performance Functions

Our analysis included 49 signalized junctions, and it can see the distribution of disputes and collisions at those intersections in Figure 5 and Table 2. Left-turn collisions (39%) and rear-end collisions (35% of the total) accounted for the majority of accidents. Left-turn conflicts at signalized junctions include a vehicle turning left that might collide with another vehicle coming from the opposite direction at a right angle. The others group accounted for 26% of all clashes. These percentages are in line which has been seen in real-world accident data, which shows that left-turn-related collisions account for a third of all collisions, rear-end collisions account for a third, and other collision types, including single-vehicle incidents, account for the remaining 34%.

8. Discussion

Integration of both intelligent vehicle sensing and communication technologies for traffic conflict analysis provides major benefits, but also presents certain problems. Potentially higher complexity and expenses are one major downside.
Budgetary constraints may hamper the development of a complete system that integrates high-end perception tools like radar and video sensors with efficient V2V and V2I communication mechanisms (Keserue et al. 2021). To implement V2I communication, significant investments are needed in the vehicles themselves and the underlying infrastructure. The costs associated with researching, developing, and maintaining such systems could be high. The successful integration of these technologies also depends on their standardization and interoperability. Ensuring interoperability between cars and infrastructure parts made by different manufacturers is a challenging problem. The associated car ecosystem needs to be standardized in order to avoid becoming incompatible and fragmented. Security and privacy concerns are also significant drawbacks. When V2V and V2I interaction is used to gather and share enormous amounts of data, privacy issues arise because it involves the transmission in position and behavioral information (Madigan et al. 2019). One of the most important issues that need to be handled is safeguarding the privacy of these discussions in order to prevent cyberattacks (Casado-Sanz et al. 2020).

Traffic conflict analysis may be improved by integrating intelligent vehicle sensing and communication technologies, but there are drawbacks as well, including high costs, privacy concerns, and the requirement for robust cyber-security measures. These drawbacks highlight the necessity of a well-rounded approach that combines state-of-the-art technology with tried-and-true safety measures.

![Figure 4](https://eprints.qut.edu.au/212594/1/Manuscript_19_07_2021_AA.pdf)

**Figure 4** Commonly utilized conflict assessment metrics in (a) An efficient traffic circumstance, (b) A less efficient traffic circumstance.

**Table 1** Comparison of Conflict Measures in Organized and Less Organized Traffic Environments.

<table>
<thead>
<tr>
<th>Conflict Measures</th>
<th>An efficient traffic circumstance</th>
<th>A less efficient traffic circumstance</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTC</td>
<td>49</td>
<td>40</td>
</tr>
<tr>
<td>PET</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>MTTC</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>DVM</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>Gap</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Delta-v</td>
<td>3</td>
<td>*</td>
</tr>
<tr>
<td>SI</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>DRAC</td>
<td>4</td>
<td>*</td>
</tr>
<tr>
<td>NC</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Decn</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Jerk</td>
<td>*</td>
<td>2</td>
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<tr>
<td>CS</td>
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<td>4</td>
</tr>
<tr>
<td>TA.Conf.</td>
<td>*</td>
<td>3</td>
</tr>
</tbody>
</table>

**Source:** https://eprints.qut.edu.au/212594/1/Manuscript_19_07_2021_AA.pdf

**Table 2** Distribution of Conflicts and Collisions by Observation Type.

<table>
<thead>
<tr>
<th>Observation type</th>
<th>Conflicts</th>
<th>Collision</th>
</tr>
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<tbody>
<tr>
<td>Left turn</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>Rear end</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>Others</td>
<td>26</td>
<td>34</td>
</tr>
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</table>

**Source:** http://dx.doi.org/10.3141/2583-07
9. Conclusion

The inadequacies of traditional crash-based safety techniques are becoming more widely recognized due to the complexity of contemporary urban traffic scenarios. Researchers are examining alternatives, like traffic conflicts, in place of actual instances, as they may offer insightful information. In the coming decades, as linked and autonomous cars become more common, the evaluation of road safety will rely more on new real-time data. The advanced technology found in smart cars’ sensing and communication networks puts them at the forefront of this shift. But there are specific difficulties associated with trying to understand and anticipate traffic jams. This research emphasizes the significance of government regulation, worldwide safety standards, and more investigation in this area. This article illustrates the possibilities for increasing the security of intelligent cars and unifying safety measures, which contribute to safer and more efficient roads. Without considerable empirical confirmation, the work focuses on conceptual and methodological issues. To assure the efficacy of traffic conflict models, further study is needed to deploy and validate them in real-world settings with intelligent vehicles.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare no conflict of interest.

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References


