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REVIEW OF THE ADAPTIVE SWEDISH TRAFFIC CONFLICT TECHNIQUE: APPLICATIONS AND IMPLICATIONS FOR ROAD TRAFFIC SAFETY

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The Swedish Traffic Conflicts Technique (STCT) is a systematic approach used to examine traffic conflicts, specifically emphasising the correlation between severe conflicts and accidents. It uses safety indicators such as average speed, post-encroachment time, deceleration rate, time to collision, and traffic flow size to evaluate the gravity of interactions between pedestrian and motorised vehicles. The development of the TCT has been significant, with studies highlighting the impact of speeding, inattentiveness, inadequate following distance, signal violations, drowsiness, excessive alcohol consumption, and reckless driving on road safety. The Adaptive STCT for road traffic safety is a significant area of research and development, aiming to enhance understanding of the global implementation and efficacy of the Adaptive Swedish TCT in enhancing road traffic safety. The STCT has been applied in various countries, including Sao Carlos, Nanjing, Ho Chi Minh City, and Qatar, and has shown significant development in identifying hazardous manoeuvres at urban intersections, facilitating the adoption of safer designs and efficient risk management measures. Nevertheless, research on the STCT's implementation on rural roads is limited; it highlights the need for further investigation and implementation in rural environments due to varying road safety issues.

Keywords: adaptive, application, development, road, swedish TCT

1 INTRODUCTION

Road traffic safety holds significant importance in transportation engineering as it aims to minimise accidents and ensure the well-being of individuals during their travels. Various researchers have highlighted this objective, such as emphasising the role of road traffic safety in mitigating human injuries, property damage, and even loss of life resulting from unforeseen incidents. To achieve this, transportation engineers rely on safety indicators such as average speed, post-encroachment time, deceleration rate, time to collision, and traffic flow size. These indicators not only aid in understanding and analysing accidents but also provide valuable data on crash incidents [1, 2, 3].

One crucial aspect related to road traffic safety is the occurrence of traffic conflicts. These conflicts arise when there is a potential collision, leading drivers to take evasive actions like braking or changing lanes due to the presence of other vehicles in proximity. Metrics such as the mean hourly conflict rate and the mean hourly severe conflict rate serve as useful measures to quantify these traffic interactions [4, 5, 6]. Several factors contribute to the incidence of traffic conflicts, including heavy traffic volumes, significant speed fluctuations, road conditions, and the effectiveness of implemented traffic safety measures [7, 8].

In transportation engineering, researchers have already conducted studies focusing on safety indicators and their consequences. These studies highlight the critical role of road traffic safety, emphasising the need for prompt action and the utilisation of various safety measures to mitigate accidents and ensure secure transportation [9, 10, 11].

It is well-known that driver behaviours play a significant role in traffic accidents. Behaviours such as speeding, inattentiveness, inadequate following distance, signal violations, drowsiness, excessive alcohol consumption, and reckless driving account for the majority of accidents [12]. Numerous research studies have specifically explored the impact of exceeding the speed limit on the likelihood and severity of accidents. For example, speeding significantly increases the probability of crashes and alters the severity of resulting accidents. Other than that, high-speed driving is a major risk factor in road traffic safety, directly affecting the probability and severity of accidents [13], [14]. These studies underscore the importance of addressing speeding behaviours to enhance road safety.

The consequences of exceeding the speed limit extend beyond increasing the likelihood of collisions. In 2021, research demonstrated that speeding also impacts the intensity of evasive manoeuvres and the time until a collision occurs in incidents involving pedestrians and motorised vehicles [15]. Furthermore, a time-to-collision threshold of 1.5 seconds can indicate danger, indicating that speeding raises the risk of car accidents [3, 16]. In order to support this notion, there is a correlation between potential conflict risks and traffic flow, as evidenced by the aggregated crash index and time to collision [17]. These studies provide valuable insights into the adverse effects of speeding on road safety.

The concept of post-encroachment time (PET) plays a vital role in evaluating the proximity of a collision event and the need for evasive manoeuvres. It serves as a metric used to assess critical conflicts in traffic situations, relying on the duration it takes for drivers to perceive and respond to emergencies [6, 18, 19, 20]. By utilising PET, transportation engineers can accurately evaluate and identify significant conflicts, helping to enhance road safety.

Several factors influence the post-encroachment time (PET) in traffic conflicts, including the braking capacity of vehicles and the distance between them. These variables directly impact the time drivers react and take evasive actions in situations with limited space between road users [6, 21]. The closer the distance between vehicles and the higher their braking capacity, the shorter the post-encroachment time, indicating a higher risk of collision. Therefore, understanding and considering these variables are crucial in assessing and managing potential conflicts on the road.

To effectively mitigate accidents and minimise hazardous conditions, the recommended collision avoidance system utilises reduced deceleration rates [22]. It is well-established that significant velocity deceleration is a major contributor to car collisions, as it increases cognitive effort and impairs driver focus. The prefrontal cortex, responsible for cognitive engagement, is particularly taxed during vehicle deceleration compared to acceleration [23, 24].

Transportation engineers can address this issue and enhance road safety by implementing reduced deceleration rates in collision avoidance systems. These systems aim to minimise the intensity of shockwaves caused by tailgating vehicles and create safer driving conditions. By reducing the need for sudden and sharp deceleration, drivers can maintain better cognitive focus and reduce the risk of accidents. Integrating reduced deceleration rates into collision avoidance systems considers the cognitive demands placed on drivers during deceleration. This approach not only improves the safety of individual vehicles but also contributes to overall traffic flow efficiency by reducing the occurrence of sudden braking and its cascading effects on other vehicles.

The Swedish Traffic Conflict Technique (STCT) is a systematic approach used to examine traffic conflicts, with a specific emphasis on the correlation between severe conflicts and accidents [15, 25, 26]. This approach utilises contradictory data on speed and time-to-accident to evaluate the severity of interactions between pedestrians and motorised vehicles. By examining road conditions and traffic data, the STCT assesses traffic safety using synthetic influencing coefficients [27]. This methodology categorises conflicts into four classifications: encounter, potential, minor, and severe, based on the conflicting velocities and proximity to accidents [28].

Since its inception in 1973, the STCT has undergone further development, but its core premise remains supported - there is a significant correlation between severe traffic clashes and accidents [26]. The traffic conflict methodology, which measures the ratio of traffic conflicts to traffic volume, is a practical approach for evaluating traffic safety at urban crossings [29]. Time-to-collision (TTC) approaches, used as indicators in the Traffic Conflicts Technique (TCT), offer clear benefits in assessing road safety. Traffic conditions play a crucial role in determining the likelihood of road accidents, with factors such as mean volume and median velocity having a significant association with accident probability [19, 20, 30]. Moreover, adverse weather conditions like rain, snow, and fog can greatly disrupt vehicle movement and potentially increase the severity of road accidents [31].

The method employed for this systematic review involved a thorough selection process of relevant studies from Semantic Scholar and Google Scholar. Seventy-four reputable journals and proceeding articles were cited and chosen based on specific criteria. Keywords such as "traffic conflict," "Traffic Conflict Technique," "Swedish Traffic Conflict Technique," "Conflict attributes," "Swedish Traffic Conflict Technique Applicability," "Swedish Traffic Conflict Technique Adaptation," and "Swedish Traffic Conflict Technique Application" were utilised to filter pertinent studies. The selection criteria included an unrestricted time range for developments in the Traffic Conflict Technique, while the studies focused on the adaptation and application of the Swedish Traffic Conflict Technique were limited to the period from 2016 to the present. The geographical region of the studies was not confined, ensuring a comprehensive global perspective. Consequently, the selected cases comprised multiple countries from Asia, Africa, Europe, and America continent with a total of 45%, 9%, 23%, and 23%, respectively, reflecting a diverse set of applications and implications for road traffic safety across different regions.

This literature review aims to gain a thorough understanding of the existing research and methodologies related to the implementation of adaptive STCT for Road Traffic Safety. Examining these strategies, we aim to reveal their capacity for enhancing road safety. This study aims to improve our comprehension of the worldwide adoption and efficacy of STCT in promoting road traffic safety by thoroughly examining available material, which in this review would be mentioned as Adaptive STCT. Nevertheless, it is important to acknowledge the lack of studies on implementing STCTs, specifically on rural roads in Indonesia. The current body of research predominantly concentrates on its application in urban areas, with limited investigation into its efficacy and obstacles on rural roads. Hence, this evaluation highlights the necessity for additional investigation and implementation of adaptive STCT in rural environments, where road safety issues may vary considerably. This study enhances the overall comprehension of how the Adaptive STCT can efficiently enhance road traffic safety by suggesting possible areas for future research and application. It emphasises the significance of considering various contexts, such as rural areas, to guarantee complete and inclusive road safety initiatives.

2 SWEDISH TRAFFIC CONFLICT TECHNIQUE APPLICABILITY

Collecting accurate accident data to predict the number of accidents is challenging due to the rarity of traffic accidents. Additionally, variations in traffic conditions during data collection can affect the precision of estimations [32]. This ethical dilemma revolves around the need to wait for a sufficient number of accidents to occur before concluding safety, causing individuals to suffer beforehand [33]. Moreover, underreporting of accidents poses another challenge, especially among vulnerable road users, impacting the reliability of accident data [34, 35, 36].

In the context of the STCT, a conflict refers to a situation where two road users are on a collision course unless one of them takes evasive action. The severity of a conflict is determined by two indicators: Time-to-Accident (TA) and Conflicting Speed (CS). A lower TA value indicates a more imminent collision, while higher CS values imply a greater conflict that requires more time and distance to prevent a collision. Higher impact speeds also lead to more severe injuries in the event of a collision [33].

For theists, a diagram (Figure 1) can be used to assess the severity of conflicts. It calculates Traffic Avoidance (TA) and Collision Severity (CS) for each road user involved in an evasive manoeuvre. The relevant road user is the one with the lowest degree of severity, determining the final level of conflict severity [33].

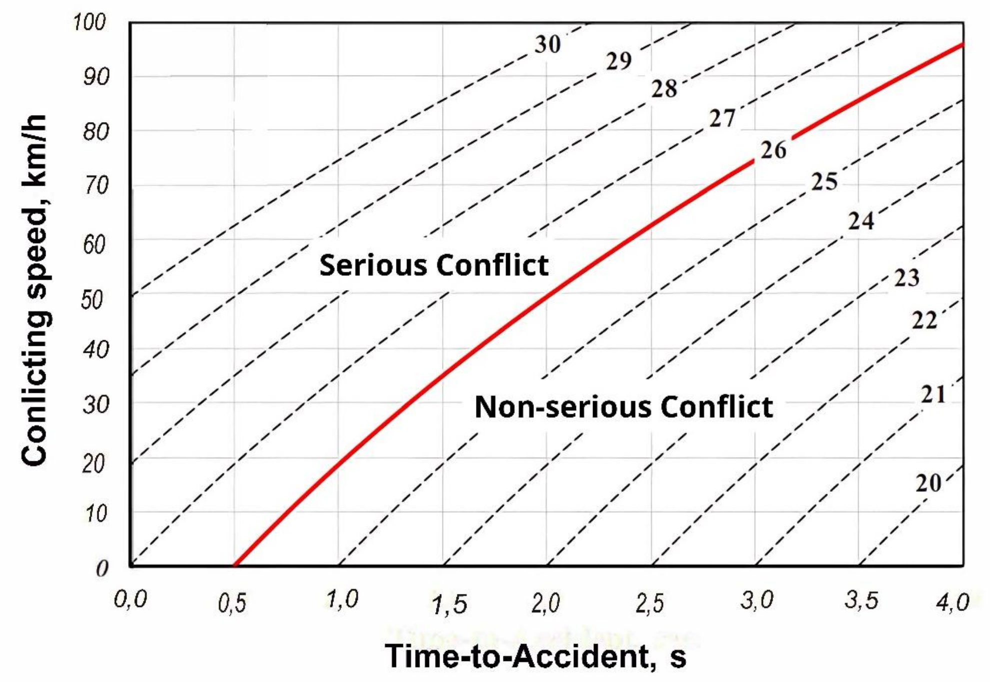

Fig. 1. Severity of conflicts [33]

Reliability in traffic conflict research refers to the consistency and accuracy of conflict detection and severity scoring. It aims to ensure that discrepancies in identified conflicts are due to differences in safety conditions rather than external factors like observer negligence or unfavourable weather. Reducing the impact of these external factors is crucial to ensure dependable results that truly reflect variations in safety levels [33].

The validity of a traffic conflict method in assessing road safety is a significant concern. The STCT stands out in this regard, as it has been extensively validated and endorsed by numerous studies. These validation studies have provided substantial evidence to support the effectiveness and reliability of the TCT in identifying conflicts that indicate potential road safety issues.

Traffic conflict analysis is a valuable approach to overcome the limitations of inadequate and unreliable accident records. Analysing vehicle paths and estimating potential collision indicators allows for the evaluation of road safety levels and the effectiveness of safety programs. This analysis plays a crucial role in enhancing active road safety measures by assessing the likelihood of vehicle collisions and evaluating the seriousness of road conflicts [37, 38, 39].

In urban intersections, traffic conflict analysis is particularly useful for identifying the most hazardous manoeuvres. It helps assess various options for junction design, taking into account factors such as road capacity, conflict areas, and accident severity. This evaluation approach ultimately improves road safety by facilitating the adoption of safer designs and effective risk management measures [40, 41, 42].

3 SWEDISH TRAFFIC CONFLICT TECHNIQUE ADAPTATIONS

A significant body of research has validated the use of traffic conflicts and encounters as effective event-based risk indicators for preventive interventions. One study enhanced the risk microsimulation analysis by developing a novel method for identifying incidents in VISSIM. This method was used to evaluate the safety of a roundabout through three distinct approaches: the Swedish Traffic Conflict Technique (STCT) with the T-Analyst tool, VISSIM/SSAM conflict analysis, and encounter-based exposure mapping [25].

The evaluation of pedestrian safety in mixed traffic scenarios has also been a focus of recent studies. A model based on scene analysis demonstrated the capability to effectively identify approximately 94.4% of potentially hazardous traffic situations using video data [43]. Another related study utilised stochastic numerical models to estimate the safety levels of traffic networks and evaluate their reliability, establishing a framework for assessing the progress of safety measures over time [44].

In urban environments, the application of the Traffic Conflict Technique (TCT) and surrogate safety metrics has been instrumental in evaluating pedestrian safety at midblock crosswalks. This approach considers variables such as vehicle acceleration, post-encroachment time (PET), driver and pedestrian compliance, and the occurrence of conflicts [45, 46]. Furthermore, a system designed to predict crash scenarios during the installation of crash-avoidance systems aims to simplify future traffic safety evaluations. This system examines the interaction between vehicle injury mitigation technology and safety systems for both drivers and vulnerable road users (VRUs) [47].

The introduction of vision-based methodologies to identify traffic conflicts involves acquiring knowledge of movement patterns from trajectories. This innovative method, which includes grouping and modelling, has proven effective in acquiring motion patterns and identifying traffic conflict instances [39]. Another proposed method combines detailed trajectory data with traffic condition information to evaluate road safety promptly. This approach supports proactive safety management and accurate evaluation of real-life traffic conflicts, with potential applications in autonomous vehicle systems [48, 49].

Various regions have implemented the STCT to enhance traffic safety through straightforward and cost-effective measures. In São Carlos, Brazil, the TCT assessment aimed to improve safety in critical regions [50]. Similarly, the traffic conflict approach has been used to evaluate traffic safety at unregulated intersections and roundabouts in the Czech Republic [51]. In Nanjing, China, an integration of hourly composite risk indices (HCRi) with unmanned aerial vehicle (UAV) photography and video processing techniques further advanced this method [52].

The application of the STCT in Ho Chi Minh City, Vietnam, involved recording and analysing conflicts at signalised junctions using video cameras [53]. In Catania, Italy, a stereo vision and GPS system capable of real-time detection of vehicle-pedestrian collisions was developed [54]. Research in Thailand utilised the STCT to explore the safety implications of auxiliary lanes at U-turns, finding that optimal road safety is achieved with a well-designed plan [55]. Additionally, a study in Doha, Qatar, used simulated vehicle paths and the Surrogate Safety Assessment Model (SSAM) to examine traffic safety [56].

The extreme value theory methodology has been applied in Surrey, Canada, to mitigate conflicts and estimate crash numbers, resulting in a substantial decrease of 63.9% in the estimated number of crashes [57]. In Penticton, Canada, this methodology was used to examine infrequent and severe traffic conflicts, such as merging and rear-end crashes, for the establishment of the STCT [58]. Indonesia's development of the TCT included manual observation, automatic video analysis, and simulations with SSAM [59]. In Nigeria, the TCT addressed issues related to unreliable crash data by collecting data through roadside observations to assess hazardous driving behaviours [60].

Studies have also focused on assessing traffic conditions on primary highways and motorways. Research involving both theoretical and empirical comparisons utilised data from Polish roadways [61]. In Bogota, Colombia, the Swedish TCT was used to evaluate the safety of preferential public transit lanes, considering factors like time to accident and opposing speed [62]. In Guangzhou, China, modifications to the PET model accounted for lane-changing features and safety standards to make accurate predictions about traffic safety in merging regions [63].

Further studies have confirmed that the STCT aligns with accident data in Győr, Hungary, in terms of both the severity of conflicts and the likelihood of accidents occurring [64]. In Loughborough, UK, an automated video analysis system using the STCT was implemented to anticipate lane change and rear-end conflicts on motorways [65]. A comprehensive study by M. Swanson et al. developed and implemented a TCT toolset to examine pedestrian-vehicle traffic conflicts in school zones in low to intermediate-income countries such as Ghana, Vietnam, and Mexico [66].

Recent advancements in detecting various traffic conflicts in work zones have been proposed by Xu and Chen, who utilised vehicle micro-behaviour data, automatic categorisation, support vector machine-based behaviour identification, and threshold-based judgment approaches in Shanghai, China [67]. Latif's evaluation of Toronto intersections resulted in the identification of road safety concerns and the development of economic remedies [68]. Arun et al. addressed a research deficiency by conducting a comprehensive analysis of traffic conflicts and surrogate safety approaches, proposing both uncalibrated and calibrated strategies for transferability. Their study utilised video surveillance to observe traffic flow at designated intersections over 48 hours [69].

These studies collectively highlight the diverse applications and effectiveness of the Swedish Traffic Conflict Technique (TCT) in evaluating and improving traffic safety in various regions around the world. By utilising different methodologies and approaches, researchers have been able to identify and address safety concerns, develop proactive safety management strategies, and enhance the accuracy of real-time traffic safety evaluations.

4 APPLICATION OF SWEDISH TRAFFIC CONFLICT TECHNIQUE

The Swedish TCT is a widely recognised and utilised method for identifying and assessing traffic conflicts. Its effectiveness has been demonstrated on various types of roads, including both urban and rural areas, as shown in Table 1. Numerous studies have focused on applying the Swedish TCT specifically to urban roads, such as the works of Suhadi and Rangkuti (2019), Heredia-Castiblanco et al. (2019), Bulla-Cruz et al. (2020), Cafiso et al. (2017), Yu and Wang (2015), and Yuan et al. (2021). These investigations have contributed to a deeper understanding of traffic conflicts in urban settings and have provided valuable insights for improving road safety. However, the application of the Swedish TCT on rural roads has been less explored. Only a few studies, conducted by So et al. (2015) and Laureshyn et al. (2017), have focused on utilising the Swedish TCT approach in rural areas [25, 54, 62, 70, 71, 72, 73, 74]. This indicates a need for further research and validation to fully understand the dynamics of traffic conflicts in rural environments and to adapt the Swedish TCT method accordingly. Figure 2 shows the development studies of TCT in the different road systems.

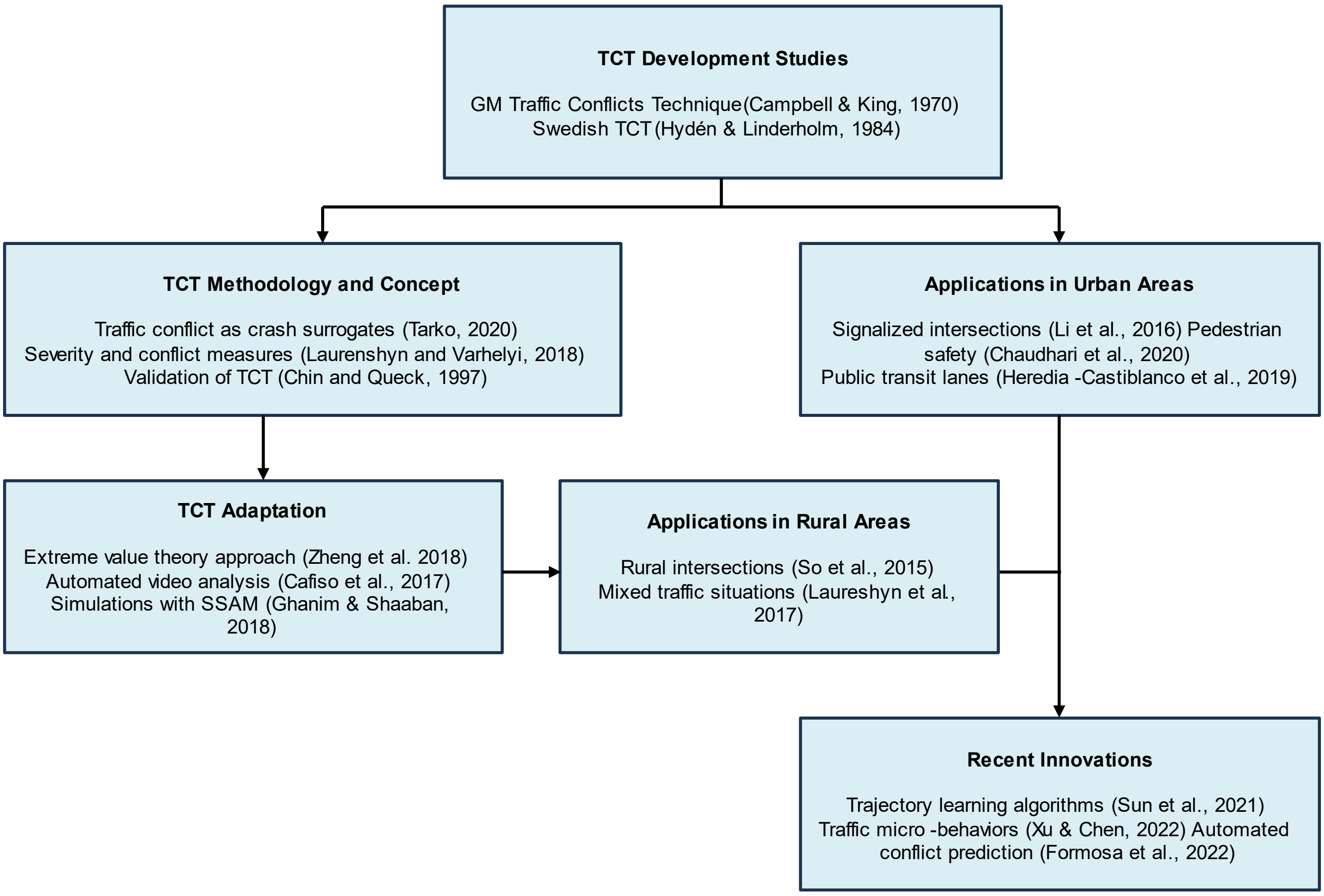

Fig. 2. TCT development studies

Table 1. Swedish TCT Application in the world

No	Study Area	Year	Adaptation	Citation
1	São Carlos, Brazil	2003	The STCT analysis has been developed through the application of simple and low-cost actions to increase traffic safety in critical places.	[50]
2	Czech Republic	2016	The paper presents the methodology for applying traffic conflict technique in the Czech Republic to estimate traffic safety at uncontrolled intersections (roundabouts).	[51]
3	Nanjing, China	2016	The STCT developed using hourly composite risk indexes (HCRi) and unmanned aerial vehicle (UAV) photography and video processing techniques.	[52]
4	Norway	2017	The STCT is based on manual detection and counting of critical events in traffic. At the same time, the Dutch Conflict Technique (DOCTOR) considers probabilities of multiple trajectories for each interaction.	[74]
5	Ho Chi Minh City, Vietnam	2017	The study developed the STCT by using video cameras to capture and analyse conflicts that potentially lead to accidents at signalised intersections.	[53]
6	Catania, Italy	2017	A stereo vision and GPS system using in-vehicle technologies can detect conflicts between vehicles and pedestrians, providing real-time information related to conflict occurrence and severity.	[54]
7	Thailand	2017	The STCT assesses the safety impact of auxiliary lanes at U-turns, with the highest level of road safety occurring if the layout includes a single component.	[55]
8	Doha, Qatar	2018	The STCT was developed by analysing simulated vehicle trajectories using the Surrogate Safety Assessment Model (SSAM).	[56]

No	Study Area	Year	Adaptation	Citation
9	Surrey, Canada	2018	The study developed the STCT by adopting the extreme value theory approach, which reduces conflict severity and leads to a 63.9% reduction in estimated crashes.	[57]
10	Penticton, Canada	2019	The study developed the STCT by using extreme value theory (EVT) to analyse rare and serious traffic conflicts, such as merging and rear-end collisions.	[58]
11	Indonesia	2019	TCT has been developed through manual observation, automated video analysis, and simulations with the Surrogate Safety Assessment Model (SSAM).	[59]
12	Nigeria	2019	The TCT was developed to collect roadside observation data in Nigeria to analyse unsafe driving behaviours and overcome the inherent problems associated with reliable, inadequate, and accessible crash data in Nigeria.	[60]
13	Bogota, Colombia	2019	The STCT evaluates road safety in preferential public transport lanes using time to accident and conflicting speed to establish the severity of a conflict.	[62]
14	India	2020	The TCT evaluates pedestrian safety at urban midblock crosswalks using surrogate safety measures like vehicle crossing speed, post encroachment time (PET), yielding compliance of driver and pedestrian, and conflict rate.	[45]
15	Guangzhou, China	2020	The modified Post Encroachment Time (PET) model accurately forecasts traffic safety in merging areas by considering lane-change characteristics and safety requirements in the process of lane changing.	[63]
16	Chongqing, China	2021	The STCT was developed by learning motion patterns from trajectories using a clustering and modelling algorithm.	[39]
17	Győr, Hungary	2021	The STCT is compatible with accident records in terms of conflict severity and probability of accident occurrence.	[64]
18	Loughborough, UK	2022	The STCT was developed by using an automatic video analysis system to predict lane change and rear-end conflicts on motorways accurately.	[65]
19	Ghana, Vietnam, Mexico	2022	A TCT toolkit was developed and piloted to analyse pedestrian-vehicle traffic conflicts in school zones in low- and middle-income countries.	[66]
20	Shanghai, China	2022	The study proposes a detection method for all types of traffic conflicts in work zones, based on vehicle micro-behaviour data and using automatic segmentation, support vector machine-based behaviour identification, and threshold-based judgment methods.	[67]

5 DISCUSSION

The examination of existing literature on the Swedish Traffic Conflict Technique (STCT) and its applications reveals significant insights and highlights the efficacy and challenges of this method in different contexts. The STCT has been widely applied and validated in urban roads, with numerous studies emphasising its utility in identifying and mitigating traffic conflicts. Research by Suhadi and Rangkuti (2019), Heredia-Castiblanco et al. (2019), Bulla-Cruz et al. (2020), Cafiso et al. (2017), Yu and Wang (2015), and Yuan et al. (2021) demonstrates the technique's effectiveness in enhancing urban road safety through meticulous traffic conflict analysis. These studies have provided valuable data on conflict rates, severity measures, and intervention strategies, contributing to the overall improvement of urban traffic safety. However, the application of STCT in rural roads remains relatively underexplored. Only a few studies, such as those conducted by So et al. (2015) and Laureshyn et al. (2017), have attempted to adapt the STCT to rural road settings. These studies indicate that rural traffic conditions and conflict dynamics differ significantly from urban environments, necessitating further research and validation of STCT in these contexts. The disparity in research focus underscores a potential gap in the literature, where rural road safety issues may not be adequately addressed using the current STCT framework.

The adaptation and validation of STCT in various countries, as shown in Table 1, highlight the technique's versatility and global applicability. For instance, studies in São Carlos, Brazil (2003) and Nanjing, China (2016) utilised the STCT to develop low-cost safety interventions and innovative methodologies, respectively. These adaptations demonstrate the potential of STCT to cater to diverse traffic conditions and safety challenges. Nonetheless, each study's findings are influenced by specific local factors such as traffic volume, road user behaviour, and enforcement of traffic regulations, which may limit the generalizability of the results.

Potential biases and limitations in the studies reviewed should be acknowledged. Many studies rely on manual observation and video analysis, which can introduce observer bias and inaccuracies in conflict detection and classification. The reliance on surrogate safety measures like post-encroachment time (PET) and time-to-collision (TTC) also presents challenges in ensuring the precision and reliability of the data. Additionally, the variation in methodologies, traffic conditions, and road user behaviour across different regions can affect the consistency and comparability of the findings. Studies employing automated video analysis and simulation techniques, such as those by Cafiso et al. (2017) and Ghanim and Shaaban (2018), offer promising advancements but still require further validation to overcome these limitations.

Moreover, the focus on urban areas in most studies presents a potential bias, as discussed earlier, as rural road conditions and traffic dynamics are distinct and may not be fully captured by existing urban-centric methodologies. The limited research on rural applications of STCT indicates a need for tailored approaches that consider the unique characteristics of rural traffic environments, such as higher speeds, lower traffic volumes, and different types of road users.

In general, the STCT has proven to be a valuable tool for the assessment and improvement of road traffic safety, particularly in urban roads, but its application in rural roads remains insufficiently explored. The variation in study methodologies and local conditions highlights the need for further research to validate and adapt STCT for diverse traffic environments. Addressing potential biases and limitations in current studies is crucial for enhancing the reliability and generalizability of the findings, ultimately contributing to a more comprehensive understanding of traffic safety across different contexts.

6 CONCLUSIONS

The adaptive developments of the Traffic Conflict Technique (TCT) have demonstrated significant advancements in traffic safety analysis across diverse global settings. The TCT has evolved from its inception to encompass various methodologies and applications, including manual observation, automated video analysis, and sophisticated simulations. These adaptations have provided invaluable insights into traffic conflicts and their mitigation, affirming the TCT's relevance and effectiveness in contemporary traffic safety research.

The state-of-the-art TCT research highlights its application in both urban and rural areas, with a predominant focus on urban settings. Studies conducted in cities like São Carlos, Nanjing, Ho Chi Minh City, and Bogota have showcased the TCT's ability to identify critical traffic conflicts and suggest practical, low-cost safety improvements. Innovations such as integrating UAV photography, in-vehicle technologies, and extreme value theory have further refined the technique, enhancing its precision and applicability. Despite these advancements, there remains a significant gap in the application of TCT in rural environments, particularly in countries like Indonesia. While urban studies have yielded comprehensive data on traffic conflicts and safety interventions, rural areas require further research to address their unique traffic dynamics and safety challenges. This research underscores the necessity for a more inclusive application of the TCT, extending its benefits to all road systems.

This research aims to explore the global implementation of the adaptive Swedish Traffic Conflict Technique (STCT) and its efficacy in promoting road traffic safety. By thoroughly examining the existing literature and methodologies, this study highlights the capacity of the adaptive STCT to enhance traffic safety through proactive conflict assessment and intervention strategies. The findings reveal that while significant progress has been made in urban settings, further exploration and adaptation are needed for rural areas.

In conclusion, the adaptive STCT holds substantial promise for improving road safety worldwide. Transportation engineers can develop more comprehensive and effective safety measures by addressing the current research gaps and expanding their application to rural contexts. This study contributes to a deeper understanding of the adaptive STCT's potential and advocates for its broader implementation, ensuring safer road conditions for all users.

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