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Analysis of traffic conflicts at big intersection types in urban areas

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Abstract. In the past decades, planners developed intersections for the car-oriented city. Above all, they should handle motor vehicle traffic efficiently. Urban areas currently have a high proportion of private cars and, as a result, congestion and high CO_2 emissions. At the same time, the importance of and demand for sustainable mobility is increasing. Pedestrians and cyclists are particularly vulnerable as the weakest road users. The goal of transport policy is to achieve "Vision Zero," i.e., no serious injuries or fatalities in road traffic (Federal Ministry of Digital Affairs and Transport, 2022). Many accidents occur primarily at intersections and junctions. Road traffic authorities in Germany generally use accident data from the accident atlas as the basis for evaluating the road safety of intersections. Planners can improve traffic safety by avoiding critical situations. To this end, an intensive study of the development of conflicts as a precursor to accidents can provide further insights. The research in this project shows that such data on traffic conflicts are not available to road authorities. The project will investigate which and how many conflicts between pedestrian, bicycle, and motor vehicle traffic frequently occur at individual intersection types, such as signalized intersections or traffic circles. The initial goal of the project is to develop a survey concept. In the future, planners should be able to use this to quickly identify risks to pedestrian and bicycle traffic at the types of intersections studied. With the help of vehicle sensor data (e.g. from emergency brake assistants), further findings on the frequency and course of conflicts are to be derived. In addition, a methodology would be developed that will enable traffic planners and municipalities to carry out risk management for intersections in the future in order to improve traffic safety and promote local mobility. From the results of the conflict analysis, we will derive recommendations for transport planning and policy. An action guide will then present the recommendations. The end of the project will be in summer 2024.

1 Research topic and relevance

In Germany, car-oriented cities have developed in recent decades. The intersections there have to handle primarily motor vehicle traffic efficiently. However, the importance of and demand for sustainable mobility is increasing. Especially in urban areas, which show a high share of motorized individual traffic and thus congestion and high CO_2 emissions. Walking and

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cycling are increasing [1]. At the same time, pedestrians and cyclists are particularly vulnerable as the weakest road users. German transport policy aims at Vision Zero so that there are no serious injuries or fatalities in road traffic [2].

The German road safety program aims to reduce the number of road fatalities by 40% by 2030 and to reduce the number of people seriously injured in accidents. With a "Pact for Road Safety", the German government wants to promote and implement measures to achieve this goal together with the states, districts, municipalities and non-public actors. One of the goals is to increase the acceptance of driver assistance systems among the population so that more vehicles equipped with them participate in road traffic [2]. In 2019, for example, 19% of passenger cars registered in Germany had an emergency braking assistant [3]. Such systems can prevent accidents in pedestrian and bicycle traffic in cities, for example. Specifically for safe cycling, the road safety program provides for traffic disentanglement [2]. However, this is not always possible, especially in intersection areas. Often, conditionally compatible traffic flows run simultaneously for efficient (motor vehicle) traffic handling.

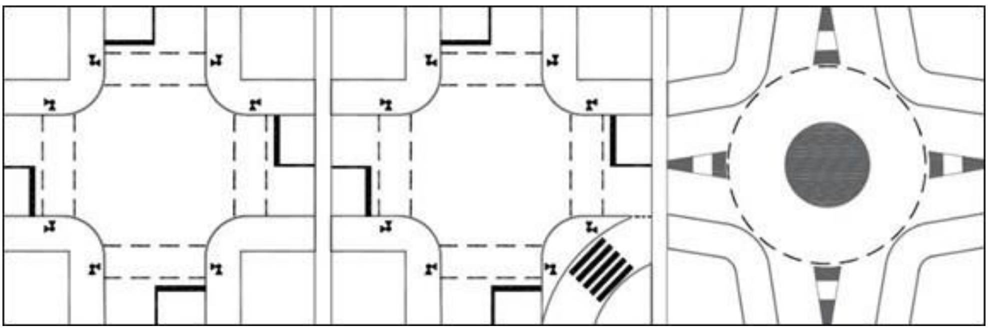
To assess the traffic safety of intersections, road traffic authorities usually rely on accident data from the accident atlas. Significant contributions to the improvement of traffic safety by avoiding critical situations can [however] be provided by an intensive study of the development of conflicts as a precursor to accidents" [4]. The investigations in this project prove that such data on near misses and traffic conflicts, however, are mostly not available to the road traffic authorities. Apparently, this is known, because the federal traffic safety program provides for "further development of the accident survey and improvement of the data situation". With the help of further knowledge about accident causes, appropriate measures can then be developed [2]. Consequently, the collection and provision of data on traffic conflicts can contribute to Vision Zero. The research project ‘RisiSens’, funded by the Hessen Agentur, addresses this goal.

Traffic conflicts are complex. Many influencing factors cause them; they proceed in different ways and happen in a very short period. The consequences of a conflict are usually not visible in retrospect, as is the case, for example, with personal injury or property damage in an accident. Therefore, traffic planners can only detect and survey them through traffic observations. In 1985, the *Verkehrskonflikttechnik* (transl. Traffic Conflict Technique) [5] compiled results and experiences from investigations in the field of hazard analysis in a manual with recommendations for traffic conflict investigations. This provides, among other things, for outlining the observed traffic conflicts by hand on a survey sheet with lines of movement. This approach is time-consuming, labour-intensive, and impractical for road authorities. In addition, it is outdated due to technological and digital developments. Therefore, the aim of the research project is to develop a contemporary and user-friendly method for the survey and analysis of traffic conflicts for local authorities. To this end, we will develop a survey concept first. The concept envisages a reduction in the personnel required for traffic monitoring using video cameras. In addition, we will use further data for the traffic conflict analysis, which will provide additional insights into the course of events and the causes.

The research project is investigating whether and to what extent driver assistance systems can use generated data to identify critical points in road traffic. The data comes from vehicles equipped with an emergency braking assistant. When an object or person approaches, the vehicle brakes automatically. The vehicle sends the braking events to the vehicle manufacturer and provides details about the conflict. This includes GPS coordinates, time, and means of transportation of the second or third party (pedestrian or cyclist). The results from our own collection and analysis of motor vehicle sensor data serves as the development basis for risk management for pedestrian and bicycle traffic.

The object or area of investigation results from the most frequent causes of accidents. Accident statistics data show that most accidents in urban areas occur mainly due to intersection and turning accidents [6]. Therefore, for Vision Zero, it is necessary to evaluate the traffic safety of intersections in particular. In Germany, three types of big intersections are common in urban areas (Fig. 1):

- Signalized four-arm intersection (without separate signalization of public traffic) (a),
- signalized four-arm intersection (without separate signalization of public traffic) with a non-signalized right-turn lane (b), and
- non-signalized four-arm traffic circle (without separate signalization of public traffic) without a bypass (c) [7].



(a) (b) (c)

Fig. 1. Three types of big intersections in urban areas.

These types are adapted to the spatial and traffic conditions on site, e.g. by number of lanes. Non-signalized four- arm intersections usually belong to the smaller intersections, i.e., those with lower traffic volumes [7]. They are not part of the research project.

Risk management for pedestrian and bicycle traffic is to apply to the roadway area of the above-mentioned intersection types in urban areas. In the future, it should be possible for road authorities to use it to assess the traffic safety of their intersections.

2 Current methods for traffic safety evaluation

In the current valid German guidelines of the *Forschungsgesellschaft für Straßen- und Verkehrswesen* (transl. Research Association for Roads and Traffic), various procedures for assessing the road safety of road traffic facilities (here: road infrastructure safety management) are presented. Based on the *Empfehlungen für die Sicherheitsanalyse von Straßennetzen (ESN)* (transl. Recommendations for the Safety Analysis of Road Networks), planners use accident blackspots to identify critical areas in the road network. One of the parameters for the safety assessment is the accident rate, i.e. the number of accidents per route length in a given period [8]. For this purpose, road authorities use accident data from the Accident Atlas, which is available as open source. The Accident Atlas statistics include traffic accidents recorded by the police, which are primarily those with serious consequences. Police generally do not report accidents with minor property damage or injuries [9]. In addition, the road space safety audit provides a method for identifying risks at intersections. The focus is on the design of the road space, and this is especially true when planning a new road construction, reconstruction, or expansion, rather than on the existing infrastructure for regular inspection. Planners also use accident data for this assessment. A survey or analysis of existing traffic conflicts is not part of the safety audit [10]. In addition, as part of the safety management of the road infrastructure, the responsible road traffic authority should inspect the infrastructure for damage or hazards at regular intervals by means of a traffic inspection.

The objects of the inspection are traffic signs (including road markings and traffic devices) and danger spots at the edge of the road and in the lateral space [11]. Another method of assessing traffic safety is traffic observation. The *Empfehlungen für Verkehrserhebungen (EVE)* (transl. Recommendations for Traffic Surveys) provide guidance for planning and conducting traffic observations [12]. The EVEs present the traffic conflict technique as a specific method for taking stock of traffic safety on the road. In this process, interview personnel or video technology qualitatively analyse the interaction behaviour of the participants. To classify the severity of the conflict, the so-called TTC (Time to Collision), i.e. the time between two road users and the collision, or the PET (Post Encroachment Time), i.e. the time difference until the first road user leaves the conflict area and the second enters it, is calculated. So far, only the manual *Verkehrskonflikttechnik* (transl. Traffic Conflict Technique) [5] describes the detailed survey of traffic conflicts [13]. Survey personnel handwrite outlines of traffic conflicts on a survey sheet and then evaluate them. The manual does not present results on traffic conflicts.

3 References to relevant theories

As early as the 1970s, scientists found out [13] that the survey of traffic conflicts could provide information about possible accident events. In February 2023, a self-organized workshop took place with representatives from nine municipalities of different sizes in Germany. The result is that the municipalities do not currently use the traffic conflict technique in practice. One of the goals of the workshop was to find out how road authorities currently evaluate the traffic safety of road facilities. The literature review to that point does not show any meaningful evidence in this regard. With the exchange of experiences with local authorities, we would like to close the knowledge gap. During the workshop, we asked them what methods, technical tools and data they use for road safety evaluation. The result shows that all nine municipalities evaluate based on accident maps. Road authorities do not have to collect data on accidents first. The accident atlas provides the data. Critical points in the road traffic system therefore only become visible to them as soon as accident blackspots become apparent. Accordingly, they can use this method to address critical points only after damage has already occurred.

They therefore often advocate "new" intersection designs, such as the "protected intersection", which should be implemented. However, new, holistic intersection designs are not always possible, for example, due to space constraints. In addition, the implementation time for new construction is long. There is also no evidence to date that this results in fewer or lower traffic conflicts. In order to make a comparison, it is first necessary to evaluate which traffic conflicts occur at existing larger intersection types. We would like to determine this as part of the research project. If the road traffic authority gains knowledge of this, it can optimize the intersection design with targeted measures, in the best case in the short term. This can reduce traffic conflicts and accidents.

Methods for surveying traffic conflicts, as applied in studies conducted so far [4, 5, 13], provide for e.g. surveys of road users, manual field observations, computer-aided video evaluations or natural driving behaviour studies. Road traffic authorities cannot always carry out these methods due to lack of resources (personnel, time, finances, suitable tools, etc.). Part of this research project is to develop an efficient survey concept for manual field observation based on the methods already in use, taking into account the framework conditions of the road authorities. As shown above, the current traffic safety assessment based on data that do not have to be surveyed by the road authorities. They do not yet have data on traffic conflicts. In addition to their own survey, one source of data could be the automotive industry, which equips its vehicles with assistance systems. Driver assistance systems prevent accidents and thus draw attention to traffic conflicts. They can contribute to road safety [4, 14]. The events of the assistance systems are stored anonymously at the vehicle manufacturers, evaluated as well as further developed with regard to their functionality if the customer contractually agrees to the data transfer. The literature review could not prove any studies to what extent data from driver assistance systems can be helpful for the detection and analysis of traffic conflicts. Therefore, this is what the research project is investigating.

4 Research hypothesis and questions

When looking at the state of research on the evaluation of intersection traffic safety, it becomes clear: There has been little research on the collection and analysis of traffic conflicts using motor vehicle sensor data. Therefore, the basis for this project will be the following hypothesis: Survey concept using motor vehicle sensor data can evaluate traffic safety of big intersection types in urban area. The research guiding questions listed below examine the hypothesis.

First, there is the question of how to survey traffic conflicts at intersections. In order to evaluate motor vehicle sensor data, surveyors must first collect traffic conflict data manually. For this purpose, we will develop a concept, with the help of which we can identify traffic conflicts easily and quickly. In a first step, a literature research finds out which factors influence traffic conflicts and how they arise. Only on this basis will it become clear whether a simple and quick survey of the conflicts is possible. Since the survey concept is to serve the road traffic authorities at a later stage, the framework conditions resulting from their structure will be take into account.

The next research question is to investigate which traffic conflicts occur frequently at big intersections. Using the developed survey concept, staff will survey, i.e. count and observe, the traffic conflicts between pedestrian, bicycle and motor vehicle traffic at big intersection types. We define the following traffic facility concepts as big intersection types:

- signalized four-arm intersection (without separate signalization of public traffic)
- signalized four-arm intersection (without separate signalization of public traffic) with a non-signalized right- turn lane
- non-signalized four-arm traffic circle (without separate signalization of public traffic) without bypass.

For the survey, it is necessary to define the study area, the number of intersections per type, the frequency and duration of the survey.

This raises the question of what information is required for the evaluation of traffic safety at intersections and what data can provide this information. This follows by an examination of motor vehicle sensor datasets using data collected through manual traffic observation and analysis and accident data from accident statistics. The self-determined data have a different information content than the vehicle sensor data. The driving assistance systems cannot for example, determine whether the person involved in the conflict has disregarded a traffic rule and whether this has led to a traffic conflict. At the same time, the analysis is intended to answer the question of whether such information, and thus what information, is necessary for evaluating the traffic safety of intersections.

Finally, the last research question will examine the risks posed by traffic conflicts for pedestrians and bicyclists at big intersection types. Through data analysis, it will be determined in which areas in the intersections the most frequent traffic conflicts occur and which information is important to increase the traffic safety of intersections. From this, we can deduce risks for pedestrian and bicycle traffic. An evaluation and analysis of these follows. Finally, it is clear whether motor vehicle sensor data are useful for evaluating the traffic safety of the largest intersection types in urban areas. A risk management system for pedestrian and bicycle traffic at big intersection types will summarize the results, which will ultimately be helpful to road authorities in identifying and mitigating critical intersection areas.

5 Approach and methods

To answer the research questions described above, this research project aims to use a mix of methods.

In order to develop a research concept, we must first clearly define the concept of traffic conflict. To do this, we first conduct a literature review. Then we know how other studies has described the term. On this basis, we know how to characterize a traffic conflict in the context of the planned study and what factors describe and influence it. With the definition of terms, we can understand which parameters are important in the survey of traffic conflicts. Traffic observation [5, 12] is suitable for manual survey. It can collect other information, such as socio-demographic data, in addition to traffic conflicts. If needed, survey personnel can collect more information about the people involved in the conflict and their subjective perceptions by conducting a survey. We do not currently conduct surveys because we only want to determine objective traffic safety. For traffic monitoring, we are investigating approaches using different recording media to gather various information (e.g., sociodemographic characteristics, traffic signal release times, direction of movement, etc.). We are evaluating the developed survey concept in the context of test surveys. We optimize the concept with the involvement of the road traffic authorities, who will apply the concept later. For this purpose, we have already conducted a workshop with representatives of the municipalities to determine the framework conditions and requirements for a survey concept.

For the survey, we apply the developed and evaluated survey concept. With the help of video cameras and survey personnel on site, we will count, observe and categorize conflicts between road users in addition to the traffic volume (traffic counting and observation). The surveyed conflicts will later serve as a basis for the evaluation of the motor vehicle sensor data, which is why the urban area of Stuttgart is suitable as a study area. Here, a particularly large number of test drives by the cooperating vehicle manufacturer have taken place, so that a large amount of data is available. For each intersection type, we will study two intersections with similar design features and traffic routing. We selected the intersections first by reviewing aerial photographs of the traffic facilities and finally by conducting a site visit. Through the survey, we aim to capture as many traffic conflicts as possible. Our current assumption is that the more pedestrian and bicycle traffic that occurs, the more frequent traffic conflicts will be. After reviewing historical data on traffic volumes and motor vehicle sensors for each intersection, we can derive survey times. We assume that higher pedestrian and bicycle traffic volumes can be expected during the warmer and drier months, which argues for a spring and summer survey.

With the observation, we would like to analyze the cause and frequency of conflicts. During traffic observation (review of video footage), we register the conflict events in tabular form. To analyze the collected data, we first evaluate it. In this context, we would like to determine which influencing factors and sequences of the conflicts predominate and in which intersection area they frequently occur. For further analysis, we will use accident data from the Accident Atlas in context with pedestrian, bicycle and motor vehicle traffic. By comparing recorded accidents and surveyed conflicts, we hope to investigate whether conflict causes and trajectories may determine certain accident categories. In addition, we will compare the results of driver assistance systems with survey data. In the process, we would like to determine whether automotive sensor data could provide further insight into the cause and frequency of conflicts. We also want to use it to see if it is sufficient for evaluating traffic safety at intersections.

Finally, using the results from the analysis of the survey and automotive sensor data, we would like to know what traffic conflicts occur for pedestrians and bicyclists at each type of intersection. Based on these findings, we will develop a risk management system for pedestrian and bicycle traffic at intersections. Companies usually use risk management to check economic efficiency or, for example, in the planning and design of nuclear power plants and chemical plants. With the help of risk management, we aim to identify, analyze, evaluate and finally manage risks [15]. According to Durth and Bald, planners can use risk analysis in road construction, for example, to evaluate road safety [16]. "Therefore, the results of risk analysis as a probability statement about the future should prevent the occurrence of the damage by appropriate preventive measures" [17]. Accordingly, we would like to investigate whether Durth and Bald's method is suitable for risk management for pedestrian and bicycle traffic at intersections. At the same time, we would like to examine other risk assessment methods of the currently valid standard [18] for transferability.

6 Objective

The overall aim of the research project is to contribute to the promotion of walking and cycling. Ensuring that streets are safe for traffic can encourage short trips or even parts of the daily commute to be made on foot or by bicycle, thus reducing motor vehicle traffic where appropriate.

The research project aims to fill the identified research gap regarding the use of motor vehicle sensor data to assess the traffic safety of large intersection types in urban areas. We also aim to gain insights into the frequency and influencing factors of traffic conflicts. The results, the developed survey concept as well as the risk management for pedestrian and bicycle traffic, will serve as an aid for road authorities to evaluate the current traffic safety of road facilities. The innovative content of the project is to develop a contemporary method based on the methods of *Verkehrskonflikttechnik* (transl. Traffic Conflict Technique) [5] and *Risikoanalyse im Straßenwesen* (transl. Risk Analysis in Road Engineering) [16], which provides for the use of technical and digital aids, such as vehicle sensor data.

By collecting and analyzing vehicle sensor data ourselves, we are investigating whether vehicle sensor data are sufficient to identify critical areas in intersections and influencing factors of traffic conflicts instead of the accident figures in the accident map. If this is possible, road authorities can use vehicle sensor data to find out whether there is a potential hazard before an accident black spot occurs. They can also then see whether, for example, structural reconstruction measures or changes to the signal program at signalized intersections are necessary.

If the research project can demonstrate the feasibility of using vehicle sensor data to assess traffic safety, the results should as possible be incorporated into the German guideline. This will make them accessible to all transportation planners. Based on this survey method and the knowledge gained from it, road authorities can then identify weak points in the infrastructure and plan and implement targeted mitigation measures.

7 Conclusion

The vehicle sensor data is only available in aggregated form. The automobile producer does not provide any raw data. We are therefore unable to track the number of conflicts in a specific period. We also do not know how many of the detected conflicts were actually conflicts or how many conflicts the sensors did not detect. Nevertheless, they can provide initial indications of critical areas. You can then collect further information on the conflicts with a manual survey. The company is currently developing the vehicle sensors and the dashboard further. With the new features, it promises more information for traffic conflict analysis. The new features will be published in the early summer of 2024, so we will examine them again directly. If the vehicle sensor data can provide more information, e.g. conflict flow, the effort required for manual collection will be less. The final results of the research project are expected to be available by the end of 2024.

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