TRAFFIC CONFLICTS AND ROAD TRANSPORT SAFETY NEW DEVELOPMENT

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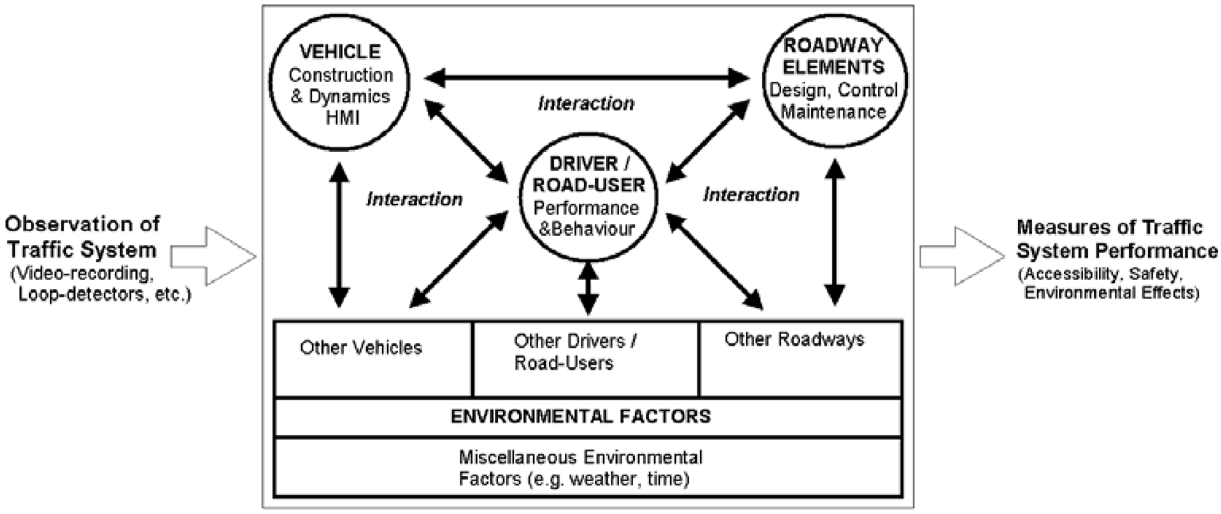
Summary:Adoption of the "Directive of the European Parliament and of the European Council No. 2008/96/EC on road infrastructure safety management" (29) brought a new impetus to road traffic safety evaluation. The consequent Czech Act No. 152/2011 Coll. on roads obliges their operators to evaluate the traffic safety on a regular basis. It brings a new challenge – evaluation of road safety using traffic conflict analysis techniques and performance measurement. This paper follows the article (28) published earlier.

Key words: traffic conflicts, road safety, conflict analysis.

1. ROAD TRAFFIC SAFETY SYSTEM DEFINITION

According to Blumenthal (6) who adopted a General Systems Theory approach as a tool for scientific study, traffic safety can be regarded as an „open system“. The traffic system can be explained by the interactions and relationships among road users, vehicles and roadway elements at a certain level of abstraction. Based on this theory a diagram of the basic elements of the traffic system was proposed, see Figure 1.

This structure model describes the macrostructure of the traffic safety problem as a theory of general systems, political influence and administration practice. It recognizes however also the importance of values at the individual level. According to this model the traffic safety has technological, behavioral, sociological and value dimensions (5).



Source: Archer (5)

Fig. 1 – Conceptual model of the main elements of the traffic system (5 according to 6)

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2. ACCIDENT DATA

The road safety is traditionally measured by the number of road traffic accidents and their severity. Although such an indicator based on traffic accidents amount (called also “direct indicator”) is useful for identifying specific problems of the location being evaluated, it is regarded as “reactive” and in principle also as inhuman (10). It is assumed that significant number of accidents must occur in order to identify a road safety problem that we can start solving. Another disadvantage of accidents as a direct indicator is quality and availability of details of the accidents and time that is required for statistical evaluation of various measures implemented for the sake of safety improvement. In particular, with respect to the incidental character of their causes. Besides, occurrence of the accidents is a result of a chain of dynamic events, which are difficult to analyze merely based on the statistical data and mostly insufficiently documented records, which provide only few qualitative details related to the causes (5, page 7).

3. EVALUATION USING NEAR – ACCIDENTS (TRAFFIC CONFLICT) TECHNIQUE

The Traffic Conflict Technique (TCT) is according to (19) the most direct of the all indirect methods of road safety measurement. It is based on observing and recording of the conflict events (near-accidents) in normal operation and in real time. The method was developed towards the end of the 1960’s in the laboratories of GM for research of their cars safety problems (25). It consisted in observing and recording the hazardous interactions between the road users, which required an evasive maneuver to avoid the threatened collision. In Czechoslovakia it was implemented on the initiative of Folprecht in 1973 at the Road and Urban Transport Institute (ÚSMD) of Prague (10). In 1988, Folprecht and Křivda incorporated this method based on the video-recording evaluation by trained observers in the lessons and research at the VŠB-Technical University of Ostrava. The method is still being successfully used for solving numerous research tasks in the field of road safety evaluation, such as (11) and (18). A similar method of traffic conflict observation based on their evaluation by direct observers on site is used at the Czech Technical University Prague (24). According to (4) TCT methods offer faster and in many aspects more informative way of estimating the expected frequency and occurrence of accidents.

4. SWEDISH TRAFFIC CONFLICT TECHNIQUE

The traffic conflict research noted significant development at the Technical University of Lund, Sweden, in the 1970’s and 1980’s. Their method of traffic conflict observation by trained observers focused on situations, in which two road users would collide if neither of them made some kind of an evasive action. The point, in which such evasive action is performed, is recorded by the observer as the “Time-to–Accident” (TA). The TA value along with the conflict speed was used to determine whether the conflict was severe or not (15). According to the country of origin this method has been named the “Swedish Traffic Conflict

Technique". Some other "national" alternative methods based on the similar principles were introduced in Europe and worldwide.

The "International Committee for Traffic Conflict Techniques" (ICTCT) jointly defined a traffic conflict as: "An observable situation, in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged" (3).

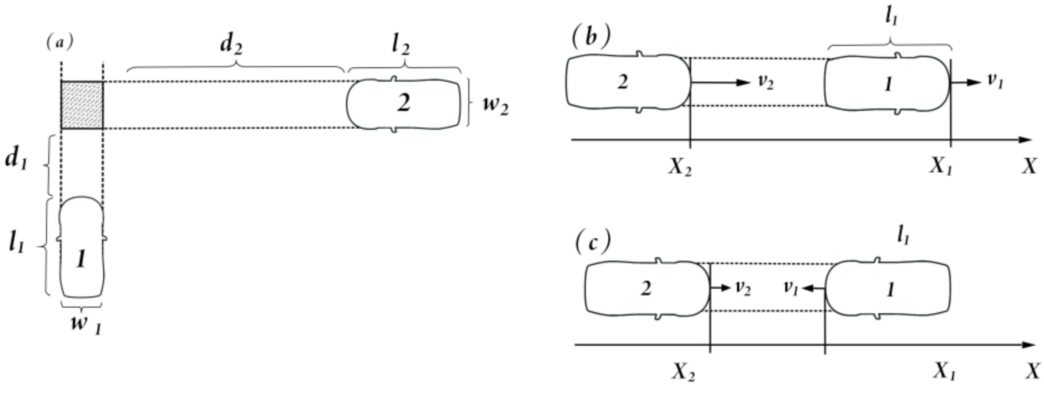
International comparative study focused on severity of identified conflict situations conducted in 1983 in Malmö with participation of 8 foreign teams using "national" TCT alternatives proved that the differences between them were not significant. The observers agreed on 75 % of identified severe conflicts (12).

The differences between the individual observers in evaluating the severity of an evasive maneuver are, therefore, a subject of frequent criticism of TCT method. This is why alternative indicators of more objective measurement were proposed, enabling getting a measure on the severity scale proven in time. The most valuable indicator of this kind is "Time-to-Collision" (TTC), defined as time required for two vehicles to collide if they continue at their present speed and on the same path (21). If the collision occurs, the TTC value becomes final and decreases in time. The critical value for assessing the conflict is, therefore, the TTC minimum during its duration.

$$TTC = \frac{d_2}{v_2}, \quad if \quad d_1/v_1 \le d_2/v_2 \le (d_1 + l_1 + w_2)/v_1$$
$$TTC = \frac{d_1}{v_1}, \quad if \quad d_2/v_2 \le d_1/v_1 \le (d_2 + l_2 + w_1)/v_2 \tag{1}$$

$$TTC = \frac{X_1 - X_2 - l_1}{v_1 - v_2}, \quad if \quad v_2 \ge v_1 \tag{2}$$

$$TTC = \frac{X_1 - X_2}{v_1 + v_2} \tag{3}$$

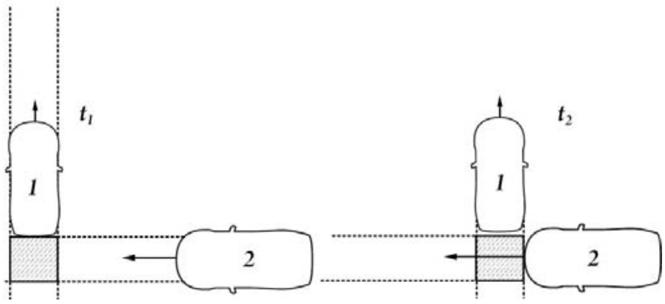


Source: Laureshyn et al. (21)

Fig. 2 – TTC calculation for perpendicular and parallel trajectories (21)

Another alternative of TTC indicator is an indicator called PET- Post-Encroachment-Time (1). (Fig. 2) PET is used in situations when the collision did not occur, but the time difference of intersection of the trajectories is found below certain limit value (19).

$$PET = t_2 - t_1 \quad (4)$$



Source: Allen et al. (1)

Fig. 3 – PET definition (1)

5. RELIABILITY AND VALIDITY OF TCT METHODS

Practical utilization of the traffic conflicts technique remained limited so far. The reasons were the doubts and thus increasing number of questions concerning validity and reliability.

The TCT method validity is mostly assessed according to the adequate correlation between the observed number of conflicts and accident records. (7, page 174). The American study (23) proved that the normal study of conflict situations can provide estimates of average frequency of accident occurrence, which are at least as accurate as those based on the historical data. In opinion of other authors (21, page 1), some problems with the validity are definitely caused by inaccurate and insufficiently processed accident data.

An important issue is also the “process validity”, i.e. whether the conflict triggering processes are the same like those, which cause accidents. Based on the data related to TA and speed values, (15) revealed that the conflicts and accidents actually share the same severity allocation and that the accidents generally reached the TA (time-to accident) value below 0.5 sec and the speed of 10 - 20 km per hour higher than the conflicts.

Reliability of the conflict measurement is mostly connected with differences caused by subjective evaluation of traffic conflicts by individual observers. From this point of view the methods using video-recording can be considered for more objective ones. According to some researchers video-recordings can provide repeated assessment, however, they do not provide the same quality as the observation by a person present on site does. The observers on site usually have a better possibility to evaluate based on direct seeing of all events ongoing in parallel than from a limited two-dimensional sequential watching the video-recordings (7, page 176).

6. AUTOMATED ANALYSIS OF VIDEO-RECORDING

The automated video-recording analysis has made a huge progress thanks to the fast development of information technologies. The present methods can record and observe more road users of various kinds (19). The big potential of this method development leads to shortening of the processing time and to significant increase of the measurement reliability. It can be expected to soon provide tools for a detailed description of movements (in coordinates and depending on time) of all road users in the observed area, for instance at the entire intersection. A number of such obtained details have huge potential, but the practical methodology of their processing has not been developed yet. The purpose of further research is to design a theoretical scope for development of a method utilizing the data obtained from the video-recordings. According to (21, page 1 and 2), this is the first attempt to develop a set of indicators, which can describe a fluent process of interactions between the individual road users related to the general safety situation in the observed area.

7. NEWLY DEVELOPED SURROGATE SAFETY MEASURES

The remarkable progress of information technologies and statistical methodologies in the recent years has accelerated development of new safety prediction and modeling methods.

The useful indirect method for traffic safety measurement should according to (27) satisfy the following two conditions:

1. An indirect method should be based on an observable non-accident event that is physically related in a predictable and reliable way to accidents, and
2. There exists a practical method for converting the non-accident events into a corresponding accident frequency and/or severity.

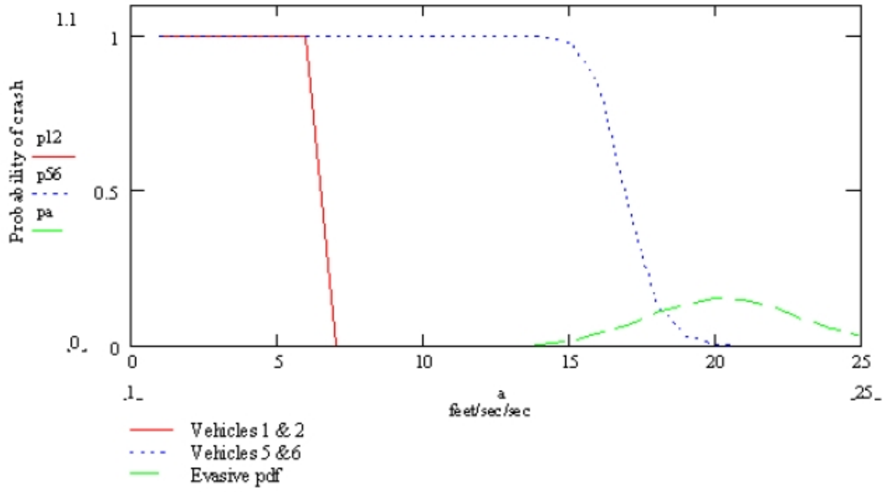
The first condition emphasizes the principal aspects of indirect method that enable meeting the second condition: development of a method of transforming the indirect technique outcomes into the meaningful outcome–frequency and severity of accidents (27).

7.1 Precise Measurement of Vehicle Interactions

This method is based on accurate measurement of vehicle interactions such as distance separations between vehicles and time separation between events. It is a promising though yet experimental method based on indirect accident information from such measurements with the use of probability causal models according to (8). This method is using the definition of traffic conflict similar to that used in the 100-Car study (9):

A near crash is any circumstance that requires a rapid evasive maneuver by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid an accident. A rapid, evasive maneuver is defined as steering, braking, accelerating or any combination of control inputs that approaches the limit of the vehicle capabilities.

To the first part of this definition, that is very similar to the ICSTCT definition (just using an American term „near crash“ instead of the European „traffic conflict“), a second condition is added here. It says that the magnitude of the evasive action should be extreme concerning capabilities of vehicle. This second condition helps exclude situations such as when two vehicles successively brake to a stop line at the intersection with one stopping behind the other. Just a small decrease in the second vehicle deceleration would cause a restend crash. But if the deceleration were typical of what drivers use when stopping this event should not be considered a traffic conflict.



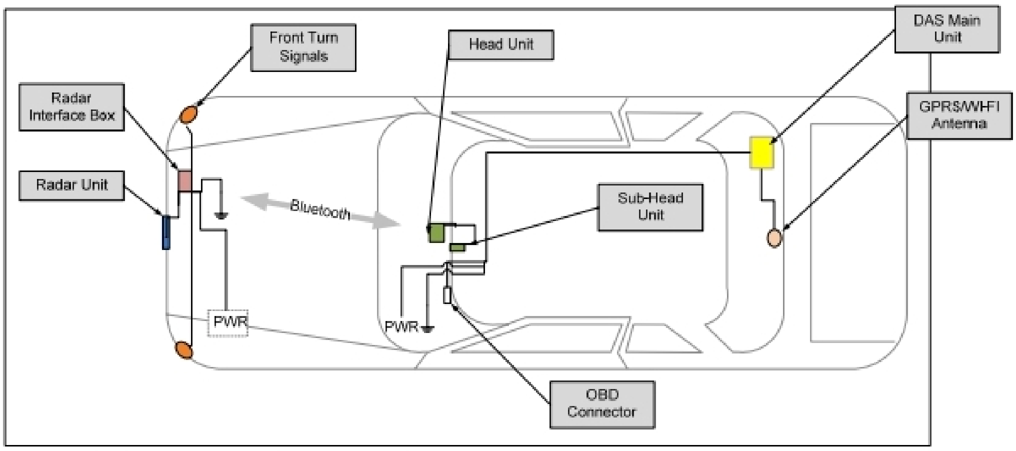
Source: Tarko et al. (27)

Fig. 4 – Crash probability versus following vehicle deceleration and probability density function for emergency deceleration

Fig. 4 plots 2 records of probability of accident versus counterfactual deceleration of the second vehicle for the two pairs of vehicles observed on the intersection stop line during congested conditions (27). The initial vehicle velocities, the following vehicle distance, reaction times and deceleration rates were estimated from trajectories extracted from video-recordings. These data confirmed a certain probability of crash. For the first pair of vehicles deceleration for the following driver below approx. 6 ft./s^2 are needed to make a crash highly probable. For the second pair this occurs for deceleration below 16 ft./s^2. Fig. 4 also shows a distribution of evasive actions characteristics of crash/near crash conditions developed from statistics of braking under emergency conditions (27). Integrating the crash probability versus deceleration curve with respect to this distribution shows a probability an event could have been a crash. For the first pair of vehicles this is zero, for the second pair about 0,14. Computing these probabilities for each of a set of events and summing these probabilities gives an expected number of crashes in a set of near accident events.

7.2 100 Cars Naturalistic Driving Study

This is essentially new complex approach to researching circumstances preceding occurrence of conflict situations and accidents. The method was developed at Virginia Tech Transportation Institute with utilization of advanced technical equipment enabling collection, storage and analysis of huge amount of data (9). Observation was performed during normal everyday driving of vehicles, owned mostly by the drivers. For data collection every car was equipped with the sensor devices, which unobtrusively and gently record the vehicle maneuvering (such as speed, acceleration/deceleration and driving direction), as well as the driver’s behavior (focus of eyes, head and arm movements) and external conditions, such as road characteristics, traffic density, weather, etc.). Fig. 5 shows positioning of parts of the data acquisition system (DAS) on the vehicle involved in the 100-Car study (9). Every car kit consisted of 5 channels of digital video, front and rear radar sensors, accelerometer, vehicle speed sensor, video-based lane tracker and GPS.



Source: Dingus et al. (9)

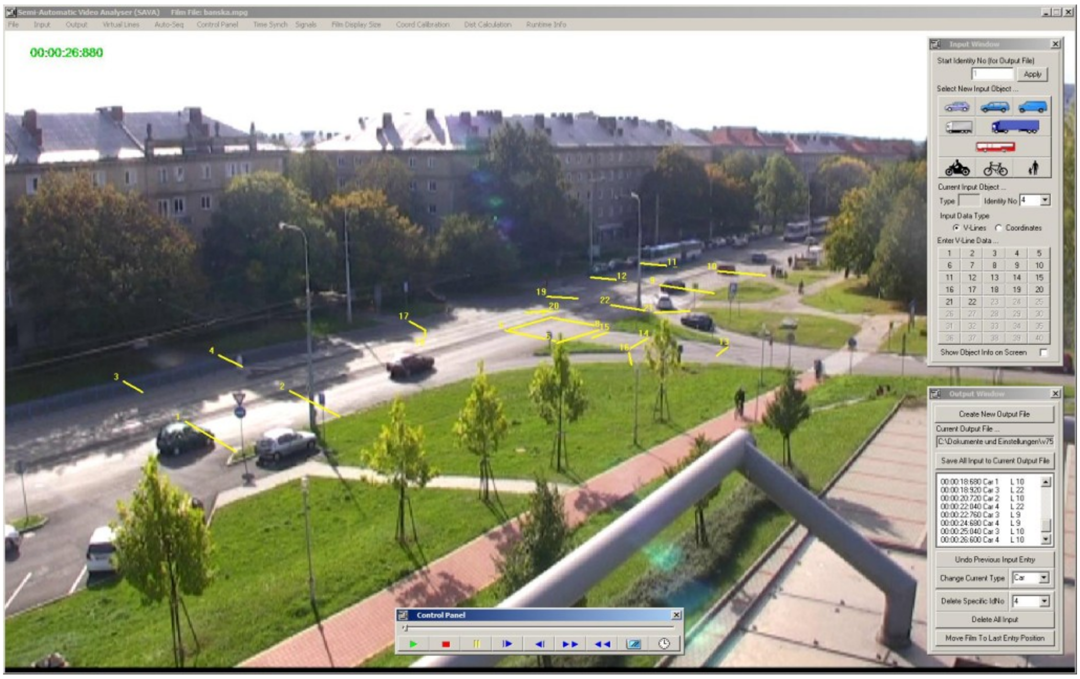
Fig. 5 – Parts of the Data Acquisition system (DAS) of the Naturalistic driving study (9)

The experiment lasted for 12 to 13 months and involved a sample of 109 primary drivers and 139 further drivers in age ranging from 18 to 73 years, 60 % male and 40 % female. More than 2 million kilometers were driven in the northern state of Virginia and metropolitan area of Washington D.C. 82 accidents of various severity occurred, 761 near-accidents and 8 295 traffic conflicts recorded. Huge amount of 6 terabytes of data was collected. The data was processed by an advanced system enabling concurrent approach of several evaluators (17).

The experiment provided extraordinarily valuable data of relations between the driver, road, vehicle, weather and traffic situation. The most important outcome of this project was that in almost 80 % of all accidents recorded in this study distraction or inattention of the driver three seconds prior the accident played a role (17). At present time the further study of large scale is in progress involving 2000 vehicles with expected data volume of 1000 terabytes.

8. PRACTICAL UTILIZATION IN THE CZECH REPUBLIC

The “Directive of the European Parliament and of the European Council No. 2008/96/EC on road infrastructure safety management" obliges the Czech Republic to introduce effective 2011 compulsory traffic safety inspections of projected and existing roadways (29). Based on public competition of ALFA and Technology agency of the Czech Republic (TAČR) for applied research and experimental development the project “Methodology of observation and evaluation of traffic conflicts in Czech environment” (shortly called “Konflikt” project) has been launched. Its goal is preparation of a practical tool for traffic safety inspection of the roadways in the country ordered to their operators by the Directive 2008/96/ES of European Parliament Council as transformed into the Czech Law Nr. 152/2001 Coll. The suggested methodology should be, after the field testing, submitted to Czech Ministry of Transportation for certification for practical utilization.



Source: Author

Fig. 6 – Screenshot from study of conflict situations taken by borrowed semi-automatic software for video-recording evaluation SAVA.

There are two TCT methods used in the Czech Republic. The VŠB-TU Ostrava uses the video-recording method according to (11) for observing and evaluating the traffic behavior at intersections, pedestrian crossings, cycling or rail crossings, mass transportation stops, etc. The ČVUT Prague uses a similar methodology based on evaluation by trained observers on site (24). Regarding the fact that the automatic video-recording method is still in the stage of development, and the semi-automatic processing of video-recording has not been used in the Czech Republic yet, utilization of some domestic TCT methodology shall be considered. Intermediate conclusions of the “Konflikt” project indicate that using of ČVUT methodology supported by enhanced system of observer training is intended (2 and 16).

Presently the author of this paper is testing software that enables semi-automatic processing of video-recordings for study of conflict situations on the selected intersections. The goal of this testing is assessment of utilization of the advanced method of video-recording processing for observation and evaluation of traffic conflicts.

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