Perspectives for surrogate safety studies in East-European countries

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Abstract. The traffic safety development in East-European countries follows in general the trends of the western countries, even though there is a time lag. The fatality numbers are decreasing, though the improvements for the vulnerable road users are less impressive compared to other road user categories.

The traditional road safety analysis based on accident history has many limitations related to accident under-reporting, low and random accident counts at individual sites and lack of details in the accident reports. The surrogate safety methods are based on observation of other-than-accident occurrences in traffic that still have a valid relation to safety and are often a more efficient (and a pro-active) way to make safety assessments.

The paper reviews the current status of the surrogate safety analysis methods, the challenges and opportunities related to today’s urban traffic situation and the new technologies for more efficient data collection. We put the method in the context of the East-European countries to see how it can contribute to the on-going traffic safety work and better understanding of accidents risk factors necessary for efficient safety counter-measures.

Keywords: Surrogate safety measures, traffic conflicts, video analysis, traffic safety, East-European countries.

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Introduction

Traditionally, road safety is described in terms of number of accidents or injuries that occur in traffic. However, it has been acknowledged that, as the safety work yields its results and the number of accidents and injuries goes down, practitioners are left with too little data to base further decisions on (Zheng et al., 2014b, Tarko et al., 2009). While on the national level there are still some benefits to get from improvements of the accident records quality (e.g. through combination of police and hospital data to reveal the scale of the under-reporting), on the level of an individual unit of a traffic infrastructure (e.g. an urban intersection) even the perfect accident history available is not of much help due to low numbers and statistical issues related to that.

Therefore, surrogate safety measures (i.e. measures not based on accident counts) are advocated as an alternative tool to describe safety and to get a prompt feedback on introduction of safety interventions. There is a great number of such measures suggested, even though only few of them are properly validated to make sure that they describe safety and not some other qualities of the traffic system (Laureshyn et al., 2016). In the Western countries, the studies based on surrogate safety measures have a long history starting from the 1960s (Perkins & Harris, 1967). The 1980s were a “golden era” for the traffic conflict techniques when nearly every country developed its own technique (Asmussen, 1984, Grayson, 1984). The last decade has been marked with renewed interest to the subject, particularly due to rapid development of the new technologies like automated video analysis that can aid in more objective, accurate and cost-efficient collection of the relevant data for the surrogate safety analysis (Laureshyn et al., 2016).

In the East-European countries such approach to safety analysis has been also known (e.g. Antov, 1986), but it has never left the academic circles and became a tool for practitioners. However, as the traffic situation in these countries seems to follow the developments in the West, it appears inevitable that road safety practitioners will have to look for alternative tools to the accident analysis. In this paper we look closer at the state of the art within surrogate safety methods and how they can be introduced in the East-European countries.

The trends of traffic safety development – Eastern and Western Europe

During the last decades, the road safety situation has improved greatly in most of European countries (Figure 1). In the Western countries (particularly those having the best road safety performance like Sweden, Denmark, the Netherlands or United Kingdom), the positive improvements started already in 1970s and for the moment the pace of improvements is relatively low. In Eastern European countries the improvements started relatively recently (last decade), but even
though there is a time lag, they seem to follow the pattern of countries with good safety records. It appears that initial improvements can be reached with relatively simple and low-cost measures, but as the safety situation gets better more complex and costly interventions are necessary. The better knowledge and understanding of the accident causation factors are necessary to keep improving the safety and further reduce the fatality numbers.

Figure 1. Road fatalities per 1 million population (ERSO, 2016b).

Another interesting pattern to be noted is the composition of the road fatalities. It appears, that improvements in safety for car occupants is more successful compared to the vulnerable road user categories (pedestrians, cyclists). Figure 2 and Figure 3 present the fatality figures for pedestrians and cyclists. While the absolute numbers are decreasing over time, the share of vulnerable road user fatalities seems to go in the opposite direction, i.e. their safety is improving at a slower rate compared to road user categories.

Figure 2. Pedestrian fatalities: a) per 1 million population; b) share of pedestrian fatalities in all road fatalities (ERSO, 2016c).

Figure 3. Cyclist fatalities: a) per 1 million population; b) share of pedestrian fatalities in all road fatalities (ERSO, 2016a).

It is important to realise that the fatality numbers per population do not take into account the actual number of trips by foot or on a bicycle (nor their length), i.e. the exposure. Thus, countries like the Netherlands and Denmark known for very extensive use of bicycles as a transportation mode, appear to have cyclist fatality rates quite similar to

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Surrogates safety measures

The limitations of the accident data can be summarised as follows:

- Traffic accidents are random and the number of accidents registered during two equal time periods under equal conditions will not most often be the same. The “true” safety characteristic is thus the “expected number of accidents” that cannot be measured but only estimated based on the accident history or using some other methods (Hauer, 1997).
- Traffic accidents are rare events and it takes a long time to collect a sufficient amount of accident data to produce reliable estimates of the expected number of accidents. During that time the traffic conditions usually change. There is also an ethical problem in waiting for accidents to occur before anything can be said about the (un-)safety.
- Not all accidents are reported. The level of underreporting depends on the accidents severity and types of road users involved. This is particularly a problem for the vulnerable road users (Elvik et al., 2009, Amoros et al., 2017, Alhajyaseen, 2015, Bagdadi, 2013).
- The actual process of the accidents and the contributing factors are often not known. Without information about the process preceding the accident it is very difficult to understand the link between (contributing) behaviour and accident and thus limits the possibilities to propose effective counter-measures in order to change/reduce this behaviour.

The surrogate safety methods are based on observation of the events in traffic which are not accidents, but have certain similarities and thus can be used to complement and, ultimately, substitute retrospective “observation” of accidents. The basic concept can be illustrated with the “safety pyramid” shown in Figure 4 (Hydén, 1987). Considering the traffic process consisting of elementary events, the base of the pyramid represents the undisturbed passages which of course are very safe and occur most of the time. At the other end, the very top of the pyramid represents the most severe events such as fatal or injury accidents and that are very infrequent compared to the total number of the events. If the form of the relation between the severity and frequency of the events is known, it is theoretically possible to calculate the frequency of the very severe but infrequent events (accidents) based on known frequency of the less severe, but more easily observable events.

![Safety pyramid](https://example.com/safety_pyramid.png)

Figure 4. “Safety pyramid” (adopted from Hydén, 1987).

The concept of severity of an event requires clarification. Most traffic conflict indicators express the severity as proximity to a collision in terms of time or space (Zheng et al., 2014b). The most common indicators of these type are Time-to-Collision (TTC, Hayward, 1971), Post-Encroachment Time (PET, Allen et al., 1978) and deceleration-based indicators (Bagdadi & Várhegyi, 2011, af Wåhlberg, 2004, Nygård, 1999, Hupfer, 1997). The potential consequences in case a collision had taken place is another dimension of severity that should preferably be taken into account in some way as well (Laureshyn, 2010). Following the goals set by Vision Zero in road safety – “no one will be killed or seriously injured within the road transport system” (Johansson, 2009) – an appropriate definition for the severity can be “a nearness to a serious personal injury” (Laureshyn et al., 2017). The potential consequences of an event are dependent on the type of road users involved and their vulnerability, speed, mass, type of collision, collision angle, etc. Some of the original traffic conflict techniques attempt to combine these two severity dimensions by having some subjective score set by an observer. Recently, some objective indicators have been proposed with the same purpose (Laureshyn et al., 2017, Alhajyaseen, 2015, Bagdadi, 2013).

The two very important properties of a surrogate safety indicator are its reliability and validity. Reliability refers to the ability to take measurements with the same accuracy regardless the location, traffic conditions, etc., thus a guarantee that the difference in measured results are due to difference in safety and not the instrument performance. If, for
example, a subjective score set by an observer is used, one can question whether the observer is really objective or is influenced by fatigue, weather or other conditions. It is, therefore, preferable to use some objective indicators based on speed, position, etc. for which the accuracy can be controlled if in doubt.

The validity refers to whether the indicator used really reflects the quality of interest, in our case road safety. It has been suggested a great variety of the indicators that potentially might be used as surrogates for safety. Unfortunately, only very few of them have ever been tested for relation with the actual accidents (Laureshyn et al., 2016). Several theoretical approaches to describe the relation between surrogate events and the accidents have been suggested:

- Estimated conversion coefficients that can be used to get a number of expected accidents based on the number of observed surrogate events (Hydén, 1987, Hauer & Gärder, 1986). It became clear quite early that the conversion coefficients differ depending on the type of road users involved and their manoeuvres. Also, the conflicts of different severity might have different conversion factors to accidents. In practice, however, due to limited numbers of both conflicts and accidents available, the researchers had to limit the disaggregation level to only few categories.

- Statistical methods based on extreme value theory (Zheng et al., 2014a, Tarko, 2012, Songchitraksa & Tarko, 2006). The basic idea of this approach is reconstruction of the probability distribution based on long-term observations of a certain parameter within “normal” range of performance that is later used to estimate the probability the parameter reaching a very “abnormal” (extreme) value. If, for example, the severity is measured with a Post-Encroachment Time indicator (time gap between one road user leaving and the other entering the conflict zone), situations with PET reaching 0 or below would mean a collision. The main concern of this approach is whether there is really a continuity between “normal” traffic and critical events like traffic conflicts and accidents (Campbell et al., 1996).

- Causal model (Davis et al., 2011). In this approach, the relation of initial conditions, possible evasive actions and their outcomes are described with a set of probabilistic equations and causal connections. Thus, for each set of initial conditions a probability of it to become a collision is estimated, and if aggregated, a total number of collision can be calculated. While very plausible theoretically, this approach is difficult to implement for complex conditions as many assumptions on road user behaviour has to be made.

The ability of a surrogate measure to estimate the expected accident frequency (so called “product validity”) is a very desirable property. However, even if this is not possible, the surrogate measure still might provide a useful information. The “relative validity” refers to the ability of a safety measure to indicate the direction of change in safety (but not the absolute values of such change). The “process validity” refers to similarities in the development and contributing factors between accidents and situations selected by the surrogate safety measure. This aspect becomes particularly important in a view of lacking details in accident records.

Emerging technologies for surrogate safety studies

One of the main drawbacks of the traditional traffic conflict techniques was their high dependence on a human observer performing the data collection. Issues like loss of attention during an observation time and subjectivity in judgements have always been the objects for critic. The labour-intensity and related high costs were also a considerable hinder to the wider adoption of such methods by practitioners.

However, lately some technical tools have been developed to aid in more efficient and objective data collection. Such tools can be classified as:

- Semi-automated tools for analysis of traffic videos (T-Analyst, 2016, Archer, 2005, Andersson, 2000). Such tools allow the operator manually process the situations of interest, measure some safety-related indicators and store them in a systematic way. While still requiring significant labour investments, such tools mitigate the problem of subjectivity in judging the severity as potentially they can provide very high accuracy of position and speed of road users with high temporal resolution;

- Fully-automated watch-dog tools (Madsen, 2016, Laureshyn et al., 2009). The primarily function of such tools is to detect situations that might be relevant and should be further examined by a human operator. Even very simple detection definitions like simultaneous arrival of two road users (not necessarily a conflict) significantly reduces the amount of video to be watched, under favourable conditions down to 10% of the original footage.

- Fully automated tracking systems (Sayed et al., 2012, Saunier et al., 2010). Such systems detect, classify and track road users in video and also calculate safety indicators based on the extracted trajectories. Even though a significant progress has been made within this area, the accuracy of detection and tracking still remains a problem, particularly when it comes to vulnerable road users that are smaller in size compared to cars and thus are more difficult to distinguish from the “noise” in the video data.

- Tracking systems based on other types of sensors and sensor fusion (Fu et al., 2017, Tarko et al., 2017, Gimm, 2014). The extension from one camera to multiple cameras and other types of sensors theoretically can improve accuracy of detection and tracking of the road users and also make the system performance more stable.
in various light and meteorological conditions. However, the cost of additional equipment and work necessary for fine-tuning of the sensors for joint use have to be further reduced in order to be feasible for traffic practitioners.

A factor that might seriously complicated the video data collection process is the rules for data protection and personal integrity. Many of the European countries have strict legislations regulating the use of video recording equipment in public places and obtaining the necessary permissions might be another hindering factor.

Discussion and Conclusions

As the road safety work in the West-European countries yields its results in form of greatly decreased road accident figures, it becomes more and more difficult to actually measure the progress and evaluate the safety interventions. It is also clear, that the fatality and injury figures that still remain will be more difficult to tackle and more knowledge about the accident causation factors and the process of accident development is necessary.

In the East-European countries, the accident numbers are still high and methods like “black spot analysis” are still in much use. However, though with some lag, the same trend of road safety improvements as in the Western countries can be seen. In case of Lithuania, the road traffic fatalities went down to a half since the year 2006. It can be expected that in a short time the problem of “too few accidents” will manifest itself in this region, too, and to be able to continue keeping the positive trend in road safety improvements other methods for safety diagnostics and evaluation will be necessary.

Another important change taking place both in the West and in the East is the increasing share of trips done by “green” transport modes like walking or cycling. These modes are also known as “vulnerable” in road safety as even minor collision with a motor vehicle may result in injuries. However, these accidents are much under-reported and the situation does not seem to improve in the near future.

We see the possible solution in the introduction of the surrogate safety measures into the daily practice in Lithuania and other East-European countries. A significant bulk of theory has already been developed and there are also practical tools available for applying this method in an efficient way. On the other hand, the situation when “there are still many accidents” in Eastern-Europe can be beneficial for the further development of the method as the validation and calibration of the surrogate measures against the actual accidents are much easier to perform.

There are still, however, some issues that require further attentions of the researchers:

- Revision and possible modifications of the available surrogate safety measures with regard to vulnerable road users (higher risk for an injury, other pre-conditions for evasive actions compared to motor traffic);
- Further validation of the surrogate indicators in a view of rapidly changing traffic conditions, safer cars, traffic culture and attitudes (e.g. higher expectancy of drivers to meet or share road with cyclists, etc.);
- Extension of the method to reflect the risk of single accidents, particularly pedestrian and cyclist falls which contribute a very high share to the total number of traffic injuries;
- Further enhancement of the technical tools to minimise the manual work and ensure the quality of the data produced.

References


