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PERSPECTIVES FOR SURROGATE SAFETY STUDIES IN EAST-EUROPEAN COUNTRIES

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Abstract. The road 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 police or hospital reports. The surrogate safety methods are based on observation of other-than-accident occurrences that still have a strong relation to safety in traffic. Such methods are often more efficient (and pro-active) for safety assessments. The paper reviews the current status of the surrogate safety analysis methods, the challenges, and opportunities related to modern urban traffic conditions and the emerging technologies for more efficient data collection. The method is put in the context of the East-European countries to see how it contribute to the on-going road safety work and a better understanding of accidents risk factors necessary for producing effective safety counter-measures.

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

1. Introduction

Traditionally, road safety is measured by a number of accidents or injuries that have occurred. 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 (Tarko *et al.* 2009; Zheng *et al.* 2014b). While on the national level there are still some benefits to attain 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 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 the safety and to get a prompt feedback on the introduction of safety interventions. There is a significant number of such measures suggested, even though only a few of them are properly validated to make sure they describe the 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 the "*golden era*" for the traffic conflict techniques when nearly every each country developed its technique (Asmussen 1984; Grayson 1984). The last decade has been marked by renewed interest in the subject, particularly due to the rapid development of the technologies like automated video analysis that 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 also been known (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. This paper examines state of the art within surrogate safety methods and how they can be introduced in the East-European countries.

2. The trends of road safety development – Eastern and Western Europe

During the last decades, the road safety situation has improved greatly in most of the European countries (Fig. 1).

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In the Western countries (particularly those having the best road safety performance like Sweden, Denmark, the Netherlands or the United Kingdom), the positive improvements started already in the 1970s, and for the moment the pace of improvements is relatively low. In Eastern European countries the improvements started 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 straightforward 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 required to keep improving the safety and further reduce the fatality and injury numbers.

Another interesting pattern to be noted is the composition of the road fatalities. It appears that improvements in safety for car occupants are more successful compared to the vulnerable road user categories (pedestrians, cyclists). Fig. 2 and 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.

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 knew for extensive use of bicycles as a transportation mode, appear to have cyclist fatality rates quite similar to Latvia or Estonia. It is common for all countries, though, that promotion of the "*green*" transportation modes like walking and cycling is on the agenda, and a further increase in the exposure (and potentially the absolute fatality numbers) are to be expected.

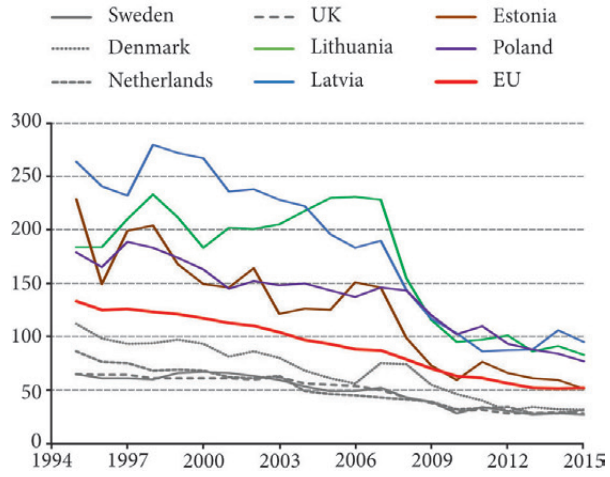

Fig. 1. Road fatalities per 1 million population according to the data of 2016 from the European Road Safety Observatory (ERSO 2016a)

3. Surrogates safety measures

The limitations of the accident data are summarised as follows:

– road accidents are random and the number of accidents registered during two equal time periods

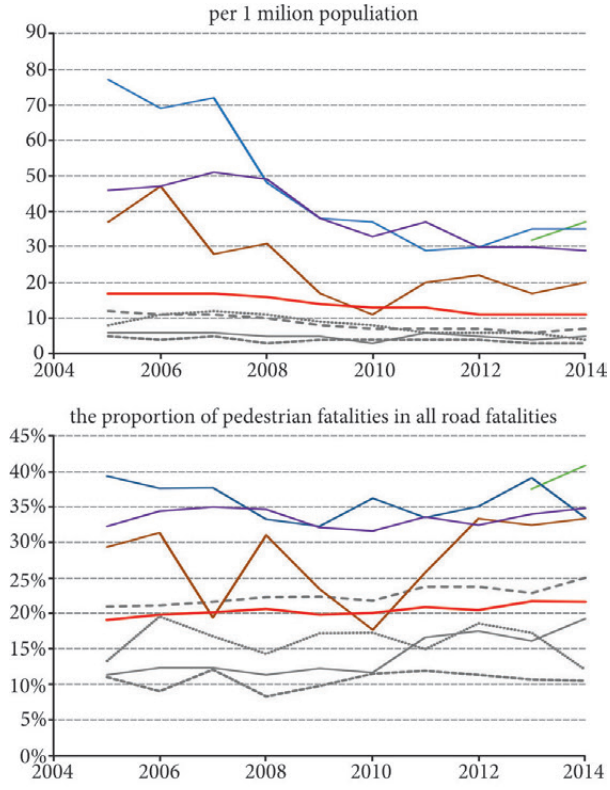

Fig. 2. Pedestrian fatalities according to the data of 2016 from the European Road Safety Observatory (ERSO 2016b)

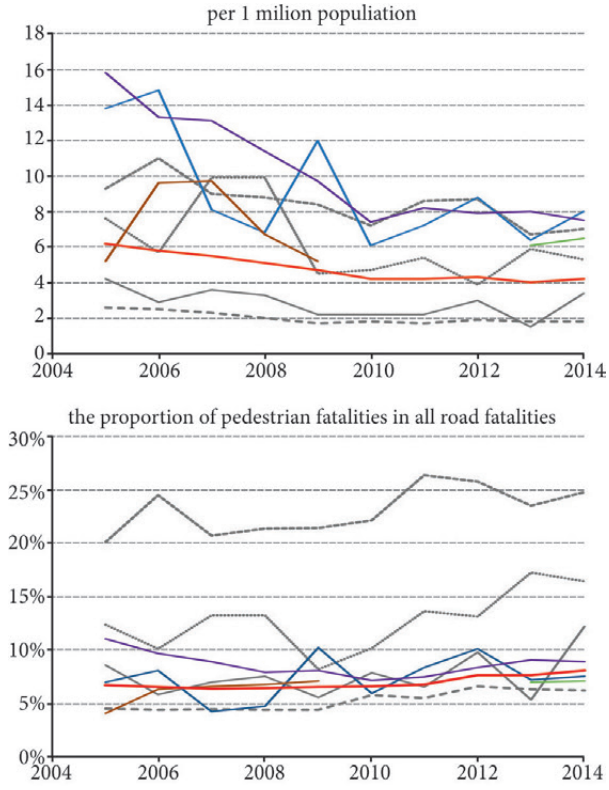

Fig. 3. Cyclist fatalities according to the data of 2016 from the European Road Safety Observatory (ERSO 2016c)

under equal conditions is not most often the same. The *true* safety characteristic is thus the *expected number of accidents* that not be measured but only estimated based on the accident history or using some other methods (Hauer 1997);
- road accidents are rare events, and it takes a long time to collect a sufficient amount of data to produce reliable estimates of the expected number of accidents. During this period 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 under-reporting depends on the accidents severity and types of road users involved. Under-reporting is particularly a problem for the vulnerable road users (Alsop, Langley 2001; Amoros *et al.* 2006; Berntman *et al.* 1995; Elvik *et al.* 2009);
- the actual process of the accidents and the contributing factors are often unknown. Without information about the process preceding the accident, it is hard to understand the link between (contributing) behaviour and accident and thus limits the possibilities to propose effective counter-measures to change/reduce this behaviour.

The surrogate safety methods are based on observation of the events in traffic that are not accidents, but have certain similarities and thus can be used to complement and, ultimately, substitute retrospective *observation* of accidents. The basic concept is illustrated with the *Safety Pyramid* shown in Fig 4 (Hydén 1987). Considering the traffic process consisting of elementary events, the base of the pyramid represents the undisturbed passages that 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, which 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 the known frequency of the less severe, but more easily observable events.

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 (af Wåhlberg 2004; Bagdadi, Várhelyi 2011; Hupfer 1997; Nygård 1999). The potential consequences in case a collision had taken place is another dimension of severity that should preferably be considered 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 " *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. 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 for the same purpose (Alhajyaseen 2015; Bagdadi 2013; Laureshyn *et al.* 2017).

The two very fundamental 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, thus a guarantee that the difference in measured results is due to the difference in safety and not the instrument performance. If for example, a subjective score set by an observer is used, the observer's objectivity can be questioned as it the attention is influenced by fatigue, weather or other conditions. It is, therefore, preferable to use some objective indicators based on speed and position, the accuracy of which can be controlled if in doubt.

The validity refers to whether the indicator used reflects the quality of interest, in our case the road safety. It has been suggested a great variety of the indicators that potentially can be used as surrogates for safety. Unfortunately, only very few of them have ever been tested for relation with the real registered accidents (Laureshyn *et al.* 2016).

Several theoretical approaches to describe the relation between surrogate events and the accidents have been suggested:
- estimated *Conversion Coefficients* used to get a number of expected accidents based on the number of observed surrogate events (Hauer, Gårder 1986; Hydén 1987). It became apperent quite early that the conversion coefficients differ depending on the type of road users involved and their manoeuvres. Also, the conflicts of different severity may have different conversion factors to accidents. In practice, however, due to limited numbers of both conflicts and accidents available, the researchers have to limit the disaggregation level to only a few categories;
- statistical methods based on *Extreme Value Theory* (Songchitruksa, Tarko 2006; Tarko 2012; Zheng *et al.* 2014a). The basic idea of this approach is a reconstruction of the probability distribution based on long-term observations of a certain parameter within "*normal*" range of performance, used later to estimate the probability the parameter reaching a very

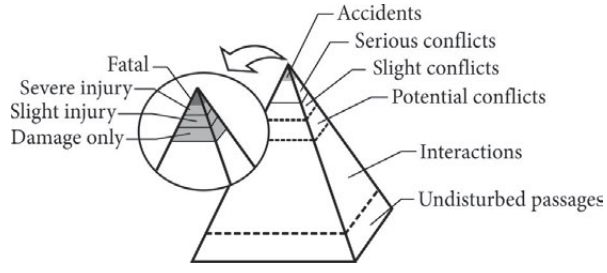

Fig 4. *Safety Pyramid*, adopted from Hydén (1987)

"*abnormal*" (extreme) value. If for example, the severity is measured with a Post-Encroachment Time (PET) indicator (time gap between one road user leaving and the other entering the conflict zone), situations with PET reaching zero or below would mean a collision. The main theoretical concern of this approach is whether there is a smooth 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 a set of initial conditions a probability of it to become a collision is estimated, and if aggregated, a total number of collision is 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 it is not possible, the surrogate measure still might provide 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 given lacking details in accident records.

4. 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 the observation time and subjectivity in judgements have always been the objects for the critic. The labour-intensity and related high costs were also a significant hinder t (T-Analyst 2016) 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 are classified as:
- semi-automated tools for analysis of traffic videos (Andersson 2000; Archer 2005; T-Analyst 2016). Such tools allow the operator manually process the situations of interest, measure some safety-related indicators and systematically store them. 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 (Laureshyn *et al.* 2009; Madsen 2016). The primary function of such tools is to detect situations that might be relevant and should be further examined by a human operator. Even very basic detection definitions like simultaneous arrival of two road users (i.e. 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 (Saunier *et al.* 2010; Sayed *et al.* 2012). Such systems detect, classify and track road users in video and calculate safety indicators based on the extracted trajectories. Even though significant progress has been made within this area, the accuracy of detection and tracking remains a problem, particularly when it comes to vulnerable road users who are smaller compared to cars and thus are harder to distinguish from the "*noise*" in the video data;
- tracking systems based on other types of sensors and sensor fusion (Fu *et al.* 2017; Gimm 2014; Tarko *et al.* 2017). The extension from one camera to multiple cameras and other types of sensors theoretically improves the accuracy of detection and tracking of the road users and 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 to be feasible for traffic practitioners.

A factor that seriously complicates 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 yet another hinder.

5. Conclusions

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

2. 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. The problem of "*too few accidents*" is expected to 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 are necessary.

3. 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 an 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 shortly.

4. The suggested solution is the introduction of the surrogate safety measures into the daily practice in East-European countries. A significant bulk of theory has already been developed, and there are also practical tools available for efficient application of this method. On the other hand, the situation when "*there are still many accidents*" in Eastern-Europe is beneficial for the further development of the method since the validation and calibration of the surrogate measures against the actual accidents are much easier to perform.

5. There are still, however, some issues that are requiring further attentions of the researchers:

- revision and possible modifications of the available surrogate safety measures with respect 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 given rapidly changing traffic conditions, safer cars, traffic culture and attitudes (e.g. higher expectancy of drivers to meet or share the road with cyclists);
- extension of the method to reflect the risk of single accidents, particularly pedestrian and cyclist falls that contribute a very high proportion of 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.

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References

af Wåhlberg, A. E. 2004. The Stability of Driver Acceleration Behavior, and a Replication of Its Relation to Bus Accidents, *Accident Analysis and Prevention* 36(1): 83–92. https://doi.org/10.1016/S0001-4575(02)00130-6

Alhajyaseen, W. K. M. 2015. The Integration of Conflict Probability and Severity for the Safety Assessment of Intersections, *Arabian Journal for Science and Engineering* 40(2): 421–430. https://doi.org/10.1007/s13369-014-1553-1

Allen, B. L.; Shin, B. T.; Cooper, P. J. 1978. Analysis of Traffic Conflicts and Collisions, *Transportation Research Record* 667: 67–74.

Alsop, J.; Langley, J. 2001. Under-Reporting of Motor Vehicle Traffic Crash Victims in New Zealand, *Accident Analysis and Prevention* 33(3): 353–359. https://doi.org/10.1016/S0001-4575(00)00049-X

Amoros, E.; Martin, J. L.; Laumon, B. 2006. Under-Reporting of Road Crash Casualties in France, *Accident Analysis and Prevention* 38(4): 627–635. https://doi.org/10.1016/j.aap.2005.11.006

Andersson, J. 2000. *Image Processing for Analysis of Road User Behaviour – a Trajectory Based Solution*. PhD Thesis. Lund Institute of Technology, Dept of Technology and Society, Traffic Engineering. 84.

Antov, D. 1986. The Use of Traffic Conflicts Technique on Urban non Signalised Intersections, in *Workshop on Traffic Conflicts and Other Intermediate Measures*, 8–10 September 1986, Budapest, Hungary.

Archer, J. 2005. Indicators for Traffic Safety Assessment and Prediction and Their Application in Micro-Simulation Modelling: a Study of Urban and Suburban Intersections. PhD Thesis. Dept of Infrastructure, Royal Institute of Technology, Stockholm. 254.

Asmussen, E. 1984. *International Calibration Study of Traffic Conflict Techniques*, vol. 5. Springer Science and Business Media. https://doi.org/10.1007/978-3-642-82109-7

Bagdadi, O. 2013. Estimation of the Severity of Safety Critical Events, *Accident Analysis and Prevention* 50: 167–174. https://doi.org/10.1016/j.aap.2012.04.007

Bagdadi, O.; Várhelyi, A. 2011. Jerky Driving – an Indicator for Accident Proneness, *Accident Analysis and Prevention* 43(4): 1359–1363. https://doi.org/10.1016/j.aap.2011.02.009

Berntman, M.; Berntman, L.; Nilsson, S. A. 1995. *Trafiksäkerhetsproblemen i Lunds kommun: sjukhusets och polisens skadestatistik*. 1988-10–1993-09. Bulletin vägbyggnad. Dept of Technology and Society, Lund University, Sweden. (in Swedish)

Campbell, K. L.; Joksch, H. C.; Green, P. E. 1996. *A Bridging Analysis for Estimating the Benefits of Active Safety Technologies*. The University of Michigan, Transportation Research Institute, Michigan, USA.

Davis, G. A.; Hourdos, J.; Xiong, H.; Chatterjee, I. 2011. Outline for a Causal Model of Traffic Conflicts and Crashes, *Accident Analysis and Prevention* 43(6): 1907–1919. https://doi.org/10.1016/j.aap.2011.05.001

Elvik, R.; Høye, A.; Vaa, T.; Sørensen, M. 2009. *The Handbook of Road Safety Measures*. Emerald Group Publishing Limited, Bingly, UK. https://doi.org/10.1108/9781848552517

ERSO 2016a. Traffic Safety Basic Facts 2016: Cyclists. European Road Safety Observatory.

ERSO 2016b. Traffic Safety Basic Facts 2016: Main Figures. European Road Safety Observatory.

ERSO 2016c. Traffic Safety Basic Facts 2016: Pedestrians. European Road Safety Observatory.

Fu, T.; Stipancic, J.; Zangenehpour, S.; Miranda-Moreno, L. F.; Saunier, N. 2017. Automatic Traffic Data Collection under Varying Lighting and Temperature Conditions in Multimodal Environments: Thermal versus Visible Spectrum Video-based Systems, *Journal of Advanced Transportation* 2017 (Article ID 5142732). https://doi.org/10.1155/2017/5142732

Gimm, K. 2014. AIM Research Intersection –Infrastructure for Research on Interacting Urban Traffic, *27th ICTCT Workshop*, 16–17 October 2014, Maribor, Slovenia.

Grayson, G. B. 1984. *The Malmö Study: a Calibration of Traffic Conflict Techniques*. Institute for Traffic Safety Research SWOV.

Hauer, E. 1997. Observational before-after Studies in Road Safety. Pergamon. ISBN 9780080430539

Hauer, E., Gårder, P. 1986. Research into the Validity of the Traffic Conflict Technique, *Accident Analysis and Prevention* 18(6): 471–481. https://doi.org/10.1016/0001-4575(86)90020-5

Hayward, J. C. 1971. *Near Misses as a Measure of Safety at Urban Intersections*. Master Degree Thesis. Dept of Civil Engineering, The Pennsylvania State University, Pennsylvania Transportation and Traffic Safety Center, USA.

Hupfer, C. 1997. Deceleration to Safety Time (DST) – a Useful Figure to Evaluate Traffic Safety? in *ICTCT Conference Proceedings of Seminar* vol. 3. 5–7 November 1997, Lund, Sweden.

Hydén, C. 1987. The Development of a Method for Traffic Safety Evaluation: the Swedish Traffic Conflict Technique. PhD Thesis. Dept of Traffic Planning and Engineering, Lund University. 57 p.

Johansson, R. 2009. Vision Zero – Implementing a Policy for Traffic Safety, *Safety Science* 47(6): 826–831. https://doi.org/10.1016/j.ssci.2008.10.023

Laureshyn, A. 2010. Application of Automated Video Analysis to Road User Behaviour. PhD Thesis. Transport and Roads, Dept of Technology and Society, Faculty of Engineering, LTH, Lund University. 202.

Laureshyn, A.; Ardö, H.; Jonsson, T.; Svensson, Å. 2009. Application of Automated Video Analysis for Behavioural Studies: Concept and Experience, *IET Intelligent Transport Systems* 3(3): 345–357. https://doi.org/10.1049/iet-its.2008.0077

Laureshyn, A.; De Ceunynck, T.; Karlsson, C.; Svensson, Å.; Daniels, S. 2017. In Search of the Severity Dimension of Traffic Events: Extended Delta-V as a Traffic Conflict Indicator, *Accident Analysis and Prevention* 98: 46–56. https://doi.org/10.1016/j.aap.2016.09.026

Laureshyn, A.; Johnsson, C.; De Ceunynck, T.; Svensson, Å.; de Goede, M.; Saunier, N.; Włodarek, P.; van der Horst, A. R. A.; Daniels, S. 2016. *Review of Current Study Methods for VRU Safety. Appendix 6 – Scoping Review: Surrogate Measures of Safety in Site-Based Road Traffic Observations*. Deliverable 2.1 – Part 4. InDeV, Horizon 2020 project.

Madsen, T. K. O. 2016. RUBA – Video Analysis Software for Road User Behaviour Analysis, in *29th ICTCT Workshop*, 20–21 October 2016, Lund, Sweden.

Nygård, M. 1999. *A Method for Analysing Traffic Safety with Help of Speed Profiles*. Master Degree Thesis. Dept of Civil Engineering, Tampere University of Technology, Tampere, Finland.

Perkins, S. R.; Harris, J. I. 1967. *Criteria for Traffic Conflict Characteristics: Signalized Intersections*. Research Laboratories, General Motors Corporation.

Saunier, N.; Sayed, T.; Ismail, K. 2010. Large Scale Automated Analysis of Vehicle Interactions and Collisions, *Transportation Research Record* 2147: 42–50. https://doi.org/10.3141/2147-06

Sayed, T.; Ismail, K.; Zaki, M. H.; Autey, J. 2012. Feasibility of Computer Vision-Based Safety Evaluations: Case Study of a Signalized Right-Turn Safety Treatment, *Transportation Research Record* 2280: 18–27. https://doi.org/10.3141/2280-03

Songchitruksa, P.; Tarko, A. 2006. The Extreme Value Theory Approach to Safety Estimation, *Accident Analysis and Prevention* 38(4): 811–822. https://doi.org/10.1016/j.aap.2006.02.003

Tarko, A.; Davis, G.; Saunier, N.; Sayed, T.; Washington, S. 2009. *Surrogate Measures of Safety*. White Paper, ANB20 (3) Sub-Committee on Surrogate Measures of Safety.

Tarko, A. P. 2012. Use of Crash Surrogates and Exceedance Statistics to Estimate Road Safety, *Accident Analysis and Prevention* 45: 230–240. https://doi.org/10.1016/j.aap.2011.07.008

Tarko, A. P.; Romero, M. A.; Bandaru, V. K.; Ariyur, K. B.; Lizarazo, C. G. 2017. Feasibility of Tracking Vehicles at Intersections with a Low-End LiDAR, in *Proc. of the 96th TRB Annual Meeting*, 8–12 January 2017, Washington D.C., USA.

T-Analyst. 2016. Software for Semi-Automated Video Processing. Available from the Internet: www.tft.lth.se/software

Zheng, L.; Ismail, K.; Meng, X. 2014a. Freeway Safety Estimation Using Extreme Value Theory Approaches: a Comparative Study, *Accident Analysis and Prevention* 62: 32–41. https://doi.org/10.1016/j.aap.2013.09.006

Zheng, L., Ismail, K.; Meng, X. 2014b. Traffic Conflict Techniques for Road Safety Analysis: Open Questions and Some Insights, *Canadian Journal of Civil Engineering* 41(7): 633–641. https://doi.org/10.1139/cjce-2013-0558

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