A methodology for the network-wide, in-built safety assessment of roads

Anastasios Dragomanovitsa, Aikaterini Deliali*, Antonino Tripodib, Paola Tiberib, Edoardo Mazziab, Marko Sevrovicc, Leonid Ljubotinac, and George Yannis\textsuperscript{a}

\textsuperscript{a}National Technical University of Athens, 5 Iroon Polytechniou str., Athens, 15773, Greece
\textsuperscript{b}FRED Engineering, 15 Via Celimontana, 00184, Rome, Italy,
\textsuperscript{c}University of Zagreb, 4 Vukeličeva str., Zagreb, 10000, Croatia

Abstract

1. Overview and motivation
Safe road infrastructure for all users is one of the pillars of the Safe System. Traditionally the safety assessment of roads has been based on the analysis of historic crash data however, this approach has several limitations, such as erroneous or unavailable crash records. Moreover, crash data may spread across a network instead of forming clusters and in this case, larger parts of the network need to be examined for countermeasures. At the same time, crashes are not always a good proxy of road infrastructure safety as factors such as human behaviour, safety culture, presence of enforcement, vehicle characteristics (e.g., percentage of heavy vehicles, vehicle age, etc.) affect crash occurrence and severity. Lastly, the analysis of crashes is a reactive approach in the sense that (unwanted) events take place and trigger correcting actions/measures so that similar events will not take place in the future.

There are several proactive approaches and methodologies that examine the in-built safety of roads, meaning that they consider road design and operational characteristics, such as the presence of medians, the roadside environment, the speed limits, etc., to determine the safety levels of roads. Existing proactive methodologies can be divided in those for the site-level and those for the network-level. Road Safety Audits (RSA) and Road Safety Inspections (RSI) are applied for site-level assessments and are not applicable for long sections as the time and cost of completing the assessment would be very high. Applied methodologies for the network-level include the AASHTO Highway Safety Manual Predictive method (AASHTO, 2010; 2014) and other crash prediction models (e.g., PRACT models), the iRAP Star Rating Protocol (iRAP Star Ratings), and a several locally developed and applied methodologies such as the New Zealand Risk Assessment method (Brondie et al., 2009) or the British Columbia (de Leur & Hill, 2015). Crash prediction models are reliable tools for predicting crashes, but they are not widely used as it is hard to develop and use them. iRAP Star Rating Protocol is more user-friendly compared to crash prediction models but it relies on many parameters and an overall detailed data collection process. The other existing proactive methodologies have not been tested in terms of transferability and generalizability.

Network-level (or network-wide) safety assessment allows for a better understanding of safety deficiencies and in turn can better guide the funding allocation for countermeasures. A network-wide in-built safety assessment methodology should achieve a good balance between validity and reliability on the one hand and data needs and cost of implementation on the other hand. This balance is critical for the methodology’s adoption by practitioners. This research aims to develop a network-wide, in-built safety assessment methodology for motorways and rural roads. A set of design and operation characteristics will be examined to determine the safety level of a road section.

2. Methodology, results and main contributions
For developing a network-wide, in-built safety assessment methodology it is critical to determine (1) a set of parameters that refer to road design and operational characteristics and the assessment will be based on these and

* Corresponding author: Aikaterini Deliali, kdeliali@mail.ntua.gr
(2) a relationship linking those parameters to crash risk. A detailed review of the existing literature focused on manuals and guidelines, project reports, scientific papers and conference proceedings identified an initial set of road design and operational characteristics that are commonly used for the assessment of roads. Let us refer to this initial set of parameters as “Set A”. Set A included 76 parameters that describe cross-sectional characteristics (e.g., number of lanes, lane width), roadside characteristics (e.g., presence and width of clear zone, presence of obstacles), presence of restraint systems (e.g., median), speed limit and operational speed, presence and quality of markings and signs, intersection/interchange characteristics (e.g., number of legs), facilities for pedestrians and bicyclists (e.g., presence of cycle paths), and incident warning systems (e.g., variable message signs).

A second review of the literature targeted the identification of relationships (if available) between the above parameters (Set A) and crash risk. The objective was to identify appropriate Crash Modification Factors (CMFs) for each parameter to quantify its safety effect. For some parameters there was no CMFs or the existing one where contradicting, i.e., some CMFs indicated an increase in crashes while others a decrease in crashes. In both cases, the parameters were excluded. Studies that analysed property-damage (PDO) crashes only were excluded as well. Through the available literature, reliable and reasonable relationships, namely crash reduction factors (RF), were identified for a subset of the parameters of Set A. Finally, 8 parameters will be used for the assessment of motorways and 11 parameters will be used for the assessment of primary rural roads. Data for the proposed parameters can be easily obtained from sources such as road authorities’ databases or mapping tools.

A RF is greater than zero and lower or equal to one. RFs equal to one indicate safe conditions. It is considered that the safety level of the section \( i \) can be determined by the relationship: \( \text{Score}_i = 100 \times \text{RF}_{1i} \times \text{RF}_{2i} \times ... \times \text{RF}_{ni} \), where \( n \) is the number of parameters and so, the number of the reduction factors. Similar mathematical forms, i.e., combined effects of all factors assuming multiplicative relationships, exist in other proactive methodologies (AASHTO, 2010; Brondie et al., 2009).

Pilot studies have been conducted on small parts of Greek motorways and rural roads to test the developed methodology. The next step is to validate the methodology using crash data from various motorways and rural roads across Europe. Essentially, there should be an agreement between the proposed methodology outcome and crash data distribution across a network. Sections found as safe, due to their low score, should have less crashes compared to sections found as unsafe. This work contributes to road safety by allowing for proactive assessments and also has the potential to improve road safety funding allocation.

3. Conclusion and future works

This research develops an in-built safety assessment methodology for motorways and rural roads. The proposed methodology enables a proactive, network-wide approach for the assessment of safety. This is appropriate and useful for road authorities for road networks that have unreliable or limited crash records. The proposed methodology has been developed with the objective to balance (a) data needs and implementation costs so that road authorities can easily use it and (b) validity and reliability so that it produces valid outcome. Future work should develop a framework for effectively and consistently collecting road data for the proposed safety assessment.

References
4. iRAP Star Ratings. Available at: https://irap.org/rap-tools/infrastructure-ratings/star-ratings/

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