Available online at www.sciencedirect.com
ScienceDirect
Transportation Research Procedia 14 (2016) 4257 – 4266
Transportation Research Procedia
www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Use of accident prediction models in road safety management – an international inquiry

George Yannis [a,*], Anastasios Dragomanovits [a], Alexandra Laiou [a], Thomas Richter [b],
Stephan Ruhl [b], Francesca La Torre [c], Lorenzo Domenichini [c],
Daniel Graham [d], Niovi Karathodorou [d], Haojie Li [d]

[a]*National Technical University of Athens, 5, Heroon Polytechniou st., 15773, Athens, Greece*
[b]*Technische Universität, Berlin, Gustav-Meyer-Allee 25, 13355, Berlin, Germany*
[c]*University of Florence, Via S. Marta, 3, 50139, Firenze, Italy*
[d]*Imperial College London, SW7 2AZ, London, United Kingdom*

Abstract

Evaluation of road safety measures appears to be the weakest component of road safety management systems in Europe. To improve Road Infrastructure Safety Management, road authorities, road designers and road safety practitioners need prediction tools, commonly known as Accident Prediction Models (APMs), allowing them to analyze the potential safety issues, to identify safety improvements and to estimate the potential effect of these improvements in terms of crash reduction. Within the above context, the objective of this paper is to present a synthesis of current practices in APMs based on both the results of a relevant survey and an extensive literature review conducted within the PRACT project. In order to present a complete overview of currently used Accident Prediction Models (APMs) by different National Road Administrations (NRAs) in Europe and worldwide, as well as the currently used data sources for the development and application of APMs a relevant survey was completed. A questionnaire was specially designed and dispatched to several NRAs in Europe and worldwide, in order to collect detailed information on APMs developed and used by them. Furthermore, a review of relevant international literature was carried out, with focus particularly on identifying those modelling approaches and specific models that may be applicable or transferable in the European context. On the basis of the questionnaire data and of the literature review results, a synthesis of current practices regarding APMs has been developed, as a basis for the identification of the most usable models as well as for the implementation of a web based APM repository. In total, 23 questionnaires were collected from 18 European countries, USA and Australia, and

---

* Corresponding author. Tel.:+ 30-210-772-1326; fax: +30-210-772-1454.
E-mail address: geyannis@central.ntua.gr

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.397

were analysed with the aim of reviewing and assessing existing APMs, in terms of theoretical approaches, characteristics of the models in use, implementation conditions, data requirements and available results, with focus on motorways and higher ranked rural roads. It was found that, despite recent advances, most National Road Administrations (NRAs) and other organisations do not systematically use such methods during decision making for the implementation of road safety treatments.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: road infrastructure; safety measures assessment; Accident Prediction Model (APM); Crash Modification Factors (CMF)

1. Introduction

Evaluation of road safety measures appears to be the weakest component of road safety management systems in Europe. Only in few countries the evaluation of road safety measures is part of the culture and a routine activity within the road safety programme, with a dedicated budget. Where this is in place the evaluation is usually limited to infrastructure and enforcement measures while the evaluation of entire road safety programmes is even more rare.

To improve Road Infrastructure Safety Management, road authorities, designers and road safety practitioners need prediction tools, commonly known as Accident Prediction Models (APMs), allowing them to analyze potential safety issues, identify safety improvements and estimate the potential safety effects of these improvements.

Within this framework, the project PRACT (Predicting Road ACcidents – a Transferable methodology across Europe) was funded by the National Road Authorities of Germany, Ireland, UK and Netherlands within the Conference of European Directors of Roads (CEDR) 2013 Transnational Research Programme – Safety. The research partners of the PRACT project are Università degli Studi di Firenze (Project Leader), National Technical University of Athens, Technische Universität Berlin and Imperial College London. The project aims at developing a European accident prediction model (APM) structure that could be applied to different European road networks with proper calibration.

The objective of this paper is to present an extensive literature review and a questionnaire survey among NRAs and researchers worldwide, both conducted to define the current state of the art, the current practices for road safety assessment within National Road Authorities (NRAs) and in research organizations as well as to identify the data availability for developing and calibrating reliable accident prediction models. The paper continues with an analysis and discussion of relevant findings and concludes by providing useful remarks on current situation in accident prediction and highlighting next steps of the PRACT project and of pertinent research in general.

2. Literature review

2.1. Highway Safety Manual and HSM related literature

Probably the most important publication in accident prediction research is the Highway Safety Manual (AASHTO, 2010; AASHTO, 2014). Besides providing key information for integrating safety analysis to highway planning, design, and operation and suggesting steps to monitor and reduce crash frequency and severity, the HSM includes a predictive method for estimating the expected average crash frequency (by total crashes, crash severity or collision type) of a network, facility or individual site.

The estimate relies upon models developed from observed crash data for a number of individual sites. Different regression models, called base Safety Performance Functions (SPFs) have been developed for specific facility types and “base conditions”, that are the specific geometric design and traffic control features of a “base” site. SPFs are typically a function of only a few variables, primarily average annual daily traffic (AADT) volumes and segment length. SPFs in the HSM have been developed through statistical multiple regression techniques using historic crash data collected over a number of years at sites with similar characteristics and covering a wide range of AADTs.

Adjustment to the prediction made by a SPF is required to account for geometric design or traffic control differences between the base conditions of the model and local conditions of the considered site. For this, Crash Modification Factors (CMFs) are used. Finally, a Calibration Factor (C) is used to account for differences between the road network for which the models were developed and the one for which the predictive method is applied.

The HSM is complemented by several reports and guides that provide guidance on the implementation of the relevant methods and procedures. In FHWA (2013a), guidance is provided on whether an agency should calibrate the safety performance functions from the HSM or develop jurisdiction-specific SPFs. Another guidebook (FHWA, 2013b), provides guidance on the statistical issues for developing SPFs and in NCHRP (2014) further guidance is provided on the calibration of HSM's Safety Performance Functions to local and current conditions.

Furthermore, a large number of CMFs are included in the HSM, for several types of roadway facilities, including freeways, speed change lanes, ramp terminals, two-way roads and at-grade intersections. Further guidance on CMFs is available through a series of complementary guides: in NCHRP (2012), guidance is provided for the development and documentation of research studies that develop CMFs, in order to attain high marks of quality during the review process to be included in the Highway Safety Manual, and in Gross et al. (2010) the process for selecting an appropriate CMF development methodology and the many issues and data considerations related to various methodologies are discussed. Additionally, in Gross & Hamidi (2011), several issues associated with the application of multiple CMFs are discussed and guidance on how to estimate the combined treatment effect when multiple treatments are installed at a given location is provided. All of the above studies and complementary guides enhance the practical applicability of the predictive methodology of the Highway Safety Manual, thus making it a very valuable tool for the road safety practitioners.

As far as the transferability of the HSM predictive method is concerned, researchers have examined the issue of effectively implementing it to conditions different from the ones for which it was developed, and properly adjusting and calibrating the various parameters and functions. Martinelli et al (2009) applied the HSM two-lane two-way rural roads segment model calibration procedure to the Arezzo province road network in Italy, in order to evaluate the effective transferability of the HSM model. By analyzing actual versus predicted accidents and residual plots, they came to the conclusion that the best approach is the base model with CMF calculation, applied to the stratified classes defined by the HSM procedure but with the calibration coefficient calculated not as a simple mean of each class coefficient but using a weighted average based on the total length of the sections in each class. La Torre et al (2014) also examined the transferability of the HSM freeway model to the Italian motorway network. Using four indicators (mean absolute deviation, calibrated overdispersion parameter, root means square error, and residual plots) to assess the performance of the calibrated models, the researchers came into the conclusion that the models show a good transferability to the Italian network especially for fatal and injury crashes. Some improvements could be made considering variable calibration factors within the datasets or crash modification factors local calibrations.

2.2. Development of Accident Prediction Models

Besides the AASHTO Highway Safety Manual, several other references exist in pertinent literature dealing with the development of Accident Prediction Models. An important initiative took place within the RIPCORD-iSEREST research project, which aimed at developing best practice guidelines for several road safety tools, including Accident Prediction Models for two-lane two-way rural roads. Within the project, a state-of the-art report (RIPCORD 2005) was developed, in which already existing APMs were discussed, regarding the choice of explanatory variables, the choice of model form and modelling process, residuals, explained variation, interpretation, predictive performance and sources of error. The general form of APM proposed according to the state-of-the-art study was the Generalised Linear Model (GLM) using a Poisson or a Negative Binomial Distribution. Furthermore, in the report, a set of criteria for assessing the quality of accident prediction models is proposed, that could be further developed into a quality scoring system.

As a next step, pilot studies on developing Accident Prediction Models for Austria, Portugal and the Netherlands were undertaken (RIPCORD 2007). The models were developed according to the Generalised Linear Model (GLM) using a Negative Binomial Distribution. From the pilot studies it became clear that the availability of detailed and good quality data is an important issue to be considered when developing APMs. If such data are not available, only a few explanatory variables can be incorporated in the models, resulting in predictions of limited accuracy.

Furthermore, a Safety Performance Function was developed for the analysis of two-lane two-ways rural roads (RIPCORD 2008), based on a three-year period (2003–2005) of accidents on the rural road network of Saxony, Germany, with a total length of 500Km. The development of the SPFs was based on the investigation and evaluation of selected accident types which are connected to the alignment of roads. The geometric parameters included in the models were curvature change rate for sections with similar alignment and curve radii as well as speed difference for transitions. Furthermore, road width, traffic volume and accident types were taken into account.

Expanding the knowledge gained by RiPCORD-iSEREST project, the RISMET research project also dealt with accident prediction. In RISMET (2011a), several accident prediction models in rural junctions were developed based on data from four European countries: Norway, Austria, Portugal and the Netherlands. Six combinations of the available data were analyzed and for each combination, three different statistical methods were applied for the model development (Poisson regression model, Poisson-Gamma hierarchical regression model and Poisson Log--Normal regression model). The developed models were assessed with methodologies such as Gelman-Rubin diagnostics (for convergence assessment), and deviance information criterion, effective model dimension, and posterior predictive checking (for model assessment).

Furthermore, in RISMET (2011b), an accident prediction model for rural road segments was developed based on data from the road network of the German federal state Brandenburg, with a Poisson regression statistical approach. The developed model was later evaluated on a 42 km long stretch of the Portuguese road IP 04 and significant differences were found between the number of accidents predicted by the model and the real accident occurrence (predicted accidents being too low). This, attributed by the researchers to a number of reasons, highlights the necessity of calibrating APMs in order to take into account local (national) conditions in terms of accident structure, driving behaviour and standard of design.

In New Zealand APMs were developed for two-lane rural roads (Turner et al. 2012), using Generalised Linear Model (GLM) approach for key crash types including head-on, loss-of-control and driveway related crashes. The models quantify the safety impact of key road features, such as: traffic flow (AADT), segment length, minimum radius of curvature, average gradient, seal width, SCRIM coefficient, mean texture depth, region, KiwiRAP roadside hazard rating, approaching vehicle speed, traffic on driveways.

Using data from interchange influence areas on urban freeways in the state of Florida, US, Haleem et al (2013) applied an interesting SPF development procedure regarding the effect of changes in median width and inside and outside shoulder widths. The study applied a promising data mining method known as Multivariate Adaptive Regression Splines (MARS).

Caliendo et al (2007) developed a prediction model for Italian four-lane median-divided motorways. The model, estimating crash frequency as a function of traffic flow, infrastructure characteristics, pavement surface conditions (including whether wet or dry) and sight distance, was developed using a stepwise forward procedure based on the Generalized Likelihood Ratio Test (GLRT).

Montella et al (2008) developed separate crash prediction models for total crashes and severe (fatal plus all injury) crashes in Italian rural motorways, using Generalized Linear Modelling techniques and assuming a negative binomial distribution error structure. The study used a sample of 2,245 crashes (728 severe crashes) that occurred from 2001 to 2005 on Motorway A16 between Naples and Canosa in Italy. The developed model for total crashes included the variables: curvature, operating speed reduction, length of the tangent preceding the curve, and traffic effect, all with a positive sign; difference between the friction demand and supply, deflection, and upgrade, all with a negative sign.

Cafiso et al (2010) attempted to define accident prediction models for two-lane rural road sections based on a combination of exposure, geometry, consistency and context variables directly related to the safety performance. The study was based on a sample of 168.20 km of two-lane local rural roads, with a 5-year accident analysis period to compensate for the low traffic flow and accident frequencies anticipated on local roads. The models proposed are also based on the Generalized Linear Modelling approach (GLM), assuming a negative binomial distribution error structure. Three of the examined models were considered appropriate, based on practical considerations, statistical significance, and goodness of fit indicators.

APMs for tunnels are developed as a separate tool as compared to general road segment models. The most commonly used tunnel APM has been developed in Switzerland by Salvisberg et al. (2004) accounting for the effect of tunnel length (which is not linear), AADT, percentage of heavy vehicles, number of tunnel bores, right shoulder width. This model has been calibrated for the Italian Motorway network by Domenichini et al. (2012) showing a very good prediction capability of the model if this is calibrated to local data with only few outliers (3 out of 52 tunnels). Caliendo et al (2013) also developed an accident prediction model for Italian motorway tunnels, based on a database of 260 tunnels with a 4-year monitoring period extending from 2006 to 2009. For the development of the model, a procedure based on the Generalized Likelihood Ratio Test (GLRT) was used, taking into account two different regression models: the Negative Multinomial (NM) regression model and the Random Effects Negative Binomial (RENB) regression model.

2.3. Web-based CMF databases and Road Safety Toolkits

A useful tool in the hands of road safety practitioners, to assist in identifying the most appropriate countermeasure for their safety needs (i.e. the countermeasure that will most likely result greater road accidents reduction) are the web-based databases of effective road safety measures, that usually including Crash Modification Factors (CMFs). Such databases are the FHWA CMF Clearinghouse (http://www.cmfclearinghouse.org), the

AustRoads Road Safety Engineering Toolkit (http://www.engtoolkit.com.au/), and the iRAP Road Safety Toolkit (http://toolkit.irap.org/).

The FHWA CMF Clearinghouse offers transportation professionals a central, web-based searchable repository of CMFs, as well as additional information and resources related to SPFs and CMFs. It is directly related and provides support to the predictive methodologies included in the Highway Safety Manual. As far as the CMF repository is concerned, while the HSM provides only a selection of the available research-based CMFs, the CMF Clearinghouse is a comprehensive listing of all available CMFs, including the ones listed in the HSM. Within the Clearinghouse, the quality of CMFs has been rated according to five categories – study design, sample size, standard error, potential biases, and data source – and a star rating (one through five) is assigned, based on the cumulative performance in the five categories.

The Austroads Road Safety Engineering Toolkit is based on research into the effectiveness of road safety countermeasures, retrieved from relevant studies in Australia and New Zealand. A total of 67 treatments, all concerning road infrastructure, are included in the Toolkit. Quantitative values for the expected crash reduction effectiveness of each measure are included in the Toolkit, however detailed information regarding the development of each expected crash reduction percentage is not available.

Finally, the iRAP Road Safety Toolkit is very similar in design and operation with the Austroads Toolkit, incorporating however less information and capabilities. Specific CMF values are not included in the iRAP Toolkit, only an assessment of each treatment's effectiveness using a four scale system (0–10%, 10–25%, 25–40%, 60% or more).

2.4. Road safety measures assessment and other related research

Further information regarding the assessment of the crash reduction efficiency of road safety measures can also be found in various handbooks, guides and relevant research projects. Probably the most important is the Handbook of Road Safety Measures (Elvik et al 2009), which includes a systematic overview of current knowledge regarding the effects of road safety measures, by presenting state-of-the-art summaries of current knowledge regarding the effects of 128 road safety measures on road safety, including Crash Modifications Factors (CMFs). Other important relevant initiatives are: (1) the "Countermeasures That Work" guide (NHTSA 2013), aimed primarily to legislation, enforcement, training and communication measures and secondarily to infrastructure treatments, (2) the ROSEBUD Handbook (ROSEBUD 2006), assessing user related, vehicle related and infrastructure related measures, by application of Cost-Effectiveness Analysis (CEA) or Cost-Benefit Analysis (CBA), (3) the CEDR Reports (CEDR 2008 & CEDR 2012), investigating in depth specific road infrastructure safety measures, and (4) the SUPREME research project (SUPREME 2007a & SUPREME 2007b), identifying best practice in road safety measures.

3. Survey methodology

In order to collect information about currently used APMs and data sources by different National Road Administrations (NRAs) in Europe and worldwide, a questionnaire was designed, with a two-fold objective: (1) to collect detailed information on APMs developed and used by the NRAs, and (2) to collect information regarding data availability, quality and definitions among European countries and worldwide.

The questionnaire comprises the following parts:

- a brief introductory part,
- Part A regarding the Decision Making Process: information on procedures followed by NRAs, their priorities and the guidelines that are used by NRAs when assessing road safety measures,
- Part B regarding Data Sources: this part focuses on data availability, data needs, quality of data and definitions among European countries and worldwide. Relevant questions aim at gathering information for data on road design, road operation, traffic, accidents and user behaviour,
- Part C regarding information on CMFs and road safety measures assessment, aiming to identify the criteria considered by NRAs in order to use a particular CMF, referring to either CMF Applicability (i.e. if the CMF can be effectively applied to the specific problem at hand) or CMF Development (i.e. if the CMF is considered reliable and of high quality), and
- Part D, aimed at gathering a summary of experience on road safety measures/CMFs, by asking to identify on a list of measures/CMFs (1) the need to implement the road safety measure in the country's road network; (2) the availability of assessment of measure/CMF; and (3) the transferability of safety effect.

A total of 23 completed questionnaires were received, mostly from National Road Authorities, but also from road managing companies, academia/research institutes or highway consultants. The questionnaires were received mostly from European Countries, namely: Austria, Belgium, Cyprus, Denmark, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Slovenia, Spain, Switzerland, UK, as well as from the United States and Australia.

4. Survey results and discussion

4.1. Decision making process

According to the questionnaire responses, most NRAs and other organizations use a specific procedure for assessing alternative road safety measures (83% responded that they always or usually do so, compared to 17% that rarely or never do so), with Cost-Benefit Analysis (CBA) being the most commonly used procedure, used by 81% of the organizations, followed by Net Present Value (NPV) and Cost-Effectiveness Assessment (CEA). It should also be noted that NRAs seem to exhibit increased preference for the CBA procedure, compared to other organizations (academia/research institutes and highway consultants).

Despite the fact that most NRAs and other organizations use a specific procedure for assessing alternative road safety measures, most (70%) rarely or never use APMs or CMFs during the assessment procedure.

The aspects/criteria considered by NRAs and other organizations during the assessment of alternative road safety measures are presented in figure 1. It seems that the safety effectiveness of countermeasures is of far greater importance than the implementation cost, the effective lifespan, previous experience or public acceptability.

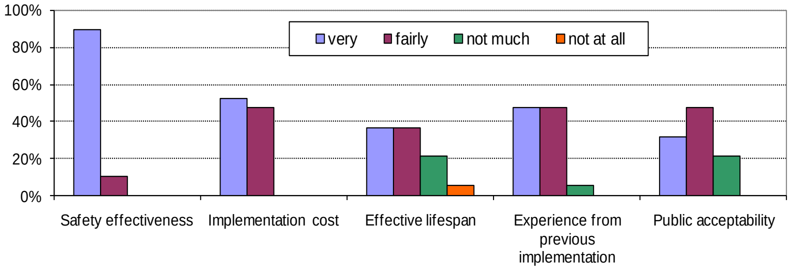

Fig. 1. Aspects/criteria considered by NRAs and other organizations during the assessment of alternative road safety measures.

61% reported that officially approved guidelines for the assessment of road safety measures exist in their country. Additionally, 50% reported that they always or usually also use other guidelines, manuals (not officially approved) or other studies, regarding road safety measures assessment.

4.2. Data sources

For safety evaluation of different design elements in road networks data about road design, road operation and traffic related parameters as well as comprehensive accident information are necessary. All these data are an essential basis for accident surveys and for accident prediction models. A general differentiation was made between motorways/freeways (generally dual carriageway roads) and two-lane two-way rural roads, and the questions focused mainly on data availability and data need for safety assessment.

4.2.1. Road design data

Questionnaire responses revealed obvious differences between motorways/freeways and rural roads with a weakening data availability on rural roads. Interestingly, NRAs reported more data available than needed for safety evaluation (i.e. data is available in the road administration but is not used in appraisal of road safety); it is possible that road design data are required for other purposes than safety assessment.

As far as motorways are concerned, the greatest amount of information is available for the number of lanes in the road network (96% availability). If more detailed information is needed (e.g. horizontal and vertical curvature, road width) there is a recognisable decrease of data availability. The tendencies for data availability between the different design aspects and Motorways/Freeways compared to rural roads are similar.

In most countries, road design data are gathered by data collections on the road site (70% of answers) and in most cases (83%) they are linked with the road chainage. In most cases (91%) road design data is stored in a databank. Other forms of storage (sometimes used supplementary) are GIS applications (65%), or other additional visualisations (48%). It is interesting that 43% use all three forms of data storage. Road design data are administrated by road authorities (road administrations or commissioned managing companies), and in most cases (2/3 of responders) the data are not publicly available, but it is possible to request data for research purposes and professional usage for accident analysis.

4.2.2. Road operation data

Road operation data in the questionnaire refer to information about availability and need of posted speed limits, road markings, other road signage, the type of junction control (e.g. priority control, stop control, signalled control) as well as data about the signalling in the case of signalled junctions.

For road operation data the same tendencies already noted for road design data were observed. There is an obvious difference between data availability on motorways/freeways and on two-lane two-way rural roads and generally a difference between data availability and data need for safety assessment. However, road operation data are a little less common than road design data. Regarding data actuality (update rate of databases) 48% of responders report update of data at every change, 13% report annual updates and 17% updates every three years or more. In general, road operation data are also not publicly available.

4.2.3. Traffic related data

Regarding motorways, 100% AADT data availability was reported. Heavy vehicle traffic data availability was reported by 96% of responders. Nevertheless, only 52% of respondents use traffic data in safety assessment, possibly due to a lack of quantitative APM models that would require such data. As far as rural roads are concerned, data availability and data need are reported slightly (about 5%) lower. Traffic related data are often publicly available. 55% of the responders reported an open access database and a further 14% reported partial free access to traffic related information.

4.2.4. Accident data

Generally there is a very high level of data availability (exceeding 90%) for accident types, accident severity and additional outside accident influences, both for motorways/freeways and for two-lane two-way rural roads. It is notable that the availability rate of prevailing accident cause data is somewhat lower. As with the coherences of road related parameters, there is an obvious rate drop between general data availability and data use for road safety assessment for the considered accident data, therefore, the data need is generally in a similar magnitude for accidents and road data. Regarding more detailed accident data (accident perpetrator, number of casualties, details on participants and user categories), availability was also reported at a high level within the NRAs.

Approximately 2/3 of the responders reported having access to digital accident databases covering a time period of at least the last 15 years. In all cases there is a delay between the accident data being recorded and being available in the databases that varies between 6 months and 3 years. For the localisation of accidents within the road network, two main practices are followed: road segment numbering along with road chainage (35% of responses), or georeferencing (17%). The remaining 48% use both methods of accident localisation, often deriving the road segment numbers and chainage from the collected geo coordinates.

The analysis of accident information is predominantly pertinent to the road authorities (high risk sites management and selection of treatments). For the preparation of annual accident statistics the statistical offices are mainly responsible, and in very few cases the road authorities. Generally the police are also involved in accident analyses because they are responsible for executive measures (e.g. speed control and inflicting regulatory offences and motoring fines).

As a general rule, detailed accident information or generally accident databases are not publicly available. Detailed accident data can be requested for accident analysis for research purposes by known and delegated institutions. Nevertheless, some information is publicly available, like summaries of accident occurrence in the accident annual reports (e.g. limited publications through aggregated data in statistical yearbooks) or published results of the research. Moreover some road authorities also publish maps showing accident and/or casualty rates as well as interactive tables with limited and well-chosen details of road accidents.

4.2.5. User behaviour data

Limited data availability (50% to 60%) is reported on factors relating to user behavior such as alcohol-impaired driving, excessive speeding, seat belt and helmet use, with data need reported approximately the same or slightly lower than availability. It should be noted that, as far as user behaviour data are concerned, the differences in questionnaire responses between motorways and rural roads are negligible.

4.3. Information on CMFs and road safety measures assessment

Respondents were also asked which criteria they use to decide whether a particular CMF or measure assessment is relevant and can be applied to address a specific problem. The replies are summarized in figure 2.

As far as criteria related to the quality and reliability of the CMF, according to its development characteristics, are concerned, NRAs and other organisations responded that they take into account criteria such as date range of data (60%), country/area of data (56%), statistical methodology (63%) and sample size (54%). From the questionnaire survey, it seems that most of the criteria are of similar importance to NRAs. Even in the cases of “road safety deficiency” or “minor road traffic volume” criteria, which exhibit the lowest percentages, more than 60% of NRAs or other organisations answered that they consider them when selecting CMFs.

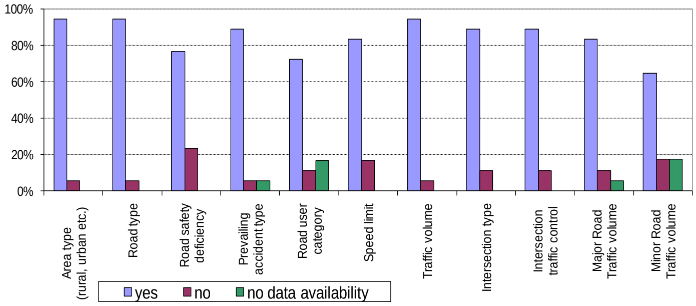

Fig. 2. Elements/criteria considered by NRAs and other organizations when selecting a CMF or safety measure, related to its applicability.

4.4. Summary of experience on road safety measures/CMFs

In figure 2 The experience of NRAs and other institutions on road safety measures and CMFs was examined in the questionnaire survey by providing two comprehensive lists of infrastructure road safety measures (different for motorways/freeways and for two-way two-lane rural roads) and requesting to identify: (a) the need to implement the oad safety measure in the country’s road network, (b) the availability of assessment of measure/CMF, and (c) the transferability of safety effect (i.e. if the measure is assessed in a different location, will the safety effect be similar and therefore transferable to the examined country).

According to the questionnaire survey, the countermeasures/CMFs presenting the highest need in motorways and divided freeways are “workzones” (86.7%), “roadside features: clear zone width” (75.0%), “high friction treatments” (73.3%) and “effect of traffic – volume/capacity – % trucks & buses” (68.8%), whereas the lowest need is exhibited by “realignment of road segments” (18.8%), “rectangular rapid flashing beacons” (21.4%), “effects of friction on motorcycle crashes” (21.4%) and animals and wildlife related safety treatments (25.0%).

In two-lane, two way rural roads, the highest need is exhibited by “roadside features: presence of a barrier” (81.3%), “shoulder type – paved/unpaved” (80.0%), “shoulder width” (78.6%) and workzones (76.9%), whereas the lowest by “countdown signals or signs” (8.3%), and several bicycle treatments: “bicycle boxes” (14.3%), “bicycle loops” (15.4%) and “effect of rumble strips on bicycles” (26.7%).

As far as availability of a CMF or countermeasure assessment is concerned, in motorways and divided freeways the highest availability is exhibited by “number of lanes” (61.5%), “roadside features: presence of a barrier” (50.0%), “variable message signs” (43.8%), “roadside features: crash cushions” and “automated speed enforcement”, both at 43.8%. The lowest by “rectangular rapid flashing beacons” (7.1%), “superelevation” (8.3%), “landscaping and vegetation” (14.3%) and “roadside features: embankment slope”, also at 14.3%.

In two-lane, two way rural roads, the highest availability is exhibited by “roundabouts” (60.0%), “passing lanes” (41.7%), “segment lighting” (41.7%) and “intersection left turn lanes” (40.0%), whereas the lowest by “roadside features: motorcycle protection devices", "right-in, right-out designs" and several bicycle treatments: "bicycle boxes", "bicycle loops" and "effect of rumble strips on bicycles", all at 0%.

Finally, regarding the transferability of countermeasures/CMFs, according to the questionnaire responses, in motorways and divided freeways, the highest transferability is exhibited by "audible road markings" (81.8%), "crash cushions" (76.9%), "presence of barriers" (75.0%) and rumble strips (75.0%), whereas the lowest by "animals and wildlife related safety treatments" (30.0%), "effects of friction on motorcycle crashes" (36.4), "effect of traffic – volume/capacity – % trucks & buses" (40.0%) and "rectangular rapid flashing beacons", "embankment slope" and "effect of ramp entrance/exit" all at 45.5%.

In two-lane, two way rural roads, the highest transferability is exhibited by "dynamic feedback speed signs" (72.7%), "audible road markings" (72.7%), "passing lanes" (70.0%) and "kerb extensions" (70.0%). The lowest transferability is exhibited by "countdown signals or signs" (11.0%), "sharrows (bicycle shared lane markings on travelled lanes)" (20.0%) and "bicycle lanes" (27.3%).

5. Conclusions

In the present paper, a state-of-the-art review of literature on accident prediction modelling was presented, along with the results of a survey based on questionnaires dispatched to several National Road Administrations (NRAs) in Europe, US and Australia, with the aim of collecting detailed information (a) on APMs developed and used by them, and (b) on the availability, quality and definitions of relevant data (crash data, traffic data, road design data and other related data). Both activities were performed within the research project PRACT.

As far as current APM practices are concerned, models are usually developed either as a single regressive equation (Safety Performance Function, SPF), valid for specific conditions, or as a combination of a base SPF developed for a standard road configuration and a set of Crash Modification Factors (CMFs) to account for differences between site conditions and the specified base conditions. A Calibration Factor can also be used to account for differences between the jurisdiction and time period of the model development and of the actual model application. Relevant existing models constitute a valuable framework that can be further developed to allow for reliable accident prediction, depending on the availability of data. Several transferability issues have been examined by pertinent research and it seems that, depending on the availability of reliable historical accident data, certain APMs can be transferred to conditions different from the ones for which they have been developed, if selected according to scientifically valid criteria.

However, despite recent advances in the field of accident prediction modelling, most National Road Administrations (NRAs) and other organisations do not systematically use such methods during decision making for the implementation of road safety treatments. According to the questionnaire survey, only 30% responded that they use APMs "always" or "usually", compared to 70% that responded "rarely" or "never", and if only NRAs are taken into account, the use of APMs is further reduced. It should also be noted that the use of APMs in decision making is more common in countries that have relevant approved guidelines or manuals, which is normally related to a more advanced road safety culture.

Since accident prediction modelling provides a scientifically sound basis for the evaluation and selection of road safety measures and for efficient decision making with limited availability of funds, it is vital that the use of APMs by NRAs in Europe, designers and road safety engineers is further promoted. A means to this cause is accident prediction modelling research, aimed in the identification of those CMFs/measures that exhibit high need for implementation combined with low CMF availability, the development of key missing CMFs, the exploration of the transferability of APMs and CMFs and finally the dissemination of the research results to all involved stakeholders.

Acknowledgements

This research was carried out within the project PRACT – Predicting Road Accidents – a Transferable methodology across Europe funded by the National Road Authorities of Germany, Ireland, UK and the Netherlands within the Conference of European Directors of Roads (CEDR) 2013 Transnational Research Programme – Safety.

References

AASHTO (2010). Highway Safety Manual, First Edition, American Association of State and Highway Transportation Officials, Washington DC.
AASHTO (2014). Highway Safety Manual, First Edition, 2014 Supplement, American Association of State and Highway Transportation Officials, Washington DC.

AustRoads Road Safety Engineering Toolkit (http://www.engtoolkit.com.au/)

Cafiso S., Di Graziano A., Di Silvestro G., La Cava G., Persaud B. (2010). Development of comprehensive accident models for two-lane rural highways using exposure, geometry, consistency and context variables, Accident Analysis and Prevention, Vol.42, pp.1072–1079.

Caliendo C., De Guglielmo M., Guida M. (2013). A crash-prediction model for road tunnels, Accident Analysis and Prevention, Vol.55. pp.107–115.

Caliendo C., Guida M., Paris A. (2007). A crash-prediction model for multilane roads, Accident Analysis and Prevention, Vol.39, pp.657–670.

CEDR (2008). Best Practice on Cost Effective Road Safety Infrastructure Investments, Conference of European Directors of Roads (CEDR) Report. Yannis G., Evgenikos P., Papadimitriou E.

CEDR (2012). Forgiving Roadsides Design Guide, Conference of European Directors of Roads (CEDR) Report. La Torre F. (published also in French Abords_de_chaussee_qui_pardonnent)

Domenichini L., La Torre F., Caputo F. J., Fanfani F., (2012). Il modello previsionale di incidentalità in gallerie autostradali. Strade & Autostrade, 1-2012 (in Italian).

Elvik R., Hoye A., Vaa T., Sorensen M. (2009). The Handbook of Road Safety Measures, 2nd Edition, Emerald Group Publishing Ltd.

Federal Highway Administration (FHWA) (2013a). Safety Performance Function Decision Guide: SPF Calibration vs. SPF Development. The University of North Carolina Highway Safety Research Center.

Federal Highway Administration (FHWA) (2013b). Safety Performance Function Development Guide: Developing Jurisdiction-Specific SPFs. The University of North Carolina Highway Safety Research Center.

FHWA CMF Clearinghouse (http://www.cmfclearinghouse.org)

Gross F., Hamidi A. (2011). Investigation of Existing and Alternative Methods for Combining Multiple CMFs. Highway Safety Improvement Program Technical Support. Task A.9 Final Technical Content.

Gross F., Persaud B., Lyon C. (2010). A Guide to Developing Quality Crash Modification Factors. Federal Highway Administration (FHWA)m Report No. FHWA-SA-10-032.

Haleem K., Gan A., Lu J. (2013). Using multivariate adaptive regression splines (MARS) to develop crash modification factors for urban freeway interchange influence areas. Accident Analysis and Prevention, Vol.55, pp.12–21.

iRAP Road Safety Toolkit (http://toolkit.irap.org/)

La Torre F., Domenichini L., Corsi F., Fanfani F. (2014). Transferability of the Highway Safety Manual Freeway Model to the Italian Motorway Network. In Transportation Research Record: Journal of the Transportation Research Board, No. 2435, Transportation Research Board of the National Academies, Washington, D.C.

Martinelli F., La Torre F., Vadi P. (2009). Calibration of the Highway Safety Manual's Accident Prediction Model for Italian Secondary Road Network. In Transportation Research Record: Journal of the Transportation Research Board, No. 2103, Transportation Research Board of the National Academies, Washington, D.C.

Montella A., Colantuoni L., Lamberti R. (2008). Crash Prediction Models for Rural Motorways,Transportation Research Board ISSN: 0361-1981.

NCHRP (2012). Recommended Protocols for Developing CMFs. National Cooperative Highway Research Program (NCHRP) Project No. 20-7(314). Carter D., Srinivasan R., Gross F., Council F.

NCHRP (2014). User's Guide to Develop Highway Safety Manual Safety Performance Function Calibration Factors. National Cooperative Highway Research Program (NCHRP) Project No. HR 20–7(332). NAVIGATS Inc.

NHTSA (2013). Countermeasures that work: A Highway Safety Countermeasure Guide For State Highway Safety Offices. 7th edition. National Highway Traffic Safety Administration Report No. DOT HS 811 727. Goodwin A., Kirley B., Sandt L., Hall W., Thomas L., O'Brien N., Summerlin D., Washington DC.

RIPCORD (2005). Accident Prediction Models and Road safety Impact Assessment: a state of the art. RIPCORD – ISEREST Consortium, Internal Report D2.1. Reurings M., Janssen T., Eenink R., Elvik R., Cardoso J., Stefan C.

RIPCORD (2007). Accident Prediction Models and Road safety Impact Assessment: results of the pilot studies. RIPCORD – ISEREST Consortium, Internal Report D2.4. Reurings M., Janssen T., Eenink R., Elvik R., Cardoso J., Stefan C.

RIPCORD (2008). Safety Performance Function. RIPCORD – ISEREST Consortium, Deliverable D.10. Dietze M., Ebersbach D., Lippold Ch. Mallschutzke K., Gatti G., Wieczynski A.

RISMET (2011a). Accident Prediction Models for Rural Junctions on Four European Countries. RISMET Consortium, Deliverable Nr 6.1. Azeredo Lopes S., Cardoso J.L.

RISMET (2011b). Applying speed prediction model models to define road sections and to develop accident prediction models: A German case study and a Portuguese exploratory study. RISMET Consortium, Deliverable 6.2. Dietze M., Weller G.

ROSEBUD (2006). Examples of assessed road safety measures – a short handbook. ROSEBUD Consortium, Research Project. Höhnscheid K., Schleh R., Lerner M., Schönebeck S., Elvik R., Veisten K., Wesemann P., Bax C., Winkelbauer M., Christian S., Machata K., Baum H., Schneider J., Filippi F., Persia L., Aloia P., Hakkert A.,Gitelman V., Broughton J., Lejeune P., Holló P., Heinrich J., Tecl J., Nokkala M., Yannis G., Thulin H.

SUPREME (2007a). Handbook for measures at the Country level. SUPREME Consortium, research project. Winkelbauer M., Machata K.

SUPREME (2007b). Handbook for measures at the European level. SUPREME Consortium, research project. Winkelbauer M., Machata K.

Salvisberg U., Allenbach R., Hubacher M., Cavegn M., Siegrist S. (2004). Verkehrssicherheit in Autobahn- und Autostrassentunneln des National-strassennetzes. Report UPI n. 51, Swiss Office for Accident Prevention.

Turner S., Singh R., Nates G. (2012). The next generation of rural road crash prediction models: final report. NZ Transport Agency research report 509, Final Report.