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Challenges and opportunities for the assessment of the effectiveness of road safety measures

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Abstract

The objective of this paper is to develop a comprehensive synthesis on current challenges and opportunities for the assessment of the effectiveness of road safety measures worldwide, with focus on the potential for transferability. This synthesis comprises the preliminary results of the work carried out in the framework of the on-going Working Group on the assessment of the effectiveness of road safety measures, of the Joint Transport Research Centre (JTRC) of the Organisation for Economic Cooperation and Development (OECD) and the International Transport Forum (ITF). Appropriate data and statistical evaluation methodologies together with systematic procedures and exchange of assessment results are considered as the prerequisites for acquiring the necessary knowledge, on which decision makers could rely for their decisions. An opportunity for producing more reliable efficiency assessment results is the intensification of international cooperation both at the methodology and at the results level allowing to maximize research investments among countries and more rapid global dissemination and use of life saving countermeasures. Governments are therefore challenged to set policies or establish guidelines that will help improve the overall quality of effectiveness assessment research and results.

Keywords: road safety measures; crash modification functions; effectiveness; assessment

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1. Introduction

As the "science of safety" (i.e. the ability to quantitatively and effectively assess the potential or expected benefits from the application of specific safety countermeasures for specific situations) has advanced in recent years, so too has the demand for more reliable estimates of the effectiveness of road safety treatments and strategies. Critically, in this era of economic crisis, the justification of investments in a field such as road safety, where large investments can potentially bring little or no results (and on rare occasions negative results), is more than necessary. These estimates are known as crash reduction factors and they form the basis for any economic evaluation of safety measures. The focus of this work is crash modification functions (CMFs). CMFs facilitate the prediction of safety effect and allow a synthesis of diverse evaluation results that in turn allows for more universal understanding of safety effectiveness measures.

Crash Modification Functions are growing in relative importance as their value and importance in safety analysis has become more apparent. However, the high quality analysis that is required to develop a reliable CMF is costly to perform. Governments are therefore challenged to set policies or establish guidelines that will help improve the overall quality of CMF research and results. The growing knowledge and interest in the quantitative assessment of safety countermeasures and the increasing application of the same is presenting an opportunity to increase international cooperation in the development and sharing of CMFs. The benefits of this cooperation include the ability to maximize research investments among countries and more rapid global dissemination and use of life saving countermeasures.

Given the potential benefits that would ensue from international collaboration, one might wonder why more has not been done to date. One reason is that the concepts related to the quantitative assessment of safety effects are still relatively nascent for practitioners and not widely understood. As these concepts have evolved, progressed and become much more refined, so too has our understanding of what makes a good CMF. In addition, the full understanding of the value of performing safety analyses utilising CMFs is only now truly beginning to permeate the highway community. In some regards, it is only now that quite a few OECD countries have passed a knowledge tipping point of sorts that invites the creation of a more cohesive approach to the development of CMFs internationally.

An additional reason for the limited official initiatives at both national and international levels could be the fact that road authorities may fear that ex-post evaluation of measures may prove that important road safety investments had little or limited impact with potential consequences for both the political and administrative authorities responsible for the programs. In addition, the comparison of a measure's cost effectiveness between different regions and between different countries may reveal high discrepancies not only in the unit cost of the measure but also in the implementation effort, thus generating questions about the practices used not only by the authorities but also by the industry. While these concerns may exist, they are natural outcomes of our increased knowledge of and approach to estimating effectiveness. As a result, such concerns must be overcome.

The objective of this paper is to develop a comprehensive synthesis on current challenges and opportunities for the assessment of the effectiveness of road safety measures worldwide, with focus on the potential for transferability. This synthesis comprises the preliminary results of the work carried out in the framework of the on-going Working Group on the assessment of the effectiveness of road safety measures, of the Joint Transport Research Centre (JTRC) of the Organisation for Economic Cooperation and Development (OECD) and the International Transport Forum (ITF), which will be finalized at the respective Final Report.

2. The Challenges

The overarching challenge presented by the interest in international sharing of CMFs is to determine what government agencies in OECD countries can do to make assessments of road safety measures systematically transferable and their results internationally acceptable. Given that CMFs will often be generated through academic research or private sector project analysis, a challenging role for Government would likely be to develop and disseminate policies and guidelines that would influence the conduct of research and appropriate documentation of results.

It is quite understandable that many factors influence the quality of research that is performed in any field. For CMFs, this is certainly true. For example, the U.S. CRF Clearinghouse shows that a study design that is statistically rigorous and includes a reference group will have an effect on the outcome of CRF-related research. Other factors such as the sample size, standard error, potential bias and the data source all have a great influence on the quality of a final result. It is in these areas and others of similar nature where the application of appropriate influence will help to both improve the final research products as well as their international acceptability. The challenges associated with identifying the full set of essential factors and then educating appropriate audiences about them are large.

Communicating the value of certain countermeasures across international boundaries and seeking their rapid adoption is a challenging prospect if certain specific information is not presented. For example, an important element in the development and application of CMFs is the identification of the target crashes and crash severities for which the CMF is most applicable. Including such information in CMF research reports could increase the value of a report and ease the applicability of a CMF in a country other than where it originated. Also, detailed information on the countermeasure itself being considered is an important reporting element for any research conducted to develop CMFs. Other specific information that can enhance the perceived value or significance of a countermeasure is information on the circumstances in which the CMF was developed. For example, information on the type of area (e.g. urban, rural, both) for which the CMF is applicable is essential information that should be documented. Other circumstantial information that would help practitioners in one country more quickly adopt countermeasures from other countries includes roadway geometry, traffic volumes, roadway functional classification, or other safety treatments applies at the site. Without such information, the transferability of CMFs across borders is significantly hampered.

Furthermore, international recommendations and guidelines for the necessity and the procedures of CMF analyses may prove to be very beneficial to countries with high inertia to change current practices that involve no evaluation and no accountability of road safety investment efficacy. Based on international recommendations, the first step may be to make CMF evaluation a procedure for all road safety investments and, subsequently, to link any following investments with the CMF results of the previous investments. The second step may well be to use a standard and uniform CMF evaluation procedure as established through continuous international cooperation in the field. Obviously, establishing a regular CMF development and usage procedure would be extremely challenging.

Assuming an ideal situation in which precise CMFs were available for all of the relevant measures, there would still be some technical difficulties - with ongoing research on how to handle them - that the practitioner should be aware of. The first kind of difficulty concerns the most appropriate way of combining CMFs. Most evaluation studies deal with the effectiveness of individual measures. Thus, when we say that e.g. the CMF for the channelization of junctions is 0.85, and the CMF for the substitution of yield signs into traffic lights is 0.70, we are implying that, on average, we expect a 15 percent reduction in the frequency of crashes, if only the channelization is implemented, and a 30 percent reduction, if only the conversion of yield signs is implemented. However, in many real-life cases, several measures are implemented simultaneously. Assume that, in a given set of junctions, channelisation is carried out and, at the same time, traffic lights replace yield signs. The relevant question is how the two CMFs should be combined so as to best forecast the expected safety performance of the treated junctions.

More than one example exist for combining multiple CMFs or for accurately predicting the effects of multiple countermeasures being sued in one site. In the United States, discussion of combining CMFs for multiple treatments continues. Currently it is acceptable to use a calculated reduction that multiplies together the effects of each individual treatment. Because such an approach can reasonably be expected to overestimate the total effects (Mounce, 2005), a rule of thumb is to limit such multiplicative combinations to no more than 3 separate countermeasures.

In Australia, it was found that 80 percent of treated sites concerned multiple treatments (Mounce, 2005). It has therefore been recommended that efforts be taken to consider "packages" of countermeasures – i.e. multiple individual countermeasures that are typically used together to address a specific problem area. For example, chevrons, shoulders, markings and guardrail may typically be used together to address horizontal curve safety. For these packages of countermeasures, it is suggested that standalone CMFs for the entire group could be developed and applied when estimating benefits.

The question of the impact of combined measures pertains to many safety decisions, and is particularly critical when assessing the outcome of road safety programmes and strategies, where packages of - usually many - measures have to be evaluated. Yet, our current knowledge about this technical issue seems to still be limited. (Elvik, 2009) A common way of proceeding is by assuming that the effectiveness of a certain measure does not depend on whether it is implemented as a stand-alone measure or as a component of a package of measures. Under this hypothesis, the CMF for a combination of measures is simply the product of all the CMFs. Considering the junction example above, were the channelization to be implemented first, the number of crashes would be 85 percent of the initial value. If yield signs were then replaced by traffic lights, the final number of crashes would be 85 percent*0.70=59.5 percent of the initial value. However, other approaches are possible (Elvik, 2009) and it seems sensible to always conduct a sensitivity analysis.

Another caveat should be made regarding the use of CMFs for assessing the impact of road safety programmes. In them, it will typically be required to forecast the number of crashes and casualties several years ahead from the base year. For example, we might be interested in setting a quantitative target for the year 2020, and in assessing the way several measures could help achieve such target. For each measure considered, the key question would be what the expected number of crashes is in 2020 in two scenarios: a first scenario in which the measure is implemented, and a second scenario in which it is not. A common method for dealing with this question consists of two steps: firstly, to determine a base scenario of the evolution of the number of crashes, usually by extrapolating past trends (business-as-usual scenario); secondly, to multiply the number of crashes in the base scenario by the CMF for the measure considered. This method can be suitable to many instances. However, it should be borne in mind that many measures included in road safety programmes do not constitute truly new measures, but rather a continuation or intensification of already implemented policies. In those cases, there is a risk that the estimated reduction of crashes is biased by a double-counting of safety benefits, since the effects of the measure affect both the trend used in the determination of the base scenario and the CMF that multiplies the number of crashes. Correcting this bias may require the development and application of complex analytical methods. A comprehensive review of current state of knowledge and practices concerning prediction of road crashes and use of effectiveness assessments in road safety programs can be found in journal Safety Science, entitled "Scientific Research on Road Safety Management" (Safety Science, Volume 48, issue 9).

Finally, there is a third issue related to the use of monetary valuation of safety benefits in cost-benefit analysis. Some international comparisons show that official estimates of the value of a statistical life vary by a factor of almost 60 between the countries with the highest and lowest estimates. (European Road Safety Observatory, 2006) This fact reflects fundamental differences in the methods of evaluation, particularly regarding so-called human costs. Generally, countries with the highest estimates of the value

of a statistical life based their evaluation of human costs (grief, pain, etc.) on the willingness to pay method, while countries with the lowest estimates usually apply the average compensations to victims and families dictated in courts. An unwanted consequence of these discrepancies is that measures regarded internationally as cost-effective and best practices may in some countries appear as having costs greater than benefits. Two possible ways of handling this is by revising the monetary valuation of crashes or favouring cost-effectiveness analysis, instead of cost-benefit analysis.

3. CMFs transfer obstacles

One of the primary obstacles to international cooperation in the sharing of CMFs is the lack of a uniform understanding of the value, importance and usage of CMFs in road safety decision making. The understanding of CMFs among countries likely ranges from little knowledge of CMFs to a level of spreading knowledge and growing use of CMFs. At this time, CMFs may be integrated into guidelines and some state, provincial or other local governments may be using CMFs systematically to some extent in their decision making. However, there are currently no countries where CMFs are routinely used nationally in a direct manner by practitioners as part of the planning, design and management of roadways. As a result, there is not yet broad demand for a full library of CMFs from the international road profession. Lack of education, knowledge and practical usage of CMFs is currently the biggest obstacle to CMF development and transferability.

Among other obstacles that exist is the lack of uniformity in the performance of related research and the reporting of research results. While there are reasonably good channels of communication for the research and other communities that are responsible for developing CMFs, there is not an international venue that promotes consistent, global approaches that will optimize the sharing of research practice and results. The Transportation Research Board in the United States may come closest to an international effort at this time through the Highway Safety Manual Task Force. Although there was somewhat broader international participation in the Task Force, by its nature and mission, the Task Force is fundamentally a U.S. or North American focused group. Thus, the international dialog and leadership necessary to advance a broader global effort on research programs is missing and serves as a hindrance to greater success in this area.

A fundamental obstacle to CMF transferability is the nature of the road safety system, which is determined by a variety of interrelations between driver behaviour, road infrastructure and vehicle characteristics that make every road traffic system unique and necessitates a specific mix of road safety measures. For example, not all successful measures are suitable for all different road traffic environments. But it is also very possible that the same interventions may lead to significantly different results in two different road traffic environments. However, scientists have identified several common safety patterns in various traffic systems, which when taken into account collectively by established CMF methodologies may result in appropriate tailor-made solutions applicable to several different traffic systems. Establishing common CMF analysis procedures is the first basic step towards the transferability of CMF experiences. The next steps will likely turn up through international cooperation in the field of progressive standardisation of CMFs.

The scientists' competition and quest for the "perfect" methodology, together with the inherent difficulties of CMF analyses, puts in question any CMF analysis with a consequence less than found in other published results. Such results expose the researcher to the risk of criticism from their peers. It is true that scientific accuracy is difficult to obtain in the field of CMFs, not only because several assumptions are necessary in the process but also because it is very difficult to separate the safety effect of a measure from the effect of several other microscopic or macroscopic measures and phenomena (including statistical randomness) taking place at the same place. In addition, the requirements to publish

original work and the resulting desire to be somewhat secretive about or restrictive with ongoing research efforts or products will deter cooperation. Similarly, language differences and lack of knowledge about who is performing such research and how one might find the results will prevent a dialog that could encourage wider collaboration and information exchange.

Furthermore, it is a real possibility that CMF analyses invited by the authorities or their political leaders will tend to use faster and less rigorous CMF evaluation methodologies. Such approaches will generally favour prevailing opinions and decisions already taken, thus creating a wide variety of non-converging CMF results. This non-convergence is a likely outcome due to the lack of appropriate data - especially the evolution of risk exposure data - and the variety of crash cost calculations. This scenario can facilitate the production of diverging CMF evaluation results at the international and national levels.

Finally, fundamental to the development of accurate CMFs is access to reliable crash data. Most countries have established crash database systems to record the location and circumstances of crashes. These data are essential to determine the number of crashes before and after the implementation of a treatment. The more accurate and comprehensive this data are, the more accurate CMFs will be. In some countries, treatment monitoring systems have been included as a module of the crash database system, allowing quick and comprehensive assessments of treatment effectiveness across parts or all of the network. Further information on the establishment of crash data systems can be found in the respective WHO Report (2010).

4. Opportunities for International Cooperation and Transferability

While many of the obstacles described above are clearly real and have a negative effect on international cooperation in this field, there are a range of opportunities to overcome these obstacles. This paper in its entirety is designed to identify these opportunities and encourage positive action to support transferability.

From the review of current global knowledge, experience and practices with CMFs it appears that there is a foundation of cooperation among some select and respected researchers that can be drawn upon to involve others and expand the cooperation. The formation of the OECD/ITF Working Group is an indicator of that potential. The publication of the Highway Safety Manual (AASHTO, 2010) by the American Association of State Highway and Transportation Officials builds on efforts in many parts of the world and is reflective of deep interest in quantitative assessment of safety decisions utilizing CMFs. Other initiatives such as projects ROSEBUD (2006), SUPREME (2007), PROMISING (2001) and Reports of CEDR (2008), PIARC (2003), ETSC (2003) and NHTSA (2010) contributed also interesting reviews of existing studies.

Another significant opportunity that exists is the advancement of thinking about what research produces a good CMF (FHWA CRF Clearinghouse, Elvik, et. al., 2009). In this light, there are good examples of how to consider a study and assess its quality. This knowledge and experience serves as a foundation in this work for identifying in advance what qualities, characteristics and specific information CMF research reports should include if they are to have the potential to be shared internationally. Many of the items mentioned above are good examples of the knowledge we have in this regard and suggest how we can use this information to critically review studies.

Most European countries set specific quantitative road safety targets and adopt related road safety strategies towards these targets, within the established priorities and the resources available. Within this framework, the efficiency assessment of road safety measures is considered to be an extremely useful tool in decision making. In particular, cost-benefit and cost-effectiveness analyses are carried out in several countries, in a more or less systematic way, at national, regional or local level. These studies are based on some estimate of the safety effects of the examined measures, in terms of crashes or casualties reduction

following the implementation of the measure. However, a more widespread or fruitful use of efficiency assessment of road safety measure is in most cases limited, apart from the various technical and institutional barriers, by a lack of knowledge and data on the safety effects of road safety measures.

Nevertheless, the importance of efficiency assessment in road safety is widely recognised, and the need for more knowledge and best practice examples is becoming more and more pronounced. Existing best practice recommendations may cover the whole range of the efficiency assessment process, from the selection and application of appropriate and standardised methodologies to the interpretation of results and the identification of most efficient measures, especially in case different alternative measures need to be compared and ranked. However, the most important uncertainties involved in developing such best practice recommendations concern the adoption of appropriate values for the safety effects of road safety measures.

In the recent years, important research efforts have been made towards the standardization of the methods for estimating the safety effects of road safety measures. The first issue examined concerns the accuracy of the estimation, so that potential bias or other confounders are eliminated; these questions mainly concern the analyses at national level. The second critical issue concerns the conditions and necessary adjustments required to allow the transferability of the safety effect estimates to different settings or countries; this question has become very important at international level, and particularly within the development of handbooks and manuals aiming to assist decision makers, researchers or other stakeholders involved in the efficiency assessment of road safety measures.

A number of manuals, handbooks and other tools have been developed in the recent years, aiming to gather, harmonize and improve the existing knowledge on the effectiveness of road safety measures. These are comprehensive and helpful international information sources, aiming to assist researchers and practitioners in assessing the effectiveness of road safety measures.

These sources are often used by countries within their national road safety efficiency assessment analyses, by adopting the values proposed (e.g. in terms of percentage reduction of crashes / fatalities, or CMFs), or by adjusting them to the local conditions. However, due to the important gaps in the knowledge concerning the transferability of such values across countries, several counties have developed their own methods and values for assessing the effectiveness of road safety measures.

Despite the considerable progress made in the evaluation of road safety measures at national and international level, resulting in important questions being successfully dealt with (e.g. confounding effects, regression to the mean etc.), a major limitation of the existing efforts concerns the need to assess the particularities of setting, context, and implementation features of a specific measure.

As a consequence, the safety effects of even the most promising road safety measures cannot be guaranteed. For these reasons, a range of values is typically proposed in each study for the safety effects of each measure examined. Alternatively, the results are often labeled as "conservative", or "best" estimates.

Although the knowledge obtained from the international literature may prove very useful in the identification of several good practices of cost-effective measures, thorough analysis on a case-specific basis is always necessary in order to optimise the effects of a measure in different countries or areas, by taking into account the extent of the implementation, the implementation period, and specific national or local requirements. Furthermore, it is necessary to ensure that such analyses are carried out in accordance with recognised standard methodologies.

Several other methodological or technical problems are common in international and national evaluations of the effectiveness of road safety measures. These are mainly related to the correct application of the evaluation techniques, the identification of ways for validating the statistical significance of the evaluation results, the proper selection of side-effects to be considered along with

safety effects and also the correct distinction between the implementation costs and negative side-effects of the measure.

Nevertheless, efficiency assessment is an important part of the preparation of national, regional or local road safety plans. At the initial stage of evaluation, safety effects are usually unknown and in order to influence any decision making process, the efficiency assessment studies have to be prepared ex-ante, using impact data from similar measures application. This stresses the need for strengthening the efforts for the estimation of appropriate values for the safety effects of the treatment examined. Moreover, it highlights the need for increasing the accessibility of this information, through the dissemination of efficiency assessment results on an international basis.

5. Conclusion

The demand for safety effectiveness measures – i.e. CMFs – is increasing both regionally and country due to increased demand for cost-effectiveness and cost-benefit assessments, which cannot be, in turn, undertaken without CMFs. While most countries use CMFs from other countries the process of transferring is imperfect and this is hampered by research findings that are not well documented.

Lack of education, knowledge, and practical usage of CMFs are currently the biggest obstacle to CMF development and transferability. Lack of uniformity in the performance of related research and the reporting of research results is another obstacle. Properly planned, conducted and documented (including the circumstances under which the CMF was developed) research will improve international transferability of CMFs. At the moment relatively few studies sufficiently meet these standards.

Communicating the value of certain countermeasures across international boundaries and seeking their rapid adoption will help to maximize research investments among countries and more rapid global dissemination and use of life saving countermeasures. Advancement of thinking about what research produces a good CMF is an opportunity. Establishing common CMF analysis procedures is the first basic step towards the transferability of CMF experiences.

There are several possible ways to begin to address the challenges and opportunities for the assessment of the effectiveness of road safety measures as highlighted in this paper. Firstly, research conducted to develop Crash Modification Functions should follow good international practices, like those treated in the OECD/ITF WG and, in particular, provide specific information that describes the countermeasure under consideration, the safety issue being addressed and the roadway environment in which it was tested. In addition, road safety policies should generally undergo economic evaluation using CMFs through properly documented processes to ensure transparency.

International dialogue and leadership is necessary to advance a broader global effort on research programs and international cooperation is needed in the field of progressive standardization of CMFs. Cooperation among selected researchers offers an opportunity to expand international dialog and collaboration on the development of CMFs. Perhaps, an international group could be composed under an existing organization (e.g. Transportation Research Board, World Road Association, etc.) to foster dialog among researchers and practitioners on CMF research and reporting standards with the aim of increasing transferability of results. Coordination of research across countries on priority countermeasures, as well as capturing documentation and reporting of CMF research in a widely available transnational database could also be of outmost interest.

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