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Methodological guidelines for developing accident modification functions

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ABSTRACT

This paper proposes methodological guidelines for developing accident modification functions. An accident modification function is a mathematical function describing systematic variation in the effects of road safety measures. The paper describes ten guidelines. An example is given of how to use the guidelines. The importance of exploratory analysis and an iterative approach in developing accident modification functions is stressed. The example shows that strict compliance with all the guidelines may be difficult, but represents a level of stringency that should be strived for. Currently the main limitations in developing accident modification functions are the small number of good evaluation studies and the often huge variation in estimates of effect. It is therefore still not possible to develop accident modification functions for very many road safety measures.

1. Introduction

There is a growing understanding of the fact that the effects of road safety measures vary systematically (Hauer et al., 2012). It is therefore not always very informative to state these effects in terms of a single point estimate. An accident modification function can provide a more informative and precise description of effects, by statistically modelling variation in effects as a function of one or more independent variables.

Developing accident modification functions is, however, not easy and requires careful attention to the quality of evaluation studies and to whether the distribution of estimates of effect in these studies displays a systematic pattern. The objective of this paper is to propose methodological guidelines for developing accident modification functions. The guidelines address the following questions:

1. How should studies serving as the basis for developing an accident modification function be selected?
2. What types of preparatory analyses are required before starting to develop an accident modification function?
3. How can independent variables in an accident modification function be identified?
4. How can outlying data points be identified?
5. How can the most suitable mathematical form of an accident modification function be determined?
6. How can one decide whether a single or more than one accident modification function best fits the data?
7. How can the quality of an accident modification function be evaluated?
8. How can the effects of analytic choices made when developing an accident modification function be evaluated (in terms of sensitivity analysis)?
9. How can heteroscedastic data best be analysed when developing an accident modification function?
10. How can accident modification functions be updated?

Ten guidelines addressing these issues are proposed. Each guideline is illustrated by an example showing how to use the guideline. All examples refer to studies of the effects on accidents of speed enforcement. The guidelines proposed are listed in Table 1. In the following sections, each guideline will be presented in detail.

2. Classify, code and select studies

The first step in developing an accident modification function is to identify the studies that will serve as a basis for developing the function. A systematic literature survey should be made to identify relevant studies. Once relevant studies have been identified, they should be classified according to study design and how well they control for potentially confounding factors. This is an essential

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Table 1
Methodological guidelines for developing accident modification functions.

Guidelines	Analysis required to comply with guidelines	Justification of guidelines
1. Classify, code and select studies	Classify studies by study design (see Table 2). Do not mix studies employing different designs in the same AMF. Code all variables that may influence effect size	Studies employing different designs do not control for the same potentially confounding factors. An AMF based on studies employing different designs may be more influenced by confounding than an AMF based on studies employing identical designs
2. Perform preparatory analysis	The potential presence of publication bias should be tested for. The relative contribution of systematic variation in estimates of effect to overall variance should be quantified. Effects of country and year of publication should be tested for	An AMF influenced by publication bias will be biased. AMFs should not be developed if publication bias is indicated. An AMF should explain systematic variation in estimates of effect; this only makes sense if systematic variation makes a predominant contribution to the overall variation in estimates of effect. Country and year of publication should be viewed as potentially confounding variables
3. Identify independent variables	At least one independent variable should be identified. Independent variables may either refer to the measure itself or the context of its use	An AMF should have at least one independent variable. Independent variables should describe characteristics of the measure or the context of its use
4. Identify outlying data points	Plot data points in a cumulative residuals plot, based on a preliminary AMF, to locate potentially outlying data points. Outlying data points should be omitted	An outlying data point may decisively influence the mathematical form of an AMF. It is not appropriate that a single data point should determine the shape of a function fitted to, for example, 40-50 data points
5. Identify the best fitting functional form	A systematic testing of various functional forms, such as linear, power, exponential etc. should be performed in order to identify the best fitting functional form	An AMF can have different functional forms, such as linear, power, exponential, etc. Exploratory testing is needed to identify the best fitting functional form
6. One or more functions	A careful examination of the residual terms of an AMF can give hints that two or more AMFs are needed to adequately summarise variation in the effects of a measure	The effects of road safety measures may not always be adequately summarised by means of a single AMF. If a more precise description of effects can be obtained by developing more than one AMF, this should be done
7. Evaluate accident modification function	AMF should be evaluated in terms of predictive performance, explanatory value, and distribution of residual terms	Unless an AMF fits quite well to the data, it cannot be applied to predict the effects of a road safety measure. Several criteria should be applied to assess the quality of an AMF
8. Perform sensitivity analysis	A sensitivity analysis should be made to assess the effects of analytic choices made when developing an AMF	When developing an AMF analytic choices are made about which studies to include, whether to develop one or more AMFs, the mathematical form of the AMF, and possibly other items. A sensitivity analysis tests how results are influenced by these choices
9. Decide on treatment of heteroscedasticity	Individual estimates of effect vary in statistical precision. This very often creates unequal variance (heteroscedasticity) across the range covered by the data	In heteroscedastic data, any function will often fit well to the part of the data characterised by small variance, but poorly to the part of the data characterised by large variance. One should assess options for minimising this problem, although it may be impossible to avoid it entirely
10. Update accident modification function	A routine for updating AMFs should be established, enabling a decision to made as to whether an updated AMF should retain the original functional form or adopt a new functional form	AMFs should be periodically updated. When an AMF is updated, rules should be established for either keeping its original mathematical form or changing the mathematical form of the function. If new data points do not fit well to any function, possible reasons for this should be examined

Table 2
Classification of road safety evaluation studies by design and control for confounding factors.

Main category of study design	Versions of study design by level of control for confounding factors	Rating for study quality (within main group)
Randomised controlled trials (experiments)	Randomised controlled trial demonstrating pre-trial equivalence of groups and controlling for treatment implementation, attrition bias and unintended effects	High
	Randomised controlled trial demonstrating or controlling for some but not all of the factors listed above	Medium
	Randomised controlled trials with evidence of systematic differences between treatment group and control group	Low
Before-and-after studies (observational)	Before-and-after studies controlling for regression-to-the-mean, long-term trends and changes in traffic volume not induced by the measure	High
	Before-and-after studies controlling for some, but not all of the factors listed above	Medium
	Simple before-and-after studies not controlling for any confounding factors	Low
Case–control studies	Case–control studies controlling for self-selection of cases and/or controls and important known risk factors by means of multivariate analysis	High
	Case–control studies controlling partly for self-selection bias and for some but not all known important potentially confounding factors	Medium
	Simple case–control studies not controlling for potentially confounding factors or simple case-series	Low
Cross-sectional studies – multivariate models	Multivariate models not known to be influenced by any of the following potential sources of error: small samples or low mean values; bias due to aggregation or averaging; outlying data points; inclusion of endogenous variables; co-linearity among independent variables; omitted variable bias; wrong functional form; inappropriate model form; inappropriate dependent variable	High
	Multivariate models not known to be influenced by most of the potential sources of error listed above	Medium
	Multivariate models known to be influenced by one or more of the potential sources of error listed above	Low