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Updating outdated predictive accident models

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ABSTRACT

Reliable predictive accident models (PAMs) (also referred to as safety performance functions (SPFs)) are essential to design and maintain safe road networks however, ongoing changes in road and vehicle design coupled with road safety initiatives, mean that these models can quickly become dated. Unfortunately, because the fitting of sophisticated PAMs including a wide range of explanatory variables is not a trivial task, available models tend to be based on data collected many years ago and seem unlikely to give reliable estimates of current accidents. Large, expensive studies to produce new models are likely to be, at best, only a temporary solution. This paper thus seeks to develop a practical and efficient methodology to allow currently available PAMs to be updated to give unbiased estimates of accident frequencies at any point in time. Two principal issues are examined: the extent to which the temporal transferability of predictive accident models varies with model complexity; and the practicality and efficiency of two alternative updating strategies. The models used to illustrate these issues are the suites of models developed for rural dual and single carriageway roads in the UK. These are widely used in several software packages in spite of being based on data collected during the 1980s and early 1990s. It was found that increased model complexity by no means ensures better temporal transferability and that calibration of the models using a scale factor can be a practical alternative to fitting new models.

1. Introduction

Reliable predictive accident models (or safety performance functions) are essential to provide and maintain safe road networks. Designers can, for example, use PAMs in the appraisal of the safety impacts of alternative design decisions, with PAMs essential to forecast accidents with and without possible interventions. Genuine high risk locations can be identified by comparing observed accidents with those predicted by PAMs given the type of site and level of traffic flow. Whereas scheme appraisal takes place prior to implementation using predicted outcomes, evaluation takes place after the event, normally using observed data. In the evaluation of safety impacts, however, simple comparisons of observed before and after accidents are known to exaggerate the effectiveness of treatments because of the regression-to-the-mean effect. This problem can be overcome using an empirical Bayes (EB) approach but its use relies on the availability of suitable PAMs (Mountain et al., 2005; Persaud and Lyon, 2007; Elvik, 2008). While the importance of PAMs is clear the quality of available models is rather less certain.

PAMs are derived by fitting regression models to data obtained from a large number of road sections or junctions. In their simplest form, such models relate expected accident frequencies to some measure of exposure (traffic flow). In more sophisticated models, additional variables describing the design features or geometry of the sites are also included. However, model fitting is by no means straightforward. High quality data are required for a large enough number of locations and accidents. The relevant data may not always be readily available and typically require the interlinking of separately maintained databases for accidents, traffic flows and design features. There is no accepted theory to indicate how accident frequency should increase with traffic flow or, indeed, with other characteristics such as hilliness or bendiness. In practice it is impossible to include every variable that could affect the mean accident rate in the models and the effect of omitted variables on the mean accident rate leads to overdispersion. For example, Walmsley et al. (1998b) tested numerous variables including verge type, road markings and presence or absence of warning signs but only a small subset of these variables significantly improved the fit of the model to the data. There is now a general recognition of the need to model overdispersion and the assumption of a negative binomial error structure is commonly used (see, for example, Maher and Summersgill, 1996). However, this is primarily for mathematical convenience, with recent research suggesting that alternative forms of error structure are now not only feasible but may also be more appropriate (Maher and Mountain, 2009; Lord and Mannering, 2010; Connors et al., 2013). Perhaps the most serious difficulty arises, however, because, over time,

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there will inevitably be changes in road, vehicle and driver characteristics such that the relationship between the dependent and independent variables may also tend to change. There may also be changes in accident risk due to behavioural changes over time, arising from a variety of factors such as driver education and training, improved vehicle and road design, safety campaigns, legislation, changes in enforcement levels and so on. Since it is not possible to quantify these and use them as extra explanatory variables in the model some models include a term to allow for long-term trends in accident risk (see, for example, Walmsley and Summersgill, 1998; Walmsley et al., 1998a, 1998b) but it is by no means clear that the pattern of change will remain stable over time (Elvik, 2010). The temporal transferability of PAMs is thus questionable, particularly when the elapsed time is large. Indeed the US Highway Safety Manual recommends that PAMs should be re-calibrated every 2–3 years and for use in a different jurisdiction (AASHTO, 2010).

Unfortunately, because the fitting of sophisticated PAMs including a wide range of explanatory variables is not a trivial task, available models tend to be based on data collected many years ago. In the case of UK roads, for example, the Transport Research Laboratory (TRL) carried out a comprehensive series of accident studies during the 1980s and 1990s. TRL developed models for various junction and link types at various levels of detail and were, indeed, amongst the first to recognise the need to model overdispersion and to propose the use of a negative binomial error structure. However, the earliest of these studies used accident data for 1974–79 to fit models for 4-arm roundabouts (Maycock and Hall, 1984) while the most recent used accident data for 1979–92 to fit models for rural dual carriageways (Walmsley et al., 1998a). In spite of the age of the modelled data and recent developments in accident modelling, the TRL models continue to be widely used by practioners in scheme design and appraisal in the UK because they are incorporated into several standard software packages such as ARCADY, PICADY and OSCADY for the design of roundabouts, priority junctions and signalised junctions respectively. However, given that, in the UK, annual personal injury accidents fell by 30% between 1985 and 2009 while annual total traffic increased by 61% (DfT, 2010a, 2010b) it seems unlikely that PAMs derived using data from some 20 to 30 years ago could provide accurate estimates of current accidents. Fitting new models for the whole range of link and junction types would be both time-consuming and expensive because of the size and level of detail of the database required. In any case, new models may only provide a temporary solution since the new models themselves could soon become outdated. A more economical long-term solution would appear to be to develop an updating strategy so that updated versions of the existing models can be used, not only now but also in the future. In the US, re-calibration of PAMs (or safety performance functions) is now standard practice. The approach recommended in the Highway Safety Manual (AASHTO, 2010), following on from Harwood et al. (2000) and Persaud et al. (2002), is to use re-scaling (by a factor given by the sum of observed collisions divided the sum of the predicted values). In this study we consider a wider range of updating strategies, both in terms of the scaling factor and the possibility of re-fitting the model, and seek to identify the best.

This research study has two principal objectives. Firstly to establish the extent to which the temporal transferability of predictive accident models varies with model complexity: specifically the extent to which the inclusion of additional design variables and modelling by accident type and individual road elements in more complex models increases temporal stability. Secondly to develop an approach that will allow currently available predictive accident models to be readily and reliably updated to any point in time. Although new predictive accident models have been developed in the last few years (for example Hashim and Bird, 2005) the updating strategy is applied to the TRL models as they remain the models most widely used by practioners in the UK. They also encompass a range of site types and are available at various levels of detail: from models relating total accidents to an overall measure of total flow, through to models for specific accident types in terms of relevant flows and a range of design variables. The suite of TRL models are thus well suited to demonstrate the approaches investigated here while recognising that more sophisticated, better fitting models may be available for some specific site types. To allow the objectives of the study to be achieved a database has been compiled containing accident data, flow data and geometric design parameters for six site categories; modern rural single carriageway A-roads, modern rural dual carriageway A-roads, urban single carriageways, urban 3-arm signalised junctions, urban 4-arm signalised junctions and 4-arm roundabouts. The aim was to include a range of link and junction types, and a range of model ages.

1.1. Aims of this paper

In an earlier paper, the authors addressed the principal methodological issues that arise in seeking practical and efficient ways to update PAMs (Connors et al., 2013). These issues were illustrated by application to a basic model for rural single carriageway roads, and include: the choice of distributional assumption for overdispersion; the choice of goodness of fit measures; questions of independence between observations at the same site in different years, and between links on the same scheme; the estimation of trends in the models; the uncertainty of predictions; the most efficient and convenient ways to fit the required models, given the considerable advances that have been seen in statistical computing software in recent years. The focus of this paper is to apply this methodology to establish the extent to which the temporal transferability of currently available PAMs varies with model complexity and to assess how best to update existing models.

Two site categories are assessed, namely, modern dual and single carriageway A-roads in rural areas which are amongst the most recent of the TRL models (Walmsley and Summersgill, 1998; Walmsley et al., 1998a, 1998b). The accident data used to fit these models were for the period 1979–90 for single carriageways and for 1979–92 for dual carriageways, although accident data were not available in every year for all schemes. A-roads are principal roads, designed to carry large volumes of long-distance traffic and here 'modern' refers to roads that meet post-1960 design standards. A rural road is defined here as a road which is not in a built up area. The highest quality dual carriageways are near motorway standard, while the lowest quality roads of both types can have sharper corners, steeper gradients and larger numbers of intersections without deceleration lanes. Initially, the goodness-of-fit of the existing suite of TRL models to current data was determined. The suite of TRL models for these roads covers a range of levels of detail: in the basic model, total accidents are simply related to a measure of traffic flow; in the most detailed models, accidents are disaggregated by type and for each type the accident frequency is related to traffic flow and a range of geometric parameters. Since the more detailed models can take account of the effects of improvements in highway design on the frequency of particular types of accidents, it seemed likely that they could offer better temporal transferability than the basic models, albeit at the expense of more input data.

In addition to simply applying the outdated models, two updating strategies were trialled. The first re-fitted the outdated models: that is, the same explanatory variables and functional form were used as in the original model but new estimates for each of the parameters were obtained The second re-calibrated the outdated models using a scaling factor to adjust for the long-term trend since the original models were fitted, whilst keeping other parameter values and the functional form the same.