The utility of historical trends to project future numbers of crashes in South Australia

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Abstract

In this paper, some simple models are examined for their utility in projecting future fatality numbers. Functions that represent the crash rate and travel exposure are fitted to time series of South Australian crash data. The model is used to examine the utility of forecasting crash numbers based on medium to long-term trends. (The model is simple as it does not seek to attribute changes to any set of factors in particular). In addition, South Australian data from 2001-2010 are examined in the light of systematic road safety changes that were made over the period corresponding to the road safety strategy that was active over the period.

The results show that fitting models to long-term trends has some utility for future predictions, but actual numbers (and shorter term trends) may significantly deviate from such a model. Furthermore, results indicate that models based on medium-term trends are an imperfect guide to the medium term future.

Finally, a discussion about recent features in the time-series of traffic fatalities is given. It is argued that to reach targets that have been set in the 2011-2020 state strategy (no more than 80 deaths per annum by 2020), a reduction in risk similar to that brought about in the previous decade by lowering urban speed limits will have to be achieved. The most effective way of achieving this will be through broadly-based changes to the road transport system that will lower risk for the greatest number of road users within the decade. However, interventions targeting narrowly defined high-risk problems (which may be cost effective) and actions to accelerate the improvement in the average safety of vehicles (which may only yield full benefits beyond the 10 year horizon of the strategy) should also be pursued.

"Prediction is very difficult, especially if it's about the future."

Niels Bohr.

Introduction

Road safety targets, in the form of a reduced number of persons killed or injured, form a part of most government road safety strategies. These targets are often used to indicate the level of aspiration underpinning the strategy. As there is a clear downward momentum in crash rates, the process of setting targets, and also the framing of a road safety strategy itself, might take note of changes that are likely over the course of the strategy.

The degree of ambition in a strategy might be judged relative to a 'business-as-usual' scenario, but identifying the 'business-as-usual' scenario is not straight-forward as it requires interpretation of past trends and projection of these interpretations into the future. If the sum of the effects of all changes to the system results in a change in crash numbers, it might be assumed and that (at least some of) these historical system dynamics will continue to reduce crash rates, even in the absence of new initiatives. (The gradual turn-over of passenger vehicles is an important example of this). Relevant too is that not all factors affecting risk and exposure, and hence the numbers of crashes, injuries and fatalities, can be influenced by government policy in the short to medium term. Other factors might fall completely outside the influence of road safety policy, such as exogenous factors that influence the amount of travel. And hence, ambition should to some extent be judged relative to the opportunity of road safety policy to affect average risk.

Stable, long-term trends are apparent in crash numbers at a state or national level (these are discussed below) but there is a degree of variance due to exogenous factors (e.g. economic factors) and natural variation, such that short-term trends may deviate from long-term trends, and the expected number of crashes. If it is apparent that fatality rates have been consistently declining at, say, five per cent per annum, how that five per cent can be attributed to specific changes to the system is much less clear. It is known that vehicles are improving with respect to both primary and secondary safety and there is continual refreshment of the fleet through normal attrition of vehicles. The link between speed and crash risk is also established and vehicle speeds may, on average, decline over time, reducing crash risks. Other broad scale changes to road networks will also effect changes to both risk and exposure, and added to these are the many smaller scale changes brought about by more narrowly defined interventions (narrow in that the intervention targets only a subset of at-risk road users e.g. graduated licensing schemes). The option explored in this paper is to set the problem of attribution aside and examine the numbers in a framework that assumes only that changes to the system are bringing about empirical changes in crash rates that are fairly stable and hence predictable. The claim to validity of such an approach is only empirical - it is valid while it works - but given stability in the trends, short to medium-term forecasts can be made.

Stable methods of projecting national fatality data were suggested by Koornstra (2007) when he presented a fatality data as a product of an exponential decline in the fatality rate (per distance travelled) and an increasing function that described the distance travelled within each country. The latter function was modelled as a Gompertz function with cyclical variations. Koornstra notes that in the current period in motorised countries, the component of the function that is a Gompertz curve is almost linear.

The objective of this paper is to forecast the time-course of seriously injured road casualties and road fatalities in South Australia using long and medium-term trends from 40 years of data to 2010 using models similar to those proposed by Koornstra. These forecasts will then be discussed in the context of short to medium term trends in fatality numbers over the period 2001-2010.

Accounting for variance in historical time series of South Australian road fatalities and casualties

Between 1970 and 2010, 9,006 people died in road crashes in South Australia. Over the same period about 97 thousand people sustained injuries requiring hospital admission. In common with most motorised countries, the annual numbers of fatalities and serious casualties in each year has been trending downward (Figures 1 and 2).

In Australia, the measure of exposure related to the distance travelled has been only intermittently reported, making the analysis of the performance of a similar forecasting model for South Australia difficult. However, reasoning that distance travelled should bear some relationship to the number of registered vehicles should allow a variation of the Koonstra model to be applied to Australian data, and elsewhere, wherever data on the number of registered vehicles is available.

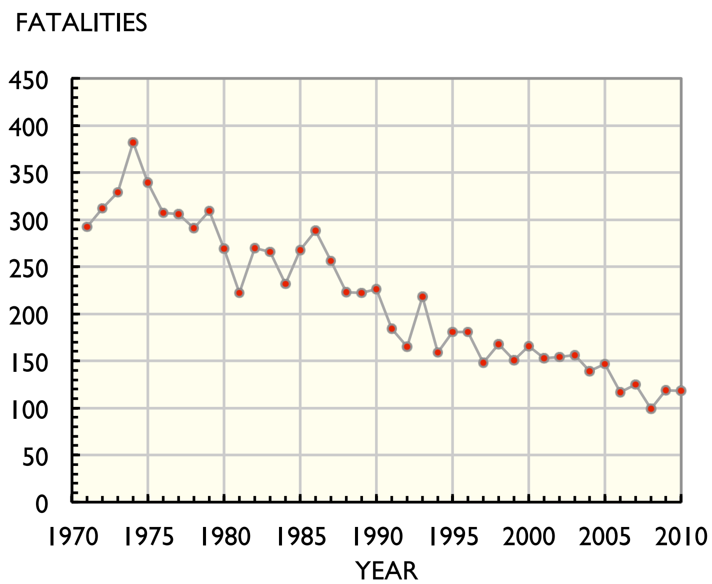

Figure 1 Annual road fatalities in South Australia 1971-2010

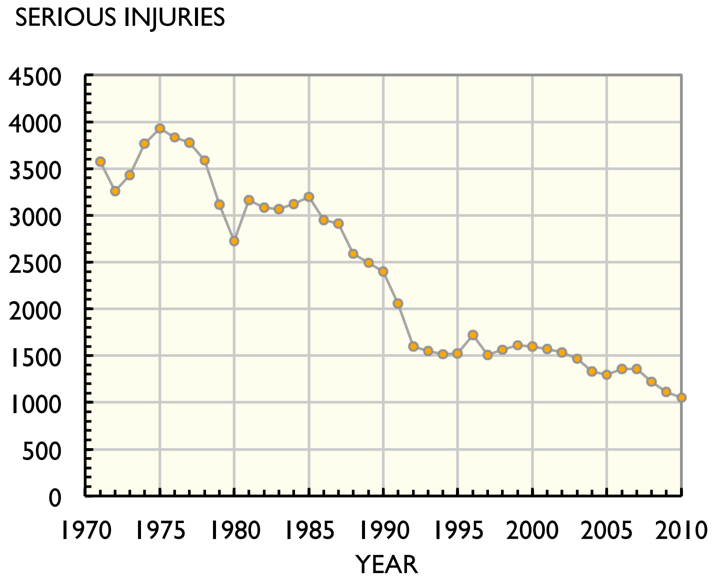

Figure 2 Annual road serious casualties (admissions) in South Australia 1971-2010

Below is a formulation for fitting simple functions to fatality or casualty data, similar to that proposed by Koornstra (2007), but using an exponential function to describe the fatality rate (per registered vehicle) and a linear function to describe the number of registered vehicles:

$$F(t) = f(t)g(t) = ae^{bt}(ct + d) \tag{1}$$

where

$f(t) = ae^{bt}$ describes the number of fatalities per registered vehicle and
$g(t) = ct + d$ is the number of registered vehicles.

The time-series of the number of registered vehicles in South Australia, and the corresponding linear trend, $g(t)$, is given in Figure 3.

The function $f(t)$ that approximates the vehicle-based-rate of fatal or serious injury crashes is found by dividing fatality and casualty numbers in each year by corresponding number of passenger vehicles in South Australia. The resulting time series of the rate of fatalities and seriously injured casualties is given in Figure 4. Also shown are lines that correspond to the functions for $f(t)$. Notable is that the slopes of these lines (b) are almost identical.

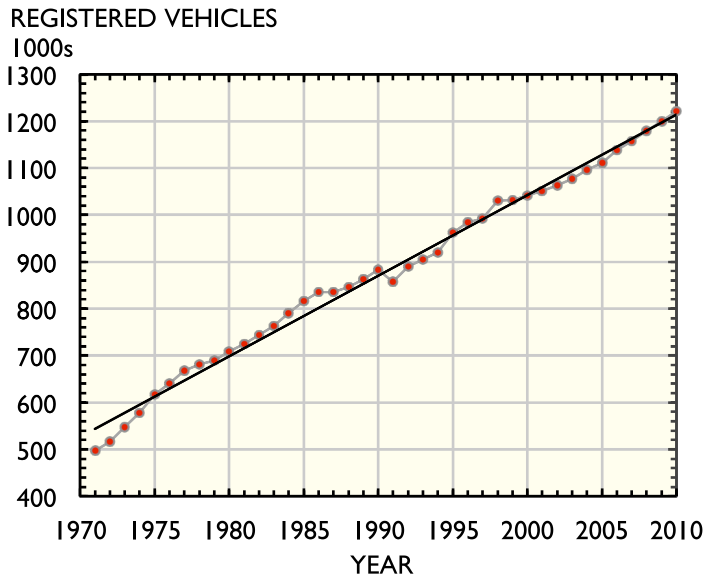

Figure 3 The number of registered passenger vehicles in South Australia 1971-2010 (Source: Department of Infrastructure, Transport, Regional Development and Local Government; Australian Bureau of Statistics)

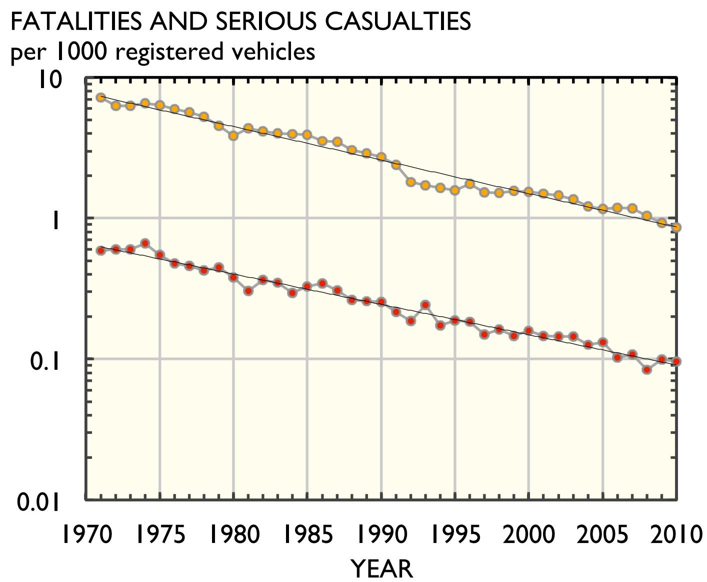

Figure 4 Time series of fatalities (lower line) and seriously injured casualties (upper line) due to road crashes in South Australia expressed at a rate per registered passenger vehicle.

Having estimated *f(t)* and *g(t)*, it is possible to assemble functions *F(t)* that approximate the time series of the raw numbers of fatally injured and seriously injured casualties of road crashes between 1971 and 2010.

Additionally, it is possible to estimate likely year-to-year variability between *F(t)* and that actual number of fatally injured or seriously injured casualties. Hutchinson and Mayne (1977) noted that the variability in the number of crashes, particularly when the mean exceeds 100 or so, is typically greater than would be predicted by randomness (the Poisson law) alone. This is due to randomness operating across years, as well as randomness operating within a year. Accordingly, the variance in crash numbers follows

$$Var(F(t)) = F(t) + kF(t)^2 \qquad (2)$$

where k has been found to be about 0.06 (Hutchinson and Mayne, 1977). Accordingly, it is now possible to plot an interval around F(t) that corresponds to two standard errors which is an estimate of the 95th percentile confidence interval accounting for the variance typically seen in national crash numbers.

In Figures 5 and 6, the time series of the annual numbers of fatally and seriously injured road casualties are plotted with the estimating functions *F(t)* and the 95th percentile confidence interval, based on Equation 2.

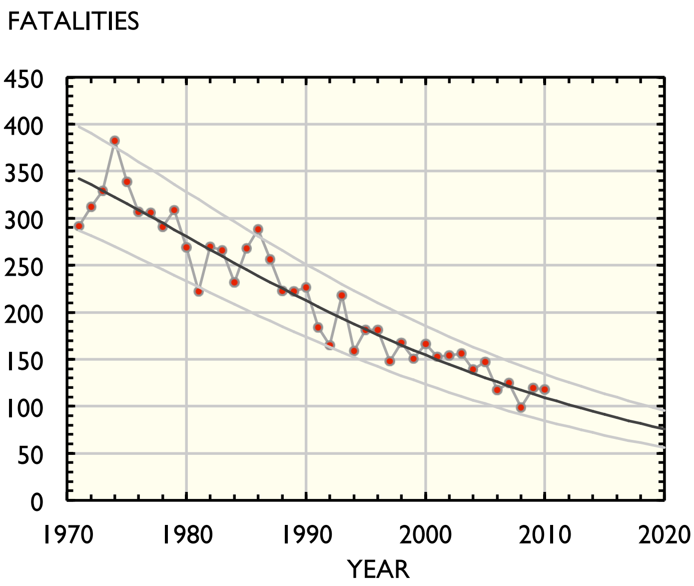

Figure 5 Time series of annual road fatalities in South Australia with the estimating function *F(t)* (see text) +/- two standard errors calculated according to Hutchinson and Mayne (1977).

Future projections

Having fitted a function that relates numbers of fatalities/seriously injured casualties to the number of registered vehicles and exponential declines in the rates (per vehicle), it is possible to project these functions forward to estimate future numbers.

It will be assumed that the functions describing the number of vehicles and the casualty rate will remain stable over the projection period. Although this is not guaranteed, the functions have been relatively stable for 40 years. It should be noted that these projections assume a rate of improvement similar to that which has been experienced from 1970 until now.

Figures 7 and 8 focus on the period 2000-2020. Shown are numbers of casualties from 2000-2010. However, the function *F(t)* is based on the entire period 1971-2010.

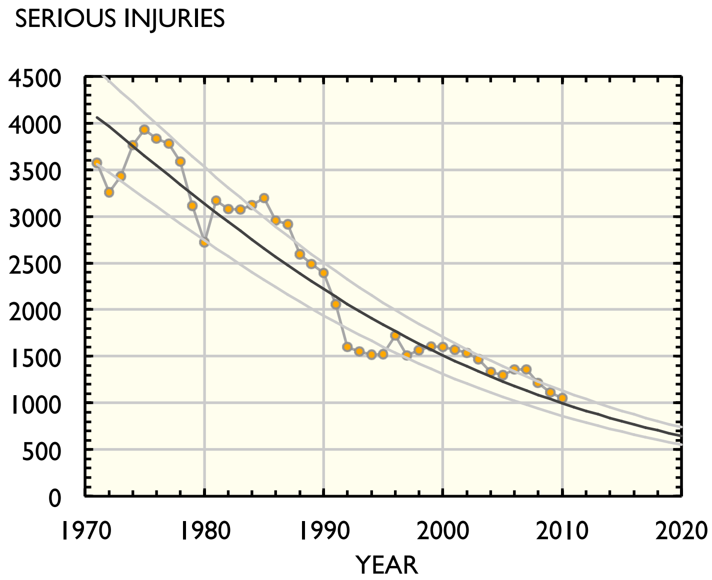

Figure 6 Time series of annual road serious casualties in South Australia with the estimating function *F(t)* (see text) +/- two standard errors calculated according to Hutchinson and Mayne (1977).

Based on these projections, it is likely that, in 2020, South Australia will have a fatal road toll of about 77 deaths +/- 20 deaths and 700 +/- 100 seriously injured casualties. The projection also indicates that the mean estimates of 100, 90 and 80 deaths per year will occur in 2012, 2015 and 2019 respectively, noting that it is entirely possible that annual tolls may now exceed 100 in any year during the remainder of the decade.

Economy as a source of additional variance in the model

Some thought has been previously given by others to what factor might explain the remaining variance in annual fatalities. Economic factors are sometimes invoked (e.g. Newstead et al, 1995) to explain variance.

Consider the period 1970-2008, with *f(t)* and *g(t)* being calculated as before, but for national fatality numbers (not shown here). Now consider the residual value between *F(t)* and the actual number of fatalities in any given year. In Figure 9, the residuals are expressed as a proportion of the actual fatality number and plotted with the trend in the Australian Bureau of Statistics measure, Domestic Final Demand (DFD) (ABS, 2009). (DFD measures the demand for goods and services in the economy). A weak correlation is apparent, suggesting that the variance not captured by the model proposed here may indeed encompass, at least in part, economic factors operating in the country at any given time. Higher final demand may indicate a greater movement of goods and people, and hence may increase the number of crashes.

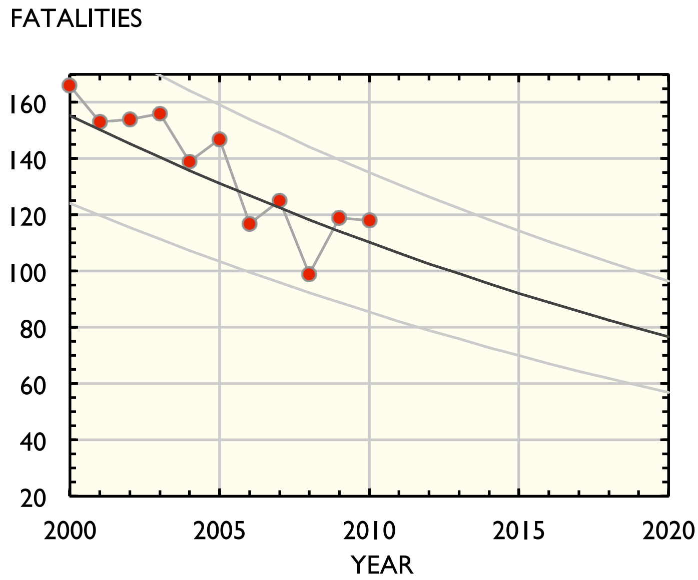

Figure 7 Time series of annual road fatalities in South Australia with the estimating function *F(t)* (see text) +/- two standard errors calculated according to Hutchinson and Mayne (1977), 2000 - 2020. Mean estimates of 100, 90 and 80 deaths per year will occur in 2012, 2015 and 2018 respectively

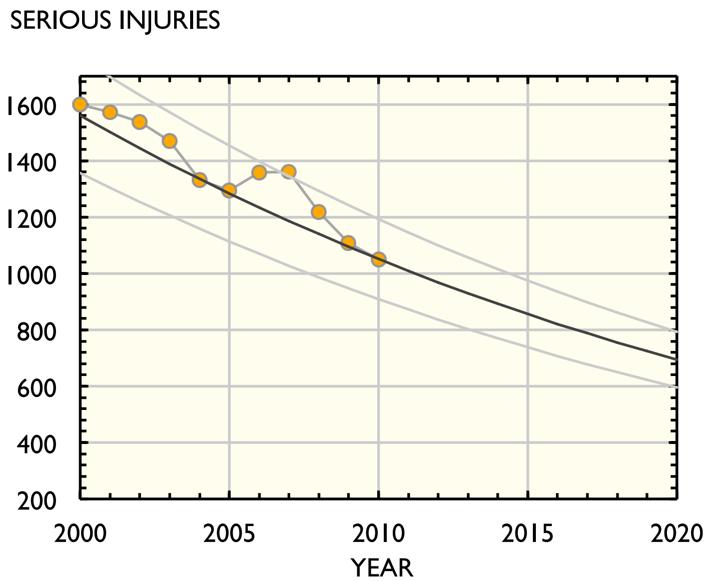

Figure 8 Time series of annual road serious casualties in South Australia with the estimating function *F(t)* (see text) +/- two standard errors calculated according to Hutchinson and Mayne (1977), 2000 - 2020.

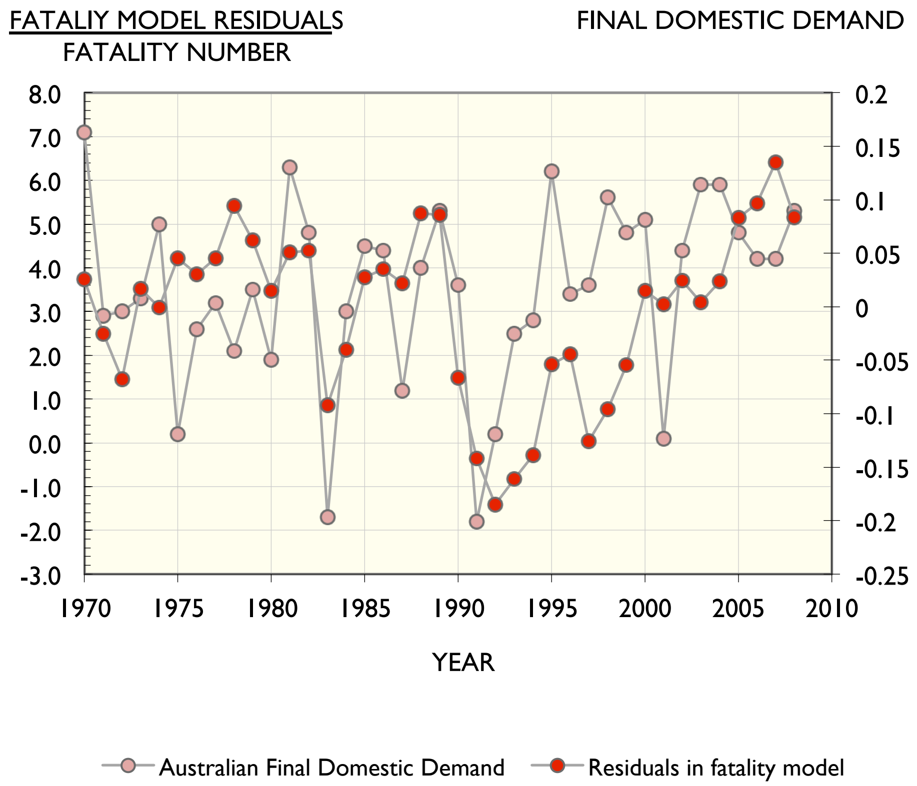

Figure 9 Model residuals for Australian annual road fatalities (as a proportion of the actual fatality number) and annual change in Australian Domestic Final Demand

The accuracy of forecasting using medium-term trends

The assumption that long-term trends can explain movements in fatalities in the short to medium term future may be questionable, and there are periods where medium term trends have deviated from the long-term trends (see Figures 5 and 6). This part of the paper explores the question of whether proximate trends may be more relevant to any given forecast period.

First, note that targets tend to emphasise fatalities and casualties in the *final* year of a strategy period, and hence forecasts are typically separated from the proximate trends by 10 years (where the strategy speaks of a decade of road safety actions).

Consider forecast fatalities in year *n*, based on the trend in fatalities/serious casualties over the period {*n*-19, …, *n*-10}. This describes the situation where the number of fatalities/serious casualties 10 years hence is predicted by the most recent 10 years of data. The error in the forecasts produced by this was examined for all years *n* = {2000,…, 2010}. For each year, the difference between the forecast and the actual number of fatalities/serious casualties was expressed as a proportion of the actual number of fatalities/serious casualties. The distribution of the error is given in Figure 11. The use of ten-year trends in each case was able to predict the actual fatality number at the end of the following decade within a band of 50 per cent of the actual number, but biased toward underestimation. (Note that this bias is not consistent. The procedure applied to years 1991-2010 produces estimates that are fairly unbiased and within +/- 40% of the actual number). This procedure used to forecast fatalities in South Australia in 2020 produces a central estimate of 70, and given the results in Figure 11, the confidence interval might be {~98,~63}, depending on the bias operating in such estimates over the forecast period.

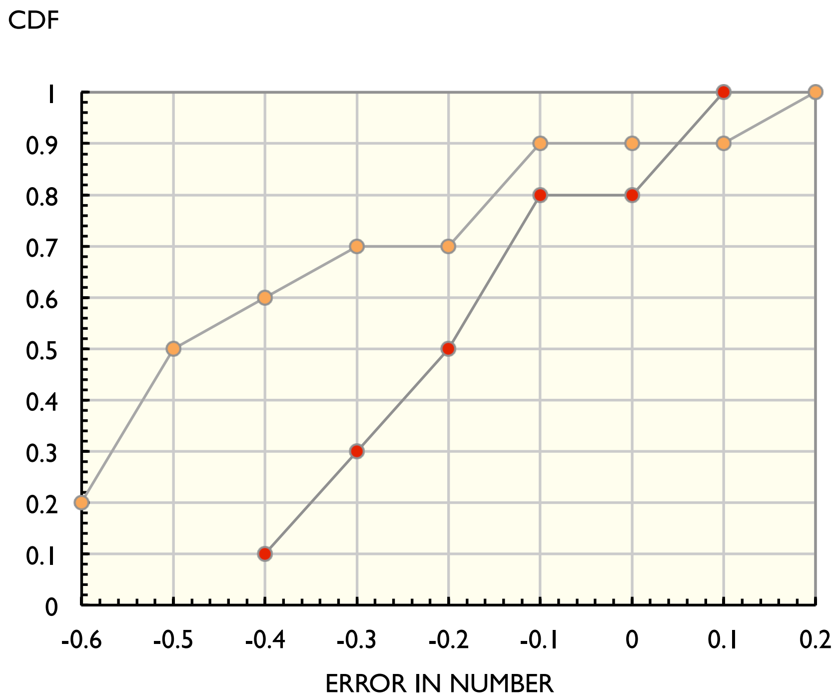

Figure 11 The cumulative distribution of the error in predicting the number of fatalities in any given year *n*, based on a forecasting model that used fatality numbers in years *n*-19 to *n*-10, n = {2000, … , 2010}. (A positive error indicates the model overestimates the actual number of fatalities.)

Percentage reductions in casualties and fatalities over 10 year periods

Thus far, this paper has not discussed target setting framed in terms of percentage reductions in fatalities or casualties. National and state strategies are proposing 30% reductions in fatalities and seriously injured casualties between 2000 and 2010 (e.g. Albenese and King, 2011). It is relatively straightforward to examine the distribution of decade-long reductions in fatal and serious injuries in South Australia. Here, relevant distributions are of

$$(\text{Fatals}_{(n-10)} - \text{Fatals}_{(n)})/\text{Fatals}_{(n-10)},$$

and the equivalent distribution of serious injury reductions. These distributions are shown in Figure 12 for *n* = {2001, …, 2010} and indicate the frequency of 10-year reductions in South Australia in recent times. It may be seen that > 30% reductions in fatalities occurred in 2 of the 10 years, and > 30% reductions in serious casualties occurred in 1 of the 10 years. Median reductions were around 15%.

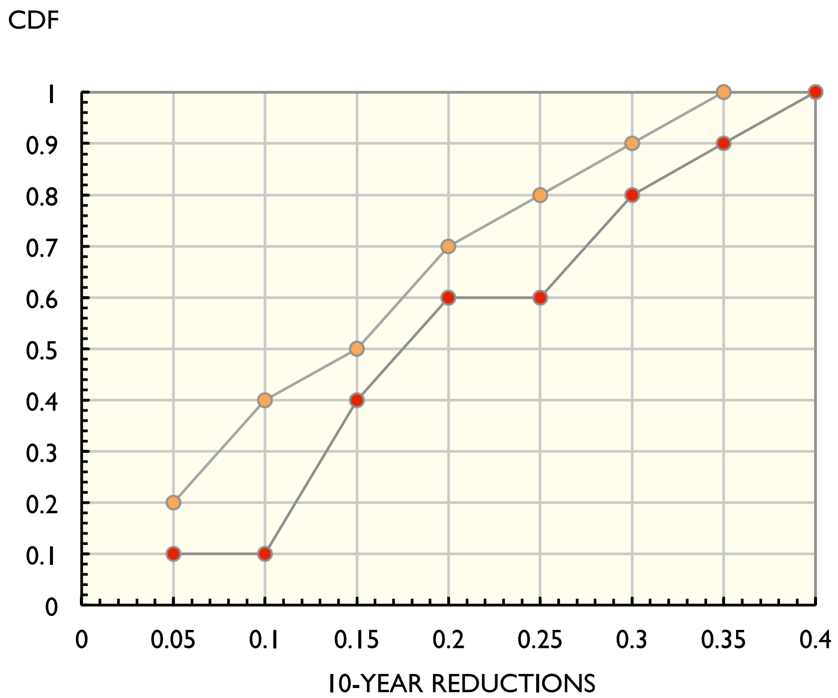

Figure 12 The cumulative distribution of 10-year reductions in road fatalities (red) and serious casualties (orange) in South Australia, for end-years between 2001 and 2010.

Discussion

This paper has presented results from variations on forecasting methods based on models developed by Koornstra (2007). Empirically, the models explain a high degree of the variance in historical numbers of fatalities and casualties but a degree of variance remains such that the forecasts are prone to error. The models suggest that South Australia may experience 70-80 fatalities in 2020, but there is no guarantee that the number might vary from this substantially. 80 represents a 32 per cent decline in fatalities over 10 years, and such a decline is seen only in a minority of 10-year intervals that ended in the period 2001-2010.

While this paper has focussed on forecasts using trends that are not attributed to any particular change to the system, systematic changes need to be acknowledged and may help to explain medium term variation in trends. The recent time series of fatalities in South Australia has specific features that may help to both understand declines in the last 10 years and to give a sense of the size of the effects that future systematic changes will need to have to reduce the road toll by 30 per cent by 2020.

- The number of fatalities that have occurred in the last five calendar years (2006-2010) have hovered at around 120 with an exceptional 99 fatalities in 2008.
- The trend over this period has been negligible.
- Different five-year periods in the recent past give quite different pictures: fatalities over the five years from 2004-2008 declined at eight per cent per annum. Fatalities over the previous five-year period declined at only one per cent per annum.

In the opinion of the author, it is entirely defensible to propose that systematic road safety changes made during the last decade had measurable effects on fatality numbers. To take one specific example, evidence is consistent with regard to speed limit reductions: year-on-year reductions in speeds were noted in surveys over the latter part of the last decade. These changes, other road safety improvements would have contributed to declines in crashes over the middle five years of the last decade.

Trends from 1998-2003 and from 2006-2010 appear more modest; while it should be acknowledged that higher fatality numbers for two years after 2008 are not enough to call the halt to the apparently strong downward trend. But in the absence of new changes to the system, neither should the possibility of a return to a slower rate of improvement, such as that seen prior to 2004-2008, be discounted. (The rate of decline in the 10 years prior to 2005 was two per cent per annum.)

What would a two per cent decline in fatalities mean over the next decade, and how would this compare to continuation of the 40-year trends? First the current ‘natural’ number of fatalities should be noted. Both 2009 and 2010 contained months in which more than 19 people were fatally injured. Such periods ought to be rare statistically. It might be said that the natural number is therefore currently around 110. Given this starting point, an average decline of two per cent would mean that about 90 people would be killed in 2020. Similar calculations applied to serious injuries would mean that about 860 people would be seriously injured in 2020. These figures may be compared to forecasts of 77 deaths and 700 serious injuries using the 40-year trends used earlier. This difference would mean that, over the decade, there would have been an additional 77 deaths and 1000 people sustaining serious injuries, corresponding to an additional monetised crash costs of $650 million (BITRE, 2009). To this figure we might add the costs of minor injury and property damage only crashes. It is clearly in the state’s interest to understand the dynamics of road crash incidence and what it is that is influencing that incidence, and to exert itself to ensure the most rapid possible declines in risk are achieved.

The South Australian Road safety strategy proposes a target of no more than 80 deaths in 2020. As this paper has shown, this figure lies near central forecasts made using the forecasting techniques presented in this paper. While a target set near the central forecast may not appear ambitious, several things should be borne in mind:

- In general, any target might be chosen from the upper part of the band of likely figures forecast for the end of the strategy period, and hence a published target of 80 might be consistent with a central target that is substantially less than 80.
- A 30 per cent reduction over 10 years has not been the typical pattern seen in crash numbers over the last decade.

The target of 80 deaths is consistent with an average three per cent decline over the next 10 years. It is also consistent with periods of modest decline (say, one per cent per annum) punctuated by a period of significant change (say, six per cent per annum for a period of four years). The target of 80 deaths per annum in 2020 means changing crash risk by a similar magnitude to that achieved during the last decade.

The focus of this paper has been on trends in the aggregate data – it has not used a “bottom up” approach where effects of individual countermeasures are summed to indicate aggregate changes in risk. Disaggregation of crash types could be used to give a sense of trends amongst individual road user types or crash types (intersection crashes, single vehicle loss of control etc.) in an effort to understand the changing nature of crash risk and exposure.

Finally, an argument that broad-based systematic changes to the system are required to effect large reductions in casualty and fatality rates does not obviate the need for smaller scale interventions. Interventions with a narrowly defined scope, say those targeting small high risk groups, may still produce effects that outweigh the costs of the interventions, and it has not been the intention of the discussion here to dismiss the proposition that such interventions are worthwhile. Similarly, other interventions, such as improving the safety of new vehicles ,may deliver benefits well beyond the 10-year horizon of the present strategy and should be pursued with this in mind.

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References

ABS (2009) 5206.0 - Australian National Accounts: National Income, Expenditure and Product, Dec 2008, Australian Bureau of Statistics, March 2009. Last viewed online on 23/5/2011 at http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5206.0Main+Features1Dec%202008?OpenDocument

Albanese A and King C (2011) New National Road Safety Strategy for Australia. Joint press release, 20 May 2011, AA084/2011 Joint. Australian Parliament House, Canberra.

BITRE (2009). Cost of road crashes in Australia 2006. BITRE118, Canberra: Bureau of Infrastructure, Transport and Regional Economics.

Hutchinson TP, and Mayne AJ (1977) The year-to-year variability in the numbers of road accidents. Traffic Engineering and Control, 18, 432-433.

Koornstra MJ (2007) Prediction of traffic fatalities and prospects for mobility becoming sustainable-safe. *Sadhana* Vol. 32, Part 4, August 2007, pp. 365–395.

Newstead SV, Cameron MH, Gantzer S, Vulcan AP (1995) Modelling of some major factors influencing road trauma trends in Victoria 1989-1993. Report 74, July 1995, Monash University Accident Research Centre, 53 p.