Predicting Casualty Numbers in Great Britain

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Monthly time series data related to road traffic and pedestrian casualties and fatalities in Great Britain are analyzed and trends are identified. These forecasts are based on extrapolation of the absolute number of casualties and not the ratio of casualties to 100 million vehicle kilometers. A short review of influences on these trends is presented, and a number of statistical forecasting autoregressive integrated moving average models are then constructed. Predictions produced are compared with government targets, and it is found that targets for fatal, serious, and slight casualty reduction are on track to be met. However, there are fewer grounds for optimism regarding pedestrian casualties.

A key performance measure of a nation's transport system is the number of people who are killed or seriously injured. National governments provide targets that traffic managers, infrastructure designers, vehicle manufacturers, and the legal system strive to achieve. The latest set of targets for Great Britain are for 2010, by which year it is hoped that compared to the average for 1994 to 1998, the number of fatal or seriously injured in road accidents will be reduced by 40%, the number of children killed or seriously injured by 50%, and the number of slight injuries per 100 million vehicle kilometers by 10%. The previous set of targets, set in 1987, sought to reduce deaths and serious injury by one-third by the year 2000, compared to the average of 1981 to 1985. This was achieved; road deaths fell by 39% and serious injuries by 45%. The success in Great Britain has come about through legislative changes intended to alter driver behavior, improve infrastructure, and improve crashworthiness of vehicles. A chronology of events affecting road safety was published by the Department of Transport (*1*).

The number of casualties is of concern throughout Europe, where there are more than 40,000 deaths and 1,700,000 injuries per year, costing some 160 billion €, and the young are most affected (*2*). Considering the ranking of European nations for number of fatalities per 1 billion km driven in 2001, Great Britain compares favorably with its European neighbors and other Organisation for Economic Co-operation and Development countries.

Its improvement in rates of road traffic injuries makes Great Britain one of the safest European countries, but its 1997 child pedestrian fatality rate per 100,000 people is one of the worst in Europe. Of concern is that since 1991, the number of road traffic casualties in Great Britain has shown a slight upward trend.

Figure 1 shows that the accident severity trends are somewhat different from the total. Thus the numbers of fatal and severe casualties have decreased markedly over the period, whereas the number of slight injuries has increased. Since 1991, the number of vehicle kilometers traveled in Great Britain has increased by more than 15%; the risk of fatal or serious injury has substantially decreased by 24.5% and 28.1%, respectively.

This paper explores recent casualty time series in Great Britain and forecasts these series to 2010. Most forecasting approaches predict casualties per 100 million km, which is problematic because it implies predicting a time series that is hard to estimate and is integral in the time series of casualties. Thus an attempt is made here for a straightforward forecasting of casualty numbers. This will reflect the strong seasonality that is inherent in the casualty time series. It is hoped this will be useful to those involved with road safety, for determining if goals for the number of those killed or seriously injured can be met or if more effort is required.

REVIEW OF PREVIOUS WORK

The main approach to forecasting killed or seriously injured (KSI) casualties has been to take a time series of annual rates and fit a negative exponential model and then to extrapolate from this. Sometimes allowance is made through use of disturbance terms for special events, like the introduction of legislation to make use of seat belts compulsory, but in general the models are univariate and incorporate few explanatory variables. A good example is the work of Broughton (*3*), who fitted extensions of the model

$$\log(\text{casualties}/\text{traffic volume}) = a + b * \text{year} + \text{an intervention term}$$

For fatalities, this model gave surprisingly good forecasts, predicting the number of fatal casualties in 2000 to be 3,312 with a 90% prediction interval of 2,892 to 3,826; there were 3,409 fatalities. Broughton's forecasts of KSI numbers and all casualties underpredicted by 4.8% and 24.8%, respectively. A major problem with this approach is that one must forecast the number of kilometers driven to allow the output of the model to be expressed as the number of casualties.

The use of kilometers as a denominator is contentious because most casualty accidents occur relatively close to the place of residence of the casualty (*4*, *5*). In addition, the certainty of estimation of a nation's annual driving is debatable. However, Nilsson argued that for comparisons over time and between nations, mortality rates should be divided by kilometerage, but Nilsson acknowledged that this is not completely satisfactory (*6*).

There has been much discussion in the literature about underlying variables that could explain casualty trends. Smeed (*7*) and Sivak (*8*), for example, pointed out that many factors influence a country's

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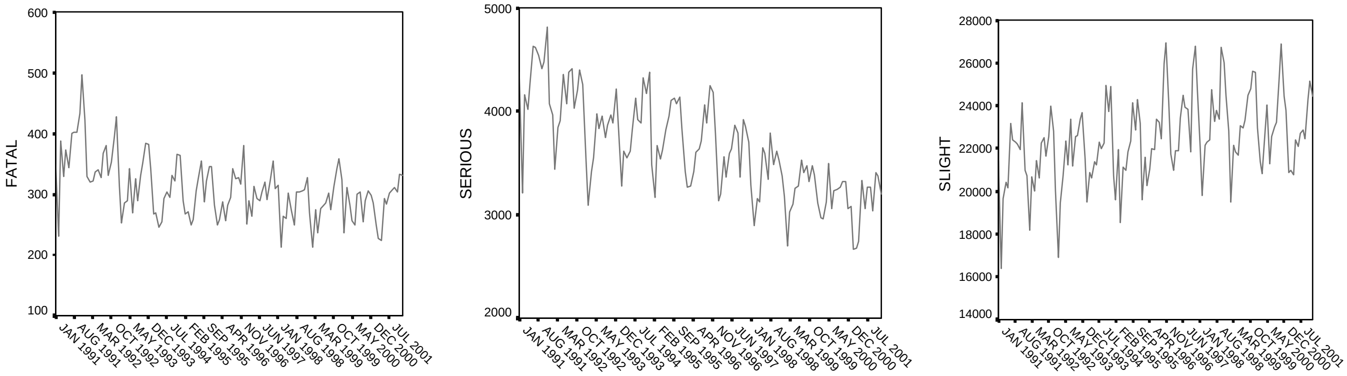
Transportation Research Record: Journal of the Transportation Research Board, No. 1897, TRB, National Research Council, Washington, D.C., 2004, pp. 142–147.



(a) (b) (c)

FIGURE 1 Accident severity trends: (*a*) fatalities, (*b*) serious injuries, and (*c*) slight injuries.

safety level, such as road safety policy, crashworthiness of cars, human behavior and attitudes, and characteristics of the road network. Bester showed that, generally, national road fatalities could be predicted by passenger car ownership, infrastructure variables, and socioeconomic variables (*9*). The literature that focuses on behavioral changes is inconclusive; there is little strong evidence of more awareness of the need for safety or compliance with speed limits. The 2002 Department of Transport casualty report indicated that from 1991 to 2001, the number of fatal and serious casualties estimated to involve blood alcohol levels above the legal limit fell by 27% and 33%, respectively (although rates of slight injuries in crashes in which blood alcohol level was above the legal level have risen by 14%, largely because of a big rise in 2001). The compliance rate for wearing of seat belts in Great Britain is one of the highest in Europe, greater than 90% (*10*). Thus, improvements may be due to infrastructural improvement and vehicle design. However, in studies of infrastructure improvement in the United States, Nolan found that infrastructure improvement did not reduce fatalities and injuries and may even have increased them (*11*). Nolan argued that KSI reduction has more to do with demographic factors, reduced per capita alcohol consumption, and improved medical technology. There is a lobby that argues that as the road infrastructure improves, there is a risk-compensation effect, and people will drive faster and take more risks (*12–14*).

Broughton, from a study of accidents in Great Britain from 1980 to 1998, reckons that improved car secondary safety or crashworthiness has reduced KSI by at least 19.7%, and for cars first registered in 1998, this reduction may be as much as 33% (*15*). Broughton pointed out that not only are cars being designed with more safety features, they are also becoming heavier and intrinsically offer more protection. Farmer et al., in a study of the effectiveness of antilock braking systems (ABS), presented a view that ABS can reduce KSI by 10% (*16*), but Broughton and Baughan from a postal survey in Great Britain of 80,000 owners of new car did not find conclusive evidence of a safety improvement (*17*). They found that among males up to age 55, the risk of accidents may drop by 16%, but among older males and women, the risk of accidents may well increase. This is because drivers tend not to have received training on the use of ABS, and there is a general lack of knowledge on how to use the system. Thus, Broughton and Baughan argue only for a modest reduction in accident risk of around 3%. Similarly, Wallis and Greaves reported that although air bags reduce the morbidity and mortality from crashes, there is a corresponding increase in the number of injuries attributable to air bags through improper deployment (*18*).

DiGuiseppi et al. analyzed child road fatalities from 1985 to 1992 and compared changing travel patterns of children (*19*). They found that the death rates of pedestrians declined by 24% per mile walked, and for cyclists death rates fell by 20% per mile cycled. But for occupants of motor vehicles, death rates fell by 42% per mile traveled. They concluded that the only way to reach the 2005 Great Britain government goal of reducing child accident rates by 33% would be to curtail walking and cycling. Generally, it appears that improved child KSI are a result of less walking and cycling, and indeed activities have shown a marked decline during that period of 21% and 8%, respectively (*20*). For cycling in Great Britain, Stone and Broughton showed that there is a downward trend in cycling casualties but not in the ratio of injuries to casualties; the ratio was 5.6 killed to 10.7 injured in 1991, which changed to 4 killed and 7.8 injured in 1999 (*21*). Thus cycling may not be safer, but rather there is perhaps less exposure.

EXPLORATION OF DATA

The data used for this study are police road traffic incidence reports know as STATS 19 (*22*), available from the United Kingdom data archive for 1991 to 2001. STATS 19 is three linked forms that are completed by police officers at the scene of a road traffic accident in which one or more persons are injured. One form records the vehicle details, another the accident details, and the third the casualty details. In this study, the accident and vehicle records were used and gave a data file of some 3.48 million cases.

These data generally are perceived as reliable, but there may well be substantial underreporting of accidents. Alsop and Langley analyzed hospital records in New Zealand, where a similar data collection system is used, and showed that less than two-thirds of all hospitalized vehicle crash victims were recorded by the police (*23*). Of those hospitalized through vehicle accidents, for those younger than 14, Alsop and Langley showed that only 49% were recorded by the police, suggesting a particular underreporting issue associated with cycling accidents. James made an extensive review of underreporting of traffic accidents and made estimates of underreporting in the Great British records (*24*). She reckoned that the fatal series is accurately recorded, but only 76% of serious casualties are recorded, and only 62% of slight injuries are recorded, giving an overall reporting of casualties of 62%. In this paper, no account is made of this probable underreporting, but it is brought to the reader's attention. However, if one assumes that there is a constant percentage bias in the seriously and slightly injured series, then one can still estimate the trend.

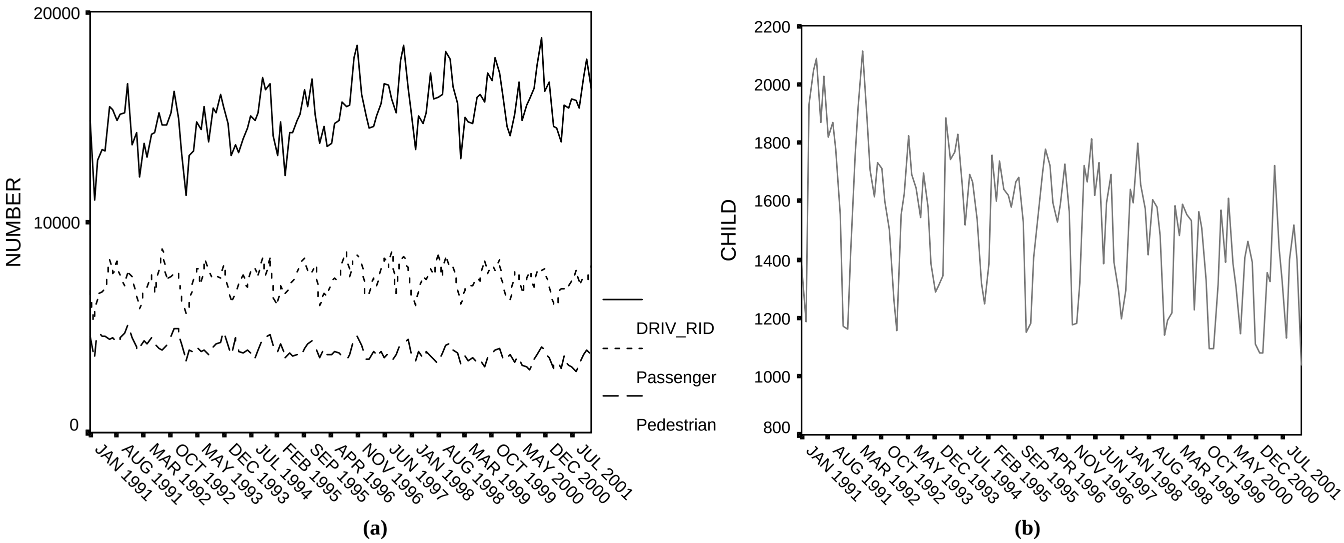


FIGURE 2 Trends in (*a*) casualty class and (*b*) child (0 to 15 years) pedestrian casualties.

In Figure 1, it is clear that all series exhibit marked seasonal fluctuations. Injuries are at a minimum from February to April and then rise steadily, peaking in the last quarter of the year. This distribution is fairly constant over the time series available. This pattern does not reflect exposure, as data from the National Travel Survey show that for 1996 the seasonal distribution of vehicle kilometers peaked in the summer. Trends in the type of casualty are displayed in Figure 2.

Thus the proportion of drivers and riders is increasing, whereas the proportion of passengers and pedestrians, which here include cyclists, is decreasing. This may reflect changes in exposure in that more people are taking single-occupant journeys in cars and fewer people are walking and cycling (*20*).

The seasonal pattern of pedestrian and child pedestrian injuries is different from those of all casualties and fatal casualties, as is shown in Figure 3.

There has been a small but insignificant upward trend in age of accident victims, from 31.66 years to 33.5 years. Female mean age of injury or death is 34.28 years, which is significantly higher than the mean male age of 31.31 years.

There is no significant trend in the age of fatalities, which have a mean age of 41.56 years. For serious and slight injuries, there is only a slight and insignificant trend in the mean age of the casualties, rising from 33 to 35 years and from 31 to 33 years for serious and slight injuries, respectively.

MODELS AND FORECASTS

Box–Jenkins seasonal models were fitted to the data for 1991 to 2000 and forecasts compared to 2001. These models, which were based on fitting autoregressive and moving average components to the data series, have a long history of use in tie series analysis and are explained in full by Bowerman and O'Connell (*25*).

Examination of the autocorrelation and partial autocorrelations revealed that despite the apparent trend exhibited in Figure 2, there is no need for differencing, and the series seems to be dominated by

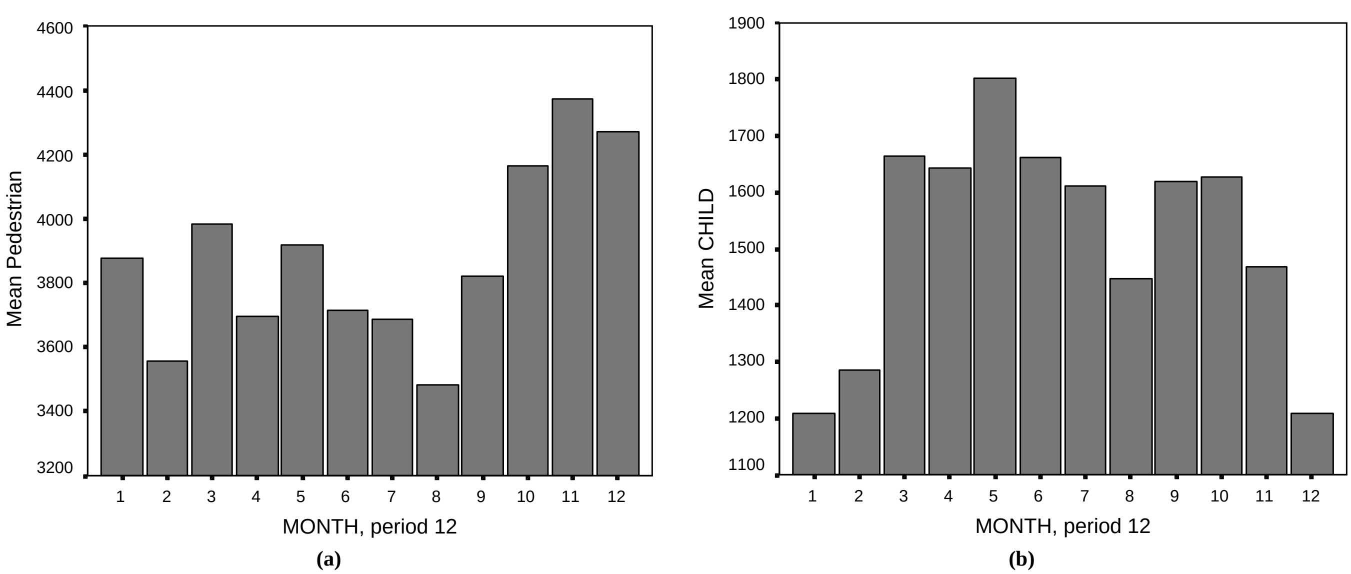


FIGURE 3 Seasonal distribution of (*a*) pedestrian casualties and (*b*) child pedestrian casualties.

TABLE 1 Coefficients and Fit and Forecast Performance of Models, by Injury

	Fatal	Serious	Slight
	Coefficient (T-Ratio)	**Coefficient (T-Ratio)**	**Coefficient (T-Ratio)**
Constant	-11.1101 (-1.9397)	-131.1627 (-3.6401)	223.5037 (2.5789)
AR1	0.9220 (12.7539)	0.8946 (9.400)	-0.2318 (-0.1091)
MA1	0.7748 (6.4890)	0.7354 (5.0759)	-0.2925 (-0.0880)
SAR1	-0.4563 (-5.0395)	-0.3800 (-3.9926)	-0.2925 (-2.9153)
Standard Error of Residuals	31.292	210.298	1175.840
AIC	1057.02	1467.66	1838.59
SBC	1067.75	1478.39	1849.32
M.A.P.E for 2001	12.14%	4.67%	3.58%
MSE for 2001	1226.9	24362.5	1106841

an autoregressive component, although there is a need for seasonal differencing. On applying nonseasonal differencing, essentially a random walk time series resulted. To derive models, over- and under-fitting were used extensively, and the optimal models were selected and the residuals checked to ensure that there were no significant autocorrelations and that they satisfied assumptions of normality.

A model of the form ARIMA(1,0,1) × (1,1,0), where ARIMA is the autoregressive integrated moving average, fitted well for the fatal and serious series, but the nonseasonal elements were not found to be significant for the slight-injury series. The parameterization, fit measures, and measures of forecast accuracy are given in Table 1. Although the nonseasonal parameters of the slight-injury series are statistically insignificant, one can see that they are the opposite of the parameters of the fatal and serious accident series.

It is speculated that the ARIMA(1,0,1) × (1,1,0) model has not been well estimated because of how slight injury is recorded, and slight-injury accidents may be overrecorded. Perhaps others who are involved in fatal or serious accidents in many cases are routinely taken for treatment. Fitting the model to the severe accident series rather than injury produced a good series. [The parameters are AR1 = –0.8584 (–6.2253), MA1 = –0.9349 (–9.4207), SAR1 = –0.2945 (–2.900), and constant = 99.8987 (1.5920); *T*-ratios are in parentheses.]

Thus it is concluded that the ARIMA(1,0,1) × (1,1,0) model is a suitable representation of the time series accidents in Great Britain. The forecasting ability of these models is displayed in Figure 4.

By fitting the ARIMA(1,0,1) × (1,1,0) model to the series 1991 to 2001 and extrapolating forward from these models and summing to give annual figures, one can obtain projections up to 2010. Rather than calling these forecasts, ARIMA models are more suited for short-term forecasts, and there is concern about extrapolating for almost the length of the data series used for fitted purposes. Nevertheless, the general trend in casualty numbers can be obtained. All the models fitted well with parameters similar to those of the models fitted over the period 1991 to 2001. The model for the slight-injury series is now well estimated with parameters AR1 = –0.8297 (–4.7948), MA1 = –0.9088 (–6.8758), SAR1 = –0.3025 (–3.1937), and constant 161.1523 (1.8733); *T*-ratios are in parentheses. The extrapolations to 2010 are displayed in Figure 5.

The prediction of fatalities for 2010 ranges from 336 to 4,829 with an expectation of 2,582, which is 28% of the 1994-to-1998 average of 3,578, which is used as the government baseline for measuring improvements. The 95% prediction interval for the KSI in 2010 ranges from 10,473 to 43,419 casualties with an expectation of about 26,946 casualties. This is a reduction of just over 43% of the baseline average of 47,656 casualties and indicates that the government target of a 40% reduction may be achieved. For slight casualties, the prediction for 2010 is 291,974, which is an increase of just over 7% on the baseline average; however, to determine if the

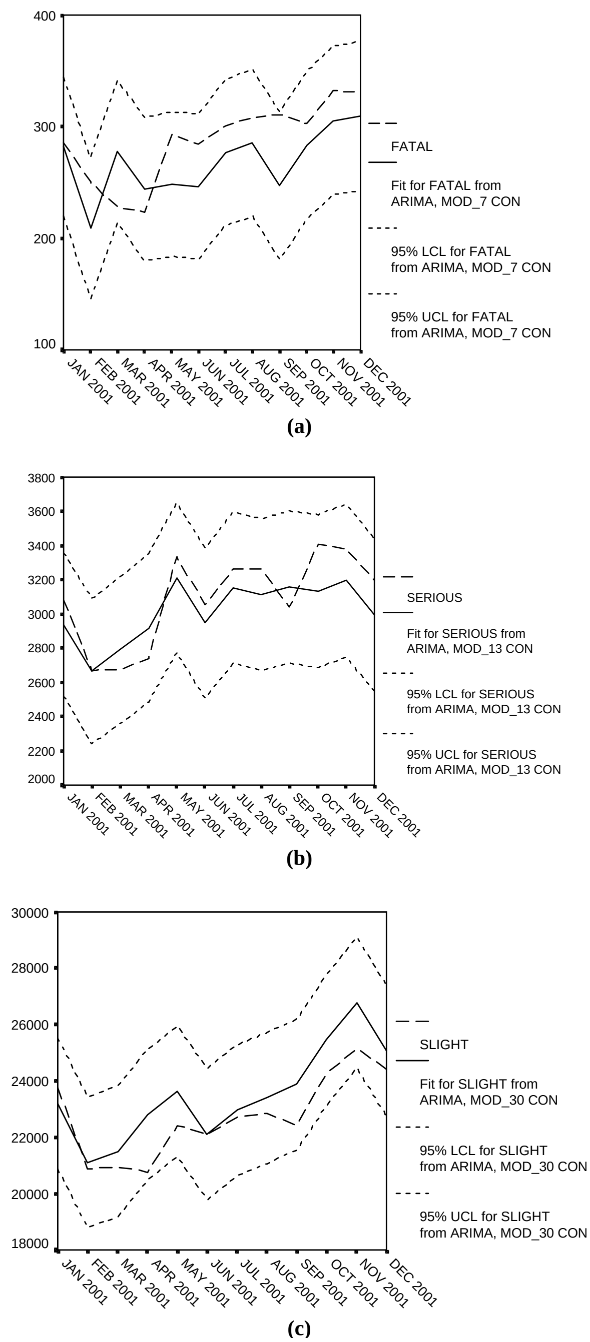


FIGURE 4 Forecast performance for (*a*) fatal, (*b*) serious, and (*c*) slight casualties.

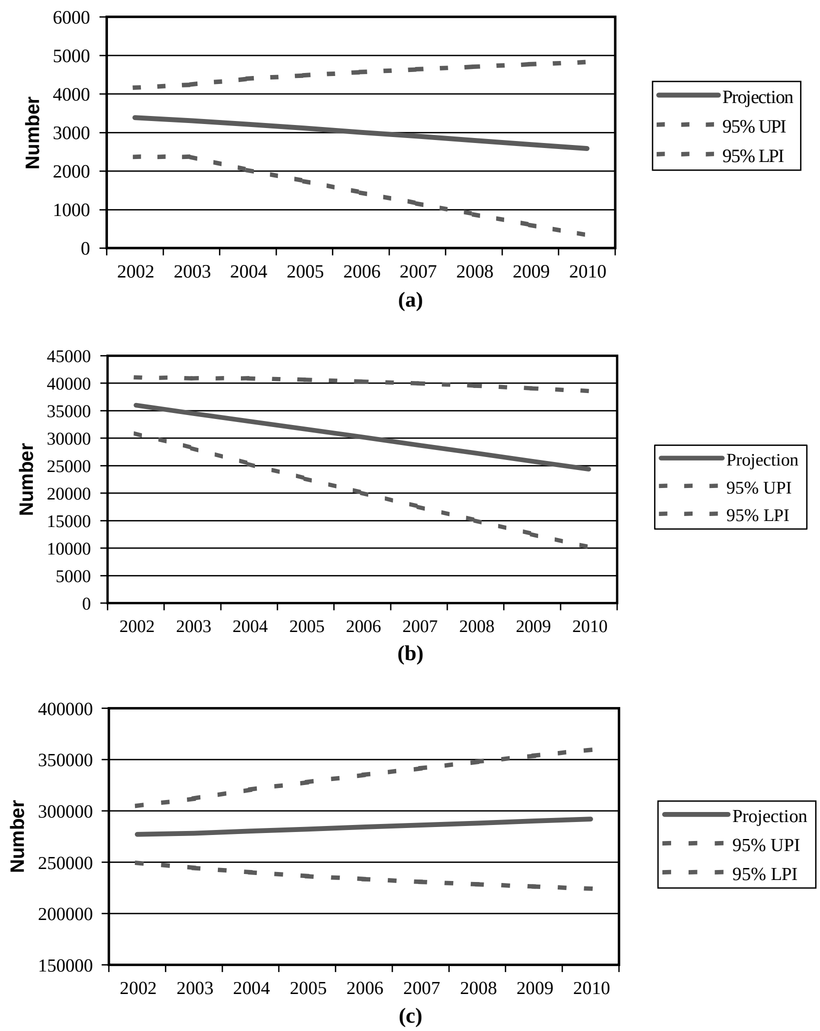


FIGURE 5 Projections of (*a*) fatalities, (*b*) serious casualties, and (*c*) slight casualties.

government's target can be met, this has to be expressed as per 100 million vehicle km. The official forecast of kilometers driven in 2010 is 552.2 billion, an increase of 25% on the 1994–1998 average; factoring this in gives a decrease in slight accidents per 100 million kilometers of just over 14%, well above the target.

The seasonal structure of pedestrian and child accidents is different from that of the fatal, serious, and slight injuries, and there was found to be no need for seasonal differencing (here a child is defined as someone younger than 16). The model of the form ARIMA(1,0,1) × (1,0,1) fitted both all pedestrian and child pedestrian casualties. A summary of the fit of this model to the period 1991–2000 is given in Table 2. A summary of the forecasting performance of the model for the two series for the 12 months of 2001 is also displayed in Table 2 and is graphed in Figures 6*a* and 6*b*.

Fitting the model over the period 1991–2001 and extrapolating to 2010 gives the annual totals of all and child pedestrian casualties.

For all pedestrian casualties, the 95% prediction intervals range from 21,706 to 47,399 with an expected prediction of 34,523. This is a reduction of 25.8% of the baseline average, taken from 1994 to 1998 of 46,543. For child pedestrians, the prediction of those injured in 2010 is 16,886 with a 95% prediction interval ranging from 12,353 to 21,419. This is only a 9.6% reduction on the baseline level.

CONCLUSIONS

Governments of many developed countries set periodic road safety targets. The latest targets in Great Britain are for 2010 and relate to the number of people killed or seriously injured on Britain's roads and the rate of slight injuries per million vehicle kilometers driven.

TABLE 2 Coefficients and Fit and Forecast Performance of Models, by Pedestrian Age

	All Pedestrian Casualties	Child Pedestrian Casualties
	Coefficient (T-Ratio)	**Coefficient (T-Ratio)**
Constant	4133.0018 (2.3792)	1538.8322 (9.7198)
AR1	0.9939 (136.6155)	0.7748 (8.1993)
MA1	0.8649 (15.6442)	0.3042 (2.2021)
SAR1	0.97736 (59.1285)	0.9775 (67.1961)
SMA1	0.6738 (6.5810)	0.6324 (6.1120)
Standard Error of Residuals	206.19	105.37
AIC	1649.07	1485.18
SBC	1663.01	1499.12
M.A.P.E for 2001	2.91%	8.27%
MSE for 2001	14279.8	17676.7

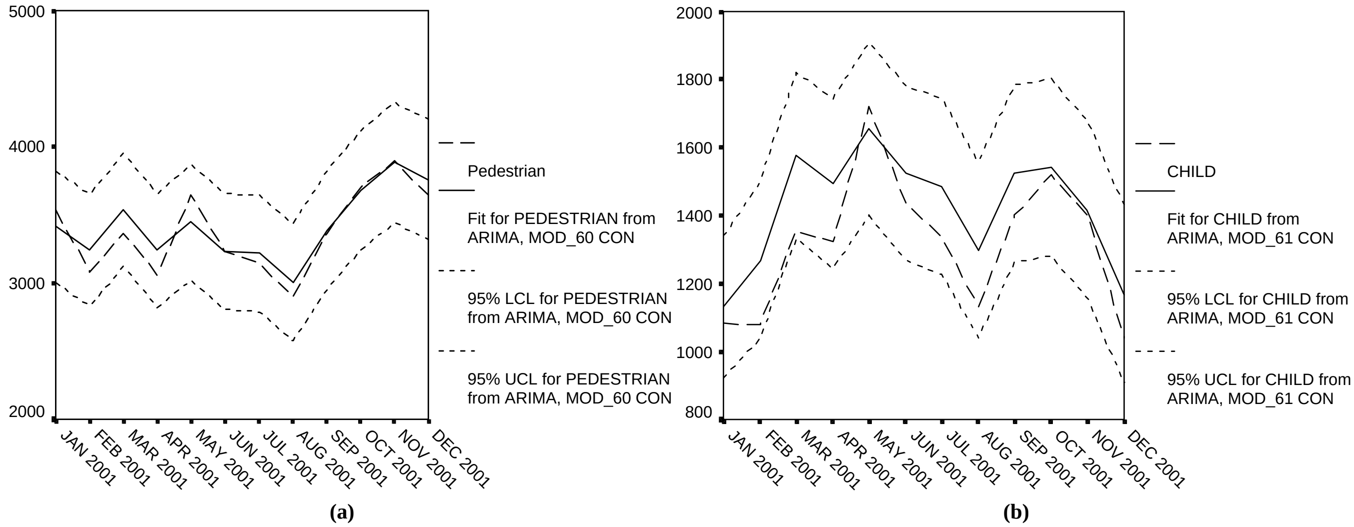


FIGURE 6 Forecast of (*a*) all pedestrian casualties and (*b*) child pedestrian casualties in 2001.

So that such long-term targets can be monitored effectively, it is important that the overall casualty figures are disaggregated and the influence of seasonality can be identified.

In this paper, a methodology for identifying these factors was suggested, and statistical modeling produced annual forecasts of casualty numbers, taking account of the anticipated annual increase in kilometers driven up to 2010. Trends in casualty numbers for fatal, serious, and slight injuries were produced, as were those of pedestrians and child pedestrians. It is anticipated that this information can be used by official agencies to monitor casualty trends for different classes of road user as well as for all road users in Great Britain combined.

ACKNOWLEDGMENTS

The authors thank the Department of Transport, Local Government and the Regions for making the STATS 19 data used in this study available via the United Kingdom data archive, www.data-archive.ac.uk/home/.

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Publication of this paper sponsored by Safety Data, Analysis and Evaluation Committee.