# An Analyses of Pedestrian and Bicycle Casualties Using Regional Panel Data

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Word count: 5197 + 3 fig/tables (750) = 5947

**Abstract**

This paper presents an analyses of pedestrian and bicycle casualties using cross-sectional time-series data for the regions of Great Britain. A fixed effect negative binomial model is used which accounts for heterogeneity in the data and the distributional properties of count data. Various factors associated with those killed and seriously injured as well as slight injuries are examined. These include the average age of vehicles in the region, the road length of various road classes, the amount of vehicle ownership in the region, per capita income, per capita expenditure on alcohol, age cohorts, and various proxies for medical technology improvements. Various specifications of the models are estimated. Generally, we find that more serious pedestrian injuries are associated with lower income areas, increases in percent of local roads, increased per capita expenditure on alcohol, and total population. Statistical effects are harder to detect in models with serious injuries for bicyclists, but alcohol expenditure is strongly associated with increased injuries. This work has implications for transport policy aimed at increasing the modal share of pedestrians and bicyclists. Further research is needed to clearly understand some of the trends found in our analyses, especially the effect of changes in medical care and technology on total injuries.

## Introduction

Transport policy in the UK has recently focused on implementing policies that reduce traffic congestion and total travel. One policy prescription is to increase non-motorized modes of transport, such as walking and bicycling, especially for short trips. As one example, the Department of Transport launched the National Cycling Strategy in 1996 with the ultimate target of doubling levels of cycling by 2002, in an environment that is both safe and convenient for cyclists. At the same time, about a quarter of all road fatalities are pedestrians, and bicyclists also have a relatively large level of fatalities relative to their exposure. The number of pedestrians killed on the roads in the United Kingdom has decreased by about 57% between 1979 and 1998, dropping to a level of 906 fatalities in 1998. Serious and slight injuries have also decreased by about 48% and 30% respectively over this time period. Bicycle fatalities totalled 158 in 1998 compared to 320 in 1979, a drop of about 51%. While the UK has one of the lowest rates of traffic-related fatalities in the world, pedestrian fatalities are relatively high compared to other European countries *(1).*

The potential risk of encouraging more people to walk or cycle for their daily travel could increase the total number of casualties associated with these modes. The decrease in pedestrian casualties over time has been associated with reduced levels of walking, resulting in less potential exposure *(2)*. Therefore, increasing the level of pedestrian and cyclist activity could increase exposure and hence the level of casualties associated with these modes unless policies to explicitly make them safer are adapted. In addition, the success of such policies in reducing vehicular travel is partly dependent on making these modes safer. Noland & Kunreuther *(3)* found that many people will not use bicycles unless infrastructure to make it safer is provided.

The objective of this paper is to analyze factors that have affected pedestrian and bicyclist fatalities and injuries over the last 20 years in Great Britain. Regional time-series data on casualties and various infrastructure, demographic, and other variables are analyzed. Our results are not conclusive but suggest some guidance for policy makers. For example, alcohol expenditure per capita is associated with pedestrian and bicyclist casualties. Increases in the relative amount of smaller minor roads is also associated with reduced casualties. Medical technology changes do not seem to be have been effective at reducing casualties over the time series of our data. We do not find conclusive effects from age cohorts, although increases in the percent of people aged 45-64 is associated with fewer casualties.

This paper is organized as follows. First we provide a brief literature review of other work that has investigated the factors associated with pedestrian and cyclist casualties. This is followed by a detailed description of the data sources. Statistical methods are then described followed by a presentation of results. This is followed by conclusions with policy implications and suggestions for further research in this area.

**Literature review**

Much of the literature on pedestrian and bicycle accidents is found in the medical sciences. This literature tends to focus on the outcome of accidents in terms of morbidity and mortality. For example, there is a large literature documenting the efficacy of bicycle helmets in reducing fatalities once an accident has occurred. The literature contains fewer studies that attempt to conduct multi-variate analyses of factors associated with the likelihood of an accident occurring and/or the likelihood of an injury. We briefly review some of those that we have located in the literature that provide some guidance on the relevant independent variables that we have analyzed in our models.

Hunter el al. *(4)* found that roadway and environmental factors are associated with pedestrian crashes in the U.S. They analyze 5000 police-reported pedestrian crashes in six states. The results showed that 75% of pedestrian crashes occur where speed limits are less than 35 mph; 21% of crashes occur where there is a sidewalk on at least one side of the roadway. This suggests some effect from various road infrastructure elements.

Harruff et al. *(5)* performed a retrospective analysis of 217 pedestrian traffic fatalities in Seattle, Washington. They concluded that elderly pedestrians were most vulnerable because they are more likely to be injured as a pedestrian and more likely to die of injuries that a younger person might survive. They found that nearly one quarter of the fatalities tested were positive for alcohol. There was little correlation of extent of injuries with vehicle type, speed zone where injury occurred, type of roadway and pedestrian activity. Minority populations were found to have a higher incidence of fatalities which may be due to environmental factors associated with lower income areas, such as high speed roads. Graham & Glaister *(6)* also find evidence to support this amongst patterns of childhood pedestrian fatalities which are strongly associated with more deprived areas.

Graham & Glaister *(6)* analyzes ward level data for England providing a high level of spatial resolution of area wide characteristics. They focus on child pedestrian casualties but also analyze all pedestrian casualties. Their results suggest that more deprived wards will have higher casualties as will those that generate more traffic (as measured via a proxy variable), more densely populated areas (with the most dense actually seeing a reduction in casualties), and the length of the road network.

LaScala et al. *(7)* conducted a spatial regression analyses of pedestrian injuries associated with motor-vehicles in San Francisco, California. The results showed that pedestrian injuries were associated with increased traffic flow and population density (as measured per kilometer of road length). Areas with higher unemployment were associated with higher injury rates while areas with more high school graduates had lower injury rates. This is similar to the results of Graham & Glaister *(6)* who used an area-wide deprivation score in their analyses. Surprisingly, they found that more children (aged 0-15) in an area was associated with fewer pedestrian injuries.

Assailly *(8)* found that the two groups most 'at risk' in European countries are 5-9 years-olds and the elderly. The children are at risk in terms of high accident involvement, whereas the elderly are at risk in terms of mortality from injuries sustained, due to increased frailty. Pedestrian injury rates peak for those aged 7-9 years in almost all European countries and a secondary peak has been observed at ages 10-14 years in the United Kingdom. They suggested that environmental factors, including overcrowded housing, traffic density, absence of play areas, and parental monitoring practices are likely to contribute to children's vulnerability.

Derlet et al. *(9)* presented an epidemiological review of 217 pedestrian injuries treated at a level one-trauma center during a one-year period. Injuries that occurred in pediatric age group patients were reviewed separately from adults. Hospital length of stay and severity of injuries was found to be much worse in adults. Seven percent of adults and three percent of children died after arrival at the hospital. This study shows that the incidence of critical injuries to pedestrians is high, and adults sustain more severe injuries than children. This would perhaps make it difficult for improvements in medical technology to have much impact on actual outcomes.

Kingma *(10)* investigated the causes of pedestrian accidents (N=534) for patients treated for injuries at the emergency unit of a hospital. Accidents in collisions with motor vehicles were the main cause (87.8%). Young children (0-9 years old) and elderly (above 60 years of age) are the most vulnerable in terms of mortality rates observed in these age groups. Preponderance of males in pedestrian accidents was observed in the accident categories of collisions with motor vehicles and bicycles, whereas a slight preponderance of females was found in collisions with other traffic.

In a retrospective study, Jehle and Cottington *(11)* reviewed the cases of 143 pedestrian accident victims admitted to a trauma center during 1982 and 1983. Alcohol consumption was present in 30% of patients; 74% of them had blood alcohol levels of more than 100 mg/dL. Alcohol-related accidents peaked in the 25-34 age group, and the non-alcohol related accidents peaked in the less than 18 and more than 55 age groups. Mean Injury Severity Score (25.0 vs 17.8, $p$-value<0.01) and mean length of stay (30.9 vs 17.2 days, $p$-value<0.005) were significantly greater in the patients who had consumed alcohol. They conclude that pedestrian victims are commonly intoxicated and that chest and spine injuries are more common in this population.

This brief review of studies analyzing pedestrian injuries and fatalities suggests several factors that have commonly been found to be associated with these incidents. These include the age of the victims, alcohol consumption, road network and environmental factors, and population. Most studies analyze individual level data, with the exception of Graham & Glaister *(6)* and LaScala et al. *(7)* both of which utilize spatial data. The analyses which follows takes the latter approach but extends it by including time-series data, at the expense of greater regional aggregation of the spatial data.

Amongst the literature analyzing bicycle-related accidents we found none that had conducted a spatial analyses. Most studies tend to analyze the extent and type of injuries associated with bicycle accidents and classify the suspected causal factors using individual level data. Ballham et al. *(12)* found that most accidents occur during morning, lunchtime and evening rush hours and that the most serious accidents occurred on major trunk roads. Younger individuals also tend to have higher accident rates, especially children *(13,14)*. Similar to pedestrian accidents, elderly victims tend to have poorer survival outcomes *(13)*.

Alcohol consumption also appears to be a relevant factor in bicycle related accidents. Andersson and Bunketorp *(15)* compared the consequences of the injuries sustained by intoxicated and sober cyclists in road traffic accidents. They found that compared with the sober group, the intoxicated cyclists more often sustained their injuries at night time, at the weekend, on their way to or from a party or a pub/restaurant and in single accidents with a greater risk of injury to the head or face.

To evaluate cycling morbidity, Kiburz et al. *(16)* studied bicycle accident and injuries among adult cyclists. Around 492 active adult bicyclists from a metropolitan area responded to a survey to determine cycle use and accident patterns. Significant factors contributing to bicycle accident included rider carelessness (58.7%), cycle malfunction (14.9%), environmental factors (36.9%), turns (22.9%) and hills (13.4%), and companion riders (15%). The use of riding helmets decreased the severity of injury and hospitalization time.

This literature suggests that some of the same factors associated with pedestrian accidents may be associated with bicycle accidents. These are the age of the victim, alcohol consumption, and various environmental factors, though the latter do not appear to have been analyzed in detail with regard to bicycle accidents. In the analyses that follows we will examine the association of many of these variables with both pedestrian and bicycle injuries.

**Data and Methodology**

Cross-sectional time-series data for the United Kingdom was used in our analyses. This data was collected for all 11 Standard Statistical Regions (SSRs) of the UK (except Northern Ireland) from 1979 to 1998. The SSRs are defined in Figure 1. The data used was obtained from several sources.

Regional data on pedestrian and bicycle road accidents over 20 years (from 1979 to 1998) was collected from the *Department of Environment, Transport and the Regions* (DETR). Over this time period, there were a total 1,122,691 pedestrian casualties and 519,098 pedal cyclists casualties. The data is disaggregated based upon three levels of severity, which are fatalities, serious injuries, and slight injuries. Fatalities include only those cases where death occurs in less than 30 days as a result of the accident. Serious injuries include, for example, fractures, internal injuries, burns, concussion, and any accident resulting in hospitalization plus those deaths that occur 30 days or more after the accident. Slight injuries may require hospital treatment but not hospitalization and include whiplash, slight cuts, and minor shock. Our analyses included only killed and seriously injured (KSI) and slight injuries. An analyses of fatalities found no interesting statistical relationships and was not pursued further with this data.

One key issue when studying pedestrian and bicyclist casualties is the quality of the data available. While fatalities that involve motor-vehicles are normally captured by most data recording systems where the police record the information, those incidents that occur off the public roadway or where a motor-vehicle is not involved may often not be recorded *(17)*. In some cases this can be a large fraction of total pedestrian and bicycle casualties, although generally they are less severe than those associated with motor vehicles. Since our concern is primarily pedestrian and bicycle crashes with motor-vehicles and those that occur on public roads, this is less of a concern, though we do acknowledge that the published data may under-represent actual casualty levels.

Data on road infrastructure includes the total road length by functional road category (motorways, trunk roads, other roads) for each region. Motorways are controlled access highways built to the highest design standards. Trunk roads are generally multi-lane or intercity roads, perhaps with some controlled access but generally not. Other roads are smaller scale roads that generally provide local access rather than inter-city travel. This data was collected from *Basic Road Statistics* published by the *British Road Federation.* The data was available for all regions over 20 years. Motorway length has increased by over 30% with other roads showing a smaller percent increase.

Data on regional vehicle ownership was also collected from the same source. Regional data on vehicles included number of cars currently licensed, vehicles per thousand population, average vehicle age, percentage of vehicles first registered in the current year, percent of households with no car, percent of households with one car and percent of households with two or more cars. In general, vehicle ownership has been increasing and the age of vehicles on the road has also been increasing.

Data on total population, household income, expenditure on alcohol, and population by age cohorts was also collected from *Regional Trends* published by the *Office of National Statistics.* These are used to control for other factors that are likely to affect casualties. Gross Domestic Product (GDP) and alcohol expenditure were adjusted for inflation and set to real values for 1998 pound sterling. Age cohort data was not available for Scotland, therefore our analyses includes only the regions of England and Wales..

Several variables could be a good proxy for improvements in medical care and technology over time. These include the length of inpatient stay in the hospital, infant mortality rate, persons waiting for hospital treatment per capita, NHS staff per capita and General Practitioners (GP) per capita *(18)*. This data was collected from *Regional Trends and* the *Compendium of Health Statistics* published by the *Office of Health Economics*. Health care data were not available for the London region.

The data in our analyses form a cross-sectional time-series consisting of repeated observations on the same UK regions. The dependent variable in our models (KSI or slight injuries) is a count variable which is a non-negative integer that is not normally distributed. This precludes the use of simple multiple regression techniques such as ordinary least squares that assume a normally distributed error term. The distribution of accidents will have a Poisson distribution but Poisson distributions have the further restriction of equating the mean and the variance resulting in over-dispersion in the error term. This can be overcome by estimating a negative binomial model *(19)*. We utilize the method derived by Hausman et al. *(20)* for estimating negative binomial models with panel data. This method has the advantage of factoring out the over-dispersion parameters and accounting for heterogeneity in the data. Other studies have also utilized this method *(18,21)*. Noland & Karlaftis *(22)* compare various modeling approaches and find that this method is one of the most robust.

**Results**

Models were estimated with pedestrian KSI, pedestrian slight injuries, bicyclist KSI, and bicyclist slight injuries as the dependent variable. Independent variables were specified logarithmically in order to minimize heteroskedasticity. Each model also was estimated with year dummy variables to control for year effects. A time trend was also estimated but in some cases the trend variable was correlated with some of the independent variables, although results were broadly similar to those shown here. Results are shown in Tables 1 and 2 with year dummy variables omitted for brevity.

Each model was estimated with and without the proxy variables for medical care and technology. This data was not available for London and thus the number of observations are lower when these variables are included. Noland & Quddus *(18)* found that these variables were associated with reductions in total traffic related fatalities. We do not find the same effect for both the pedestrian and bicyclist KSI models (model B in Tables 1 and 2). For example, we would expect that increased in inpatient stays in the hospital would be associated with more killed and seriously injured. In other words, improvements in medical care and technology have lead to reductions in the length of time patients need to stay in the hospital. However, for pedestrian and bicyclist KSI this effect does not give the expected relationship. The same is true of per capita National

Health Service (NHS) staff. We would expect an increase in staffing levels to reduce KSI. The length of time people wait for hospital treatment represents resources devoted to medical care and we find this to have the opposite sign for the pedestrian KSI model and it is not significant in the bicyclist KSI model.

These results on the medical care and technology variables suggest several possible interpretations. First, it could be that the type of changes in medical care and technology that have resulted in fewer fatalities in traffic accidents with motor vehicles have not reduced non-motorized fatalities and serious injuries. It could also be that the inclusion of both fatalities and serious injuries in our dependent variable is inappropriate as we would not expect as much of an effect on injuries, which predominate the count. This interpretation is supported by the results in Noland & Quddus *(18)* that found similar effects with models using all serious injuries as the dependent variable. Tests with pedestrian and bicycle fatalities as the dependent variable did not reveal any statistically significant relationship. A further interpretation could be that accidents involving pedestrians and bicyclists are relatively severe and medical practitioners have had little ability to influence outcomes as much as they have with other traffic-related fatalities and injuries.

We would not expect the medical technology proxy variables to have any association with slight injuries, but we do find some effects. In both models the number of persons waiting for hospital treatment is both positive and significant, while for the bicyclist slight injury model the average length of inpatient stay is negative and significant.

Various road infrastructure variables were also tested in the model. These include the percent of the roads in each region that represent each functional road category. In theory, we would expect that more motorways might be related with fewer pedestrian and bicycle KSI as most high speed traffic would use the motorways. We would also expect that as other road classes increase, such as trunk roads, that KSI might increase.

We do find that as the percent of motorway mileage increases there is a negative association with pedestrian KSI and pedestrian slight injuries. This effect is most pronounced in model (A) which does not include the medical technology variables and for model (D) which does. For bicyclist KSI the results are less conclusive, with model (A) showing a negative association while model (B) shows a positive association. Effects are less significant for bicyclist slight injuries (models C and D).

Trunk roads also generally show the expected effect. For pedestrians these seem to be positively associated with KSI and slight injuries, although there is no significant effect in models B and C. The same result seems to hold for bicyclist KSI and slight injuries. The “other roads” category, which includes all secondary and tertiary roads shows a strong negative effect for pedestrian and bicyclist KSI, but not for slight injuries. Therefore, there does seem to be some indication that when a region has more minor roads, casualties will be lower.

The final infrastructure variable analyzed is trunk road mileage per land area. We see this as partly a measure of development density to control for the amount of rural land in a given region. We find that it is associated with lower slight injuries of both pedestrians and bicyclists, so this may represent an urbanization effect resulting in fewer non-motorized injuries. Since we control for population, which has a positive association, this is intuitively appealing in that urbanized areas should have lower average speeds than more rural areas, perhaps resulting in fewer casualties. It also has a positive association with bicyclist KSI in model (B), but not in the model excluding medical technology variables.

Several vehicle-related variables are included in the models. We would expect older vehicles to perhaps be more likely to be involved with pedestrian or bicyclist accidents, either due to mechanical breakdown or the demographics of the drivers (i.e., lower income households will tend to own older vehicles). The models with medical technology variables confirm this hypothesis in that there is a positive association with both pedestrian and bicyclist KSI. An alternative hypotheses is that as newer vehicles are safer (due to new safety regulations or better technology), the vehicles are driven more carelessly. This is the risk compensation hypothesis proposed by Peltzman *(23)*. If this were occurring then we would expect pedestrians and bicyclist KSI to increase with more new vehicles on the road, but we find no evidence of this in our data.

Demographic and socio-economic factors were analyzed. Per capita income has generally been found to be positively associated with traffic accidents. For pedestrian KSI we actually find a negative association. This is, however, consistent with other work that has suggested that more deprived areas tend to have higher pedestrian casualty rates *(6)*. We do, however, find that slight pedestrian injuries appear to be positively associated with increased income. Reduced bicyclist KSI also appears to be associated with increased income, although this effect is only found in model (B).

Alcohol consumption is measured by per capita expenditures on alcohol. We expect that increases in per capita alcohol expenditure would increase both pedestrian and bicyclist casualties. We find this to be the case for KSI's for both pedestrians and bicyclists, but not for slight injuries. Whether this is due to increased intoxication of motorists or of the non-motorized victims cannot be determined from our data, but we do find this be one of the most robust and significant effects in the KSI models.

Total population tends to be positively associated with increased KSI of both pedestrians and bicyclists. This is partially an exposure variable that controls for the expected level of pedestrian and bicycle traffic. It is not associated with bicyclist slight injuries and shows some negative association with pedestrian slight injuries.

Population age cohorts are also included in the model. The literature suggests that children in particular are at risk of being pedestrian and bicycle casualties. Therefore, we would expect that a larger population of young people would result in more casualties. Our results tend to support this for bicycle KSI's, which shows a positive association with increased population of the 0-14 age group, but not for pedestrian KSI's, which is not statistically significant for the 0-14 age group. We do find that the 45-64 age group, which is generally considered the safest group of drivers, results in fewer KSI's for both modes. This would tend to suggest that it is the driver behavior rather than the pedestrian or bicyclist behavior that leads to this reduction. However, this population age cohort is also positively associated with an increase in slight pedestrian injuries. More elderly (65 or over) in the population is positively associated with more bicycle KSI, but not, as one would expect, more pedestrian KSI.

Overall, these models present an interesting analyses of factors associated with pedestrian and bicycle casualties. We find some support for hypotheses in the literature, such as possible associations with alcohol consumption, more deprived regions, and road infrastructure. Medical technology effects appear counter-intuitive and age cohort effects are not completely convincing. We discuss these results further and implications for policy and research in our concluding section.

**Discussion and Conclusions**

This paper has used time-series cross-sectional data from the British regions (within England and Wales) to evaluate various factors that affect pedestrian and bicyclist casualties. We view this work as providing a preliminary assessment of how various factors affect pedestrian and bicycle KSI and slight injuries. While smaller scale more detailed area-wide data can provide additional insights, such as the work of Graham & Glaister *(6),* our study benefits from the use of time-series data. This allows us to better control for heterogeneity in the data, that is, other unmeasured factors that may affect our dependent variables. However, this is done at the expense of analyzing data on the smaller scale spatial factors that may affect both pedestrian and bicycle casualties.

With these caveats, however, we find some interesting results which may be relevant for policy. Some of these are well supported in the literature, such as the influence of alcohol on the probability of casualties. We find that increased expenditure on alcohol is positively associated with increased pedestrian and bicyclist KSI's, though whether this is due to intoxication on the part of the vehicle driver or the non-motorized victim, cannot be determined. Clearly, from a policy perspective, limiting alcohol consumption can be beneficial.

Our analyses of medical care and technology variables suggested that these have been ineffective at reducing the most serious injuries and fatalities. Other research in this area which analyzes all motor-vehicle fatalities, has found a strong relationship with these sort of proxy variables *(18,21).* We suspect that the use of KSI as the dependent variable is one of the reasons for this unexpected result, although analyses done with fatalities as the dependent variable showed no statistical relationship. From a policy perspective one needs to consider whether medical resources could be more effectively deployed to reduce the incidence of pedestrian and bicyclist KSI's.

Our analyses of age cohorts is less persuasive. While the literature has adequately identified that many pedestrian and bicyclist casualties are children and younger people, our analyses shows little clear relationship between regional population age characteristics and the likelihood of casualties. A larger population in the 45-64 age group seems to be most closely linked with fewer KSI's for both modes. Whether this is due to fewer potential child victims or a larger low risk driving group is unclear. Further work is clearly needed to examine what type of drivers put younger age groups at highest risk.

Our analyses also shows that road infrastructure, expressed as the amount of each functional road class within a region, can affect casualties. More minor roads in a region seems to be associated with fewer KSI's. If minor roads tend to have lower speeds, then this suggests that strategies to limit speeds may be effective at reducing casualties.

For policy makers promoting increased pedestrianization and bicycle transport it is important to understand these underlying trends. While this study gives few definitive answers, further analyses of more disaggregate time series data (and the development of these databases) is clearly warranted.

## Acknowledgements

This research was funded by a grant from the UK Engineering and Physical Sciences Research Council. The authors take full responsibility for the content of the paper and any errors or omissions.

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## Table 1: Negative binomial model: Pedestrians

| | Pedestrians killed or seriously injured (KSI) | | | | Pedestrians with slight injuries | | | |
|---|---|---|---|---|---|---|---|---|
| | (A) | | (B) | | (C) | | (D) | |
| | Coeff | t-stat | Coeff | t-stat | Coeff | t-stat | Coeff | t-stat |
| ***Medical care and technology variables*** | | | | | | | | |
| **ln(average length of inpatient stay in the hospital)** | | | -0.193 | -1.67 | | | 0.041 | 0.61 |
| **ln(NHS staff per thousand population)** | | | 0.104 | 1.86 | | | -0.003 | -0.09 |
| **ln(persons waiting for hospital treatment)** | | | -0.128 | -1.95 | | | 0.107 | 2.74 |
| ***Road infrastructure variables*** | | | | | | | | |
| **ln(percent of motorway)** | -0.075 | -2.59 | -0.054 | -0.77 | 0.024 | 1.21 | -0.093 | -2.04 |
| **ln(percent of trunk road)** | 0.260 | 2.33 | 0.012 | 0.09 | 0.106 | 1.29 | 0.196 | 2.47 |
| **ln(percent of other road)** | -0.511 | -3.61 | -0.337 | -2.42 | -0.026 | -0.30 | 0.022 | 0.27 |
| **ln(trunk road per thousand sq km of area)** | -0.052 | -0.49 | 0.027 | 0.24 | -0.236 | -3.26 | -0.302 | -4.21 |
| ***Vehicle related variables*** | | | | | | | | |
| **ln(vehicle age)** | 0.019 | 0.13 | 0.348 | 1.82 | -0.075 | -0.83 | -0.163 | -1.49 |
| **ln(vehicles per thousand population)** | 0.043 | 1.01 | 0.009 | 0.16 | -0.020 | -0.70 | -0.049 | -1.34 |
| **ln(percent households with no car)** | 0.017 | 0.16 | 0.046 | 0.48 | -0.134 | -2.16 | -0.088 | -1.56 |
| ***Demographic and socioeconomic variables*** | | | | | | | | |
| **ln(GDP per capita 1998 £)** | -0.400 | -1.55 | -0.843 | -3.43 | 0.173 | 1.23 | 0.478 | 3.62 |
| **ln(per capita expenditure on alcohol, 1998 £)** | 0.187 | 1.88 | 0.179 | 1.86 | -0.032 | -0.50 | -0.058 | -0.92 |
| **ln(total population)** | 0.119 | 1.66 | 0.282 | 3.03 | -0.044 | -0.97 | -0.113 | -1.88 |
| **ln(percent population aged 0-14)** | -0.031 | -0.11 | -0.149 | -0.53 | 0.055 | 0.31 | 0.196 | 1.19 |
| **ln(percent population aged 15-24)** | 0.226 | 2.19 | -0.015 | -0.14 | -0.070 | -1.12 | -0.013 | -0.21 |
| **ln(percent population aged 25-44)** | -0.446 | -1.87 | -0.212 | -0.89 | -0.030 | -0.20 | 0.118 | 0.82 |
| **ln(percent population aged 45-64)** | -1.402 | -5.43 | -0.774 | -3.09 | 0.955 | 6.38 | 0.490 | 3.31 |
| **ln(percent population aged 65 or over)** | 0.392 | 1.73 | 0.087 | 0.36 | -0.247 | -1.83 | -0.206 | -1.46 |
| **Constant** | 12.614 | 3.42 | 12.589 | 3.46 | 5.619 | 2.65 | 4.508 | 2.20 |
| **Number of observations** | 200 | | 180 | | 200 | | 180 | |
| **Log likelihood function at convergence** | -1079.658 | | -932.582 | | -1155.246 | | -993.242 | |
| **Log likelihood function at zero** | -1465.790 | | -1465.790 | | -1471.037 | | -1471.037 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log likelihood ratio index** | 0.263 | | 0.364 | | 0.215 | | 0.325 | |

* year dummy variables not displayed for brevity

## Table 2: Negative binomial model: Bicyclists

| | **Cyclists killed or seriously injured (KSI)** | | | | **Cyclists with slight injuries** | | | |
|---|---|---|---|---|---|---|---|---|
| | **(A)** | | **(B)** | | **(C)** | | **(D)** | |
| | **Coeff** | **t-stat** | **Coeff** | **t-stat** | **Coeff** | **t-stat** | **Coeff** | **t-stat** |
| ***Medical care and technology variables*** | | | | | | | | |
| **ln(average length of inpatient stay in the hospital)** | | | -0.434 | -2.76 | | | -0.214 | -2.49 |
| **ln(NHS staff per thousand population)** | | | 0.199 | 2.78 | | | 0.060 | 1.28 |
| **ln(persons waiting for hospital treatment)** | | | 0.001 | 0.01 | | | 0.187 | 3.89 |
| ***Road infrastructure variables*** | | | | | | | | |
| **ln(percent of motorway)** | -0.075 | -1.91 | 0.178 | 2.13 | 0.028 | 1.21 | -0.093 | -1.59 |
| **ln(percent of trunk road)** | 0.369 | 2.34 | -0.200 | -1.20 | 0.108 | 1.04 | 0.190 | 1.92 |
| **ln(percent of other road)** | -0.552 | -2.67 | -0.359 | -1.85 | 0.051 | 0.47 | 0.107 | 1.04 |
| **ln(trunk road per thousand sq km of area)** | 0.035 | 0.23 | 0.414 | 2.81 | -0.201 | -2.20 | -0.266 | -2.89 |
| ***Vehicle related variables*** | | | | | | | | |
| **ln(vehicle age)** | 0.208 | 1.05 | 0.665 | 2.68 | 0.111 | 1.05 | 0.027 | 0.21 |
| **ln(vehicles per thousand population)** | 0.024 | 0.41 | -0.025 | -0.39 | -0.086 | -2.28 | -0.037 | -0.86 |
| **ln(percent households with no car)** | 0.300 | 1.98 | 0.272 | 2.00 | 0.023 | 0.30 | 0.110 | 1.60 |
| ***Demographic and socioeconomic variables*** | | | | | | | | |
| **ln(GDP per capita 1998 £)** | -0.216 | -0.61 | -0.794 | -2.50 | -0.065 | -0.36 | 0.228 | 1.42 |
| **ln(per capita expenditure on alcohol, 1998 £)** | 0.368 | 2.83 | 0.502 | 3.98 | -0.030 | -0.40 | 0.006 | 0.08 |
| **ln(total population)** | 0.225 | 2.14 | 0.540 | 4.41 | -0.056 | -0.95 | 0.003 | 0.04 |
| **ln(percent population aged 0-14)** | 0.780 | 1.91 | 0.612 | 1.56 | 0.031 | 0.14 | 0.072 | 0.35 |
| **ln(percent population aged 15-24)** | 0.363 | 2.49 | 0.062 | 0.42 | -0.036 | -0.45 | 0.086 | 1.15 |
| **ln(percent population aged 25-44)** | -0.354 | -1.03 | -0.309 | -1.00 | 0.077 | 0.41 | 0.026 | 0.15 |
| **ln(percent population aged 45-64)** | -2.199 | -5.95 | -1.129 | -3.37 | 0.369 | 1.91 | -0.168 | -0.90 |
| **ln(percent population aged 65 or over)** | 0.946 | 2.86 | 1.005 | 3.06 | -0.225 | -1.30 | -0.028 | -0.16 |
| **Constant** | 3.494 | 0.70 | -0.978 | -0.20 | 7.242 | 2.80 | 4.444 | 1.81 |
| **Number of observations** | 200 | | 180 | | 200 | | 180 | |
| **Log likelihood function at convergence** | -934.108 | | -800.894 | | -1094.106 | | -940.351 | |
| **Log likelihood function at zero** | -1224.808 | | -1224.808 | | -1318.298 | | -1318.298 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Log likelihood ratio index** | 0.237 | | 0.346 | | 0.170 | | 0.287 | |

* year dummy variables not displayed for brevity

**Figure 1**

**The Standard Statistical Regions (SSRs) of the United Kingdom (except Northern Ireland)**


East Anglia
East Midlands
Northern region
Northwestern
Scotland
Southeast
Southwest
Wales
West Midlands
Yorkshire
London