THE EFFECT OF 20 MPH TRAFFIC SPEED ZONES ON ROAD INJURIES IN LONDON, 1986-2006: A CONTROLLED INTERRUPTED TIME SERIES ANALYSIS

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ABSTRACT

Objective: To quantify the effect of the introduction of 20 mph traffic speed zones on road collisions, injuries and fatalities in London.

Design: Observational study based on analysis of geographically-coded police road casualties data, 1986 to 2006. Analyses were made of longitudinal changes in counts of road injuries within each of 119,029 road segments with non-zero casualty counts using conditional fixed-effects Poisson models. Estimates of the effect of introducing 20 mph zones on casualties within those zones and in adjacent areas were adjusted for the underlying downward trend in traffic casualties.

Setting: London, UK

Main outcome measures: All casualties from road collisions; those killed and seriously injured (KSI)

Results: Overall, the introduction of 20 mph zones was associated with a 41.9% (95% CI 36.0 to 47.8%) reduction in road casualties after allowing for underlying time-trends. The percentage reduction was greatest in younger children, and greater for the category of killed or seriously injured casualties than for minor injuries. There was no evidence of casualty migration to areas adjacent to 20 mph zones, where casualties also fell slightly by an average of 8.0% (95% CI 4.4 to 11.5%).

Conclusions: 20 mph zones are effective measures for reducing road injuries and deaths.

Keywords: wounds and injuries, road traffic crashes, traffic calming, 20 mile-per-hour zones

Word count: 213

INTRODUCTION

Road injuries are among the leading causes of loss of life and disability worldwide,(1) and they are projected to make an increasingly important contribution to public health burdens over the coming decades,(2) especially in low- and middle-income settings.(3) Internationally, there is debate around how transport infrastructural development needed to meet the United Nations Millennium Development goals can be achieved without adding to the burden of injury that is currently disproportionately borne by poor pedestrians, particularly children and young adults.(4) (5) (6) The United Kingdom has a comparatively good road injury record, with injury rates among the lowest in Europe. Nonetheless, in 2006 there were 2,858 deaths and 26,066 serious injuries on roads in England and Wales,(7) and reduction in their number remains a major aim of public policy.(8)

There is good evidence internationally for the effectiveness of reducing the speed and volume of traffic for reducing injury rates.(9) (10) (11) One strategy for reducing speeds in urban areas is the use of road engineering interventions such as vertical deflections (humps), chicanes and other physical alterations to prevent motorised traffic travelling at more than 20 mph. 20 miles-per-hour (mph) zones are a type of area-wide traffic calming which use road engineering measures to physically slow traffic. Over the last 15 years or so, in London, as in many areas of the United Kingdom, 20 miles-per-hour (mph) zones have been established.

Depending on the local environment, a range of vertical and horizontal deflections, as well as other measures, are implemented. Typically, zones are marked by terminal signs at the entrance and exit of the zone, and traffic calming measures (such as speed humps, chicanes and raised junctions) are placed every one hundred metres. The design of 20 mph zones vary, but all are designed to ensure slower traffic speeds using self-enforcing engineering and design features that comply with Traffic Signs and General Directions 2002 regulations. When proposing 20 mph zones, local authorities are legally required to consult with relevant stakeholders such as the emergency services, local residents and organisations representing road users. Limited evidence suggests that the self-enforcing 20 mph zones are effective in reducing traffic speeds to an average of 17 mph, an average reduction of 9 mph (12). However, the benefit of these 20 mph zones in reducing road casualties has not been conclusively established.

With relatively robust data on road traffic injuries, London provides a good case study for evaluating the effect of 20mph zones. Here we report a detailed assessment of such schemes, based on analysis of twenty years of geographically referenced road casualties data in London.

METHODS

Analysis was based on Police Stats19 data, 1986 to 2006, which record the date, location and number and type of casualties for all injury-related road collisions (damage only collisions are excluded). Stats19 data record the severity of each casualty as slight, serious, or fatal. A casualty is defined as serious if the person is detained in hospital as an in-patient or has any of the following injuries (whether or not they are detained in hospital): fractures, concussion, internal injuries, crushings, non-friction burns, severe cuts and lacerations, or severe general shock requiring medical treatment. A casualty is classified as fatal if the person dies within 30 days of the collision. Using a geographical information system (GIS), these casualty data were linked to a detailed road segment database which included the characteristics of all classified and unclassified roads in London. For each financial year (April to March), each segment of road between junctions was classified according to the type of road, and whether or not it was in a 20 mph zone or adjacent to a 20 mph zone. Each segment was further classified by the super output area (SOA) in which it was located. A super output area is a small geographical area, defined for the reporting of census statistics, which on average contains a population of around 1,500. Where a super output area boundary or 20 mph zone cut across a single road segment, that segment was divided into smaller segments as necessary. In total, the database for London contained 298,644 separate road segments as detailed in Table 1.

Each segment was further classified by the date engineering works started (decision date) on the 20 mph zone (where relevant), and the date it commenced in operation, which may have been several years from the date of decision. Thus, using these dates, each road segment was classified as pre-intervention, under construction, or post-implementation. The intervention status was assumed to change only at the beginning of each financial year, so that a change from 'under construction' to 'post-implementation' status, for example, occurred on the 1st April following the implementation date. We had decision and implementation date information on 385 of the 399 20 mph zones introduced in London between 1991 and 2007.

The geographical information system was also used to generate *adjacent areas* around 20 mph zones, which included all roads connecting junctions within 150 metres of the perimeter of the 20 mph zone. In this way, three types of roads were defined: (i) those that were within or would become part of a 20 mph zone, (ii) those that were part of an area adjacent to a 20 mph zone, and (iii) all other roads (Figure 1).

Linkage of the Stats19 data to road segments was done by a combination of spatial overlay and the use of text descriptor of road location. In brief, the algorithm assigned a road injury to the nearest road segment of the type indicated in the Stats19 report. Road injuries occurring more than 50 metres away from a road segment of the appropriate type were assigned to the nearest road segment, regardless of type. Road injuries occurring more than 100 metres from any road segment were excluded from the analysis (Figure 2).

From the combined data set, counts of casualties and collisions were generated for each road segment and year. The road segments enable stratification of the results by intervention status, adjacency status and by borough. Road casualty data provided the basis of stratification by age-group (0-5, 6-11, 12-15, 16+) and gender.

Statistical methods

The primary focus was to characterize the influence of the 20 mph zones on casualties and collisions within segments after allowing for underlying trends over time. It is very difficult to define appropriate population denominators for *rate* estimation on individual road segments and, as road user data were not collected, analyses were based on the patterns of change in annual counts within each road segment. Therefore for optimal control of confounding, the analysis instead compares pre- post *change* in injury counts within 20 mph zone relative to trends seen on other roads. The estimated effect is therefore specific to 20 mph zones compared with other roads. Technically, to implement this we used conditional fixed effects Poisson models using Stata's `xtpoisson` command. The number of casualties or collisions, $y_{s,t}$ in road segment s in year t is defined as follows:

$$Y_{s,t} \sim Poisson(\mu_{s,t})$$

$$\mathrm{Log}(\mu_{s,t}) = \alpha_s + S(t,z_s) + \boldsymbol{\beta} x_{s.t}$$

where:

α_s is the road segment effect

$S(t,z_s)$ is a function of year to allow for London-wide trends in casualties or collisions, dependent on road segment characteristics z_s

$x_{s.t}$ is a vector of indicator (0,1) variables identifying road segments in 20 mph zones and (separately) adjacent areas, after the zone had been put into operation

$\boldsymbol{\beta}$ is a vector of coefficients representing the effect of 20 mph zones and adjacent areas on casualties.

The α_s nuisance parameters are 'conditioned out' in the conditional fixed effects Poisson model, allowing models to be based on annual *counts* of casualties and collisions within each road segment. For transparency, the underlying trends in casualties and collisions ($(S(t,z_s))$) were fitted using linear terms. The results for the 20 mph zone effect may be interpreted as the before-after change in the number of casualties within road segments within 20 mph zones *allowing for the (broadly downward) trends in casualties on other roads*. Robust standard errors were obtained using jackknife procedures, clustering on borough (n=32). Analyses were stratified by age-group and gender.

Sensitivity analyses were carried out to examine a number of model assumptions, including:

(i) use of other smooth functions of time and terms for individual years to control for the underlying trend in casualties and collisions over time;

(ii) restriction of analyses to minor roads only (B roads, minor roads, and other roads);

(iii) restriction of analyses to the period 2000-2006 to examine the effect of the more recently-introduced 20 mph zones;

(iv) analyses to examine the effect of potential influence of regression to the mean arising from the fact that high injury numbers may have been a factor in the decision to implement a 20 mph zone in some areas. For this, we repeated the analyses excluding data for periods of three, four and five years before the implementation of each 20 mph zone;

(v) analyses to examine whether the effect of 20 mph zones is modified by location (Inner versus Outer London).

RESULTS

Over the period 1987-2006, there has been a more-or-less steady decline in the number of road casualties in London, with similar patterns for all casualties and for those killed and seriously injured casualties. The decline appears marginally steeper in the most recent years. The length of road inside 20 mph zones has increased rapidly since the mid 1990s, and the casualty numbers on those road segments have fallen steeply in recent years.

Effect of 20 mph zones

The effect of the 20 mph zones on casualties and collisions is summarized in Table 2. The models used to derive these estimates allow for the (generally) downward trend over time in the annual number of casualties and collisions in London.

Overall, they suggest that the introduction of the 20 mph zones has led to a reduction in casualties and collisions of around 40%. Casualties as a whole were reduced by 41.9% (95% CI 36.0 to 47.8%), with slightly larger point estimates for the reductions in all casualties in children 0-15 years, and in the numbers killed or seriously injured. Killed or seriously injured casualties in children were reduced by half. The point estimate of the reduction in number of people killed was slightly smaller at 35.1% (95%CI 1.9 to 72.0%).

Pedestrian injuries as a whole were reduced by a little under a third, but again with higher point estimates for pedestrian injuries in children 0-15 years (similar for boys and girls), and in the number of killed or seriously injured casualties in children. The observed reductions were largest for the youngest children (0-5 and 6-11 years). There was a smaller reduction in cycling casualties, 16.9% (95%CI 4.8

to 29.0%), than for any of the other major groups of outcomes. The reduction of cycling casualties was also greater in children 0-15 years and in killed or seriously injured casualties.

Casualties involving riders of powered two-wheeled vehicles declined by a little under a third, and those of car occupants fell by half. In both cases, the estimates for the effect on killed or seriously injured casualties was slightly greater than for casualties overall.

Casualties in areas *adjacent* to 20 mph zones also showed evidence of small (generally single figure) percentage reductions following implementation of the zones. The only point estimates of relative increase were for deaths overall, pedestrian killed or seriously injured casualties, child pedestrian killed or seriously injured casualties and cycling killed or seriously injured casualties, but for these outcomes the results were also consistent with no effect or reduced risk. This suggests that casualties inside 20 mph zones are not being displaced to nearby roads.

The general trend in casualties and collisions over time in London, an annual decline of 1.7%, was equivalent to a 15.8% reduction over ten years, or a 29.0% reduction over twenty years. Thus, in broad terms, the *additional* effect of the 20 mph zones was that of a step reduction in casualties and collisions by an amount that has taken over 20 years to achieve on roads without 20 mph zones.

Sensitivity analyses

Alternative methods of control for long term trend in casualties and collisions had only minor effect on the point estimates and confidence intervals for the 20 mph zone effect on each of the major outcomes. For example, fitting indicators for individual years yielded an estimate of reduction in all casualties within 20 mph zones that was slightly lower at 36.5% (29.5 to 43.5%); that for killed or seriously injured casualties was 42.0% (33.4 to 50.6%). Excluding motorways and A roads from the analysis made little difference to the pattern of results. We found no evidence that the effect of 20 mph zones differed between Inner and Outer London, suggesting that the effect of the intervention is not modified by location.

When analyses were restricted to the years 2000-2006, the period with the lowest annual numbers of casualties, the results for the 20 mph zone effects showed slightly smaller percentage reductions: the results for all casualties, killed or seriously injured and all pedestrian injuries were 22.7% (15.3 to 30.1%), 28.4% (17.8 to 39.0%), and 21.6% (12.9 to 30.4%), respectively. In the case of cycling casualties, the point estimate suggests almost no effect, -1.3% (-22.3 to 19.8%).

Removing data for 3, 4 and 5 years before the introduction of the zones had little effect on the results for the main categories of casualty outcome, the point estimates reduction in risk generally being slightly *greater* than the analyses based on data for all years. This suggests that regression to the mean is *not* the explanation for the observed 20 mph zone effects.

Avoided casualties and potential benefit from extending zones in London

In 2005/06 there were 31,202 road casualties in London, 691 within 20 mph zones. Using the more conservative risk reduction estimates based on 2000-2006 we estimate that 20 mph zones are preventing 203 casualties each year, of which 27 are killed and seriously injured casualties, and 51 are pedestrian casualties.

To estimate the potential for further reduction from extension of 20 mph zones, we applied the same risk reduction estimates to all other minor/residential road segments in super output areas not currently inside a 20 mph zone where there had been >=0.7 casualty per km/year over 2004-06 (the casualty threshold where the societal benefits of 20 mph zones outweigh the costs over a 10 year time horizon, see (13)). These calculations suggest the potential for a further reduction of 692 casualties, including 100 killed or seriously injured casualties, and 114 pedestrian casualties each year (assuming current casualty rates).

DISCUSSION

This study provides the most detailed evidence to date of the effect of 20 mph zones on road casualties and collisions in a major metropolitan area. Its results suggest that such zones are effective in reducing casualty risks, especially with regard to serious injury and death, and that the benefits are greatest among younger children. In the context of the wider evidence about the health burdens associated with road injuries, this evidence supports the rationale for 20 mph zones not just in major cities in Britain, but also in similar metropolitan areas elsewhere. Indeed, even within London, there is a case for extending the currently limited provision of such zones to other high casualty roads.

A limitation of the analysis is the potential lack of completeness and accuracy of routinely recorded data. There is known under-reporting of road injuries in the Stats19 data. However, reporting in London is relatively good compared to the rest of the United Kingdom and for such under-recording to affect the results of our analysis one would have to invoke *selective* changes over time in recording of injuries in 20 mph zones compared with other road types. National evidence suggests that the rate of under-reporting overall has not substantially changed over time.(14)

This analysis could not take into account the potential impact of other road safety initiatives, such as road safety cameras. *If* they were introduced more frequently in 20 mph zones and adjacent areas than elsewhere, it is possible some degree of the apparent 20 mph zone effect is attributable to these other measures. But it seems unlikely that such 'confounding' could account for the greater part of the substantial effects observed on casualties within the 20 mph zones compared with other roads.

We were able to link more than 99% of casualties to road segments and assign a date specific intervention status to road segments in 96% of 20 mph zones in London. The results also appear fairly robust to the various forms of sensitivity analysis we performed. In particular, the results based on excluding data for up to five years before the introduction of 20 mph zones suggest no significant bias arises from regression to the mean (a theoretical concern because high casualty numbers may form part of the rationale for introducing 20 mph zones).(15) Moreover, the fact that casualties also fell slightly on roads adjacent to 20 mph zones argues against diversion of casualty risk. The results were also not materially affected by using model specifications that compared the change in road casualties within 20 mph zones with that on other minor roads (which are similar in type to the roads within 20 mph zones).

The pattern of findings lends some support to the interpretation that 20 mph zones reduce the *severity* of injuries more than the frequency of collision – which might be explained by slower motor vehicle speeds. It is gratifying that large reductions were observed in the number of killed and seriously casualties, especially in children. A somewhat counter-intuitive observation is the apparently large reduction in injuries to car occupants. It is important to remember, however, that all changes are expressed in *relative* terms, and it is quite possible that a relatively large reduction in car occupant casualties might occur with slower vehicle speeds and perhaps some diversion of traffic away from previously used "rat runs", even though car occupant casualties are relatively few in number.

As the majority of collisions occur on roads which in the UK are inappropriate for 20 mph zone implementation (A Roads), further casualty reduction from implementing 20 mph zones may be limited in settings such as London where a large proportion of residential areas have already been traffic-calmed. Future gains in road safety may be more likely from interventions which also address the risks of major roads.

What we cannot answer from this analysis is how 20 mph zones compare with the effect of other possible forms of traffic control systems – including such innovative ideas as re-designing road layouts to make the space more shared between pedestrians, cyclists and motor vehicles. Further research is also needed on the impact of traffic calming in other settings in which the background decline in injury rates may be less dramatic, particularly in low and middle income settings, in which 85% of road traffic related injuries occur,(3) and where there has been little evaluation of the impact of traffic calming schemes.(16)

Our conclusion, however, is that 20 mph zones do offer a worthwhile public health intervention and can be recommended as part of health-orientated transport policies.

What is already known on this topic

Road injuries are among the leading causes of mortality and disability worldwide.

There is evidence that reducing the speed and volume of traffic can reduce road traffic injury rates.

What this study adds

20 mph zones are effective measures for reducing road injuries with no evidence of casualty migration to nearby roads.

GUARANTOR

Chris Grundy

CONFLICT OF INTEREST

All authors declare that the answer to the questions on your competing interest form are all No and therefore have nothing to declare.

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CONTRIBUTORS

CG, RS, PE, BA, and PW all contributed to the design of the study, analysis of the data, and interpretation of results. JG contributed to the design of the study and interpretation of the results. All authors contributed to the writing of the manuscript.

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Table 1. Characteristics of road segments by area type

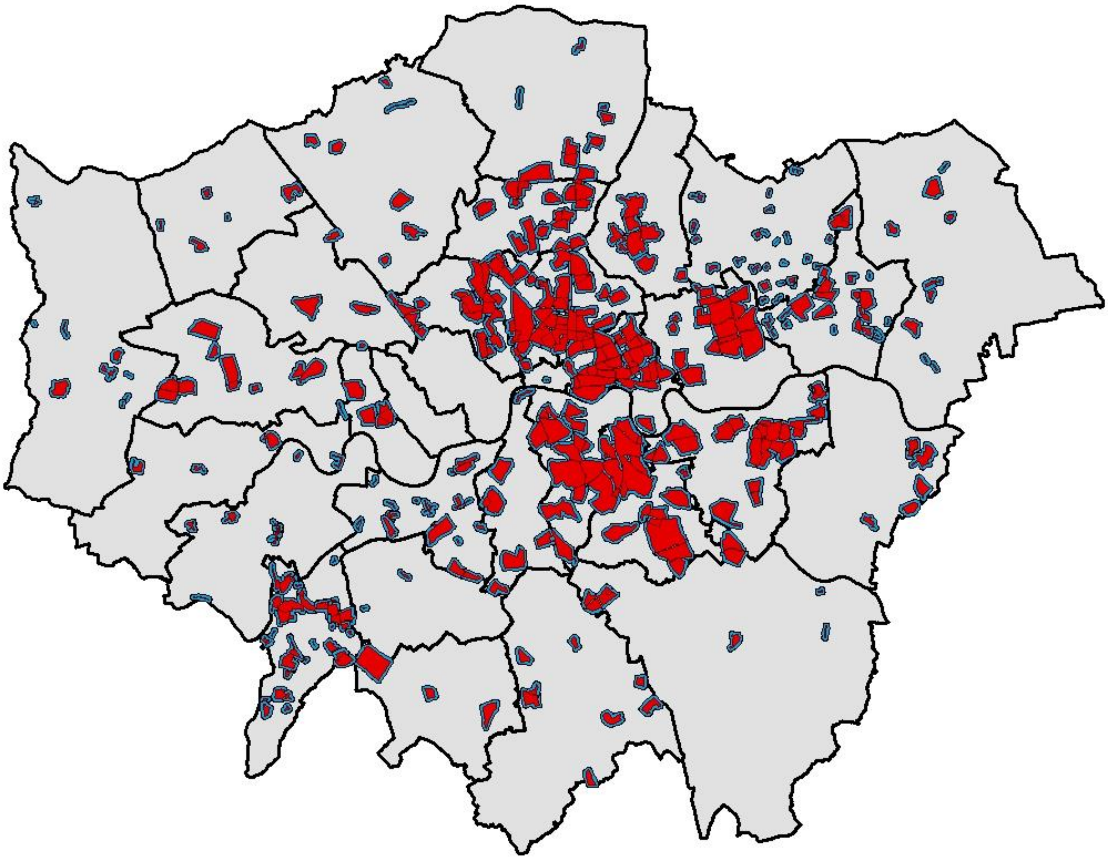
	20 mph zones	Areas adjacent to 20 mph zones	Other roads
Length of roads in kilometres (column percentage) by road type			
Motorways	0 (0%)	3 (0%)	130 (1%)
A roads	14 (1%)	584 (26%)	1732 (12%)
B roads	39 (2%)	111 (5%)	385 (3%)
Minor	1739 (86%)	1307 (59%)	9529 (68%)
Other	214 (11%)	211 (10%)	2136 (15%)
Total	2006 (100%)	2216 (100%)	13913 (100%)
Percent of road kilometres in inner London	1263 (63%)	1109 (50%)	2780 (20%)
Number of injuries financial year 2006			
minor	523 (91%)	5865 (87%)	20836 (87%)
serious	52(9%)	782 (12%)	2920 (12%)
deaths	1 (0%)	41 (1%)	182 (1%)
Number of injuries 1987-2006			
minor	39766 (85%)	204262 (85%)	520167 (84%)
serious	7002 (15%)	33946 (14%)	89433 (15%)
deaths	220 (0%)	1642 (1%)	4366 (1%)
Number of injuries after implementation			
minor	1704 (89%)	22130 (87%)	
serious	210 (11%)	3015 (12%)	
deaths	8 (0%)	182 (1%)	

Table 2. Effect (percentage reduction) of introducing 20 mph zones on casualties and collisions in 20 mph zones and in adjacent areas, and the annual average decline in casualties and collisions on other roads, 1986-2006

	Percent reduction (95% CI) following introduction of 20 mph zones		Annual average percent decline in casualties and collisions (underlying trend)
	In 20 mph zones	In areas adjacent to 20 mph zones	
Casualties			
All casualties	41.9 (36.0 to 47.8)	8.0 (4.4 to 11.5)	1.7 (1.5 to 1.9)
All casualties (0-15 yrs)	48.5 (41.9 to 55.0)	9.7 (4.5 to 14.9)	3.4 (3.1 to 3.7)
KSI *	46.3 (38.6 to 54.1)	7.9 (2.2 to 13.5)	3.8 (3.4 to 4.1)
KSI* (0-15 yrs)	50.2 (37.2 to 63.2)	5.4 (-8.1 to 18.8)	5.2 (4.7 to 5.8)
Killed	35.1 (-1.9 to 72.0)	-21.1 (-52.3 to 10.2)	4.0 (3.4 to 4.6)
Pedestrian casualties			
All pedestrians	32.4 (27.1 to 37.7)	4.3 (-1.0 to 9.6)	3.4 (3.2 to 3.6)
0-15 yrs	46.2 (36.8 to 55.5)	5.3 (-1.3 to 11.9)	3.9 (3.6 to 4.3)
KSI*	34.8 (22.2 to 47.5)	-2.1 (-13.6 to 9.3)	5.5 (5.2 to 5.9)
KSI*, 0-15 yrs	43.9 (26.6 to 61.3)	-4.5 (-23.0 to 14.0)	6.1 (5.5 to 6.7)
Male, 0-15 yrs	45.5 (35.6 to 55.3)	8.2 (0.7 to 15.7)	4.1 (3.7 to 4.5)
Female, 0-15 yrs	47.2 (33.1 to 61.2)	0.9 (-10.0 to 11.7)	3.7 (3.4 to 4.0)
0-5 yrs	47.0 (28.7 to 65.2)	9.9 (-11.8 to 31.6)	4.0 (3.5 to 4.5)
6-11 yrs	50.8 (40.9 to 60.8)	3.7 (-8.5 to 16.0)	4.8 (4.3 to 5.2)
12-15 yrs	26.3 (5.9 to 46.7)	6.3 (-4.1 to 16.7)	2.8 (2.5 to 3.1)
Cyclists			
All cyclists	16.9 (4.8 to 29.0)	4.6 (-2.5 to 11.7)	2.0 (1.3 to 2.7)
KSI*	37.6 (14.4 to 60.9)	-2.1 (-19.5 to 15.2)	3.1 (2.2 to 4.0)
0-15 yrs	27.7 (6.3 to 49.1)	6.2 (-10.8 to 23.2)	4.7 (4.1 to 5.3)
16+ yrs	7.3 (-10.3 to 24.9)	7.2 (-0.11 to 4.6)	1.4 (0.7 to 2.0)
Powered 2-wheeled vehicle riders			
All casualties of powered 2-wheeled vehicles	32.6 (21.7 to 43.4)	9.4 (2.7 to 16.1)	0.6 (0.2 to 1.0)
KSI*	39.1 (19.0 to 59.1)	3.2 (-10.2 to 16.6)	2.4 (1.9 to 3.0)
Car occupant			
All car occupants	52.5 (42.5 to 62.4)	11.5 (6.4 to 16.5)	1.1 (0.8 to 1.5)
KSI*	61.8 (52.0 to 71.7)	24.4 (15.7 to 33.0)	2.8 (2.2 to 3.5)
Collisions			
All collisions	37.5 (31.6 to 43.4)	7.4 (3.8 to 11.0)	1.8 (1.6 to 2.0)
KSI*	44.2 (36.6 to 51.7)	7.5 (2.0 to 13.1)	3.8 (3.4 to 4.1)
Involving ≥1 pedestrian	30.1 (23.5 to 36.5)	4.1 (-1.3 to 9.4)	3.4 (3.2 to 3.6)
Involving ≥1 cyclist	16.6 (5.6 to 22.7)	4.4 (-2.7 to 11.5)	2.0 (1.3 to 2.7)
Involving ≥1 powered 2-wheeled riders	31.7 (21.2 to 42.3)	9.8 (2.8 to 16.8)	0.6 (0.1 to 1.0)

* – KSI = killed or seriously injured

Figure 1. Location of 20 mph speed zones in London (1991-2007)



20 mph zones (red)
Adjacent areas (blue)
Local Authority Boundaries Crown and OS copyright.

Figure 2. Flow diagram of the number of injuries (deaths) and road segments used in analysis.