Epidemiology, cost and prevention of road traffic crash injuries in Strathclyde, Scotland

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EXECUTIVE SUMMARY

Background

Road traffic crash (RTC) injuries affect 20 to 50 million people worldwide every year, causing premature death or disability as well as incurring large costs to individuals and society. In the UK, the number of RTC casualties is underestimated if based solely on police records, as many casualties are unreported to the police. "Safety" (speed and red light) cameras have shown to be an effective way of combating RTCs and in 2000 a national scheme was rolled out in the UK.

Aim and objectives

The overall aim of the study was:

> To investigate the epidemiology, cost and prevention of RTC injuries in the Strathclyde police region of Scotland.

The specific objectives of the study were:

1. To establish the overall epidemiology and accuracy of reporting of RTC injuries in Strathclyde.

2. To determine the epidemiology of RTC injuries and the effectiveness of safety cameras at the camera sites in Strathclyde with special reference to different road users, RTC types and severity, before and after camera installation.

3. To estimate the economic burden of hospital admissions due to RTC injuries in Strathclyde and at the camera sites before and after installation.

Methods

Nine years (1997 to 2005) of police road casualty records (STATS19) and National Health Service hospitalisation records (SMR01) from the Strathclyde region were linked.

The linkage resulted in nearly 11,000 police casualty records relating to approximately 30,000 hospital and death records. Unlinked RTC hospital and police casualties (nearly 9,000 and 70,000 respectively) were also utilised in the analysis.

The study employed a range of epidemiological and economic methods. These included descriptive epidemiology (evaluating distributions of linked and unlinked records, length of stay and cost analysis), analytical epidemiology (examining associations using chi square and logistic regression models) and interventional epidemiology (before and after study). The economic evaluation utilised weighted mean costs.

The focus of analysis was threefold: 1. Epidemiology of RTC, injuries and accuracy of police recording, 2. Epidemiological impact of safety cameras, 3. Cost of road traffic crashes a) in Strathclyde and b) at safety camera sites.

Results

Epidemiology of RTC injuries in Strathclyde: Older age and less protected road users (i.e. pedestrians and two-wheeled vehicle users) had a higher risk of a more severe outcome in RTCs. Head injuries were more common among pedestrians and pedal cyclists, while car occupants more often suffered injuries to the thorax and abdomen/lower back/lumbar spine.

Accuracy of police reporting: 45% of RTC hospital admissions were not recorded by police. Casualty characteristics significantly associated with underreporting were: no third party involvement, older age, casualties from early in the study period, type of road user (especially pedal cyclist), hospitalisation as a day case and female gender.

Seriously injured casualties recorded by police (STATS19) declined in frequency more than the RTC hospitalised injuries (SMR01) (38% and 21% respectively). Linked SMR01 casualties that were coded "slight" by the police increased by 5% over time, while linked SMR01 casualties coded "serious" declined by 27%.

Safety camera impact: Compared to the rest of Strathclyde, there was a significantly greater downward linear time trend of RTC incidence at the camera sites. The impact of cameras on RTCs over time appeared stable. Cameras seemed to be effective in reducing the incidence of serious or fatal RTC injuries, as well as injuries associated with multiple-vehicle and non-junction RTCs.

Cost of RTC casualties in Strathclyde: Total inpatient costs were conservatively estimated at £7.3 million yearly (linked records). Head and lower extremity injuries incurred the highest total costs (28% and 34% respectively). Pedestrian injuries, constituting 36% of the total, incurred 44% of total costs. Casualties from deprived areas, and pedestrians in particular, incurred higher hospital costs than other road user groups.

Cost of RTCs at safety camera sites: 17% of all injured before safety camera installation were hospitalised, while 13% of casualties after installation were hospitalised. The mean costs of (surviving) casualties admitted to hospital declined by 24% after installation and the mean daily cost declined by 55%.

Conclusions

RTC injury incidence in Strathclyde declined over the study period, which is in line with expectations of developed countries. Young and elderly people as well as unprotected road users carry a disproportionately great RTC injury burden.

Many hospitalised RTC casualties were not recorded by police and there appears to have been an increasing tendency over time for police officers to report injuries as slight rather than serious.

National (UK) statistics of RTCs should be interpreted with caution in the light of these findings and routinely linking police and hospital data would enhance the quality of RTC casualty statistics. Linking police and hospital RTC records provide a more comprehensive source for road traffic analysis than any of the sources separately. Routine data linkage would also facilitate the evaluation of time trends in relation to national road casualty reduction targets.

The study indicates that the most costly RTCs occur in areas with high levels of deprivation, a history of pedestrian RTCs, elderly and child casualties, roads with many non-junction RTCs and 30 mph speed limits.

The evaluation of safety cameras strongly suggests that they are effective in reducing both road casualty incidence and severity and that the reduction in incidence is sustained over time. Additionally, safety cameras in Strathclyde may have contributed to a saving of over £5 million. Cameras thus fulfil an important public health, as well as law enforcement, function and should continue to play a central role in traffic calming.

This study has demonstrated the value of utilising multiple data sources in the road traffic injury field.

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DEFINITIONS, GLOSSARY AND ABBREVIATIONS

AIS — A*bbreviated Injury Scale*: is an anatomical scoring of injury severity. The scores range from 1=minor injury to 6= unsurvivable although the difference between each step of the scale are not equal.

BAC — *Blood Alcohol Concentration*: intoxication level of alcohol used in medical or legal situations. It is calculated by mass per volume and affected by weight, gender and body fat. BAC range from 0.02% (one standard drink) to 0.40%, which is the lethal level for 50% of the population.

Casualty — *Casualty*: is in this context referred to as a person who are injured or killed in a road traffic crash.

CT — *Computed Tomography*: medical imaging method used to produce three dimensional and other types of type scans.

Crashes — *Crashes*: are here referred to as the road traffic incidence commonly referred to as "accidents". "Accidents" is not an acceptable term in traffic injury research as it implies that the incident is related to fate, chance or the act of god.

CVC — *Cervical Vertebral Column*: is the medical term for what is more commonly referred to as whiplash injuries, which are often associated with rear end road traffic crashes.

DALYs — *Disability Adjusted Life Years*: a combination of morbidity and mortality in number of healthy years lost.

DfT — *Department for Transport*: is the UK transport department and 'provides leadership across the transport sector to achieve its objectives, working with regional, local and private sector partners to deliver many of the services'.

DSM — *Diagnostic and Statistical Manual of Mental Disorders:* provides diagnostic criteria for mental disorders, including PTSD.

ETSC — *European Transport Safety Council*: 'is a Brussels-based independent non-profit making organisation dedicated to the reduction of the number and severity of transport crash injuries in Europe. ETSC provides an impartial source of expert advice on transport safety matters to the European Commission, the European Parliament, and Member States.'

FUA — *Follow-up Admission*: any hospital admissions after the first admission.

GIS	*Geographical Information Systems*: 'captures, stores, analyzes, manages, and presents data that refers to or is linked to location.'
GNP	*Gross National Product*: measure of national income and output (GNP = 'Value of all goods and services produced in a country in one year, plus income earned by its citizens abroad, minus income earned by foreigners in the country.'
GROS	*General Register Office for Scotland*: 'are responsible for the registration of births, marriages, civil partnerships, deaths, divorces, and adoptions' in Scotland.
ICD-9/10	*International Classification of Diseases, 9th and 10th revisions*: 'the international standard diagnostic classification for all general epidemiological, many health management purposes and clinical use.'
Injury	*Injury*: is in this context synonymous with trauma i.e. physical or emotional harm. Injury in this study is referred to as trauma inflicted by road traffic crashes.
ISD	*Information Services Division, Scotland*: 'national organisation for health information, statistics and IT services.'
KSI	*Killed or Seriously Injured*: abbreviation used in UK road casualty statistics based on police judgement of severity.
LoS	Length of hospital stay
MAIS	Maximum Abbreviated Injury Scale: if there are multiple injuries involved, as often is the case of RTCs the highest AIS (see above) is used as MAIS.
MRI	*Magnetic Resonance Imaging*: medical imaging technique to visualise structure and function of body. MRI is more detailed than CT.
MUARC	*Monash University Accident Research Centre*: 'is Australia's largest injury prevention specialist.' Conducting 'research, consultancy and training include safety in all modes of transport, in the workplace, in the community and in the home.
NHS	*National Health Service*: publicly funded health care in UK
OR	Odds Ratio: describes the strength of association and is often derived using logistic regression.
PCS	*Post-Concussion Syndrome*: a milder form of head injury with a range of symptoms.

PIC *Personal injury collision*: term used to describe injury RTCs in safety camera project when analysing RTC blackspots.

PTSD *Posttraumatic Stress Disorder*: an anxiety disorder that can develop after traumatic event with or without injury. It is a severe and ongoing emotional response to extreme psychological trauma.

RTCs *Road Traffic Crashes*: this term has been selected as the most appropriate for this study and is used throughout the thesis. Other abbreviations commonly used elsewhere are MVA (Motor Vehicle Accidents), PIC (Personal Injury Collisions) and RTA (Road Traffic Accidents).

SIMD *Scottish Index of Multiple Deprivation*: deprivation measure developed for Scotland comprising seven different domains (current income, employment, health, education, skills and training, housing, geographic access and crime).

SMR01 *Scottish Morbidity Records 01*: hospital discharge records in Scotland.

STATS19 Road traffic crash records collected in UK by the police, including information on crash circumstances, vehicle and casualties.

TRL *Transport Research Laboratory*: UK base institution that provides independent research, consultancy, advice and testing for all aspects of transport.

WHO *World Health Organisation*: a specialized agency of the United Nations (UN) that acts as a coordinating authority on international public health (copied from Wikipedia).

CHAPTER 1. OVERVIEW OF THE EPIDEMIOLOGY, COST AND PREVENTION OF ROAD TRAFFIC CRASHES

Contents of the Chapter 1

Global burden of injuries

Injury is a worldwide problem [1]. It accounts for a large proportion (9%) of overall mortality and global burden of disease (12%), estimated using disability-adjusted life years (DALYs) or healthy years lost due to premature death or disability [2]. Road traffic crashes (RTCs) account for about 25% of all fatal injuries in the world and 22% of injury-related DALYs. RTCs especially affect young people - over 50% of RTC fatalities occur in young adults (aged 15-44). In 2000, an estimated 1.26 million people died in RTCs and this is only the tip of the iceberg, as RTC injuries affect between 20 and 50 millions every year (the wide range of this estimate is because of the known under-reporting of casualties) [3]. In total, it is estimated (conservatively) that between the first fatal road traffic crash in 1896 (a pedestrian in London hit at 4 mph) [4], and the end of 1997, 25 million people have lost their lives in RTCs [1]. According to the World Health Organization (WHO), globally, an average of 3,242 people lose their lives through traffic injuries every day [1] (a yearly toll of 1,183,330 fatalities). In the European Union more than 50,000 people are killed and 150,000 disabled for life, in RTCs every year. This leads to 200,000 families who are either bereaved or have a family member who is disabled for life [5].

RTC injury rates vary immensely between different parts of the world and 90% of fatalities occur in the low and middle-income countries [2]. Africa and Latin America have high RTC mortality rates (e.g. El Salvador: 41.7 per 100,000 population) [1], which stands in stark contrast to the Netherlands, Sweden and the United Kingdom (UK), which have the lowest rates (6.8, 6.7 and 5.9 per 100,000 population respectively) [6].

Pedestrians and two-wheeler users (bicyclists, occupants of mopeds and motorbikes) are especially vulnerable in traffic and carry a heavy burden of the injury total, particularly in low- and middle-income countries (due to more mixing with other road users and a greater diversity and intensity of traffic) [1]. A review of 24 studies of developing countries showed that in 16 of these studies pedestrians accounted for between 41% and 75% of the total RTC fatalities [7]. In high-income countries the proportions are different and in France, Germany and Sweden car occupants comprise more than 60% of RTC fatalities, while countries such as Japan, Denmark and UK have less than 47% car occupant fatalities of the total (these nations have a higher rate of pedestrian fatalities (over 20%)) [8]. In India 26% of all RTC fatalities occurred in bicyclists (1993) [7] compared to 22% in Netherlands of (1990)[9], and only 2% in United States of America (USA, 1995) [9].

RTC is one of the major causes of trauma admissions. In a review of 15 studies of developing countries, between 30 and 86% of trauma admissions were due to RTCs [7]. A US study showed that out of 80,000 children who were involved in an RTC 12,800 (16%), received some form of health care [10]. There are major consequences to RTCs including both physical and psychological disabilities. Children appear to recover physically faster than adults [11], but they suffer a high rate of psychological problems [12,13]. A study of emergency department attendees, following RTC, showed that 55% of people still suffered from the consequences a year after the RTC [14]. The people who were seriously injured in this study were twice as likely to experience travel anxiety, post traumatic stress disorder (PTSD), work and financial consequences, a year after the RTC.

1.1 Time trends in incidence of road traffic crashes

RTC injuries have been a part of society since the introduction of the moving vehicles in the end of the 19th century. The injury rates increased until the 1960s to 1970s when the trend turned in developed countries. The turnaround in trends was probably mainly due to a wide range of road safety measures (e.g. seatbelt use traffic calming interventions etc.) [1]. This section includes a review of the current global time trends comprising future estimates and time trends in Scotland.

1.1.1 Global time trends

The total count of RTCs and its consequences in terms of injuries and fatalities is continuously rising in the world, although there is a clear difference in time trends in high and low-income countries.

High income countries (including UK) have experienced a decline in fatal RTC incidence since the 1960s , while there has been an increase in low and middle income countries [1,15].

A research study by the World Bank [15] estimated that the future count of the world's road fatalities will increase by about 66 percent between 2000 and 2020, but this will be divided very unequally across the countries where a 28% decline is expected in the high-income countries while countries like China and India can expect major increases (92 and 147% respectively). By 2020 high-income countries are predicted to have less than 8 fatalities per 100,000 pop while low-income countries have nearly 20 per 100,000 pop.

1.1.2 Time trends in Scotland

In Scotland, RTCs (in which someone was killed or injured) increased up until the mid 1960s where it reached a plateau (at about 23,000 RTC per year) until the end of the 1970s [16]. There was only a temporary dip in the RTC count during fuel crises in the early 1970s. From the early 1980s onwards there has been a declining trend of RTCs and in 2006 there were 13,000 injury RTCs. In terms of casualties, comparing casualty counts in 1996 with 2006, this shows a reduction in all casualty severity categories: fatalities (357 vs. 314), serious (4,041 vs. 2,625) and total (21,716 vs. 17,267).

1.2 Risk factors and causes of road traffic crashes

There are a variety of factors associated with the occurrence of RTCs. The risk factors can, broadly, be categorised in four groups: factors influencing exposure to risk (e.g. deprivation), crash involvement (young male), crash severity (speed or seatbelt use) and severity of injuries after RTC (lack of early care) [1].

In this section, risk factors associated with exposure to risk and crash involvement are discussed. Risk factors associated with crash and injury severity are discussed further in section 1.3.4 (including type of road user).

1.2.1 Age and gender patterns by road traffic crash risk

The disproportionate male to female ratio, in terms of RTCs, is recognised world-wide [17]. According to Australian figures males were involved in 63% of total crashes and 86% of alcohol related crashes although males comprise only half of the driving population [18].

In Scotland, males in the age group 17-22 and 30-59 had double the driver RTC rate compared with females from the same age group (11 per thousand population, versus 5.1 and 6.2 per thousand population in 1999). During 1981-85 the rate of RTCs involving female drivers increased while RTCs involving male drivers decreased and the ratio fell from 4:1 (1981-85) to 2:1 (1999) [19].

Females are more involved in non-fatal than in fatal crashes which may reflect the fact that females are more often injured in urban crashes at lower speed. There is also a higher rate of females involved in crashes in high-income countries than in low-income countries [3].

1.2.1.1 Driving behaviour related to age and gender

The variation in male/female death rates is likely to be caused by difference in speed, alcohol use and other factors that influence the outcome in serious and fatal crashes [17,20]. Males are generally considered to be more inclined to take risks than females including alcohol and speed [20-23] and younger drivers are more likely to engage in more risky behaviour (such as speeding and drink driving, see further section 1.2.2.3) [20-25]. Young drivers are also more confident in their ability and perceive some driving situations less hazardous than older drivers [22].

Behavioural risks in terms of psychology are discussed further in section 1.2.6.

1.2.1.2 *Exposure to road traffic crash risk related to gender and age*

Some of the male/female differences could possibly be explained through different rates of exposure to risk [26,27]. A US study of crashes and gender, involving over 11 million crashes, found that the reason for greater death rates in male drivers compared to female drivers was the difference in miles driven (male/female ratio 1.74). Males have more fatalities per crash (male/female ratio 1.97[27]). Females, however, have more crashes per mile driven (male/female ratio 0.90 [27]) including both injury crashes and all reported crashes [26]. Other research has found that male drivers have a higher frequency of crashes involving single vehicles [25], which includes 'loss of control' of the vehicle, and these types of crashes are more likely to have a fatal outcome [28]. In terms of driver hospitalisations, over double as many males as females were involved in 'loss of control' type of crashes compared to crashes with other vehicles (where the rate war nearly equal between males and females) [28].

Males are more likely to have a crash at night-time than females (1.2 time the female rate) while females more often have crashes during daytime hours (1.4 times the male rate) [26]

Younger drivers have a high crash rate per mile driven, but a lower rate of death per crash. This could be due to the fact that younger people are better protected because of their overall better health [27]. The fatal and serious injury rates in Scotland were 1.12 per thousand populations for 16-22 year old car users while only 0.42 per thousand populations for car users 23-59 year old [29].

1.2.1.3 *Risk related to children and elderly*

Children in the developing world are at higher risk of RTC injury than in the developed world, but they account for a relatively small proportion of the reported casualties [3]. In contrast, children in USA and UK account for a higher proportion of RTC casualties than other countries. UK has three times as many casualties under the age of nine compared to Italy. Reasons behind this include social patterns (walking to school etc) and population distributions.

In Scotland, 18% of RTC emergency admissions were children (2004). Children had, on average, a shorter length of stay than adults (3 days v 4.1 days) and the total inpatient days due to RTC for the year was 18,166 [30]. Boys (0-14) had over double the fatal injury risk of girls in RTCs in Scotland (OR 2.38 in 2002-06), while equal risk of a fatal pedestrian RTC in the same time period; the fatal child pedestrian m:f ratio declined from 2.03 in 1982-86 to 0.95 in 2002-06 [31].

Older drivers have a high crash rate per mile driven, but research indicates that older drivers primarily are a risk to themselves rather than other age-groups [32]. There is on the other hand, research indicating that the claim that older people have a higher crash rate per mile driven may be explained by the "low mileage bias", which means that drivers, independent of age, have a higher risk of RTC when driving a lower annual mileage [33].

Older people have a higher risk of severe or fatal injury outcome from RTC due to their vulnerability [33] and the risk of dying in a crash may be more related to this factor than to a decline of motor skills associated with aging [32].

In terms of pedestrian RTCs, children under nine and people older than 50 are at greatest risk (18.8% and 49% respectively) [34]. In England and Wales there was a decline in pedestrian and cycle child-fatalities in 1985-1992. One of the main reasons for this decline, however, was that children travelled more by car than walked or cycled [35]. Child pedestrians are more often hit by male drivers under the age of 40 [36] and it has been suggested that the pedestrian is at fault in a third of the collisions [34].

Elderly and RTC risk is discussed further in section 1.2.6 on psychopathology.

1.2.2 Substance use and road traffic crash risk

The effects of alcohol are well researched but there are fewer data on other substance use (including medical and recreational drugs) in relation to RTC [1]. It is more difficult to assess the impact of these, as measuring drugs is not as straightforward as with alcohol [37,38]. According to WHO there is currently no strong evidence that drugs increase crash risk significantly and they call for studies to assess this urgently [1]. This subject will therefore not be explored further here.

1.2.2.1 *Alcohol intake and risk of road traffic crash*

The risk of involvement in a crash increases significantly at blood alcohol concentration (BAC) above 0.04 g/dl. [39]. The crash risk increases by at least 9 times at 0.05-0.09 BAC and at very high BAC (>=0.15) the crash risk increases 3-600 fold compared to zero BAC [40]. The risk of a fatal crash is 4.8 times more common for young drivers (aged 16-20) with alcohol levels of BAC equal to or over 0.08, compared to no alcohol [41].

In the 'SUN' countries (Sweden, UK and the Netherlands) the proportions of fatally injured drivers with a BAC over 0.1 is 14%, 20% and 17% respectively, which may reflect each country's legal limits (0.02, 0.08 and 0.05 g/dl respectively), penalties and enforcement [42]. In the UK (1999) 48% of all fatally injured adult pedestrians and 33% of all fatally injured drivers, tested positive for alcohol [43].

1.2.2.2 *Police detection of drink driving*

An Australian study showed that police detected 80% of drink driving incidents between 6 pm and 6am. During daytime, however, there was a higher risk of alcohol detection through RTC investigation rather than routine enforcement [18]. This both reflects the fact that police enforcement is more likely to occur during evenings and weekends when alcohol consumption is higher and that more RTCs occur during the daytime when more cars are on the roads.

There has been a reduction in RTC related drink driving arrests in Scotland from 3.8% in 1986 to 2.1% in 1999. The number of drink drive crashes fell 35% between 1988 and 1999 and the numbers of casualties fell by 39% over the same period. There are no estimates of RTC involvement of drivers influenced by alcohol lower than the legal limit of 0.08 BAC [29].

1.2.2.3 Drink driving involvement and age

Driving under the influence of alcohol is more common among younger people [18,23]. In an Australian study, drivers aged 18 to 25 years were involved in half of all the drink drive arrests that were detected through a crash. Additionally, alcohol detection following a road crash was more likely for old and young drink drivers than middle-aged drink drivers. In this study, drink-driving RTCs comprised 2% of all reported crashes, but according to the study this should be seen as an under-estimation of the true level of alcohol related crashes [18].

1.2.2.4 Alcohol and risk of pedestrian road traffic crash

An Australian study found that 46% of pedestrian fatalities aged 16 or over had consumed alcohol and, in total, 59% of males and 17% of female fatalities had a detectable BAC.[44]

A study from USA of pedestrian casualties showed that they were more likely to be binge drinkers, alcohol dependent and drug dependent than compared to the remaining population of unintentional trauma [45].

In a Swedish study, alcohol was detected in 19% of pedestrian fatalities and males tested positive more often than females (24% v 11%) [46] and the mean age of the fatalities with detected alcohol was lower than the remaining group (49 years v 59 years). Additionally a greater proportion of victims testing positive occurred during nights and weekends [46], which is similar to other findings [47].

In Scotland, 31% of all pedestrian casualties had consumed alcohol and of these, 87% were male. Pedestrian casualties were twice as likely to be admitted to hospital if they have been drinking and pedestrians aged 40-49 were much more likely to be in a RTC if they had been drinking than other age groups [47].

1.2.2.5 Smoking and risk of road traffic crash

The relationship between smoking and RTCs was analysed in an Israeli study. Cigarette smokers made up 28% of study population, while 40% of drivers in RTC were smokers (p=0.005). The frequency of being involved in RTC as drivers was 0.69% for smokers and 0.4% for non-smokers. The reason for this, suggest the authors, could be that a driver who smokes is distracted from paying attention to driving. Smokers may also have a greater risk of an underlying disease that could affect their performance. Additionally, a "person who risks his health by smoking might be a less cautious driver as well". [48]. This statement is supported by a more recent study showing that smokers are more likely to drink drive, binge drink, travelling with a drunk driver, having a previous RTC injury and be less likely to use seatbelts [49].

1.2.3 Vehicle speed and road traffic crash risk

Speed influences the risk of RTC in several ways. With higher speed, a driver's time to react is shorter, it is easier to lose control of a vehicle and it is harder for surrounding road users to judge the speed of an oncoming vehicle (with high speed) and have time to avoid it. The stopping distance of a vehicle also increases with higher speed [50].

1.2.3.1 Definition of speed-related road traffic crashes

A major factor in both frequency of occurrence of RTC and severity of resultant injuries includes inappropriate and excessive speed (driving too fast for prevailing conditions and surpassing the speed limit exceedingly).

A UK report states that approximately 15% of crashes are reported as having "excessive speed" as a contributory factor [51]. Several other factors are also regarded speed-related, including 'following too close' or 'losing control in a bend' and it is therefore probable, that speed influences more RTCs than the 'excessive speed' factor alone indicates. Combining 'excessive speed' with relevant additional factors, suggests that speeding causes one third of fatal RTCs.

1.2.3.2 Speed related to road traffic crash incidence

It is estimated that the greatest reduction in road casualties could be achieved through reducing the speed of the fastest drivers. Furthermore, RTCs would increase by 10% if the proportion of speeders doubled and if the average speed increased by 1 mph, RTCs would go up by 19% [52]. RTC frequencies are also expected to drop by 5% if the average speed is reduced by 1 mph, but this general rule varies according to type of road.

In UK urban areas 4% of RTCs were due to speeding while an additional 21 % had other speed related factors. Findings also suggest that if everyone kept within the speed limit, the RTC rate would drop by 20% [53]. In a 1994 TRL investigated the impact of traffic speed on the number RTCs. The findings suggested a 5% increase in injury RTCs per 1 mph increase in average speed [54].

1.2.3.3 Speeding drivers

Speeders (drivers flashed by a speed camera or stopped by police) have been found to be 'RTC magnets' i.e. more prone to be in a RTC [55]. In terms of speed cameras, drivers are more likely to get caught speeding further away from their home: only 15% of people caught speeding by a fixed camera live within 2 km of the camera site and 63% live further away than 15 km [56].

1.2.4 Deprivation and road traffic crash risk

It is well known that deprivation is associated with injury risk. A study of pedestrian casualties in USA showed that these casualties were more likely to be black, unemployed, unmarried, alcohol or drug dependent, low income and educational achievement, not have a driving licence and of younger age [45].

A Swedish study of childhood injuries found that socio-economic differences in traffic injuries increase with the child's age and peak at ages 10-14 and 15-19 [57]. A study of child injury fatalities in England and Wales showed that child pedestrian from social class V are five times more at risk of a fatal injury than children in social class I [58], which is similar to a Swedish study showing a 20-30% higher risk of child pedestrian and bicyclists from manual worker families compared to children from high and intermediate level salaried families [59].

A study of young drivers found that there was 80% higher risk for young drivers from manual worker families of injury in traffic compared to young drivers with parents of higher socioeconomic status [60].

A Scottish study of pedestrian road traffic casualties found that residents from the 15% most deprived areas were nearly four times as likely to be in an RTC than residents from the 15% most affluent areas (19.9 versus 5.1 per 10.000 people per year) [61].

Lower socioeconomic levels are also related to worse injury severity [62].

1.2.5 Seasonality and road traffic crash risk

There is a seasonal trend to RTCs and in Scotland adult car user casualties vary by month and the annual averages over the years 1995-99 showed a peak in October-November. This peak had 31% more 'adult car user casualties' than April, which had the lowest rate. The peak time of day for adult car user casualties was from 4 to 6 pm [29].

1.2.6 Psychopathology and road traffic crash risk

Social problems at a young age can be associated with risky driver behaviour. A study showed that a history of school suspension carried an increased risk of repeated RTCs injury [63]. The risky behaviour included not using a seatbelt, drink driving, riding with a drunk driver, binge drinking, and speeding for excitement. Having a history of school suspension was also associated with drink driving convictions and suspension of license.

Personality disorders (borderline and/or antisocial) were associated with higher risk of a fatal RTC outcome for males aged 26 or over (in a study of males only) [64]. Young drivers with high levels of aggression or alienation from society may carry an increased risk of RTC [65].

Anxiety was associated with higher RTC incidence in a study of professional drivers [66].

There are indicators that cognitive impairment related to Alzheimer's disease is associated with pedestrian fatalities among older people [67] and that this group is often partially responsible for the RTC, injured in traffic situations of low complexity; involved in RTCs with reversing vehicles and injured in off road RTCs [68].

1.2.7 Previous road traffic crash or injury and road traffic crash risk

Having a previous injury can increase the risk of an RTC in different circumstances. People with a previous traumatic brain injury have double the risk of RTC compared to no injury, while those with brain injury after stroke incidents do not [69].

1.3 Consequences of road traffic crashes

The consequences of RTCs may be serious and long-lasting. They include the more tangible effects of injuries such as stay in hospital, disability and loss of income, but also less obvious psychosocial effects. Children appear to physically recover faster than adults [11], but they suffer a high rate of psychological problems. One study showed that over half of RTC casualties still suffered from the consequences a year after the RTC [14] and casualties who were seriously injured in this study were twice as likely to experience travel anxiety, PTSD,, work and financial consequences a long time after the RTC. Age, alcohol, type of road user and vehicle speed all play a major part in how serious a RTC will be for an individual.

This section comprises three main parts. The first holds a discussion on injuries resulting from RTC including both characteristically differences between life threatening and disabling injuries as well as a review of head injuries and so called "whiplash" injuries. This also includes a discussion on the long-term effects of injuries.

The second part includes a review of risk factors that are associated with how severe a RTC may be for an individual including specific discussion on age and gender, alcohol, type of road user and speed of vehicle. Vehicle speed is of extra interest in this study as part of the assessment includes speed cameras.

The final part discusses the psychosocial effects of RTCs and the risk factors for RTC injury associated with psychosocial disorders.

1.3.1 Road traffic crash injury and sequelae

RTCs results in a range of physical injuries including everything from trivial to fatal. Fatalities constitute about 1% of casualties (results from this study, see further results section 4.1.1.1) and are only the tip of the injury ice-berg. As RTC injuries can be quite different in terms of threat to life and disability, many sophisticated scoring methods have been developed to aid in making fast and accurate decisions on how to prioritise injured casualties and how to best provide care.

1.3.1.1 Life-threatening and disabling injuries

Life threatening injuries usually differ from disabling injuries in various respects [70,71]; injuries to legs or neck are most disabling while injuries to the abdomen/pelvis, chest and head are more likely to be fatal [70]. For example, strain of the cervical spine (often referred to as "whiplash") constitutes the majority of car occupant injuries and, although these injuries score low on the abbreviated injury score (AIS 1, see glossary for explanation), they constitute a high proportion of insurance costs and after-effects including sick leave [11,34,72]. In a study of over 20,000 car occupants, nearly 10% of casualties with AIS1 sustained permanent medical impairment [73]. By contrast, if chest injuries with a severity of AIS 2-4 are survived, there are no or few disability consequences [71,73]. Furthermore, although hospitalised casualties result in longer periods of disability, most of the disability burden is carried by non-hospitalised casualties [74].

1.3.1.2 Head and neck injuries resulting from road traffic crashes

RTCs are the most common cause of severe head injury [75,76] and can cause substantial disability as well as less obvious effects such as residual cognitive impairment or emotional problems [77]. Milder forms of head injury consequences include post-concussion syndrome (PCS) consisting of headaches, fatigue, depression and anxiety, insomnia, concentration difficulties and emotional changes, such as irritability and mood swings [78]. There is, however, limited information the prevalence of PCS in RTC head injured people for several reasons. Firstly, these symptoms are common in the general population; secondly, it is difficult to diagnose with Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) scans; lastly, findings using neuropsychological tests may be distorted by litigation i.e. the study-subject may be suing for compensation and could be motivated to perform under his/her ability in tests [79].

Cervical vertebral column (CVC) injuries (whiplash injuries) affect at least one person in 8 out of 10 RTCs involving two cars [34] and it more often affects women than men [34,72]. Women are also on sick-leave for longer from the consequences of CVC and about one in every nine people who suffer

CVC are still on sick-leave 4-6 years after the time of injury [72]. CVC victims may suffer from headache, thoracic and low back pain, fatigue, sleep disturbance and other ill health [80].

1.3.1.3 Long-term effects of road traffic crash injury

Children recover quicker from RTC injuries than adults and long-term effects increase significantly after the ages 40-50 (a study showed that 16% of children and 47% of adults suffered long term effects[11]). The physical impairments include incapacity to perform simple movements, needing to rest more, physically slower and tires more often than previously. The after-effects decline over time for adult casualties from about 60% at 6-9 months to 40% at 4-4.5 years post-RTC and more severe injuries cause a higher rate of long-term effects.

Long-term effects also include unemployment, lower incomes, learning performance, reduced scope for social contacts and difficulties with personal and domestic tasks [11].

A UK study showed that at three years post-RTC 5% of injured RTC casualties were having further surgery and 4% were still outpatients [81].

1.3.2 Risk factors associated with injury severity

There are several risk factors that contribute to the severity of injury and, according to WHO, the main ones are: lack of crash protection in-vehicle, insufficient roadside protection, not using protective devices in vehicles, not using protective crash helmets, speeding and the consumption of alcohol [1]. Injury type and severity is also very dependent on what type of road user is involved and the most common injury among car occupants is CVC injuries [34] while the majority of head injuries are suffered by pedestrians.

1.3.2.1 *Age and gender as risk of road traffic crash consequences*

Males are overall approximately three times more likely to die in RTCs compared to females [2] and males have consistently higher mortality rates than females in all nations, regardless of income level or age group (even in terms of children aged 5-14) [1]. In high-income countries the age group 15-29 years have the highest RTC injury rate, while in low- and middle-income countries the over 60s have the highest rate [1]. According to WHO, in 2002 180,500 children were killed in RTCs and 97% of these were in low and middle income countries.

In contrast to incidence, females are at higher risk of more severe outcomes from RTC injuries than males [82]. They have an increased risk of a fatal traffic injury compared with males and studies have reported varying increased risk of fatality of up to 50% [83,84]. These findings, however, appear to be limited to younger females (age 20-35 [84]). The reason for this is not clear; it is possible that it could be due to the fact that females live, on average, six years longer than males. Males may therefore be less healthy than females at an older age i.e. an injury is more likely to be fatal [83]. Another theory holds that as the increased risk in relation to age, for women, is similar to the childbearing years (preteen to late 50's), it could be related to biological reproductive factors [84]. Furthermore, there have been to date no female crash dummies made, but a Swedish group of researchers are currently in the process of developing a uniquely female dummy [85].

Older drivers are more vulnerable to the "traumatic effect of crashes". Drivers aged 80 or over have a five times greater risk of a fatal injury than drivers aged 40-49 years. Younger drivers (<30 years), however, had less than 80% risk of a fatal crash compared to drivers aged 40-49 years [83].

1.3.2.2 *Alcohol and risk of road traffic crash consequences*

Alcohol consumption can both increase [86] and decrease the risk of a fatal outcome of an RTC depending on the alcohol concentration. The risk of a fatal RTC among drivers with a blood alcohol concentration (BAC) of <0.10 was 50% less than for sober drivers, while a BAC of >0.19 tripled the risk of a fatal injury compared to sober drivers. However, BAC >0 and <0.05 is associated with 45% greater risk of driver errors than sober drivers and at BAC > 0.20 the risk increases by 700% [83].

1.3.2.3 Type of road user and risk of road traffic crash consequences

The injury consequences of RTC vary widely on several factors. In terms of type of road user, pedestrians and motorcyclist are more likely than other road users to suffer severe injuries [87], especially head injuries [88]. In a study in the European Union, motorized two-wheelers had a 20 times higher risk of being in a fatal RTC compared to car occupants. Cycling and walking carries about 7-9 times the fatality risk of car occupants [89]. Public transport is the safest option and travelling by bus carries a 10 times lower risk of a fatal RTC than travelling by car.

The majority of killed pedestrians die of an injury to the head and pedestrian injuries, in general, are dominated by knee/lower leg and head injuries [34,90,91]. Pedestrians are also more likely to sustain pelvic injuries than other road users. Car occupants on the other hand are more likely to sustain abdominal and spinal cord injuries [88].

Different injury characteristics, according to type of road user, also affect the time of death in relation to the crash; car occupants are more likely to die at the site of the crash due to ruptured thoracic aorta while pedestrian deaths more often occur in hospital through a head injury [91].

Pedestrians are more likely to die in RTCs than other casualties [88]. In 1999 pedestrians made up 18% of all casualties in Scotland and 30% of those were fatal or seriously injured compared to 19% of the remaining casualties [29].

1.3.2.4 Vehicle speed and risk of road traffic crash consequences

Severity of injury is highly related to speed of the vehicle. The probability of a belted car occupant (in a front seat) becoming severely injured triples as speed increases from 20 to 30 mph, and at 40 mph it is five times greater [92]. For pedestrians there is a significant change between 30 and 40 mph where mainly non-fatal injuries become mostly fatal [93].

Two thirds of all crashes resulting in death or serious injury (KSI) occur on roads with a speed limit of 30 mph or less [94]. If everyone adhered to the speed limit, it is estimated that the RTC rates would drop by 20% [53].

A study of fatal RTC data found that a very high proportion of the vehicles involved in fatal RTCs had exceeded the speed limit excessively, although those vehicles made up a very small proportion of the traffic in total. For example, drivers speeding at 50 mph, on a 30 mph urban road, make up about 1% of total traffic but 7% of all fatal-RTC-involved vehicles [51].

Driving at 70 mph or more increases the odds of fatality by 164% compared with speeds less than 35 mph [83] and a US study has estimated that if speed limits were set to <=65 mph nationwide (USA) 3,000 lives would be saved every year [95].

1.3.2.5 Other factors relating to risk of road traffic crash consequences

The weight of a casualty is related to risk of serious injury and fatality. The odds ratio for fatality was 1.013 for each kilo increase in body weight and 1.08 for serious injury. This could, partly, be due to other 'co-morbid' factors in overweight people [96].

1.3.3 Psychosocial sequelae

Road traffic crashes can have major psychological impact, even if the physical injury was only minor or if there were no injury at all [97] and often cause posttraumatic stress disorder (PTSD), phobic travel anxiety, general anxiety or depression [14]. These problems are similar to what people suffer from through a large disaster e.g. the Lockerbie airplane crash. However, the support resources available for a 'run-of-the-mill' RTC-victim is not the same and after the physical injuries are treated they are left to deal with psychological effects themselves [98]. On the other hand subjects accepting the responsibility of the RTC and even other peoples' death appear to suffer little distress or guilt during interviews [99].

1.3.3.1 Prevalence of psychosocial disorders following road traffic crashes

Common psychological after-effects includes frequent depression, sleeplessness and restlessness/nervousness and a slow-down of intellectual processes [11]. Children are often affected by posttraumatic stress disorder (PTSD) and a prevalence of 25% PTSD in RTC child-casualties [12] and 43% of PTSD and/or an indication of clinically significant depression and anxiety [13] have been recorded. Parents of child-casualties are also affected by PTSD (15%) and this is more prevalent in parents who witness or are involved in the RTC, but PTSD in children or parents is not related to injury severity [12]. The injury score AIS is not necessarily a good indicator of PTSD but patients' own ratings of the severity of their injury is highly correlated with PTSD [100]

1.3.3.2 Psychosocial long-term effects following road traffic crashes

At one year after the RTC 55% of respondents in a UK study said they still had medical, psychiatric, legal or social problems. The people who were seriously injured were twice as likely to experience travel anxiety, PTSD, work and financial consequences, a year after the RTC [14]. Similarly, it has been reported that two fifths of casualties suffered from anxiety or depression three months post-RTC (especially those suffering from multiple injuries) [99]. Nearly a quarter of casualties had psychiatric problems after one year, and during the first year after the RTC 11% of the subjects satisfied DSM-II-R criteria (Diagnostic and Statistical Manual of Mental Disorders) for post-traumatic stress disorder [99]. A fifth of the casualties suffered from travel anxiety that was disabling which is similar to the findings of a Canadian study that 18% of people had a fear of driving 3-4 years post-RTC [101].

1.3.4 Risk factors associated with psychosocial disorders following a road traffic crash

Female passengers suffers a higher level of phobic travel anxiety than male passengers after a RTC [14].

Motorcyclists are more likely to suffer psychiatric disorders than other casualties, which could be due to more severe injuries and social vulnerability [99].

A previous history of major depression is a risk factor for developing PTSD after an RTC [102]. Seriously injured RTC casualties are twice as likely to experience travel anxiety, PTSD, work and financial consequences, a year after the accident [14]. Casualties with severity score >4 have more financial and physical problems than others and they are more likely to suffer depression [81].

1.4 Validity of road traffic casualty reporting

There is growing evidence that the sources of information on RTC casualties are incomplete and especially police recorded data [103-105]. Police records are the main source of information on RTCs in most countries although it may be misleading to rely only on police data [106-110] especially in terms of non-fatal injuries [111]. A special cause for concern is where police data are used to evaluate severity level of RTCs, as the judgement of severity by a police officer is not necessarily accurate [111-113].

This section begins with a summary of what type of casualties are missed by the police, followed by a review of official recommendations on linking police and hospital RTC records. The section ends with a review of exercises in linking hospital and police records worldwide and in UK.

1.4.1 Characteristics of casualties missed by the police

Severe RTCs in UK are estimated to be underreported by as much as 50% and it has been hypothesised that this has risen over later years [103] as the decrease in STATS19 serious RTC casualties is much steeper than in RTC hospital admissions [110,114].

RTCs in motorcyclists and pedal cyclists are most likely to be unreported by the police, especially where no other vehicles were involved [109,113,115-118]. Underreporting has also been linked to pedestrians [113] and children [113,116], as well as RTC casualties claiming financial compensation and casualties that had been in control of a motor vehicle [109].

Information on severe RTCs is more common than for RTC causing minor injuries [117] although these data are necessary in order to do research on "whiplash" injuries [119], which is a major burden both from an economic and human suffering perspective [72,80].

1.4.2 Recommendations on road traffic casualty linkage

To overcome the problem of incomplete RTC registers, the UK Department for Transport (DfT) recommends that periodic comparisons of STATS19 and hospital inpatient data on road casualties should be carried out. DfT propose that one-to-one matching of STATS19 and hospital inpatient records be performed to try to validate the time trends of more seriously injured casualties reported by STATS19 [120]. Such a linkage is currently in process for England [121].

In the light of evidence that linked databases are less biased than those based on police records alone [108] the European Transport Safety Council (ETSC) recommends linked databases as the basis for injury reporting in order to meet the needs of EU road safety policy support [122]. The ETSC asserts that "information about injuries has to come from hospital records but additional, linked data are needed" and that the objective of these databases is "monitoring of reporting completeness and injury patterns and identifying road safety priorities".

One of the main problems with linking data is sharing different data sources. There are usually legal limitations and other restrictions that need to be overcome [1] apart from data sources often not being synchronised.

Linking data aims to achieve a more complete and comprehensive view to the complex nature of RTCs, but there is also a cost-beneficial aspect of utilising several data sets in road traffic injury prevention; the costs incurred by linking or using several data sets, is far lower than the costs associated with misjudging RTC statistics [110].

1.4.3 Linking hospital and police records of road traffic casualties worldwide

Linkage exercises have been attempted for some time in many countries [117,123-127] including UK [118,121,128,129]. In Australia an iterative procedure including name identifiers was implemented for ten years .[117,127]. In a European project linking hospital and police data (PENDANT), three countries were included using separate methodologies and different information [125]: France utilised a manual method resulting in a small number of records; the Netherlands linked police and hospital data for the whole nation over seven consecutive years (and reported substantial problems with levels of recording of police records [123]); Spain linked police and emergency department records from Barcelona for one year. Sweden has come some way in completing a full national linked police-hospital database, which to date includes two-thirds of the country [124].

1.4.4 Linking hospital and police records of road traffic casualties in UK

In UK, various linkages have been performed including one London based study linking police and emergency department data in three hospitals to estimate the extent of RTC injuries across the city [128]. A further two studies carried out by the Transport Research Laboratory (TRL, [118,130]) used a national sample of 16 and 18 hospitals collecting emergency department and inpatient data that were linked to STATS19 over one and three years respectively. The TRL data linkage did not, however, include the full medical database [123]. In 1994-94, the TRL linked over 8,000 English records from the Trauma Audit and Research Network (TARN) [123,129]. Lastly, the TRL also linked police and hospital data from three hospitals in Manchester 1993 for six months [131].

In Scotland, the TRL performed a substantive linkage of a sample of casualties over 16 years (1980-1995) providing an overview of trends in clinical data including International Classification of Disease (ICD) codes translated to Maximum Abbreviated Injury Scale code (MAIS) for each of the six body regions and length of stay in hospital [132].

The different linkages produced varying linkage rates (% of hospital records that linked to a police record): Australia 64% [117], England 70-87% [128] and 46% [118].

1.5 Costs of road traffic crashes

Although the sequelae of RTCs, in terms of immediate injury impact, have been investigated in great detail [34,70,91], little is known about the long-term health and economic consequences of RTCs, and the financial costs are probably greatly underestimated [133].

Estimating the economic impact of road traffic crashes is important. It aids in comparing the RTC impact with other causes of mortality and morbidity, as well as providing a basis for cost benefit analysis of interventions and promoting understanding of the scale of the problem [1].

The remainder of this section includes a review of where different costs are derived from followed by what cost estimates include and cost by injury and road user.

1.5.1 Types of costs incurred by road traffic crashes

Valuating RTCs economically is usually based on a combination of tangible costs, such as hospital costs (direct cost of injury), long-term care costs, loss of productivity or cost of vehicle damage, and more indirect costs such as an evaluation of human suffering and loss of life. Many of these methods are difficult and controversial. One method is called "willingness-to-pay", which estimates what people would like to pay for avoiding injury or death and another compares lost life with lost earnings and is referred to a the "human capital" method [1].

The UK cost estimates of RTC comprise several elements. The value of preventing a casualty has been estimated by Department for Transport [134] to include the following:

- loss of output due to injury (earnings and employers costs etc).
- ambulance and of hospital treatment costs.
- human costs, based on "willingness to pay" values (representing "pain, grief and suffering to the casualty, relatives and friends, and, for fatal casualties, the intrinsic loss of enjoyment of life over and above the consumption of goods and services").

Additionally, costs for crashes also include:

- costs of damage to vehicles and property.
- costs of police and insurance.

1.5.2 Costs of road traffic crash injuries

Costs of road traffic crashes vary between countries –from as low as 0.3% of Gross National Product (GNP) to over 4%. In high-income countries RTC costs make up a larger proportion of GNP (about 2%) than in low-income countries (about 1%) [3].

Costs associated with RTC injuries are often higher than other types of injury [135] and the highest RTC injury hospital costs are incurred by injuries to the lower extremities (hip/thigh and knee/lower leg) and head injuries. Estimates from Australia suggests these make up 33% and 27% respectively

[136], similar to USA findings [137]. Both of these studies also found that severe spinal cord and brain injuries cost more per case.

Hospitalised pedestrians RTC casualties incur high costs; in a study from New Zeeland they comprised 10% of casualties but incurred 18% of total costs [138].

A linkage exercise completed in Italy (linking hospital and police RTC records) estimates that the costs of RTC casualties make up 1.3% of total hospital costs [126].

1.6 National road safety policy

Several countries set national targets in order to help place road safety higher on the national agendas of priorities. Targets help secure resources and to evaluate progress. The targets should preferably be long-term and easy to measure. Some examples of fatality reduction targets are: Australia -10% (8 years), USA -20% (12 years), European Union -50% (10 years), Finland -37% (10 years), France 50% (5 years) and Sweden 50% (11 years) [1].

In 2000, the UK government set national targets for reducing casualties by 2010. The reduction targets and the achievement in 2006 (in brackets) were as follows (quoted directly from Road Accidents Scotland 2006 [16]):

By 2010 it is hoped that there will be, compared with the average for 1994-98:

- a 40% reduction in the number of people killed or seriously injured in road accidents (30,6%).
- a 50% reduction in the number of children killed or seriously injured (39,0%).
- a 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 million vehicle kilometres (7,2%).

The report, however, acknowledge that there may be problems with the reporting of casualties to the police and therefore STATS19 (police RTC recording) may not be a reliable source to use when estimating RTCs.

1.7 Prevention of road traffic crashes

Preventing RTCs has been an ongoing challenge since the start of the moving vehicles, beginning through legislation in UK: a ban on riding on footpaths in 1835 and a speed limit on self-propelled vehicles of 4mph in the country and 2mph in towns in 1865 [139]. Standardised road signs have been in place since early 1900s and the first automatic traffic lights were installed in the mid 1920s.

This section covers a short review of the three E's of injury prevention (engineering, education and enforcement). This is followed by a section on specific RTC prevention measures including highly successful measures such as road humps and daytime running lights. The section ends with a detailed account of speed cameras, both worldwide and in UK.

1.7.1 The three E's in prevention: Engineering, Education and Enforcement

Today there is an immense collection of preventive measures to choose from, all relating to one or all of the three E's: *Engineering*, *Education* and *Enforcement*, as well as the more time related terms of *primary*, *secondary* and *tertiary* prevention. Primary prevention aims to avoid RTCs (e.g. speed cameras), secondary prevention aims to make RTCs less severe (e.g. seat belts) and tertiary prevention aims to reduce the negative impact from the RTC (e.g. hospital treatments). For example, engineering on primary level includes safer roads (e.g. footpaths) or good visibility in cars, while on secondary level engineering includes seat belts or side impact bars.

1.7.2 Types of road traffic crash prevention

The more successful interventions include seat belt laws (secondary engineering and enforcement prevention) and graduated driving licensing systems (primary educational and enforcement prevention). The seat belt laws enforced in the UK produced a 15% reduction in hospital admissions [140] and graduated driving licensing systems generates a crash reduction of 4-60%, the wide range may, according to WHO, be due to varying methodologies used [1].

The focus of the following sections is on primary enforcement and engineering prevention in traffic calming, as part of the study involves speed cameras. Speed cameras are discussed in section 1.7.3.

1.7.2.1 Red light cameras

In terms of camera enforcement there are fixed speed cameras and red light cameras, as well as moving police patrols with radars. Red light cameras were installed in Glasgow 1991-93 and the RTCs caused by red light running fell by a third including both injury and non-injury RTCs. The study also revealed that other factors must have contributed to the overall decline, since injury RTCs in the 'crossing carelessly' category declined by 54% (44% of the total reduction in injuries) over the same period [141].

1.7.2.2 Moving radar

The effectiveness of 'moving mode radar' speed enforcement over two years was assessed in Victoria, Australia. The project included up to 73 units and also comprised television advertising relevant to the mobile radar enforcement. The study found that there was a four-day residual enforcement effect on casualty crashes in rural areas, but the effect diminished five to seven days afterwards. In the region where the enforcement had been present, there was a 28% reduction of crashes during the first four days. Outer Metropolitan regions, however, showed no reduction in crashes when mobile radar was used [141,142].

Covert (unmarked car) mobile radar speed enforcement has been shown to be more effective in reducing casualty crashes than overt (marked car) enforcement. This was especially true in rural region of Victoria, during the 1 to 4 days after covert mobile radar enforcement had been in place. These circumstances gave a net 22% reduction in casualty crashes. The combination of overt and covert enforcement also gave a reduction, while using overt enforcement only was not as effective [143].

1.7.2.3 Changing speed limits

Victoria, Australia, also made changes to speed zones in order to be in line with the rest of the nation. The rationalisation meant that some speed zones were increased while others were decreased. Certain speed zone alterations resulted in highly significant casualty crash reductions i.e. the change from 100 to 80 km/h reduced casualty crashes by 46% and the decreased speed limit of 75 to 60 km/h resulted in a 43% reduction. Increasing the permitted speed from 75 to 80 km/h resulted in an increase in casualty crash frequency of 10.7% (highly significant) [144]. According to a policy review of speed management by Dft [145] speed limits by themselves have a very small impact on vehicle speeds. Research suggests that reducing speed limits, but not using any other intervention reduce the average speed by only a quarter of the reduction required e.g. only an average of 2.5 mph slower for a change of 40 to 30 mph limit [54].

1.7.2.4 Road engineering

Road humps, chicanes and other road engineering measures reduces speed in urban areas by 10 mph on average and are very effective at reducing child pedestrian casualties. Road engineering is far better in achieving lower speeds and RTC reduction than static signs alone [146].

Vehicle activated signs also appear to reduce speeds and the incidence of collisions [147]. These signs give a message about appropriate speed or an upcoming hazard and activate when an individual car is e.g. driving too fast towards a hazard such as a bend or junction.

Applying an edge-line to a road without a centre line appears to increase speed, while replacing a centreline with an edge-line decrease speed. The effects of adding an edge-line to a road with a centreline were unclear in this study [148].

1.7.2.5 Adaptive speed limiters

Another way of reducing the speed is, according to Dft [147], to employ adaptive speed limiters in vehicles. These are already fitted to heavy goods vehicles, which maximises their speed to 56 or 60 mph depending on how heavy they are. The technique of extending this, to adapt to any given road, already exists, and involves using a digital map in the vehicle and a global positioning system that, by satellites, can identify the location of a vehicle. These systems can either give drivers information about the speed limit, or be used together with an "adaptive speed control system". The benefits of this system could be great, potentially resulting in a 35% reduction in RTCs. This in turn would free police and courts to deal with other crimes [147].

1.7.2.6 Daytime running light

There is evidence that the use of daytime running lights (DRL) in cars and motorcycles might reduce RTCs. According to a European review [149], findings from different studies show that a reduction of 'multi-party' road traffic accident of 5-15% is achieved (car crashes) and that possibly 32% of motorcycle crashes are avoided. This review also included a cost-benefit calculation of how many lives could be saved, and injuries avoided, if DRL was introduced in the 12 EU nations that has not yet implemented mandatory DRL. This calculation is based on the assumptions that DRL reduces 15% of fatalities, 10% of serious injuries and 5% of slight injuries of 'multi-party daytime accidents' (which is estimated to be 40% of the total). This could result in 2,359 fatalities, 17,507 serious injuries and 51,113 slight injuries avoided annually in Europe.

1.7.3 Speed cameras

Several studies evaluating speed cameras have concluded that they contribute to reducing the incidence of RTCs [150-157], fatalities and injuries [158-160] although the evidence so far is relatively weak [161]. No studies, to this author's knowledge, have reported in detail either the epidemiological impact or the type of crashes that are influenced by cameras.

1.7.3.1 Speed cameras in Australia

Australia has had speed cameras for a long time and back in 1989, the Victorian Government announced a new Road Safety Strategy to break the escalating RTC trend [162]. This included the introduction of red light cameras and slant radar speed cameras. The evaluation of this initiative, undertaken by Monash University Accident Research Centre (MUARC), included several factors believed to have contributed to the road trauma reduction i.e. increased random breath testing and speed cameras (both supported by publicity), reduced economic activity, reduced alcohol sales and improved the road system through treatment of RTC blackspots. Results showed that a combination of anti-speeding and drink-driving programs contributed to reductions in serious casualty crashes by an estimated 22-25%. Adding the RTC blackspot treatments to these reductions resulted in an overall decrease, through road safety initiatives, by 23% in 1990, rising to 30% in 1993-1996 [150,151].

These findings were challenged by White et al. Examining the RTC trends and the implementation of speed camera visually suggested that the major increase in speed camera traffic infringement notices did "not occur until at least two years after crash numbers had started to decline" [163]. The criticism was met with MUARC highlighting certain details in their reports. According to Cameron et al, the 'serious casualty crashes' (referred to by White et al) peaked in 1988 and represented only a third of all crashes while the peak in 'casualty crashes' happened in 1989. Additionally Cameron et al state that "It is emphasised that MUARC's research has been confined to assessing factors which contributed to the reductions in road trauma in Victoria during the 1990s. MUARC has not evaluated the factors that may have been responsible for the turnaround in crashes of each level of severity prior to 1990" [164].

1.7.3.2 Speed cameras in New Zealand

New Zealand has used visible mobile speed cameras since 1993. They have been located in specific areas that have had many speed related crashes. In 1997, a trial began using hidden speed cameras in some 100 km/h roads. For the initial year of operation, the covert cameras (together with publicity) were associated with reduced speed, RTCs and casualties both at the camera sites and on other 100 km/h roads, while the overt cameras had a more localised effect [153].

1.7.3.3 Speed cameras in Europe

A Swedish study of speed cameras reported both a reduction in speed and the incidence of RTCs. There were a significant reduction at the black-spot site (to the date of the report), but also on the road as a whole (the total stretch between two cities). There was, however, a suspicion that this intervention would follow a similar pattern as a signpost intervention on the same road stretch, in 1990 (a light-sign stating that this is an 'Accident Blackspot'). The RTC rates dropped dramatically for two years (until 1992), but thereafter returned to the previous rates. As a conclusion, Kronberg et al, believed that there is a tendency for drivers to reduce speed initially while they learn how the speed cameras work/where they are and that the drivers have to be faced with new 'surprises' to keep them unsure about the extent of the surveillance [152].

A recent study in Barcelona found a reduced risk of RTC with rate ratio (RR) 0.73 comparing before and after camera installation [157]. It was estimated that 364 collisions were prevented and 507 fewer people injured during the two year following the camera installation.

A study in Norway of 64 camera sites showed a reduction in injury RTC of 20% and a reduction in 26% on roads which complied with both having a high density and rate of RTC [165] [165].

1.7.3.4 Speed cameras in UK

The first speed cameras in Britain were set up in West London 1992. These cameras were estimated to have reduced the incidence of road fatalities by 70%, seriously injured by 27% and slight injuries by 8% at the camera sites, during the initial three years of operation [158]. In early 1990s, the costs and benefits of traffic light and speed cameras were investigated involving 10 police forces in England and Wales and evaluating 78 red light camera sites and 174 speed camera sites [166]. All but one of the selected areas showed a decrease in RTCs post camera installation. RTCs were on average reduced by 18% for red-light cameras (0.48 RTCs per site per year) and by 28% for speed cameras (1.25 RTCs per site per year). In total, the red-light cameras were estimated to produce a potential reduction of 116 injury RTCs per year and the speed cameras possibly to have prevented 525 injury RTCs per year. The outcome of this project appears to have prepared the ground for the Safety Camera pilot projects (see later).

A study in Wales of mobile speed cameras at 101 sites resulted in a lower than expected frequency of injury crashes at the sites (51% reduction) and surrounding areas (up to 500 meters) and these reductions were sustained for two years after intervention [156].

In Cambridgeshire, a study was set up to develop a method to deal with seasonality and trend in evaluating speed cameras at the same time as it aided in distinguishing between real effects from the cameras and regression to the mean. The study observed a 31% decrease in injury RTC [154]. In a continuation of the same study, it appeared that in the immediate vicinity of the cameras there were RTC reductions of nearly 46% but a lower reduction was found in the surrounding areas [155].

1.7.3.5 New speed camera strategy in UK: Safety cameras

Included in the Government's road safety strategy published in 2000 [167] was a cost-recovery component in safety camera and red light camera enforcement, which allows using money from fines for operational costs, road safety education and research. The UK safety camera pilot scheme began in April 2000 and utilises safety cameras in an attempt to reduce RTC rates in identified RTC black-spots. Camera location is determined by rigorous analysis of both personal injury collisions (PIC) and speeding history on RTC-prone roads. Positioning cameras based on these analyses serves both to avoid accusations that the cameras are used to make revenue and also 'to ensure that the maximum benefits are achieved' [168]. The pilot scheme was regarded as highly successful and was rolled out nationally in 2001-2002.

Safety cameras appear, according to recent research, very effective in reducing PICs in black-spot areas. Results, from the thee year evaluation [160], showed that there were 33% fewer injury collisions and 40% fewer people killed or seriously injured at the camera sites, when controlled for long-term trends. This includes a total of 870 fewer people killed or seriously injured and 4,030 fewer injury collisions.

In Strathclyde, it was reported that vehicle speed declined greatly once cameras were installed. Before the speed camera installation, 64% of vehicles exceeded the speed limit. Three months later, when the camera houses were set up, the proportion of speeding vehicles declined to 37%. This then declined further, to 23%, when the cameras were flashing [169].

1.7.3.6 Safety cameras in Strathclyde region

The national safety camera programme is operated locally by regional Safety Camera Partnerships between police and local authorities. Strathclyde safety camera partnership was one of eight pilot camera schemes established in UK in 2000. It initially only covered Glasgow City but has since expanded to include the local authorities of the whole of West of Scotland i.e. North Lanarkshire, South Lanarkshire, Argyll & Bute, East Dunbartonshire, West Dunbartonshire, Renfrewshire, East Renfrewshire, Inverclyde, East Ayrshire, North Ayrshire, South Ayrshire as well as Glasgow City. The region comprises over two fifths of Scotland's population - about 2.3 million - and suffers from a relatively high rate of social deprivation. Strathclyde region has a diverse combination of rural and urban roads. The area should formally be called Strathclyde Police Force Area, but is here referred to Strathclyde region for simplicity.

The criteria for safety camera installation have altered slightly over the years, but have always involved assessing evidence of the contribution of speeding to RTC rate and severity. The evaluation of the partnerships has involved assessing how they perform in terms of RTC reduction in a number of pilot areas in the UK. Included in the remit of the partnerships was an assessment of the impact of the cameras through research, which is why the collaboration with Glasgow University and National Health Service (NHS) Ayrshire & Arran was initiated in 2002 (leading to the 'context study' of this PhD, see below).

The study 'Health Impact of Safety Cameras' commenced in 2002 and initially aimed to consider the health impact (in its widest sense) of the introduction of camera sites of the pilot project in Glasgow and throughout the (then) Strathclyde partnership area. The study initially included 12 cameras subsequently expanded to include 48 camera sites. The Partnership currently operates 136 cameras (see later).

1.7.3.7 Summary of five speed camera evaluations

Summary of methods used in five speed camera studies are outlined in Table 1.

Table 1 Methods, results and limitations of five speed camera studies

Author	Study design	Results	Limitations / solution
Hess S & Polak JW, UK, 2003	Before and after study including calculating severity weights.	Cameras showed the largest effect (46% decrease of weighted injury RTC) in the immediate vicinity (250 m), but also had significant effect on larger areas.	Long-term means were assessed in order to control for regression to the mean. Seasonality and time trends were also controlled for.
Christien S M et al. UK, 2003	Controlled before and after study of 101 mobile speed camera sites where two methods of assessing effectiveness were evaluated (circular zone around the camera sites and distance from sites).	Injury crashes were reduced with a significant rate ratio of 0.49 and cameras had a sustained effect two years after intervention.	Camera sites were matched with control sites on posted speed limit, road class and RTC. As a controlled before and after study, with well matched intervention and control sites, the sites will (if at all) be equally affected by regression to the mean.
Chen G et al. Canada, 2000	Before and after study of 30 mobile speed cameras over two years.	Daytime RTC reductions: 25% of RTC, 11% injuries (casualties collected by ambulance) and 17% reduction in fatalities.	Controlling for trend, seasonality, and amount of driving, but no assessment of regression to the mean.
Elvik R, Norway, 1997	Controlled before and after study of fixed speed cameras at 64 sites.	20% reduction in injury RTC (26% reduction on roads with both high RTC density and rates).	The empirical Bayesian method was used in controlling for general trends in the number of RTCs and regression to the mean.
Hooke A et al. UK, 1996	Before and after study including 174 camera sites with (usually) 3 years before installation from 9 different police forces.	Overall reduction in RTCs at sites at 28% (ranging 21% to 48% in police areas).	Different collection methods in police forces could affect number of RTCs included. No control for trends or other confounders.

1.8 Summary of Chapter 1

- The time trends in road traffic crash (RTC) incidences in the UK are downward. Globally, however, it is estimated that by 2020 RTC fatalities will increase by 66% (compared to 2000).

- Several factors increase the risk of RTCs and these include being male, young, deprived, under the influence of alcohol and/or smoker. Underlying causes include exposure and risk taking. Aggression, anxiety disorder, a previous traumatic brain injury and Alzheimer's disease are also associated with a higher risk of RTCs.

- Speed influences the risk of RTC in many ways: shorter time available to react, easier to lose control, difficulty for other road users to react in time and longer stopping distance. Speeding may be defined as inappropriate speed (driving too fast for prevailing conditions) or excessive speed (surpassing the speed limit exceedingly). If vehicle speed were reduced, the incidence RTCs would drop (by an estimated 20% if everyone kept within the speed limit).

- Disabling injuries are typically different from life threatening injuries; injuries to legs or neck are most disabling while injuries to the abdomen/pelvis, chest and head are more likely to be fatal. Although hospitalised casualties have longer disability, the majority of disability burden is carried by non-hospitalised casualties. In general, children recover quicker than adults.

- RTCs are the most common cause of severe head injury and may result in a range of problems from severe disability to less obvious effects such as residual cognitive impairment or emotional problems. One of the most common injuries following an RTC is cervical vertebral column (CVC) injury (whiplash). CVC victims may suffer from headache, thoracic and low back pain, fatigue and sleep disturbance and other ill health. CVC may require several years sick-leave and more often affect females than males.

- Long-term effects from RTC injuries include physical impairments as well as unemployment, lower incomes, reduced learning performance, reduced scope for social contacts and difficulties with personal and domestic tasks.

- RTCs may have major psychological impact, even if the physical injury was only minor or if there was no injury at all. Psychological sequelae include posttraumatic stress disorder (PTSD), phobic travel anxiety, general anxiety and depression.

- Severity of injury is correlated with several variables including old age, being female, being an unprotected road user (e.g. pedestrian), personality disorders, non-use of seatbelt and speed. The combination of speed and being relatively unprotected makes motorized two-wheelers especially vulnerable in traffic and carries a heavy burden of the injury total.

- There is growing evidence that the routine statistics (especially police recorded data) on RTC casualties are incomplete. Minor injuries, RTCs with no third party involvement, and two-wheel road users are most likely to be missed by police. A special cause for concern is where police data are used to evaluate the severity level of RTCs, as the judgement of severity by a police officer is not necessarily accurate. A way of overcoming this problem is to link police records with hospital data, which has been done in trials in the UK. Linking records is recommended by a variety of authorities.

- Relatively little is known about the costs of RTCs and there are various ways of estimating these. Valuations are usually based on a combination of tangible costs, such as hospital costs (direct cost of injury), long-term care costs, loss of productivity or cost of vehicle damage, and more indirect costs such as an evaluation of human suffering and loss of life (e.g. the willingness-to-pay method).

- Costs associated with RTC injuries appear more costly than other types of injury, especially those incurred by injuries to the lower extremities and head injuries.

- Setting national targets is a common method in prioritising road safety on national agendas. In 2000, UK government set national targets for reducing casualties by 2010. These included a 40% reduction in all killed or seriously injured (50% for children) and a 10% reduction in the slight casualty rate.

- There are many countermeasures in combating RTC injury. These can be categorised under one or all of the so-called three Es: *Engineering*, *Education* and *Enforcement*, as well as the time related terms of *primary*, *secondary* and *tertiary* prevention. Initiatives include seatbelt use, changing speed limits, road engineering (e.g. road humps), daytime running lights and speed cameras.

- Several studies evaluating speed cameras have concluded that they contribute to reducing the incidence of RTCs, fatalities and injuries although the evidence so far is relatively weak. Australia, New Zealand and UK began installing speed cameras in early 1990's.

- A new speed camera (called safety cameras) initiative was rolled out in UK in 2000 and Strathclyde region was one of the pilot camera schemes. This scheme was aimed at reducing fatal and serious injuries and includes several criteria for installing safety cameras based on the history of serious/fatal injuries and speed on the road. The scheme has shown to be effective with 33% fewer injury collisions and 40% fewer people killed or seriously injured at the camera sites.

CHAPTER 2. AIM AND OBJECTIVES OF THE STUDY

CONTENTS OF CHAPTER 2

2.1 Context of the study

This study was a result of a collaboration between Strathclyde Police, Glasgow University and NHS Ayrshire & Arran. The study included retrospective and prospective analysis of cost and health implications following RTCs that occurred prior to, and after, the establishment of safety cameras. This involved determining economic, individual and social implications of RTCs that occurred at selected camera sites.

2.2 Rationale

Road casualties remain a major public health challenge in all countries. The implementation of evidence based countermeasures is hindered by a lack of high quality research and, in particular, the near impossibility of conducting randomised controlled trials in a highly pollicised sector of public policy. To investigate the epidemiology of RTCs in Strathclyde, and to try to determine the effectiveness of safety cameras in reducing injury incidence and severity, this study exploited the availability of routinely collected road casualty data in both the police force and the NHS in Scotland's most populous region.

2.3 Aim and objectives

The overall aim of the study was:

> To investigate the epidemiology, cost and prevention of RTC injuries in Strathclyde.

The specific objectives of the study were:

1. To establish the overall epidemiology and accuracy of reporting of RTC injuries in the Strathclyde region of Scotland.

2. To determine the epidemiology of RTC injuries and the effectiveness of safety cameras at the camera sites in Strathclyde with special reference to different road users, RTC types and severity, before and after camera installation.

3. To estimate the economic burden of hospital admissions due to RTC injuries in Strathclyde and at the camera sites before and after installation.

2.4 Research questions

1. What is the epidemiology of RTC casualties in Strathclyde region and how reliable are the routine data?

2. What are the epidemiological characteristics of RTCs that are prevented through safety camera enforcement?

3. What hospital admission costs are incurred by different types of injuries and casualties in Strathclyde and at safety camera sites?

2.5 Null hypotheses

1. Police RTC records include all hospitalised road traffic casualties.

2. All types of RTCs are equally preventable through safety camera enforcement.

3. The economic burden of RTC hospital admissions is equal for all injury and casualty characteristics in Strathclyde and before and after camera installation on safety camera sites.

2.6 Summary of chapter 2

- This study was a result of a collaboration between Strathclyde Police, Glasgow University and NHS Ayrshire & Arran.

- Aim: To investigate the epidemiology, cost and prevention of RTC injuries in Strathclyde.

- The study direction was threefold:

    1. Epidemiology and accuracy of reporting of RTC injuries.

    2. Epidemiology of RTC injuries and the effectiveness of safety cameras at the camera sites

    3. Economic burden of hospital admissions in Strathclyde and at safety camera sites.

CHAPTER 3. METHODS

Contents of Chapter 3

3.1 Overview of methodological approach

The study comprised a variety of epidemiological approaches that play a major part in modern traffic injury research. Additionally, the epidemiological findings were supplemented by economic information to enhance the utility of the results. This section includes an overview of the methodology used starting with a brief history on how epidemiological methods have been used in public health and more specifically in road traffic injury research. It also includes an account of the three main strands of epidemiological methods: descriptive, analytical and interventional.

The section ends with a description of the economic evaluation utilised in the study and what study setting and period were incorporated.

3.1.1 Epidemiological methods

Epidemiological methods are often used in public health research. One of the more famous early (even founding) applications of epidemiological methods was in London during the outbreak of cholera in 1854, where Dr. John Snow, through plotting the disease on a map, identified a water pump which (by removing the handle) ended the disease. Epidemiology has traditionally been utilised for infectious and chronic disease and it has only more recently been used for road traffic injury research. By searching PubMed (an electronic search engine for medically published research) using the words “traffic”, “injuries” and “epidemiology” five-yearly a clear pattern emerges (see Figure 1): in 1965 only 7% of articles on “traffic” “injuries” contained “epidemiology”, while in 1985 31% and 2005 39% did.

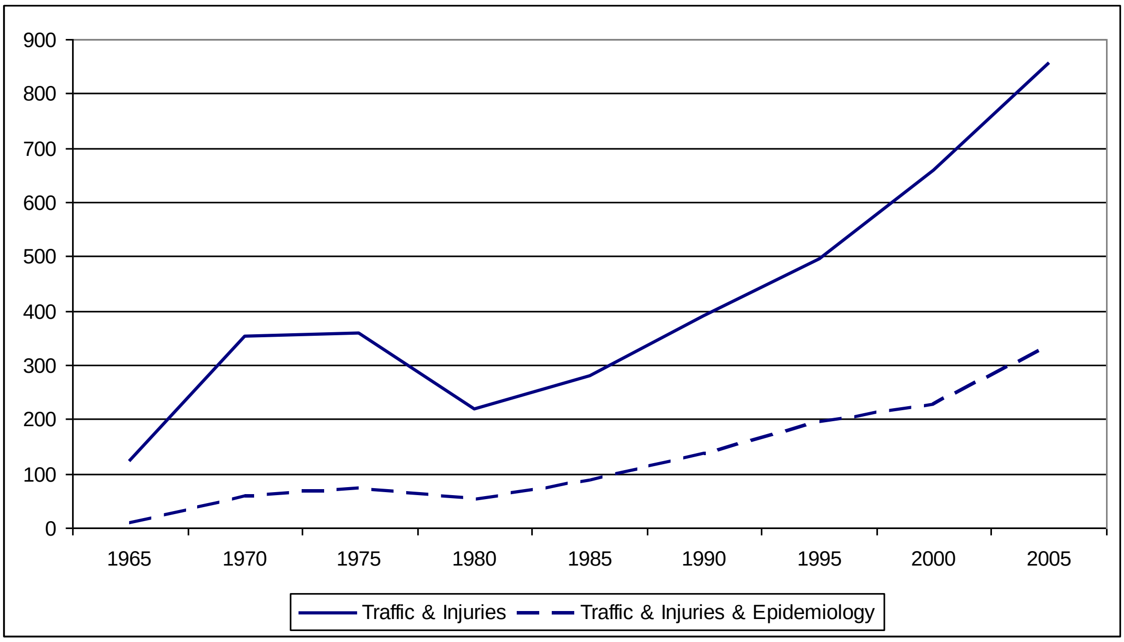


Figure 1 Number of publications on PubMed with search terms: epidemiology, traffic and injuries by year

Epidemiological methods are commonly divided in to three categories, which all, to some extent, has been utilised in this study: descriptive, analytical and interventional.

3.1.1.1 Descriptive epidemiology

Descriptive epidemiology has been used to illustrate the scale of the problem, in this case road traffic injuries and its consequences. The results are most often displayed in tables without statistical tests and include counts and percentages. In this study descriptive analyses have been used to show the distribution of linked and unlinked records, length of stay and in all cost analysis.

3.1.1.2 Analytical epidemiology

Analytical epidemiology in this study included assessing time trends using linear regression and examining associations using chi square tests and logistic regression models. Regr Regression analysis was used several times in assessing time trends including time trends of linked and unlinked records.

Chi square tests were used when comparing the epidemiological characteristics of RTCs in Strathclyde region with the RTC characteristics at the safety camera sites and logistic regression was used when assessing the impact of various factors in whether or not an RTC was recorded by the police.

3.1.1.3 Interventional epidemiology

The gold standard of interventional epidemiology is the randomised controlled trial, but this was impossible in the context of this study for several reasons. Firstly, most of the safety cameras were already installed when the study commenced and, secondly, the safety camera initiative is a nationwide scheme where there would have been extremely difficult to intervene in the methodology. It was therefore decided to use a before and after intervention analysis, hereafter referred to as Pre and Post safety camera installation (Pre and Post SCI). This involved assessing rates and calculating rate ratios of Pre and Post SCI by various factors to determine the epidemiological effect (if any) of the safety cameras.

3.1.2 Economic evaluation

The epidemiological investigation was extended to an economic evaluation and costs were applied to the descriptive epidemiological analysis of injury, length of stay and characteristics of RTC casualties. This enabled the calculation of an economic estimate of savings to an intervention for future cost-benefit analysis. Safety cameras, for example, are relatively costly to install and run though they generate funds through fines.

Additionally, cost estimates may be utilised to help understand where an intervention might have the greatest economic impact. The economic estimates produced in this study represent only a small proportion of the total costs, incurred by RTCs, as only acute hospital costs are included (see information on other costs in section 1.5). These are, however, substantial and will aid in understanding some of the economical impact of RTC casualties.

3.1.3 Study setting and period

The Strathclyde police region of Scotland is a mixed urban-rural region that is home to more than 2.3 million residents (around two-fifths of the population of Scotland). It includes eight police force domains namely Argyll, Bute and West Dunbartonshire, Ayrshire, Glasgow Central and West, Glasgow North East and East Dunbartonshire, Glasgow South and East Renfrewshire, North Lanarkshire, Renfrewshire and Inverclyde, South Lanarkshire. Scotland's largest city, Glasgow, is situated in Strathclyde.

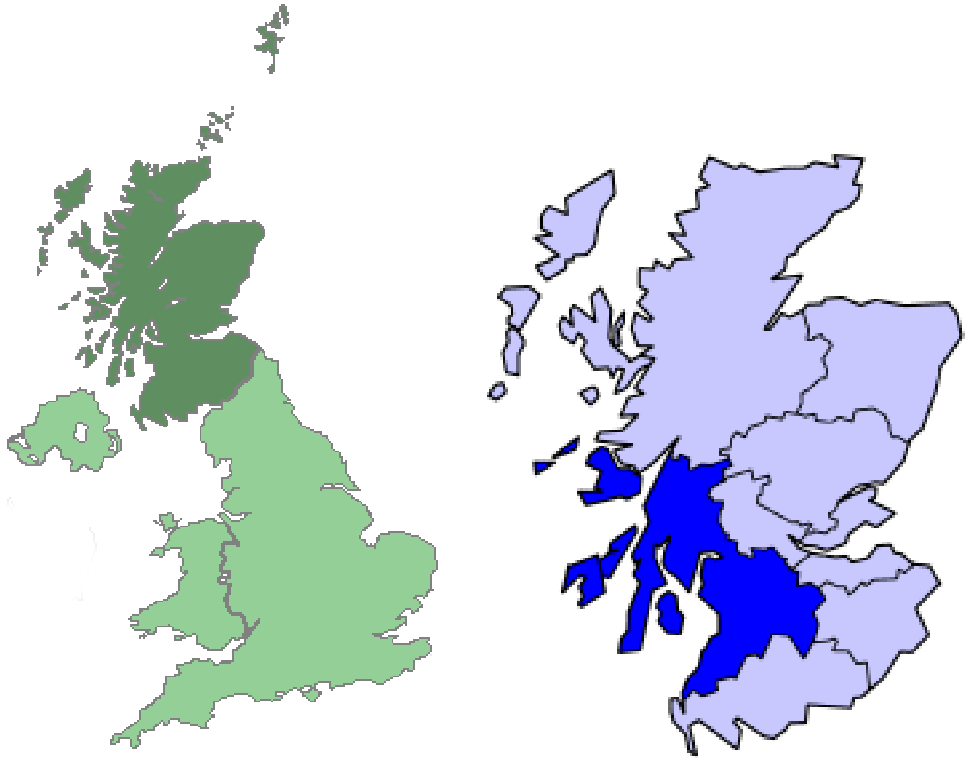


Figure 2 Map of UK to the left with Scotland in a darker shade. Map of Scotland to the right with Strathclyde in a darker shade.

Strathclyde contains concentrations of severe social deprivation, a factor that is correlated with the risk of RTCs (particularly pedestrian casualties) and perhaps also their likelihood of being reported.

The whole recorded RTC population of Strathclyde region was utilised i.e. not just a sample.

The study period included nine years (1997 to 2005) for RTC occurrence and an additional 6 months of hospital admissions. Safety cameras were installed from 2000 to 2004. The study began in autumn 2002 and over the years additional data were made available and consequently the study period was expanded (from 2003 to 2005/6).

3.2 Data sources

The data used for the study came from two main sources namely the police records for PICs (STATS19) and Scottish Morbidity Records (SMR01). These two data sets were linked by Information Statistics Division Scotland (ISD). Additionally, deprivation classification, population estimates, camera site information and cost estimates were utilised. More specifically, the six data sources and their origins utilised in this study were:

- Police records on road traffic crashes: STATS19 (from Strathclyde Police)
- Hospital admissions: Scottish Morbidity Records (SMR01, from ISD)
- Deprivation categories: Scottish Index of Multiple Deprivation (SIMD, from Scottish Executive through ISD)
- Population estimates (from General Registry of Scotland)
- Safety camera site information (from Strathclyde Safety Camera Partnership)
- Cost estimates (from Department of Transport)

All, apart from the cost estimates, were collated and/or retrieved by the author. The cost estimates were obtained and adapted to Scottish inpatient records with the help of a health economist.

STATS19 data, safety camera site information and population estimates were retrieved and updated as time passed (approximately yearly, beginning in 2003). SMR01 data were combined with the STATS19 data in the linkage process by ISD, as were the relevant SIMD data (see section 3.3).

The remainder of this section includes a more detailed account of police road casualty records (STATS19), NHS hospitalisation records (SMR01), Scottish index of multiple deprivation (SIMD) and data supplied by the Strathclyde Safety Camera Partnership.

3.2.1 Police road casualty records: STATS19

The STATS19 recording system is used UK-wide and is used to inform all national statistics on RTCs involving personal injuries. STATS19 was first introduced in 1949 and appeared in its current form in 1979. It is reviewed every 5 years and updated from January 2005.

STATS19 should include all RTCs involving death or personal injury caused by one or more vehicles (if reported to the police within 30 days of occurrence [170]). STATS19 hold information on casualties, RTC circumstances and vehicles.

The RTC circumstances and outcomes are well described in STATS19, which comprises 29 variables on general RTC circumstances, 22 on vehicle (including driver) information and 13 on casualty involvement and outcome. There is one 'general' record for each PIC, while there is one record for each injured person and vehicle involved.

3.2.2 NHS hospitalisation records: Scottish morbidity records 01

SMR data have been collected since 1961 and is one of the worlds first and most complete national health data sets. SMR data are used for both epidemiological monitoring and NHS management purposes. The inpatient record (SMR01, non-obstetric and non-psychiatric) hold one record for every episode of care, including three types of information i.e. patient identification and demographic details, episode management and clinical information[171]. This incorporates the international classification of diseases (ICD, which comprise the external code for identifying RTC victims and injury classification) and length of stay [172].

The study involved all hospitalised traffic related casualty-records from SMR01, for Strathclyde region 1997-2005.

3.2.3 Scottish index of multiple deprivation

Deprivation is virtually synonymous with poverty and comprises a number of dimensions apart from economic. It is a concept that is widely used in public health research.

Road traffic crashes and their sequelae are highly correlated with deprivation and as Strathclyde region is one of the most deprived areas of UK, it is of great importance to include a measure of deprivation in any study of public health in this location.

The Scottish Index for Multiple Deprivation (SIMD) is a relatively new development in Scotland and provides deprivation measure for each electoral ward, which is smaller than for example post code sectors (as used in Carstairs deprivation scores [173]), and it is recommended that SIMD is used for analysis of data back to 1997 [174]. SIMD is based on seven different domains: income, employment, housing, health, education, skills and training and geographic access to services and telecommunications. It provides a rank on data zone level (6,505 in Scotland) for each of the different domains and one overall rank (most deprived = 1, least deprived 6,505) [175]. Using the relative ranks allows for analysing SIMD in deciles or vigintiles i.e. decile 1 includes the 10% most deprived data zones (vigintile 1 = 5% most deprived) and decile 10 the 10% least deprived data zones (vigintile 20 = 5% least deprived) [176].

SIMD (2004) was applied to the linked and unlinked data through transforming full postcodes of casualties and drivers and thereafter applied by ISD in the linkage process.

Population estimates in Strathclyde region were obtained from the General Register Office for Scotland (GROS) for 1997-2005. Population denominators were used in calculating casualty rates per 100,000 population.

3.2.4 Strathclyde Safety Camera Partnership

The Strathclyde Safety Camera Partnership was the main collaborator in the study and provided help on retrieving police data and identification of RTCs on camera sites. For general information on Strathclyde Safety Camera Partnership see section 1.7.3.6.

3.2.4.1 Camera site selection methods

Strathclyde Police have performed various analyses in order to determine the most appropriate roads on which to place safety cameras. There were two different organisations identifying RTC clusters in Strathclyde region i.e. all council road departments and Atkins Consultancy. The councils identify RTC clusters on a biannual basis for their whole region (a requirement under the 1988 Road Traffic Act), using the criteria of 8 injury RTCs per 500 metres in a three-year period to be considered a cluster. This information is then used to assess sites for possible remedial treatment. The councils method concentrates on counts of RTCs and does not distinguish clusters in terms of severity or junction collisions. In cities and towns these clusters tend to be mainly at junctions. Atkins Consultancy performs cluster analysis specifically for the Safety Camera Partnership. This is done using the regulations as set out by the Scottish National Handbook [177] which includes regulations for fixed camera sites. A summary of this follows:

- *Site length:* Between 400-1500 metres
- *Number of fatal and serious collisions (KSI):* At least 4 KSI per km in last three calendar years (not per annum)
- *Number of personal injury collisions (PIC):* At least 8 PIC per km in last three calendar years
- *Causation factors*: Causation factors indicate that speeding was a contributory factor in some or all of the collisions – collision sites that are clearly not speed-related have been de-selected
- *85th percentile speed at (or approach to) collision hot spots*: 85th percentile speed at or above guidelines (10% above speed limit plus 2mph - i.e. 35mph in a 30 zone) for free-flowing traffic (excluding any rush-hour periods)
- *Percentage over the speed limit*: At least 20% of drivers are exceeding the speed limit
- *Site conditions are suitable for the type of enforcement proposed*: Loading and unloading the camera can take place safely
- *Distribution of collisions*: Collisions are clustered close together around a single stretch of road or junction

3.2.4.2 Sites and crashes selected

The Safety Camera Partnership provided data on 47 safety cameras installed between 2000 and 2004, including map coordinates of the cameras and installation dates. Camera sites were defined by Strathclyde Police as a stretch of road surrounding the camera, radiating 500 metres (usually) in each direction from the camera.

Data on the RTCs occurring at the camera sites before and after installation of the safety cameras (Pre and Post SCI) were retrieved in collaboration with the Partnership, Strathclyde Police Information Resources Department and the author using geographical information system software and police RTC casualty reports. An illustration of a safety camera site is shown below.

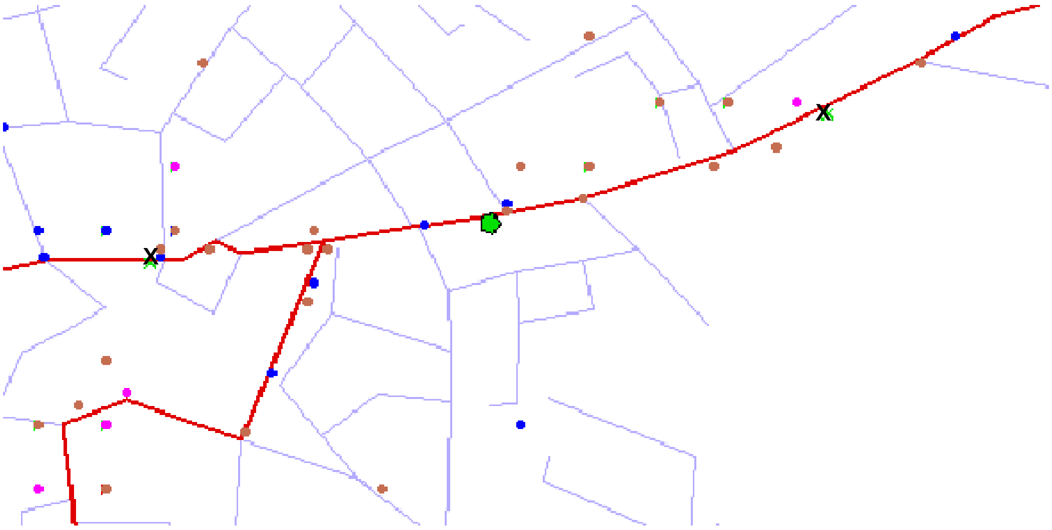


Figure 3 Map from ArcView of safety camera sites
[Pentagon illustrates the camera, Xs the limits of the site and the dots the RTCs.]

3.3 Linkage of police and hospital road traffic casualty records

As discussed previously in section 1.4, the idea of police-NHS record linkage is not new. Linking police RTC records with hospital records is helpful to achieve a more accurate estimate of RTC frequencies and its impact. In this study, linkage enabled estimates of the accuracy of police recording of RTC casualties, assessing the health impact of safety cameras and producing cost estimates.

This section includes an account of how this linkage differed from others. This is followed by information on the perimeters set for linkage i.e. what was included from police and hospital records in the linkage. The section ends with information on how the linkage was performed by ISD. This takes account of the matching standards utilised in linking the data, the results of the linkage and the estimated accuracy of the linked data base.

3.3.1 How this linkage differs from others

The linked data in this study differ from other studies in one, or several, of the following ways:

- All available follow-up hospital admissions (up to 8 years for 1997) were included
- Fatalities arising from RTCs were included (also fatalities occurring long after the RTC).
- The study period in this study was relatively long (9 years).
- Address postcodes were utilised for most of the linking, which should enhance data accuracy.

This aided in assessing the full impact on the NHS of more serious injuries and any temporal changes.

3.3.2 Parameters for linkage

In order to link police and hospital databases, approval was sought both at Strathclyde Police (informal procedure including justification of linkage etc) and ISD (formal application procedure that went through their Privacy Advisory Committee).

Linkage was performed by ISD Scotland in 2006.

3.3.2.1 Police road casualty records: STATS19

STATS19 records from Strathclyde region, including all PICs occurring in the years 1997 to 2005, were retrieved from Strathclyde Police Information Resources. Postcodes, age, gender and date of RTC were supplied to ISD for linkage. Postcodes were more frequent in the latter years of STATS19 records.

The first study year was determined by the need to have at least three years of data available prior the installation of safety cameras. The last year was determined by when the linkage materialised i.e. as much as possible. The end year altered over time as the linkage procedure became delayed.

3.3.2.2 NHS hospitalisation records: SMR01

The selected admissions for this study were those ICD-9 and ICD-10 (international classification of diseases, 9th and 10th revisions respectively) diagnostic codes for RTC injuries (ICD-9: E810-E819; ICD-10: V01 - V82, V87, V89.2). All non-traffic RTC injuries were excluded (as STATS19 does not record non-traffic RTCs, defined by ICD-10 as "any vehicle accident that occurs entirely in any place other than a public highway" [178]).

The SMR01 data were internally linked with all hospital episodes belonging to an individual over time. This allowed episodes constituting a single continuous inpatient stay (including intra- and inter-hospital transfers) or re-admissions to be identified.

Death records with mention of RTC were obtained from General Register Office for Scotland (GROS) and attached to the SMR01 data or directly to a STATS19 record (if death was instant and no hospitalisation was required).

For initial admissions, the hospitalisation data were restricted to hospitals located within or bordering Strathclyde region (to allow for RTC casualties admitted to neighbouring hospital care) namely: Greater Glasgow, Argyll & Clyde, Ayrshire & Arran, Forth Valley, Lanarkshire, Lothian, and Dumfries & Galloway board areas. Subsequent admissions included the whole of Scotland, but not the remainder of UK (as these records are not available to ISD). All casualties were included independent of residence, as it was the location of the RTC that was relevant (i.e. all RTCs within the Strathclyde Police Force area were included).

3.3.3 Data linkage methods and results

STATS19 and SMR01, for Strathclyde region 1997-2005, were linked by ISD Scotland. ISD link databases routinely and were considered the safest option for this procedure.

3.3.3.1 Matching standards

The linkage methods involved matching postcodes, age, gender and date (of RTC and admission) and a default partition (link due to high probability weight utilised by ISD [179,180]). The concept is initially based on a capture-recapture study by Razzak and Luby [181], who used it to estimate TRI (death and injuries) in Pakistan. Anita Morrison, when working in the Paediatric Epidemiology and Community Health (PEACH) unit, has thereafter adapted the method [182] and it was modified slightly further considering the requirements of this study (see standards set in Table 2Table 2. For further information on the (probabilistic) linkage method performed by ISD see appendix V).

3.3.3.2 Linkage results

57% of the linked records utilised postcodes for matching, 36% had postcodes missing but an exact match on age, gender and date, and 7% had a high probability (direct) match (see Table 2). The linkage resulted in over 10,000 police road casualty records that related to approximately 30,000 hospital and death records.

Table 2 Matching standards and linkage results –table provided by Information Statistics Division

	Frequency	Percent	Valid Percent	Cumulative Percent
A : Exact match on age, sex, date & pcode	4057	37.8	37.8	37.8
B : Exact match on age, sex & pcode - date 1 day before	1084	10.1	10.1	47.8
C : Exact match on sex, date & pcode - age within 2 yrs	438	4.1	4.1	51.9
D : Exact match on sex & pcode - age<=2 yrs, date=1 day out	134	1.2	1.2	53.2
E : Exact match on age, sex & date - pcode near exact	405	3.8	3.8	56.9
F : Exact match on age, sex, & date - pcode missing	3855	35.9	35.9	92.8
G : Default partition - link due to high probability weight	772	7.2	7.2	100.0
Total	10745	100.0	100.0	

3.3.3.3 Estimated accuracy of linkage

Historically, the Scottish Medical Record Linkage system has been shown to have 3% false positive and 3% false negative rates [183], but due to the limited identifying information available, this RTC linkage may not have achieved as high accuracy. As names or unique common person identifiers were not available, it was, according to ISD, impossible to estimate the true positive and false negative linkage rates with any degree of accuracy. However, ISD performed rigorous clerical checking of a large sample of best matching pairs at a wide range of probability weights. Depending on whether a postcode was available or not different probability thresholds were set.

A crude estimate of the false negative rate was 2.6% - i.e. 2.6% (1,802) of the unlinked STATS19 records were missed links (i.e. should have been linked). A crude estimate of the false positive rate (see appendix V for an explanation of how this was calculated) was 15.6% - i.e. 15.6% (1,607) of the linked STATS19 records were false positives (i.e. should not have been linked). As a result, the number of missed linked records was nearly the same as the number of incorrectly linked records i.e. resulting in a correct number of records. This does not, however, avoid possible misclassification bias when characteristics of linked data are considered.

3.4 Characteristics of the linked police-hospital data base

STATS19 and SMR01 contribute different information and this section describes which variables from STATS19 and SMR01 were utilised in the linked and unlinked databases. Additionally, a description of an analysis that was required in selecting what follow-up admissions were related to the RTC is included here, together with the results of this analysis. The section ends with information on the statistical power of the study.

3.4.1 Police road casualty data: STATS19

Police RTC records comprise three different areas: casualty information, vehicle information and information about the RTC circumstances. In this study the main information used came from the casualty and context records. For a data guide of STATS19 see appendix ii.

3.4.1.1 Casualty demographics

Casualty demographics included age, gender and postcode. Postcodes were used to retrieve the Scottish Index of Multiple Deprivation (SIMD).

Age was divided in to subcategories of 0-14, 15-24, 25-34, 35-44, 45-54, 55-64 and 65+, which appears to be common and sensible categories often utilised in injury analysis. SIMD is described in detail in section 3.2.3.

3.4.1.2 Casualty severity

Severity of injury is defined by a police officer as being fatal, serious or slight [184]:

> The definition of a fatal injury is where the death occurred within 30 days of RTC.

Serious injury includes fracture, internal injury, severe cuts, crushing, burns (excluding friction burns), concussion, severe general shock requiring hospital treatment, detention in hospital as an in-patient, either immediately or later and injuries to casualties who die 30 or more days after the RTC (from injuries sustained in that RTC).

Slight injury includes sprains, whiplash injury (not necessarily requiring medical treatment), bruises, slight cuts, slight shock requiring roadside attention, persons who are merely shaken and who have no other injury should not be included unless they receive or appear to need medical treatment. Although not all fatal or serious injuries recorded by the police will require hospital admissions, all hospital admissions should (by definition) be recorded as either fatal or serious casualties on STATS19.

3.4.1.3 Crash characteristics

Vehicle type in combination with casualty class (driver/rider, passenger and pedestrian) determined what type of road user the casualties were. Road users were grouped as pedestrians, pedal cyclists, moped or motorcyclists, car occupant or occupant of other vehicle. Drivers/passengers were also analysed in some instances.

RTC circumstances included information on whether or not it was a junction related RTC (within 20 metres of a junction) and if the RTC occurred in daylight or darkness. Numbers of casualties and number vehicles involved in the RTC were also retrieved (both grouped in to one, two and three or more). Time of RTC was defined by years (1997-2005) and in analysis of safety cameras this was further divided in to pre or Post SCI.

RTC map coordinates were utilised when retrieving collisions occurring on camera sites.

3.4.2 NHS hospital discharge data: SMR01

The SMR01 variables most important in this study were the injury definitions and length of hospital stay. These were analysed and aggregated to a form to suit the amount of data and analyses performed. For a data guide of SMR01 and GROS see appendix iii and for information on selected ICD codes see appendix iv.

3.4.2.1 Injury definitions

Injuries were identified from the top level of the ICD external causes of injury as: Injuries to the abdomen, lower back or lumbar spine; ankle and foot; elbow and forearm; head; hip and thigh; knee and lower leg; neck; shoulder and upper arm; thorax; wrist and hand. A single injury could therefore conceal several sub-diagnoses within the same heading e.g. head injury. Multiple injuries were excluded in analysis of specific injuries as it would be difficult to determine which injury was the main source of length of stay.

3.4.2.2 Length of hospital stay

Determining length of hospital stay (LoS) was a rather complex procedure (and was accomplished after receiving the linked data set as described in section 3.3.3), as all follow-up admissions available within the full time period were included in the SMR01 data supplied by ISD. The key processes involved in selecting the follow-up admissions (FUA) relevant to the RTC were as follows:

i. All admissions that were deemed transfers were aggregated (<2 days between visits) with the previous admissions and LoS were summed (15% of SMR01 records including FUA records). *Rationale and method*: These were probably not separate hospital episodes, but transfers between wards. These were included with previous admission (excluding the information on diagnosis, but adding on LoS). Death records were included as separate records whether or not they were adjacent to a hospital admission in time.

ii. All first admissions were included (first admissions were those SMR or GROS records that were directly linked to the STATS19 records through ISDs linkage process based on date, postcodes etc.) (36% of SMR01 records including FUA records). *Rationale and method*: These were the admissions that ISD had considered as appropriate to link to the casualty information and no further judgement was made on these.

iii. All follow-up admissions (FUA) with a different external causal diagnosis were excluded (12% of FUA records i.e. excluding 1st admissions). *Rationale and method*: Other external causes, such as assault or poisoning, are unlikely to be related to a RTC

iv. All FUAs with a diagnosis deemed related to the initial injury were included. (28% of FUA records). *Rationale and method*: This was determined by statistical analysis where P values were calculated using chi squared tests; criteria for inclusion for further analysis were that no more than 1 cell could have an expected count of <5 and a significant p value of <0.2. A total of 41 follow-up diagnoses (FUD) were considered significantly related to one or more injuries. The specific injury that was related to a FUD was identified by analysing the proportions of those in relation to all injury categories and the FUD that had more than 30% over the expected proportion of FUD were considered statistically related (e.g. the follow-up diagnosis "cerebrovascular diseases had a p value of 0.09 (i.e. statistically related to one or more of the 1st diagnoses) and casualties with injuries to the thorax, 13% of total casualties, had 21% of this diagnosis i.e. 62% over the expected rate). See table of chi square statistics in appendix VI.

v. FUAs within 6 months of a previously included FUA (i.e. an admission linked to the first admission in some way) were included (19% of FUA records). *Rationale and* *method*: Since hospital admissions are not everyday occurrences for the large majority of the population, together with the assumption that it is unlikely that two (or more) unrelated admissions would be closer in time than 6 months, the decision was made that admissions close in time (to an RTC related admission) were more likely, than not, to be as a consequence of the RTC. Admissions of patients that had been put on waiting list within 182 days of previous admission were also included, while admissions put on waiting list before RTC were excluded.

vi. The remaining FUAs were excluded (41% of SMR01 records). *Rationale and method*: This was a large number of FUAs and many of these may have been false negatives (as in missed links).

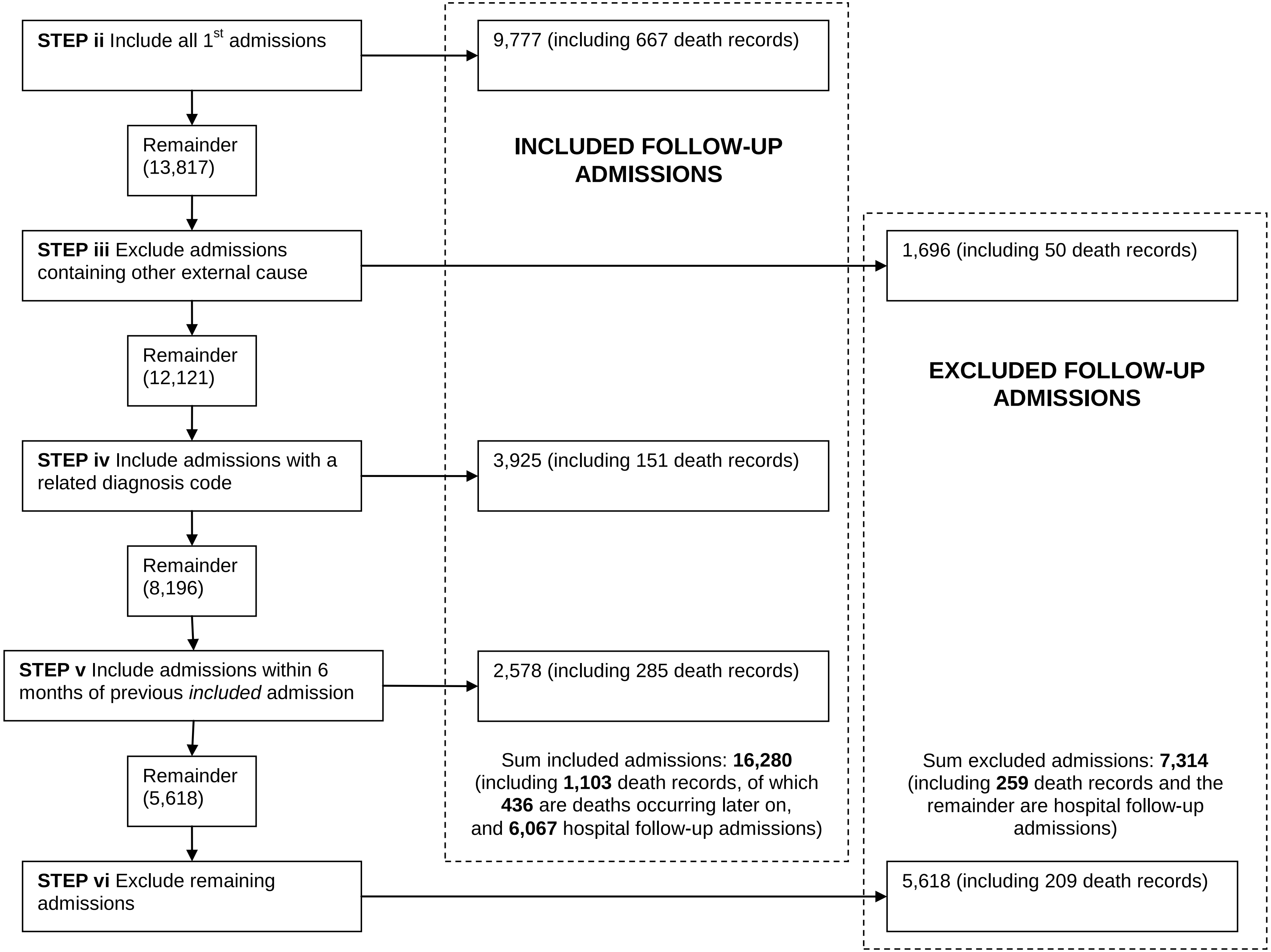
The initial number of all records was 30,080, but this were before aggregating transfers and excluding 2005 RTCs. Subsequently, there were a total of 23,594 records left of which 13,817 were FUAs. 7,314 of FUAs were excluded (53%). The final number of casualties was 9,777 (of 10,737) and the final number of records (SMR and GROS) was 16,280, of which 6,067 (37%) were FUAs. The table below shows the final distribution of records according to the selection methods utilised and Figure 4 shows a flow-chart of the process step by step.

Table 3 Distribution of records by selection criteria and steps

				Selection											
				Excluded				Included							
				Other external factor				Other external factor							
				No		Yes		No				Yes			
				1st record		1st record		1st record				1st record			
				No		No		No		Yes		No	Yes		
				Other	Death	Other	Death	Other	Death	Other	Death	Death	Other	Death	Total
Related factor	No	Within 6 m of previous adm	No	3339	72	589	16			9060	665		50	2	13793
			Yes	2070	137	422	16	2293	282			3			5223
	Yes	Within 6 m of previous adm	No			393	5	1545	22						1965
			Yes			242	13	2229	125			4			2613
Total				5409	209	1646	50	6067	429	9060	665	7	50	2	

A further selection, limiting time of FUA inclusion to 1.5 years after RTC, was used in order to provide equal exposure time for FUAs for all casualties. All FUAs, as included in the above selection were used in some analysis (see further details in section 3.5 including the specific methods used for analyses).

Figure 4 Flow chart of the selection process of follow-up admissions stemming from road traffic crashes between 1997 and 2004 (next page), excluding step i, which was aggregating transfers.


STEP ii Include all 1st admissions
9,777 (including 667 death records)
Remainder (13,817)
INCLUDED FOLLOW-UP ADMISSIONS
STEP iii Exclude admissions containing other external cause
1,696 (including 50 death records)
Remainder (12,121)
EXCLUDED FOLLOW-UP ADMISSIONS
STEP iv Include admissions with a related diagnosis code
3,925 (including 151 death records)
Remainder (8,196)
STEP v Include admissions within 6 months of previous included admission
2,578 (including 285 death records)
Remainder (5,618)
Sum included admissions: 16,280 (including 1,103 death records, of which 436 are deaths occurring later on, and 6,067 hospital follow-up admissions)
Sum excluded admissions: 7,314 (including 259 death records and the remainder are hospital follow-up admissions)
STEP vi Exclude remaining admissions
5,618 (including 209 death records)

Each casualty was analysed as one record where only the aggregated LoS of all selected FUAs were included. Different variables were added for different time limits i.e. FUAs within 6 months, 1.5 years and the full available period. For example, a casualty may have had 15 days LoS within the first 6 months of RTC, another 4 in the 1.5 years to come (19 days LoS at 1.5 year) and an additionally 2 in the remaining time period (= 21 days for the full period, which depends on when the RTC occurred).

In order to include day surgery in calculation of LoS these were counted as 0.5 days.

"Length of stay" analysis is very complex due to the highly skewed distribution of such data (not symmetrical and with a long tail to the right, see figure). This distribution is very unlike the *normal* distribution (bell-shaped symmetrical) which is required for most statistical tests. Attempts were made to transform the LoS data in this analysis in order to achieve a normal distribution using both the natural logarithm (LN) and square root. The distribution before and after (LN) transformation is shown in Figure 5 and Figure 6 and the conclusion is that the transformation did not work i.e. the Kolmogorov-Smirnov test showed a sign. value of less than 0.05 = not a normal distribution (see Table 4). Tests of means with 95% confidence intervals were therefore not made on this data.

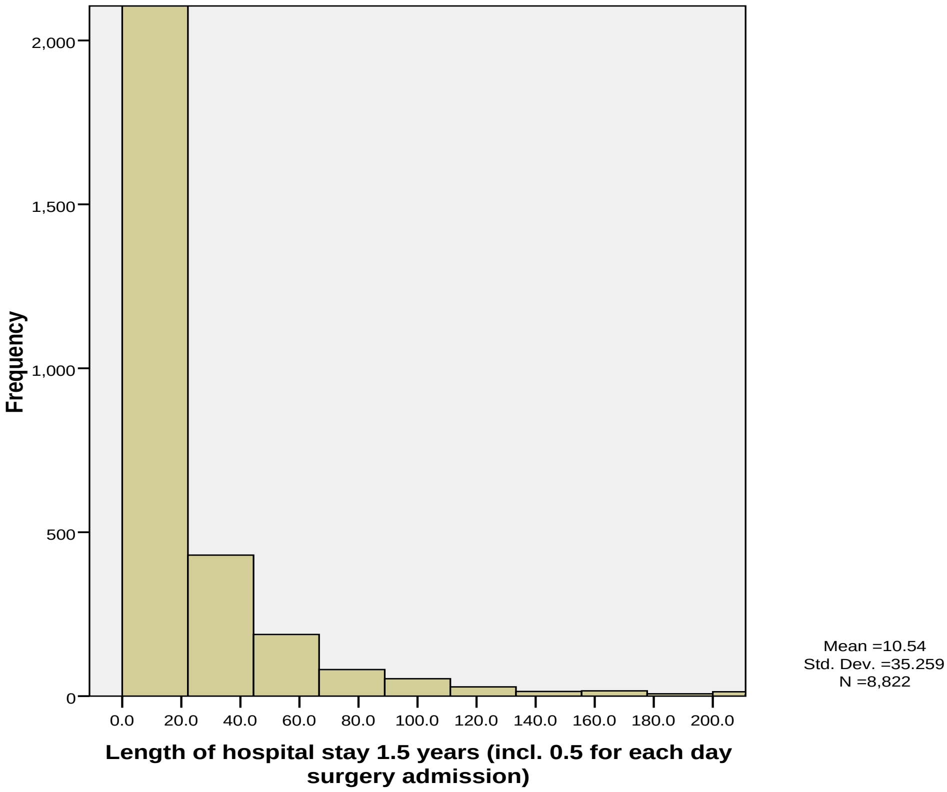


Figure 5 Histogram of aggregated length of hospital stay for the selected admissions limited to 1,5 years (the y-axis should have been 8,000 and x-axis 1,200 in order to display all cases, but this would not have illustrated the skewness so well).

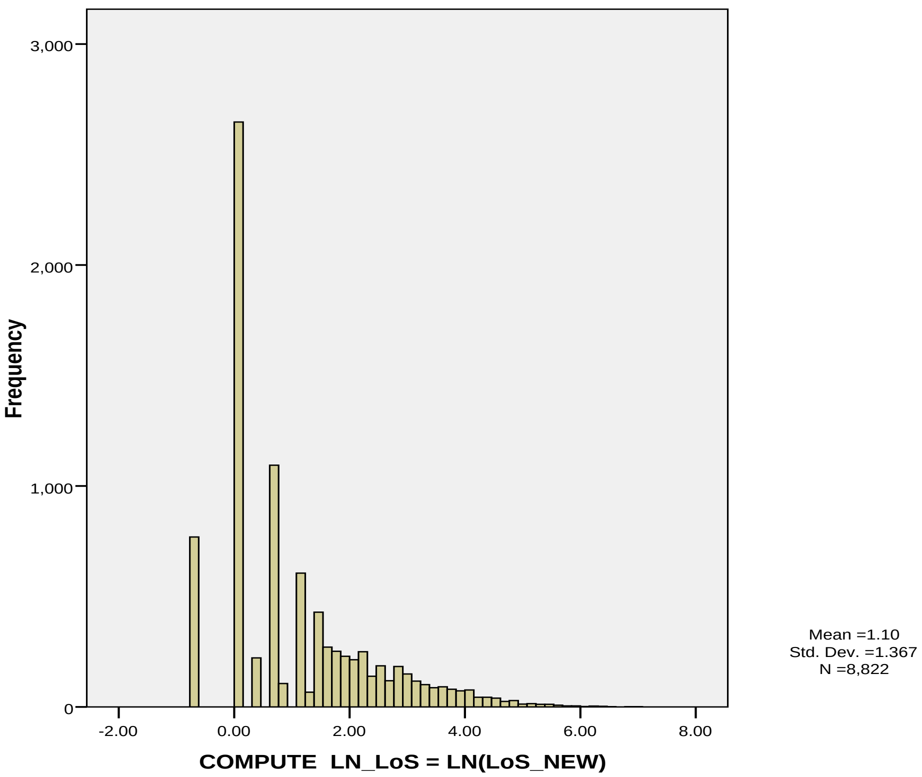


Figure 6 This is LoS (as in figure 5 above) transformed using the natural logarithm

Table 4 Tests of Normality of log transformed LoS values

	Kolmogorov-Smirnov(a)		
	Statistic	df	Sig.
COMPUTE LN_LoS = LN(LoS_NEW)	.176	8822	.000

a Lilliefors Significance Correction

3.4.3 Unlinked SMR01 and STATS19

The SMR01 records with ICD diagnostic codes for RTC injuries (ICD-9: E810-E819; ICD-10: V01 - V82, V87, V89.2) that did not link to a STATS19 record were also made available (about 9,000 casualties). The unlinked SMR01 data excluded all non-traffic RTC injuries (as STATS19 does not record non-traffic RTCs, defined by ICD-10 as "any vehicle accident that occurs entirely in any place other than a public highway" [178]). Non-traffic SMR01 records made up about 28% of the total unlinked SMR01 RTC casualties at the start of the process. The unlinked SMR01 records were not internally linked i.e. they did not hold the follow-up admissions. This data set was only utilised in the analysis of accuracy of police recording.

All STATS19 casualty records that did not link to a hospital admission were also made available (70,000 casualties). All casualty data sources by survivors and fatalities are detailed in Table 5 below.

Table 5 Number of casualties in each data set

	Unlinked		*Linked*		Unlinked	
			SMR01			
	STATS19					
	Slight casualties	KSI casualties	*Slight casualties*	*KSI casualties*		Total
Survivors	63,059	6,391	3,473	6,325	8701	87,949
Fatal in both GROS and STATS19				884		884
Fatal in GROS only			39	7		46
Fatal in STATS19 only		78		9		87
Total	63,059	6,469	3,512	7,225	8,701	88,966
Additional GROS fatal records (fatalities occurring later than 30 days post RTC)						
Fatal records 1 - 6 months			29	44		73
Fatal records 6 m - full time period			48	147		195

3.4.4 Statistical power

As highlighted before, this study included the whole recorded RTC population of Strathclyde region i.e. not just a sample. This proved to have sufficient statistical power to detect before-and-after differences at camera sites as well as statistically significant associations of other epidemiological analyses (see result sections 4.1and 4.2).

3.5 Analyses

Analyses in this study were mainly epidemiological and, as stated in the section of aims and objectives, the intention was to work in three parallel and connected directions, namely: general epidemiology (incorporating the important methodological issue of data validity), the effect of safety cameras and the economic impact of RTCs (applied to the general epidemiology and safety camera assessment). This section considers these three strands of research separately, as each part of the study included some specific methods (although many methods overlapped or were the same). Additionally, the cost methods are here divided in two as the general costs in Strathclyde region is based on all casualty costs, while the analysis of safety camera sites calculates the most expensive casualty of an RTC.

3.5.1 Epidemiology of road traffic crashes, injuries and accuracy of police recording

The methods discussed here relates to the first objective:

> To establish the overall epidemiology and evaluate accuracy of reporting road traffic casualties in Strathclyde region

And research question:

> What is the epidemiology of RTC casualties in Strathclyde region and how reliable are the routine data?

3.5.1.1 Records used

Linking hospital and police RTC records produced three groups of records: linked hospital/police records, unlinked hospital records and unlinked police records. These three data sets were all utilised when assessing time trends and general epidemiology. The analysis tested whether there was a difference in linked/unlinked records and if patterns of recording changed over time.

3.5.1.2 Study period

The study period was 1997-2005 inclusive. As the definitions for the road user categories in the STATS19 data changed slightly in 2005, the time period was restricted to 1997-2004 in the analysis of road users.

3.5.1.3 Severity categories in STATS19 and SMR01

One of the main variables of interest in the analysis was the measurement of severity as utilised by the police to describe the seriousness of the injury suffered by a casualty. In recording an injury the police officer selects a severity grading from three levels: fatal, seriously injured, and slightly injured [184]. Details of these can be found in section 3.4.1.2, but to reiterate: "fatal" means a casualty dying within 30 days of a RTC, "serious injury" means a casualty requiring hospital treatment (but not always admission) and "slight injury" means includes sprains and whiplash injuries.

Fatalities were also determined by using the linked data –in particular the follow-up admissions. In this analysis, this involved using a cut-off point for fatalities at 1.5 years post RTC instead of the police fatality definition (casualty dying within 30 days of RTC). For information on how follow-up admissions were deemed related to the RTC, see section 3.4.2.2.

The police fatality definition was used when assessing linked and unlinked data, while the longer time period was used in assessing injury severity by RTC determinants (age, gender and SIMD etc).

3.5.1.4 Linked and unlinked categories

For the purpose of this analysis, the data were grouped into three categories: casualties with only STATS19 records, casualties with only SMR01 records, and casualties with both SMR01 and STATS19 records (linked data). Subgroups of linked and unlinked police coded severe and slight casualties were also assessed. Comparing the number of identified road casualties in SMR01, which were also recorded ("linked") in STATS19 records with those that were not ("unlinked") indicates the extent of underreporting of hospitalised road casualties in the police data.

3.5.1.5 Assessing time trends

Casualty reductions over time were assessed by comparing the first three years with the middle and last three years. Three yearly groups were used to iron out any random fluctuations in the data, especially where fatalities were included. Population based three year groups were calculated and the percentage changes between the first and last group are shown. Time trends were also assessed with a trend gradient and p values derived from linear regression (using all years separately). Tables showing all years (counts and percentages) were also constructed.

3.5.1.6 Tests of association with epidemiological characteristics

Pearson's chi-squared statistic was used to test for association of which factors influenced whether or not a RTC hospital admission was recorded by the police (linked and unlinked SMR01). The following variables were tested: age (0-14, 15-24, 25-34, 35-44, 45-54, 55-64 and 65+), gender of casualty, road user (car user, pedal cyclist, pedestrian, moped/motorcycle rider and other vehicle), length of stay in hospital (day case, 1, 2-3, 4-7, and >7 nights stay), third party involvement, Scottish Index of Multiple Deprivation (SIMD), year, month and day of week of crash.

Using binary logistic regression, univariable odds ratios and 95% confidence intervals were calculated for each variable of interest. To assess the interrelationship between the variables, multivariable binary logistic regression analysis was performed, which produced adjusted odds ratios and confidence intervals.

3.5.1.7 Length of hospital stay analysis

As a further validation of the severity reporting in STATS19, an analysis of the type of injury in relation to police severity coding and length of stay (LoS) in hospital (including admissions from the first 6 months after the RTC) was performed to determine whether there were any time trends in LoS in relation to severity codes. Selection methods for follow-up admissions are detailed in section 3.4.2.2. This analysis is, to date, only descriptive and tests may be performed in the future. The length of stay analysis includes LoS means and casualty proportions by (nonfatal) single injury and police severity .in three year groups. Injuries were grouped as follows: Injuries to the abdomen, lower back or lumbar spine; ankle and foot; elbow and forearm; head; hip and thigh; knee and lower leg; neck; shoulder and upper arm; thorax; wrist and hand.

3.5.2 Epidemiological impact of safety cameras

The methods discussed here relates to the second objective:

> To determine the epidemiology and effectiveness at the safety camera sites with special reference to different road users, RTC types and severity, before and after installation for the years 1997 to 2005;

And research question:

> What are the epidemiological characteristics of RTCs that are prevented through safety camera enforcement?

3.5.2.1 Records used in safety camera (STATS19) evaluation

Only STATS19 records were utilised as no SMR01 records were available at this stage (this evaluation was made before the linked data was completed, see further in the section in study weaknesses about difficulties in retrieving the data 5.3.2.2).

3.5.2.2 Study period in safety camera (STATS19) evaluation

The analysis utilises police casualty records (STATS19) for nine years (1997-2005).

The study period was also divided into before and after safety camera installation (Pre SCI and Post SCI), further details in section 3.5.2.6.

3.5.2.3 Safety cameras included in study

In this analysis all 47 speed camera sites installed between 2000 and 2004 (44 of which were fixed and three mobile, as described in 3.2.4) were included in nearly all analysis. The exception was when assessing camera effectiveness over time. In this analysis, the earliest installed cameras (12 sites), were excluded as these sites did not have as stringent installation criteria as the latter ones. Including cameras with less potential of effectiveness would distort the results over time as they would make up a substantial proportion of the 2nd and 3rd year results.

RTCs at camera sites were identified using geographical information system software. A camera site was defined as a stretch of road (usually) 500 metres before a speed camera to 500 metres after a camera. The RTCs were selected within this range.

The types of RTCs were categorised using the information recorded in STATS19, which included whether or not a RTC was junction related, the number of vehicles involved in the RTC, whether there was pedestrian involvement, the environmental conditions during the crash, casualty severity (defined by the police as fatal, serious or slight [184]), and the number of casualties per RTC.

3.5.2.4 Assessing time trends in safety camera (STATS19) evaluation

Statistical significance was assessed by chi square tests (including the Mantel-Haenszel test for linear association) and whether or not there was overlap of the 95% confidence intervals of the rate ratios. Time trends were also assessed using linear regression.

3.5.2.5 Test of epidemiological characteristics in safety camera (STATS19) evaluation

To determine whether the epidemiological characteristics of RTCs at camera sites and in the rest of Strathclyde were comparable before cameras were installed, chi square tests were performed on some key variables describing the characteristics of the RTCs and crash circumstances.

Nine variables were tested comparing the "before" (Pre SCI) characteristics of RTC with the remainder of Strathclyde: whether crashes were junction related, number of casualties per RTC, severity of RTC according to STATS19, number of vehicles involved in RTC, type of weather/road surface/light conditions/day of week when RTC occurred, pedestrian RTC vs. vehicle only RTC.

3.5.2.6 Pre and post camera installation

The data were analysed both in relation to the camera sites themselves and in comparison with the remainder of Strathclyde. Before safety camera installation (Pre SCI) and after (Post SCI) daily RTC rates were calculated. 'Pre SCI days' were all days available for analysis in the nine years before camera installation for each camera, and 'Post SCI days' were the number of available days after camera installation. The number of days Pre SCI and Post SCI varied for every camera, as installation dates differed, but the total number of days was always nine years.

<u>RTC rates</u> Pre and Post SCI were calculated as follows:

Daily rate = N of RTCs / N of days

<u>Rate ratios</u> = "after" RTC rate / "before" RTC rate

<u>Standard Error</u> (SE):

SE log (rate ratio) = $\sqrt{(1/d1+1/d2)}$

where d1 is N RTC exposed and d2 N RTC unexposed

<u>Error factor</u> (EF):

exp {1.96 * SE log (rate ratio)}

<u>95% confidence intervals</u>:

rate ratio / EF to rate ratio * EF

3.5.3 Cost of road traffic crashes in Strathclyde region

The methods discussed here relates to the first part of the third objective:

> To estimate the economic burden of RTC hospital admissions in Strathclyde (and at the "safety camera" sites before and after installation)

And research question:

> What hospital admission costs are incurred by different types of injuries and casualties in Strathclyde (and at safety camera sites)?

3.5.3.1 Records used in RTC cost in Strathclyde region

Only the linked dataset was included in cost part of the study. This was for two reasons. Firstly, unlinked STATS19 had no hospital admissions available to attach costs to and, secondly, the unlinked SMR01 records had no follow-up admissions available (and could therefore not provide full information on costs).

3.5.3.2 Study period for RTC cost in Strathclyde region

The study period of RTC casualties was 1997 to 2004 inclusive and 1997 to July 2006, for hospital admissions. This permitted the inclusion of a maximum of 1.5 years of hospital admissions for all casualties subsequent to the RTC. Hospital episodes relating to a casualty, with the first admission in the end of 2004, could include all admissions up until July 2006, while a first admission at the start of 2000 could include follow-up admissions until mid 2001. Thus allowing for a relatively extensive follow-up time as well as including most casualties available over eight years.

3.5.3.3 Follow-up admissions in RTC cost in Strathclyde region

Follow-up admissions (FUAs) were selected utilising a method consisting of both the likelihood of a specific follow-up diagnosis occurring, in relation to the initial injury, and how close in time the follow-up admission happened (both in terms of time since RTC and time since last included FUA) (see further section 3.4.2.2).

Two time frames for FUA inclusion were employed:

- The full period of available FUAs. This was only utilised when looking at specific RTC years, as there was more available time for FUAs relating to RTCs that occurred earlier (e.g. 1998) than later (e.g. 2004).

- FUAs 1.5 years following the RTC. This allowed us to utilise all RTCs occurring between 1997 and 2004 as the available FUA records stretched to July 2006 inclusive. This time frame was the most used in the analysis as it allowed for a relatively large time-frame and the inclusion of nearly all available RTCs.

3.5.3.4 Weighted mean costs

Costs were calculated by specialty per day of length of stay. The costs used were weighted mean costs generated from each health board area's mean total gross cost, weighted by the proportion of discharges in each health board during that year. Costs obtained from ISD's Cost Book from the year 2005/06 [185], which includes around 90% of the NHS net operating costs, giving information on the boards that provide hospital and community care directly to patients. This part of the analysis was performed by health economist Kirstin Dickson at NHS Ayrshire & Arran. All weighted mean costs by speciality are detailed in a table in appendix i.

Total of costs were the sum costs of hospital admissions (initial plus follow-up admissions with specific time frames being detailed in tables). Costs were applied for *each hospital day* by speciality and whether it was an inpatient stay or a day case. E.g. if a casualty had related admissions (see section 3.4.2.2 for selection methods of follow-up admissions) of 4 inpatient days and one day as a day case in orthopaedic surgery (£599.67 and £936.29 per day respectively) plus two days in general surgery (£510.11 per day) the total cost would be: £599.67*4 + £936.29*1 + £510.11*2 = £4355.21. This sum of cost from all selected LoS were utilised in analysing mean costs by top level injury and other epidemiological variables (see next section).

Mean costs were calculated including only the casualties that had an admission e.g. total cost of inpatient admissions / number of casualties with an inpatient admission, or total cost of head injury diagnosis / number of casualties with this diagnosis.

Costs were specified in pounds sterling (£).

3.5.3.5 Costs by epidemiological variables

Costs were analysed by the following variables: injury type, road user and vehicle type, Scottish Index of Multiple Deprivation (SIMD) of place of residence, age of casualty and over time.

Injuries were analysed by top level of ICD-diagnosis codes (injuries to the head, knee and lower leg etc.) A single injury could therefore conceal several sub-diagnoses within the same heading e.g. "head injury" includes "injury of cranial nerves" as well as "injury of eye and orbit" etc. Multiple injuries were excluded in the cost analysis as it would be difficult to determine which injury was the main source of the cost.

Road users were defined as driver/rider, passenger (vehicle or pillion passenger) and pedestrian and vehicle type included car, motorcycle or moped, pedal cycle, goods vehicle, other vehicle and bus or minibus. Age groups were: 0-14, 15-24, 25-34, 35-44, 45-54, 55-64 and 65+.

3.5.3.6 Cost of fatalities

There were many fatalities in the data that were never admitted to hospital and these were excluded from the mean cost calculations although the fatality count is still shown in tables. This is to show the full impact of the categories analysed. Fatalities (defined here by death occurring within 1.5 years of the RTC) that did have admissions were analysed separately from surviving casualties with hospital admissions, in cost calculations.

Cost of fatalities can be included with a willingness to pay estimate, but this is beyond the scope of this study.

3.5.3.7 Distribution of cost

The full hospital cost for casualties including 1.5 years post RTC were not normally distributed (but had a very skewed distribution Figure 7) and attempts were made to transform the data using the the natural logarithm (LN) and square root. The distribution before and after (LN) transformation is shown in Figure 7 and Figure 8 and the conclusion is that the transformation were not successful (the Kolmogorov-Smirnov test showed a sign. value of less than 0.05 = significantly different from a normal distribution, see Table 6). Tests of means with 95% confidence intervals were therefore not made on this data.

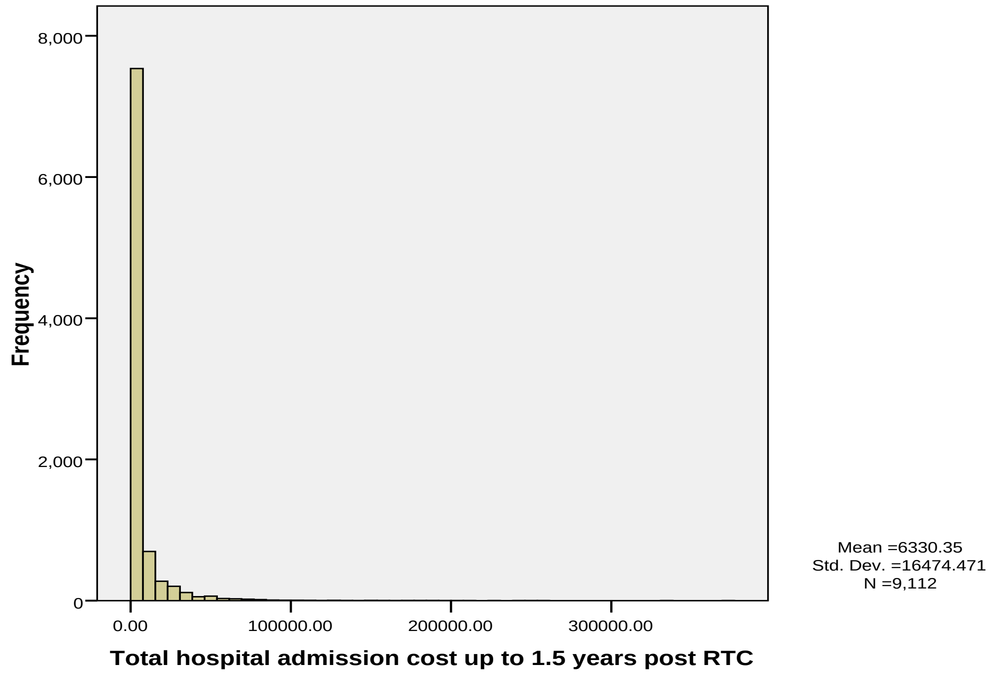


Figure 7 Hospital admission costs up to 1,5 years post RTC

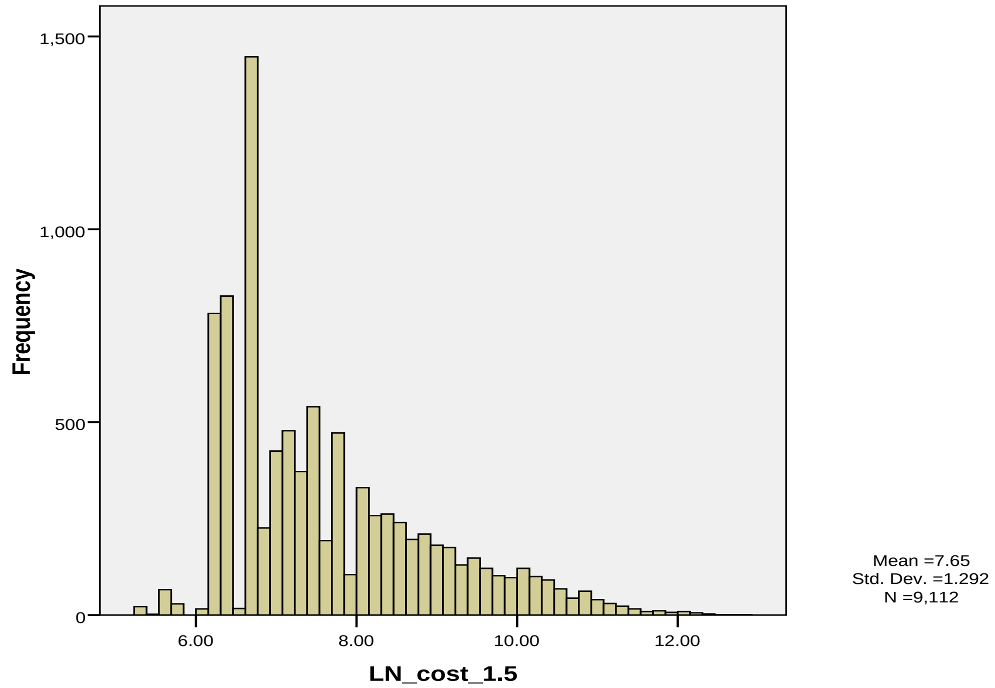


Figure 8 Log transformed hospital admission costs up to 1,5 years post RTC

Table 6 Tests of Normality of log transformed cost

	Kolmogorov-Smirnov(a)		
	Statistic	df	Sig.
LN_cost_1.5	.136	9112	.000

a Lilliefors Significance Correction

3.5.4 Cost of road traffic crashes at safety camera sites

The methods discussed here relates to the second part of the third objective:

> To estimate the economic burden of RTC hospital admissions (in Strathclyde and) at the "safety camera" sites before and after installation

And research question:

> What hospital admission costs are incurred by different types of injuries and casualties (in Strathclyde and) at safety camera sites)?

3.5.4.1 Records used in RTC cost at safety camera sites

Similar to what was discussed in the previous section this part of the study only utilises the linked data (as unlinked STATS19 do not have any hospital admissions and unlinked SMR01 records have no follow-up admissions attached). All safety camera sites available were used (N 47, see section 3.2.4.1 for information on how sites were chosen) and crashes were selected as described in section 3.2.4.2.

3.5.4.2 Study period in RTC cost at safety camera sites

The inclusion period in this analysis was slightly different from the analysis described in section 3.5.3. Admissions and associated costs were included for the first 6 months only post RTC, in order to ensure a standard period at risk for all RTC casualties to be hospitalised, as it was more important here to include as many RTCs after as possible i.e. RTCs from 2005 were also included as the shorter follow-up period allowed for this.

3.5.4.3 Epidemiological variables included in RTC cost at safety camera sites

Casualties were analysed by the following categories: casualty severity, type of road user and injury type. RTCs were analysed by casualty severity, junction / non-junction related and number of vehicles involved in the crash. Casualty severity was based on whether an injury caused no hospitalisation, hospitalisation of surviving casualties and fatalities. Type of road user included driver/rider, vehicle or pillion passenger and pedestrians as defined by STATS19.

3.5.4.4 Injury definitions in RTC cost at safety camera sites

In analysing costs by injury, ICD-10 diagnoses were used (e.g. injury to the head). If a casualty sustained more than one injury, we selected the injury that was found to be most costly in analysis of all casualties in Strathclyde, see section 3.5.3.5, as the injury label for the casualty. Injuries were grouped further in to the categories “head and neck”, “abdomen, lower back, lumbar spine and thorax”, “upper limb” and “lower limb”, to create large enough groups of casualties for injury analysis.

3.5.4.5 Costs per road traffic crash at safety camera sites

The most expensive casualty was used in analysing severity by RTCs. Junction was defined as any RTC occurring within 20 metres of a junction and non-junction outside 20 metres of a junction (as defined by STATS19). Number of vehicles in RTC were defined by single, two and three or more vehicles –derived from STATS19.

3.5.4.6 Maximum and mean maximum costs

Maximum costs and costs per day were analysed. Maximum cost was the highest hospital cost for a single casualty in an RTC, whether or not the outcome was fatal. The "costs per day" were calculated using the sum of maximum RTC costs (i.e. not actual sum costs) and using the number of days before camera installation (Pre SCI) and after camera installation (Post SCI) as the denominator.

Mean maximum cost and cost per day are useful proxy indicators of injury severity, and also to determine what type of casualties and RTCs cameras have had the optimal cost-benefit.

3.6 Summary of Chapter 3

- Several epidemiological methods were used including descriptive epidemiology (evaluating distributions of linked/unlinked data, length of stay and cost analysis), analytical epidemiology (examining associations using chi square tests and logistic regression models) and interventional epidemiology (before and after study).

- The economic evaluation utilised weighted mean costs generated from each health board area's mean total gross cost, weighted by the proportion of discharges in each health board during that year.

- The study setting was Strathclyde region of Scotland and comprised nine years (1997-2005). All RTCs in the region were included and these had sufficient statistical power to detect before-and-after differences at camera sites as well as statistically significant associations of other epidemiological analyses.

- Data from multiple sources were linked including police RTC records (STATS19), NHS hospitalisation records (SMR01) and Scottish index of multiple deprivation

(SIMD), which together with information on camera sites made up the greater part of data used in the study.

- Linkage was performed by ISD Scotland who used matching standards together with probabilistic methods for linkage. The linked database included all follow-up admissions and major work was performed in determining which follow-up admissions were related to the initial admission.

- The linkage resulted in nearly 11,000 police road casualty records that related to approximately 30,000 hospital and death records. Unlinked RTC hospital and police casualties (nearly 9,000 and 70,000 respectively) were also utilised in analysis.

- The variables most used in analysis were from STATS19: casualty demographics, severity of casualty, vehicle and road user type, RTC conditions and RTC map co-ordinates and from SMR01: injury type, road user (both defined by ICD codes), length of hospital stay and SIMD (attached through postcodes).

- The approach to the analysis was threefold: 1. Epidemiology of road traffic crashes, injuries and accuracy of police recording, 2. Epidemiological impact of safety cameras, 3a. Cost of road traffic crashes in Strathclyde region and 3b. Cost of road traffic crashes at safety camera sites.

CHAPTER 4. RESULTS

Contents of Chapter 4

4.1 Epidemiology of road traffic crashes, injuries and accuracy of police recording

This section presents the results from analysis of the general epidemiology of RTCs in Strathclyde region including time trends and characteristics of casualties, as well as an assessment of why some hospitalised casualties were recorded by police and others not. It begins with the time trends in STATS19 and SMR01 followed by determinants of RTC and severity, risk of hospitalised casualties not being recorded by police (univariable and multivariable analysis) and injury and length of hospital stay.

The results in this section relate to the first objective:

> To establish the overall epidemiology and evaluate accuracy of reporting road traffic casualties in Strathclyde region

And research question:

> What is the epidemiology of RTC casualties in Strathclyde region and how reliable are the routine data?

4.1.1 Time trends in STATS19 and SMR01

Over the nine years 1997-2005, nearly 89,000 people were injured on roads in Strathclyde region (counting all sources of data).

Contrasting SMR01 admission rates with STATS19 killed and seriously injured (KSI) rates suggests both that STATS19 had fewer casualties in this category and that the decline over time was steeper (Figure 9) The total decline in STATS19 KSI rates was 38%, compared to the SMR01 reduction in rates of 21% (comparing the first and last three years).

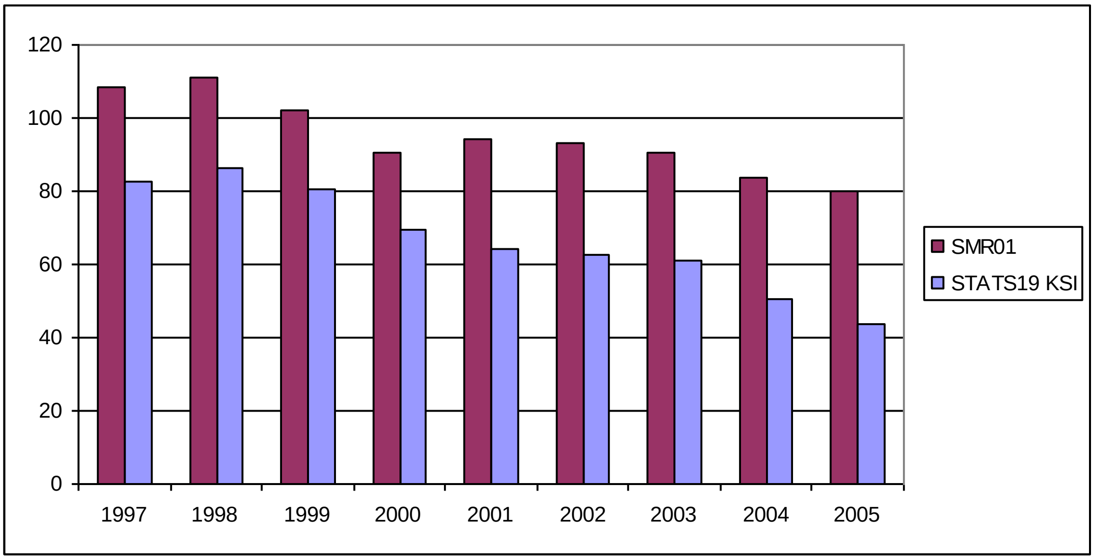


Figure 9 Casualties by SMR01 road traffic crashes admissions and STATS19 killed and seriously injured records in Strathclyde region 1997-2005 per 100,000 population

4.1.1.1 Distribution of STATS19 data over time and severity

Fatal casualties in Strathclyde, as recorded by STATS19, comprised just over 1% of the total in all years (Table 7). The relative proportions of serious and slight casualties changed over time and injuries coded as serious decreased from 18% to 12% of the total while injuries coded as slight increased from 81% to 87%.

There was a significant downward trend over the study period in the overall numbers of road casualties in STATS19 (trend gradient -12.7 and -18%, from 431 per 100,000 pop. in the first three years to 355 in the last three years (Table 8). There were considerable differences in casualty reduction across the three severity categories: fatalities declined by 7% (trend gradient -0.088, a non-significant reduction), serious casualties by 40% (trend gradient -5.089, a significant reduction) and slight injuries by 13% (trend gradient -7.599, a significant reduction).

Table 7 Casualty severity STATS19 data, Strathclyde, 1997-2005

Year of RTC		Police severity grading of casualty: Fatal	Serious	Slight	Total
1997	Count	117	1,786	8,173	10,076
	% of row	1.2%	17.7%	81.1%	100%
1998	Count	116	1,858	8,146	10,120
	% of row	1.1%	18.4%	80.5%	100%
1999	Count	109	1,734	7,607	9,450
	% of row	1.2%	18.3%	80.5%	100%
2000	Count	106	1,475	7,512	9,093
	% of row	1.2%	16.2%	82.6%	100%
2001	Count	117	1,342	7,391	8,850
	% of row	1.3%	15.2%	83.5%	100%
2002	Count	92	1,324	7,048	8,464
	% of row	1.1%	15.6%	83.3%	100%
2003	Count	116	1,271	7,046	8,433
	% of row	1.4%	15.1%	83.6%	100%
2004	Count	107	1,036	6,969	8,112
	% of row	1.3%	12.8%	85.9%	100%
2005	Count	91	897	6,679	7,667
	% of row	1.2%	11.7%	87.1%	100%
Total	Count	971	12,723	66,571	80,265
	% of row	1.2%	15.9%	82.9%	100%

Table 8 Road traffic crash casualty rates in Strathclyde per 100,000 population and trend gradient

	Three year averages			**% Change from 1997-99**			
Police severity grading	**1997-99**	**2000-02**	**2003-05**	**2000-02**	**2003-05**	**Trend gradient**	**p value**
Fatal	5.0	4.6	4.6	-7%	-7%	-0.088	0.127
Serious	78.2	60.8	47.0	-22%	-40%	-5.089	0.000
Slight	348.0	322.1	303.9	-7%	-13%	-7.599	0.000
Total	431.2	387.5	355.5	-10%	-18%	-12.777	0.000

All years were utilised in estimating the trend gradient, which was calculated using linear regression

4.1.1.2 Distribution of the linked vs. unlinked STATS19 and SMR01 records

The proportion of linked STATS19 casualties out of total STATS19 casualties were assessed and this showed that there were little difference in the distribution i.e. in all periods between 12.5 and 14.7% of total STATS 19 records were linked (Table 9).

Table 9 Distribution of linked and unlinked STATS 19 casualties over time (1997-2005) in Strathclyde

Year of RTC		Unlinked STATS19	Linked SATS19 and SMR01	Total
1997	Count	8,745	1,331	10,076
	% of row	86.8%	13.2%	100%
1998	Count	8,836	1,284	10,120
	% of row	87.3%	12.7%	100%
1999	Count	8,214	1,236	9,450
	% of row	86.9%	13.1%	100%
2000	Count	7,862	1,231	9,093
	% of row	86.5%	13.5%	100%
2001	Count	7,551	1,299	8,850
	% of row	85.3%	14.7%	100%
2002	Count	7,257	1,207	8,464
	% of row	85.7%	14.3%	100%
2003	Count	7,322	1,111	8,433
	% of row	86.8%	13.2%	100%
2004	Count	7,033	1,079	8,112
	% of row	86.7%	13.3%	100%
2005	Count	6,708	959	7,667
	% of row	87.5%	12.5%	100%
Total	Count	69,528	10,737	80,265
	% of row	86.6%	13.4%	100%

More than half of all casualties hospitalised following an RTC were identified in STATS19 records. The proportions over time did not change greatly (varying between 50 and 60%, Table 10). Of the SMR01 casualty records, 55% could be linked over the whole study period, suggesting an underreporting rate for hospitalised RTC casualties of 45%.

Table 10 SMR01 data on road casualties unlinked and linked (to police data, STATS19), Strathclyde 1997-2005

Year of RTC		Unlinked SMR01	Linked SATS19 and SMR01	Total
1997	Count	1159	1331	2490
	% of row	46.5%	53.5%	100
1998	Count	1262	1284	2546
	% of row	49.6%	50.4%	100
1999	Count	1091	1236	2327
	% of row	46.9%	53.1%	100
2000	Count	831	1231	2062
	% of row	40.3%	59.7%	100
2001	Count	838	1299	2137
	% of row	39.2%	60.8%	100
2002	Count	907	1207	2114
	% of row	42.9%	57.1%	100
2003	Count	940	1111	2051
	% of row	45.8%	54.2%	100
2004	Count	818	1079	1897
	% of row	43.1%	56.9%	100
2005	Count	855	959	1814
	% of row	47.1%	52.9%	100
Total	Count	8701	10737	19438
	% of row	44.8%	55.2%	100

The highest proportion of STATS19 linked records was in 2001 (14.7% of all recorded casualties) and in SMR01 the highest proportion of linked records was in 2000 (60.8%). The lowest linked proportion was in 2005 for STATS19 and 1998 for SMR01 (12.5% and 50.4% respectively).

4.1.1.3 Time trends of linked and unlinked data

A significant decline was observed in RTCs in all linked and unlinked SMR01 and STATS19 categories (Figure 10 and Table 11). The decline in unlinked SMR01 data, however, appears to have levelled out over the final six years of the study period. There also appears to be a higher proportion of SMR01 casualties with a STATS19 record during the middle time period (2000- 2002).

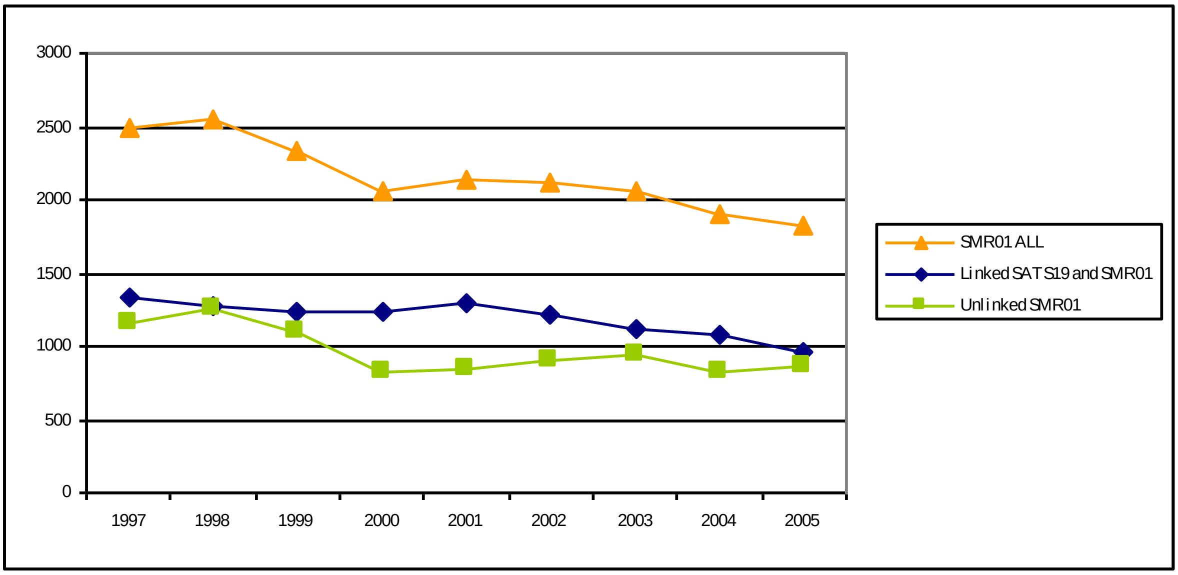


Figure 10 Numbers of SMR01 road traffic crash records over time by total, linked to STATS19 and unlinked records

Table 11 Road traffic crash casualty rates in Strathclyde per 100,000 population by linked and unlinked data

	Three year averages			% Change from 1997-99			
Data sources	**1997-99**	**2000-02**	**2003-05**	**2000-02**	**2003-05**	**Trend gradient**	**p value**
Unlinked STATS19	375.2	332.7	309.3	-11%	-18%	-11.12	0.000
Linked STATS19 and SMR01	56.0	54.8	46.2	-2%	-17%	-1.656	0.002
Unlinked SMR01	51.1	37.8	38.4	-26%	-25%	-1.957	0.015
Total STATS19	431.2	387.5	355.5	-10%	-18%	-12.777	0.000
Total SMR01	107.1	92.6	84.6	-13%	-21%	-3.614	0.000
Total ALL	482.3	425.3	393.9	-12%	-18%	-14.735	0.000

Trend gradient calculated using linear regression (all years were utilised in estimating the trend gradient)

There was a relatively high proportion of the unlinked SMR01 casualties in the first three-year period (3,512 out of 8,701 i.e. 40 %). This could reflect the general time trend in RTC casualty reduction, rather than a linkage problem in earlier years (as a similar proportion of SMR01 were linked to STATS19 over time, see Table 12).

In summary, about one third (33%) of linked SMR01 records and 18% of all SMR01 records were recorded as slight by the police and a little over half of KSI STATS19 records linked to an SMR01 record .

Table 12 Linked and unlinked SMR01 and STATS19 by year and police severity grading

		Unlinked STATS19		Linked STATS19 and SMR01			
Year		Slight casualties	KSI casualties	Slight casualties	KSI casualties	SMR unlinked	Total
1997	Count	7,708	1,037	465	866	1,159	11,235
	% of row	68.6	9.2	4.1	7.7	10.3	100
1998	Count	7,732	1,104	414	870	1,262	11,382
	% of row	67.9	9.7	3.6	7.6	11.1	100
1999	Count	7,322	892	285	951	1,091	10,541
	% of row	69.5	8.5	2.7	9.0	10.4	100
2000	Count	7,203	659	309	922	831	9,924
	% of row	72.6	6.6	3.1	9.3	8.4	100
2001	Count	6,990	561	401	898	838	9,688
	% of row	72.2	5.8	4.1	9.3	8.6	100
2002	Count	6,624	633	424	783	907	9,371
	% of row	70.7	6.8	4.5	8.4	9.7	100
2003	Count	6,677	645	369	742	940	9,373
	% of row	71.2	6.9	3.9	7.9	10.0	100
2004	Count	6,563	470	406	673	818	8,930
	% of row	73.5	5.3	4.5	7.5	9.2	100
2005	Count	6,240	468	439	520	855	8,522
	% of row	73.2	5.5	5.2	6.1	10.0	100
Total	Count	63,059	6,469	3,512	7,225	8,701	88,966
	% of row	70.9	7.3	3.9	8.1	9.8	100

Of a total 89,000 casualties 22% had an SMR01 record of which 12% linked to a STATS19 record (see Figure 11).

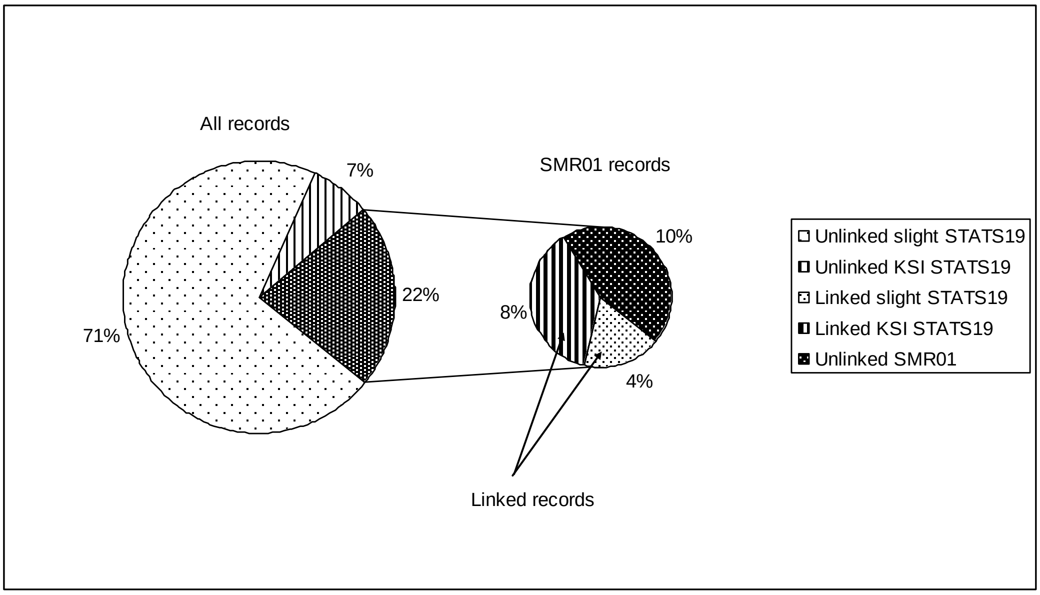


Figure 11 Proportions of linked and unlinked STATS19 and SMR01 records 1997-2005

The only category (of linked and unlinked casualties) that showed an increase in numbers over the study period was the STATS19 slight casualties linked to SMR01 records (+5% comparing first and last three years, Table 13), while the numbers of both linked and unlinked STATS19 KSI (killed or seriously injured - combined fatal and serious casualties) decreased substantially (-27% and -47% respectively). There were increases over the study period in the proportion of records that could be linked to SMR01 of both total KSI (47% in 97-99 and 55% in 03-05) and total slight casualties (5% in 1997-99 and 6% in 2003-05, not shown in table).

Table 13 Road traffic crash casualty rates in Strathclyde per 100,000 population by linked and unlinked data and police severity grading

Data sources	Police severity grading	Three year averages 1997-99	2000-02	2003-05	% change from 97-99 2000-02	2003-05	Trend gradient	p value
Unlinked STATS19	Slight casualties	331.1	305.5	286.0	-8%	-14%	-7.741	0.000
	KSI casualties	44.1	27.2	23.2	-38%	-47%	-3.379	0.001
Linked STATS19 and SMR01	Slight casualties	16.9	16.6	17.8	-2%	5%	0.142	0.700
	KSI casualties	39.1	38.2	28.4	-2%	-27%	-1.799	0.007
Unlinked SMR		51.1	37.8	38.4	-26%	-25%	-1.957	0.015

Trend gradient calculated using linear regression (all years were utilised in estimating the trend gradient).

4.1.2 Determinants of road traffic crashes and severity

The determinants of RTC incidence and severity analysed included age, gender, deprivation, type of road user and whether or not a third party was involved in the RTC.

4.1.2.1 Age: incidence and severity

Young people, aged 15-24, made up the largest number of total casualties (20,256 i.e. 23% and 782 per 100,000 population), while older people (55-64 and 65+) had the lowest (7% / 8% and 268 / 228 per 100,000 pop respectively, Table 14).

The older age groups, however, had a high proportion of casualties that were admitted to hospital (24% and 34% of total within the oldest age group respectively) i.e. an older RTC casualty was more likely to sustain injuries that required hospital admission compared to younger casualties. Furthermore, the oldest group had a very high mortality rate - as many as 4% of these casualties had died within 1.5 years of the RTC (compared to 0.6% of the youngest and 1-1.4% in the other groups, see Table 15).

Children (0-14 year olds) were the most likely to be unrecorded by police and made up 24% of total unlinked SMR01 data and 47% of SMR01 child RTC records. At the same time a relatively large proportion of STATS19 recorded child casualties had been admitted to hospital (20%), which was the second highest proportion after the oldest age group (22%).

Table 14 Linked and unlinked STATS19 and SMR01 by age group, data for 1997-2005

		Unlinked STATS19	Linked STATS19/ SMR01	Unlinked SMR01	Total
0-14 years	No. of casualties	9476	2305	2046	13827
	Per 100,000 pop	256.0	62.3	55.3	373.5
	Row %	69%	17%	15%	100%
	Column %	14%	21%	24%	16%
	% of total STATS19	80%	20%	-	100%
	% of total SMR01	-	53%	47%	100%
15-24 years	No. of casualties	16344	2205	1707	20256
	Per 100,000 pop	631.7	85.2	66.0	782.9
	Row %	81%	11%	8%	100%
	Column %	24%	21%	20%	23%
	% of total STATS19	88%	12%	-	100%
	% of total SMR01	-	56%	44%	100%
25-34 years	No. of casualties	14597	1565	1292	17454
	Per 100,000 pop	516.4	55.4	45.7	617.4
	Row %	84%	9%	7%	100%
	Column %	21%	15%	15%	20%
	% of total STATS19	90%	10%	-	100%
	% of total SMR01	-	55%	45%	100%
35-44 years	No. of casualties	12057	1357	1158	14572
	Per 100,000 pop	383.6	43.2	36.8	463.6
	Row %	83%	9%	8%	100%
	Column %	17%	13%	13%	16%
	% of total STATS19	90%	10%	-	100%
	% of total SMR01	-	54%	46%	100%
45-54 years	No. of casualties	7470	1072	759	9301
	Per 100,000 pop	276.8	39.7	28.1	344.7
	Row %	80%	12%	8%	100%
	Column %	11%	10%	9%	10%
	% of total STATS19	87%	13%	-	100%
	% of total SMR01	-	59%	41%	100%
55-64 years	No. of casualties	4669	824	620	6113
	Per 100,000 pop	204.5	36.1	27.2	267.7
	Row %	76%	13%	10%	100%
	Column %	7%	8%	7%	7%
	% of total STATS19	85%	15%	-	100%
	% of total SMR01	-	57%	43%	100%
65+ years	No. of casualties	4913	1409	1119	7441
	Per 100,000 pop	150.7	43.2	34.3	228.3
	Row %	66%	19%	15%	100%
	Column %	7%	13%	13%	8%
	% of total STATS19	78%	22%	-	100%
	% of total SMR01	-	56%	44%	100%
Total	No. of casualties	69526	10737	8701	88964*
	Per 100,000 pop	339.1	52.4	42.4	434.0
	Row %	78%	12%	10%	100%
	Column %	100%	100%	100%	100%
	% of total STATS19	87%	13%	-	100%
	% of total SMR01	-	55%	45%	100%

*2 casualties with missing age details

Table 15 Injury severity by age excluding unlinked SMR01 and year 2005

Age group	Sight injuries Count	% of row	Hospital admissions Count	% of row	Fatal (within 1.5 y) Count	% of row
0-14	8761	80.5	2057	18.9	61	0.6
15-24	14732	88.2	1775	10.6	204	1.2
25-34	13419	90.3	1279	8.6	155	1.0
35-44	10763	89.7	1099	9.2	135	1.1
45-54	6624	87.1	877	11.5	107	1.4
55-64	4130	84.7	680	13.9	65	1.3
65+	4389	77.4	1055	18.6	229	4.0
Total	62818	86.5	8822	12.2	956	1.3

4.1.2.2 Gender: incidence and severity

A higher proportion of STATS19 male casualties was admitted to hospital than females (25% vs. 18%, using all available data) and there were more male casualties in total (516 compared to 360 per 100,000 pop, Table 16). Including 1.5 years follow-up time (which excludes unlinked SMR01 and year 2005 records) also showed that more males than females had fatal outcomes of RTC, see Table 17 and Figure 12. The difference was most pronounced in ages 25-34 and no difference could be observed in childhood.

Males also made up a larger proportion of total unlinked SMR01 records (66%) and 45% of total male SMR01 records were unlinked.

Table 16 Linked and unlinked STATS19 and SMR01 by gender, data for 1997-2005

Gender		Unlinked STATS19	Linked STATS19/ SMR01	Unlinked SMR01	Total
Male	No. of casualties	37,733	6,994	5,732	50,459
	Per 100,000 pop	385.5	71.5	58.6	515.5
	Row %	75%	14%	11%	100%
	Column %	54%	65%	66%	57%
	% of total STATS19	84%	16%	-	100%
	% of total SMR01	-	55%	45%	100%
Female	No. of casualties	31,795	3,743	2,969	38,507
	Per 100,000 pop	296.8	34.9	27.7	359.5
	Row %	83%	10%	8%	100%
	Column %	46%	35%	34%	43%
	% of total STATS19	89%	11%	-	100%
	% of total SMR01	-	56%	44%	100%
Total	No. of casualties	69,528	10,737	8,701	88,966
	Per 100,000 pop	339.2	52.4	42.4	434.0
	Row %	78%	12%	10%	100%
	Column %	100%	100%	100%	100%
	% of total STATS19	87%	13%	-	100%
	% of total SMR01	-	55%	45%	100%

Table 17 Injury severity by gender excluding unlinked SMR01 and year 2005

Age group	Sight injuries Count	% of row	Hospital admissions Count	% of row	Fatal (within 1.5 y) Count	% of row
Male	34,024	84.2	5,690	14.1	680	1.7
Female	28,796	89.4	3,132	9.7	276	0.9
Total	62,820	86.5	8,822	12.2	956	1.3

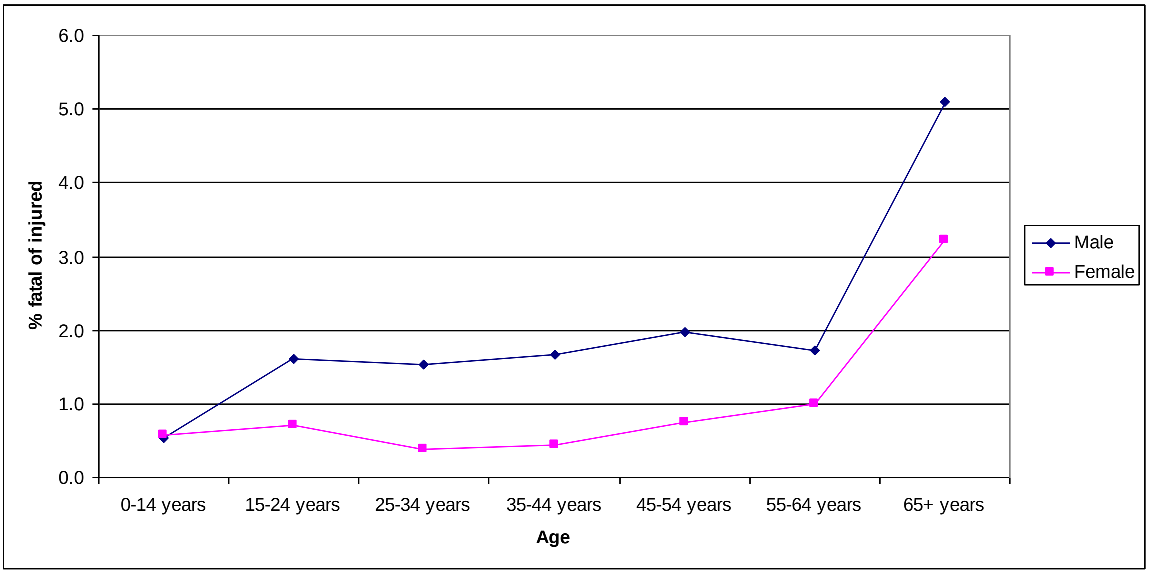


Figure 12 Percentage of injured that had a fatal outcome within 1.5 years, by age and gender

4.1.2.3 Deprivation: incidence and severity

There were large numbers of casualties from the most deprived areas (38% from SIMD quintile 1 and 22% from SIMD 2, while only 12% of casualties were from SIMD 5, Table 18).

Deprivation appeared to have had no effect on whether a hospitalised casualty was recorded by the police or not (55-56% of SMR01 RTC records also had a STATS19 record, Table 18).

There appeared to be no pattern in fatality risk related to SIMD, Table 19.

Table 18 Linked and unlinked STATS19 and SMR01 by SIMD, data for 1997-2005

SIMD		**Unlinked STATS19**	**Linked STATS19/ SMR01**	**Unlinked SMR01**	**Total**
1 (most deprived)	No. of casualties	15,228	3,943	3,204	22,375
	Row %	68%	18%	14%	100%
	Column %	37%	38%	39%	38%
	% of total STATS19	79%	21%	-	100%
	% of total SMR01	-	55%	45%	100%
2	No. of casualties	9,104	2,363	1,867	13,334
	Row %	68%	18%	14%	100%
	Column %	22%	23%	22%	22%
	% of total STATS19	79%	21%	-	100%
	% of total SMR01	-	56%	44%	100%
3	No. of casualties	6,498	1,727	1,382	9,607
	Row %	68%	18%	14%	100%
	Column %	16%	17%	17%	16%
	% of total STATS19	79%	21%	-	100%
	% of total SMR01	-	56%	44%	100%
4	No. of casualties	5,135	1,229	965	7,329
	Row %	70%	17%	13%	100%
	Column %	13%	12%	12%	12%
	% of total STATS19	81%	19%	-	100%
	% of total SMR01	-	56%	44%	100%
5 (least deprived)	No. of casualties	4,894	1,102	903	6,899
	Row %	71%	16%	13%	100%
	Column %	12%	11%	11%	12%
	% of total STATS19	82%	18%	-	100%
	% of total SMR01	-	55%	45%	100%
Total	No. of casualties	40,859	10,364	8,321	59,544
	Row %	69%	17%	14%	100%
	Column %	100%	100%	100%	100%
	% of total STATS19	80%	20%	-	100%
	% of total SMR01	-	55%	45%	100%
	Missing data	28,669	373	380	29,422

Table 19 Injury severity by SIMD excluding unlinked SMR01 and year 2005

	Sight injuries		Hospital admissions		Fatal (within 1.5 y)	
SIMD	Count	% of row	Count	% of row	Count	% of row
1	13,164	78.6	3,290	19.6	301	1.8
2	7,919	78.7	1,921	19.1	228	2.3
3	5,547	77.7	1,420	19.9	173	2.4
4	4,439	79.9	1,016	18.3	100	1.8
5	4,280	81.2	882	16.7	107	2.0
Total	35,349	78.9	8,529	19.0	909	2.0

4.1.2.4 Road user: incidence and severity

Both SMR01 and STATS19 data have information available on road user (external cause in ICD-10 and casualty class/vehicle type in STATS19). Contrasting road user categories showed which types of casualties were more likely to be missed by police records. In Table

20, both the STATS19 and the equivalent ICD-10 definitions were included (using the STATS19 definition for unlinked STATS19 and linked STATS19/SMR01 and ICD definition for unlinked SMR01).

Pedal cyclist and motorbike/moped casualties were most likely to be hospitalised (47 and 44% of all in respective category recorded, Table 20). Motorcyclists had the highest risk of having a fatal outcome within 1.5 years of RTC (3.6% of injuries recorded by police) followed by pedestrians (2.3% Table 20).

Nearly two thirds of the total injured casualties were car occupants (62%). 38% of hospitalised car occupants (SMR01) did not have a STATS19 record and 10% of all injured car occupants in STATS19 could be linked to SMR01.

The proportions of unlinked SMR01 were higher than linked in the following categories: pedal cyclists, motorcycles/mopeds, and other vehicle.

The road user type that appeared most likely to be missed by police recording was pedal cyclists: 22% of total unlinked traffic related hospital admissions, although only comprising 6% of total casualties. And while 47% of all recorded injured cyclists were admitted to hospital (2,145 of total 4,531), 82% of these had no STATS19 record. In STATS19, there were 2,769 pedal cycle casualties, of which 14% linked to an SMR01 record.

The unlinked SMR01 records contained a substantial proportion of pedestrians (19%), which was a similar proportion to the total recorded pedestrian casualties (20%). 30% of hospitalised pedestrians had no STATS19 record and of all pedestrians, recorded injured in STATS19, 24% were linked to SMR01.

Table 20 Linked and unlinked STATS19 and SMR01 by road user, data for 1997-2004

Vehicle type/road user STATS19 definition	ICD-10 definition		Unlinked STATS19	Linked STATS19/ SMR01	Unlinked SMR01	Total
Pedestrian	Pedestrian	No. of casualties	10,933	3,515	1,502	15,950
		Row %	69%	22%	9%	100%
		Column %	17%	36%	19%	20%
		% of total STATS19	76%	24%	-	100%
		% of total SMR01	-	70%	30%	100%
Pedal cycle	Pedal cyclist	No. of casualties	2,386	383	1,762	4,531
		Row %	53%	8%	39%	100%
		Column %	4%	4%	22%	6%
		% of total STATS19	86%	14%	-	100%
		% of total SMR01	-	18%	82%	100%
Motorcycle or moped	Motorcycle rider	No. of casualties	1,882	649	781	3,312
		Row %	57%	20%	24%	100%
		Column %	3%	7%	10%	4%
		% of total STATS19	74%	26%	-	100%
		% of total SMR01	-	45%	55%	100%
Car (incl. taxi)	Car occupant	No. of casualties	42,024	4,736	2,958	49,718
		Row %	85%	10%	6%	100%
		Column %	67%	48%	38%	62%
		% of total STATS19	90%	10%	-	100%
		% of total SMR01	-	62%	38%	100%
Other vehicle*	Other vehicle**	No. of casualties	5,595	495	843	6,933
		Row %	81%	7%	12%	100%
		Column %	9%	5%	11%	9%
		% of total STATS19	92%	8%	-	100%
		% of total SMR01	-	37%	63%	100%
Total		No. of casualties	62,820	9,778	7,846	80,444
		Row %	78%	12%	10%	100%
		Column %	100%	100%	100%	100%
		% of total STATS19	87%	13%	-	100%
		% of total SMR01	-	55%	45%	100%
	Missing data (all from year 2005)		6,708	959	855	6,708

* Bus or minibus, Goods vehicle, Other vehicle

** Bus occupant, Occupant of pick-up truck or van/ heavy transport, Other land transport

Table 21 Injury severity by SIMD excluding unlinked SMR01 and year 2005

	Sight injuries		Hospital admissions		Fatal (within 1.5 y)	
Road user	Count	% of row	Count	% of row	Count	% of row
Pedal cycle	2,386	86.2	356	12.9	27	1.0
Motorbike or moped	1,882	74.4	557	22.0	92	3.6
Pedestrian	10,933	75.7	3,186	22.1	329	2.3
Car	42,024	89.9	4,275	9.1	461	1.0
Other vehicle	5,582	91.9	447	7.4	46	0.8
Totalt	62,807	86.5	8,821	12.2	955	1.3

4.1.2.5 Third party involvement: incidence and severity

Casualties involved in a collision with third party (e.g. car-pedestrian, car-car, motorbike-lorry etc) made up the majority (79%) of total casualties. More non-collision casualties than collision with third party casualties were admitted to hospital. (34 and 17% respectively, Table 22). Non-collision casualties also had a higher risk of dying compared to collision casualties (1.8 and 1.2% of injuries were fatal within 1.5 years post RTC respectively, Table 23).

Casualties that were in non-collision or collision with a stationary object appeared to be more likely to be missed by police recording. 62% of these SMR01 records did not have a corresponding record in STATS19, while only 39% were missed in an RTC with third party involvement.

Table 22 Linked and unlinked STATS19 and SMR01 by collision/non-collision, data for 1997-2005

		Unlinked STATS19	Linked STATS19/ SMR01	Unlinked SMR01	Total
Collision with third party	No. of casualties	58,448	8,582	3,377	70,407
	Row %	83%	12%	5%	100%
	Column %	84%	80%	39%	79%
	% of total STATS19	87%	13%	-	100%
	% of total SMR01	-	72%	28%	100%
Non-collision or collision with stationary object	No. of casualties	11,080	2,155	3,573	16,808
	Row %	66%	13%	21%	100%
	Column %	16%	20%	41%	19%
	% of total STATS19	84%	16%	-	100%
	% of total SMR01	-	38%	62%	100%
Total	No. of casualties	69,528	10,737	6,950	87,215
	Row %	80%	12%	8%	100%
	Column %	100%	100%	100%	100%
	% of total STATS19	87%	13%	-	100%
	% of total SMR01	-	61%	39%	100%
	Missing data			1,751	1,751

Table 23 Injury severity by collision/non-collision, excluding unlinked SMR01 and year 2005

	Sight injuries		Hospital admissions		Fatal (within 1.5 y)	
Type of RTC	Count	% of row	Count	% of row	Count	% of row
Collision with third party	52,897	87.1	7,112	11.7	741	1.2
Non-collision or collision with stationary object	9,923	83.8	1,710	14.4	215	1.8
Total	62,820	86.5	8,822	12.2	956	1.3

4.1.3 Risk of hospitalised casualties not being recorded by police: univariable and multivariable results

Univariable and multivariable logistic regression were used in analysing association of characteristics of hospitalised casualties to whether or not they were recorded by police.

4.1.3.1 Univariable results

The following categories of admitted RTC casualties were associated with a significantly increased risk of being unrecorded in STATS19 (see Table 24): no third party involvement, age 0-14, earlier years (in this data set), road user (other than car), length of stay in hospital, day of week and month of crash. The SIMD score and gender of casualty were not significantly associated with a risk of being unrecorded in STATS19.

Table 24 Results from univariable logistic regression

Reference category	Category tested	Sign. (p value)	Odds ratio (not adjusted	95% Confidence Interval for odds ratios Lower Bound	Upper Bound
Third party involvement	No third party involvement	<0.0001	4.33	4.03	4.64
Age group 0-14	Age group 15-24	0.0002	0.87	0.79	0.95
	Age group 25-34		0.93	0.84	1.02
	Age group 35-44		0.93	0.84	1.04
	Age group 45-54		0.77	0.69	0.87
	Age group 55-64		0.83	0.73	0.94
	Age group 65+		0.87	0.78	0.96
Year 2004	Year 1997	<0.0001	1.15	1.02	1.30
	Year 1998		1.30	1.15	1.46
	Year 1999		1.16	1.03	1.32
	Year 2000		0.89	0.78	1.01
	Year 2001		0.85	0.75	0.96
	Year 2002		0.99	0.87	1.12
	Year 2003		1.12	0.98	1.27
Car occupant	Pedal cyclist	<0.0001	7.37	6.54	8.30
	Moped or motorcyclist		1.93	1.72	2.16
	Pedestrian		0.68	0.63	0.74
	Other vehicle occupant		2.73	2.42	3.08
Length of stay >7 days	Day case	<0.0001	1.36	1.21	1.53
	1 overnight stay		0.94	0.85	1.04
	2-3 overnight stay		0.88	0.79	0.98
	4-7 overnight stay		0.86	0.76	0.97
Male	Female	0.4948	0.98	0.92	1.04
Saturday	Sunday	0.0309	1.17	1.05	1.30
	Monday		1.09	0.98	1.22
	Tuesday		1.10	0.98	1.23
	Wednesday		1.11	1.00	1.24
	Thursday		1.11	0.99	1.24
	Friday		0.99	0.89	1.10
December	January	<0.0001	1.26	1.08	1.48
	February		1.15	0.98	1.35
	March		1.26	1.08	1.47
	April		1.52	1.31	1.77
	May		1.59	1.37	1.84
	June		1.52	1.31	1.76
	July		1.74	1.51	2.02
	August		1.76	1.53	2.03
	September		1.50	1.29	1.74
	October		1.26	1.09	1.46
	November		1.05	0.90	1.22
SIMD 5 (most affluent)	SIMD 1 (most deprived)	0.9780	0.98	0.89	1.09
	SIMD 2		0.98	0.87	1.09
	SIMD 3		0.97	0.86	1.10
	SIMD 4		0.96	0.84	1.09

4.1.3.2 Multivariable results

All variables were included in multivariable testing using logistic regression (see Table 25). The factors significantly associated with hospitalised casualties not being recorded by the police were: no third party involvement, age (progressively higher OR with older age), year (hospitalised casualties in the earlier years appear to be slightly less likely to be recorded by the police), vehicle occupant (pedal cyclist were over 8 times as likely to be missed by police compared to a car occupant), length of stay (day cases were less likely to be recorded by police) and gender (females were less likely to be recorded by the police).

Table 25 Results from multivariable logistic regression model

Reference category	Category tested	Sign. (p value)	Odds ratio (sing. In bold)	95% confidence intervals for odds ratios: Lower Bound	Upper Bound
Third party involvement	No third party involvement	<0.0001	**3.43**	3.13	3.76
Age group 0-14	Age group 15-24	0.0806	1.12	0.99	1.27
	Age group 25-34	0.0002	**1.30**	1.13	1.49
	Age group 35-44	<0.0001	**1.38**	1.19	1.59
	Age group 45-54	0.0002	**1.34**	1.14	1.56
	Age group 55-64	<0.0001	**1.51**	1.28	1.78
	Age group 65+	<0.0001	**1.80**	1.56	2.07
Year 2004	Year 1997	0.0022	**1.26**	1.09	1.46
	Year 1998	<0.0001	**1.46**	1.26	1.69
	Year 1999	0.0426	**1.17**	1.01	1.36
	Year 2000	0.0024	0.78	0.67	0.92
	Year 2001	0.0032	**0.79**	0.68	0.92
	Year 2002	0.8803	0.99	0.85	1.15
	Year 2003	0.5456	1.05	0.90	1.22
Car occupant	Pedal cyclist	<0.0001	**8.85**	7.63	10.26
	Moped or motorcyclist	<0.0001	**2.12**	1.83	2.44
	Pedestrian	<0.0001	**1.60**	1.44	1.78
	Other vehicle occupant	<0.0001	**2.67**	2.30	3.09
Length of stay >7 days	Day case	0.0003	**1.30**	1.13	1.50
	1 overnight stay	0.0006	**0.81**	0.71	0.91
	2-3 overnight stay	0.0063	**0.83**	0.73	0.95
	4-7 overnight stay	0.0060	**0.81**	0.70	0.94
Male	Female	<0.0001	**1.18**	1.09	1.28

4.1.4 Type of injury by road user

There was large variation in the type of injury sustained by type of road user. All injuries showed significant differences by road user (using logistic regression).

Head injuries were the most common injury of total admitted casualties (44%) and sustained by 57% of pedal cyclists and 54% of pedestrians. Both pedal cyclists and pedestrians were about twice as likely to sustain a head injury compared to a car occupant.

Knee and lower leg injuries were the second largest injury type (22%), incurred by 35% of pedestrians and 26% of drivers of motorbikes and mopeds (equally common as head injuries for the latter group). A motorbike or moped casualty was 2.5 times and pedestrians 3.7 times as likely to suffer knee and lower leg injury compared to car occupants. Motorcyclists and drivers of mopeds were also very likely to get hip and thigh injuries (over twice as likely compared to car occupants).

Thorax injuries were more commonly sustained by car occupants than other road users as were injuries to the abdomen, lower back and lumbar spine (30% and 17% of all car occupants respectively).

Drivers of two wheeled vehicles (motorbikes, mopeds and pedal cycle) were more likely to suffer injuries to the elbow and forearm.

Table 26 Injury by road user: results from univariable logistic regression. Reference category: car occupant

Injury diagnosis	Category tested	Sign. (p value)	Odds ratio	95% Confidence Interval for odds ratios Lower Bound	Upper Bound	% with injury
Injuries to the abdomen, lower back, lumbar spine	Pedal cycle	0.0000	0.75	0.55	1.02	13.1%
	Motorbike or moped		0.95	0.76	1.19	16.0%
	Pedestrian		0.71	0.63	0.81	12.5%
	Other vehicle		0.89	0.69	1.15	15.2%
	Car (ref cat)					16.7%
Injuries to the ankle and foot	Pedal cycle	0.0047	0.55	0.28	1.09	2.3%
	Motorbike or moped		1.43	1.00	2.05	5.9%
	Pedestrian		1.24	1.01	1.53	5.1%
	Other vehicle		0.62	0.35	1.10	2.6%
	Car (ref cat)					4.2%
Injuries to the elbow and forearm	Pedal cycle	0.0000	2.14	1.57	2.91	14.1%
	Motorbike or moped		2.77	2.20	3.49	17.6%
	Pedestrian		0.99	0.84	1.18	7.1%
	Other vehicle		1.47	1.07	2.00	10.1%
	Car (ref cat)					7.1%
Injuries to the head	Pedal cycle	0.0000	2.19	1.77	2.70	56.9%
	Motorbike or moped		0.55	0.46	0.66	25.0%
	Pedestrian		1.95	1.79	2.13	54.1%
	Other vehicle		1.19	0.98	1.43	41.7%
	Car (ref cat)					37.6%
Injuries to the hip and thigh	Pedal cycle	0.0000	1.37	0.94	1.99	8.6%
	Motorbike or moped		2.21	1.71	2.85	13.3%
	Pedestrian		1.57	1.34	1.84	9.8%
	Other vehicle		1.28	0.91	1.80	8.1%
	Car (ref cat)					6.5%
Injuries to the knee and lower leg	Pedal cycle	0.0000	1.59	1.21	2.09	18.5%
	Motorbike or moped		2.52	2.08	3.07	26.5%
	Pedestrian		3.75	3.35	4.18	34.9%
	Other vehicle		1.39	1.08	1.79	16.6%
	Car (ref cat)					12.5%
Injuries to the neck	Pedal cycle	0.0000	0.35	0.22	0.58	4.4%
	Motorbike or moped		0.59	0.44	0.81	7.2%
	Pedestrian		0.11	0.08	0.14	1.4%
	Other vehicle		0.90	0.66	1.21	10.5%
	Car (ref cat)					11.6%
Injuries to the shoulder and upper arm	Pedal cycle	0.0010	1.24	0.90	1.71	12.0%
	Motorbike or moped		1.56	1.23	1.97	14.6%
	Pedestrian		1.19	1.03	1.37	11.6%
	Other vehicle		1.40	1.06	1.85	13.4%
	Car (ref cat)					9.9%
Injuries to the thorax	Pedal cycle	0.0000	0.26	0.19	0.37	9.9%
	Motorbike or moped		0.50	0.40	0.62	17.3%
	Pedestrian		0.17	0.15	0.20	6.7%
	Other vehicle		0.56	0.44	0.70	18.8%
	Car (ref cat)					29.5%
Injuries to the wrist and hand	Pedal cycle	0.0000	1.33	0.89	1.98	7.6%
	Motorbike or moped		2.18	1.67	2.85	11.9%
	Pedestrian		0.60	0.48	0.74	3.6%
	Other vehicle		0.76	0.48	1.18	4.5%
	Car (ref cat)					5.8%

4.1.5 Reporting levels by injury and length of hospital stay

There was considerable variation on the LoS across injury and severity diagnoses. While increasing proportions of almost all diagnoses were diagnosed as slight rather than serious over the study period, the pattern of LoS was far less consistent (see Table 27).

The numbers of hospitalised abdominal/lower back/lumbar spine injuries were quite similar over the years (only 10% reduction), but the proportion of these injuries coded as slight increased (from 38 to 48%) while the cases coded as severe decreased (from 60% to 49%). However, LoS of serious and slight coded injuries of this type increased over time.

Injuries to the head decreased by 15% overall over time, and while cases coded severe declined by 38%, cases coded slight increased by 19%. Head injuries were increasingly coded as slight (from 35% to 50% of cases with this injury type) and less often coded serious over time (from 55% to 40%). It is possible that head injuries became progressively less serious, but the overall LoS does not support this (LoS was higher in the last year group compared to the 1st; mean LoS rose from 5.1 to 8.1 – not including fatalities).

Hospitalised cases due to neck injuries declined 8% overall, but cases coded as severe declined by 43% while slight injuries increased by 22%. This possible shift in coding practices was reflected in the mean LoS where the mean LoS for slight neck injuries has tripled from 2.7 to 9.2, serious cases, however, also showed an increased mean LoS (6.2 to 11.1).

Thorax injuries decreased by 24% overall although the slight coded injuries and fatalities increased, while cases coded as serious decreased by 45%, although overall LoS remained similar.

Table 27 STATS19 severity proportions and mean length of stay of hospital admissions by (single) injury, comparing 1st and 3rd three year time periods

Single injury description	Years	Total Number	Proportions of severity code			Mean LoS		
			Fatal	Serious	Slight	Serious	Slight	Total
Injuries to the abdomen, lower back, lumbar spine	1997-1999	202	2%	60%	38%	6.8	3.4	5.5
	2003-2005	181	3%	49%	48%	14.9	5.1	10.1
Injuries to the ankle and foot	1997-1999	48	0%	75%	25%	8.1	2.2	6.6
	2003-2005	42	0%	52%	48%	5.1	6.9	5.9
Injuries to the elbow and forearm	1997-1999	107	1%	51%	48%	4.3	3.3	3.8
	2003-2005	67	0%	52%	48%	3.2	4.3	3.7
Injuries to the head	1997-1999	824	10%	55%	35%	5.8	3.9	5.1
	2003-2005	697	10%	40%	50%	15	2.4	8.1
Injuries to the hip and thigh	1997-1999	89	0%	82%	18%	24.7	20.5	24
	2003-2005	92	1%	79%	20%	22	13.1	20.3
Injuries to the knee and lower leg	1997-1999	361	0.6%	77%	23%	11.1	8.8	10.6
	2003-2005	264	0.4%	75%	25%	10	8.4	9.6
Injuries to the neck	1997-1999	138	4%	49%	47%	6.2	2.7	4.5
	2003-2005	127	8%	30%	62%	11.1	9.2	9.8
Injuries to the shoulder and upper arm	1997-1999	87	0%	57%	43%	4.1	3.2	3.7
	2003-2005	75	0%	49%	51%	7.2	8.3	7.8
Injuries to the thorax	1997-1999	310	7%	65%	28%	6.1	4.8	5.7
	2003-2005	236	13%	48%	39%	6.4	5.4	6
Injuries to the wrist and hand	1997-1999	39	0%	56%	44%	3.2	1.5	2.5
	2003-2005	32	0%	37%	63%	3.8	1.2	2.1

4.2 Epidemiological impact of safety cameras

This section presents results from the analysis of the effect of safety cameras. In order to assess whether cameras have an effect on RTC incidence and/or severity, the first part of the analysis included a comparison of characteristics of RTCs in Strathclyde region with the characteristics of RTCs at sites before safety camera installation) (Pre SCI). If the characteristics did not differ significantly, comparison of time trends was possible. The second part of analysis assesses differences in daily rates and characteristics of RTCs Pre and Post SCI (after safety camera installation).

The results in this section relate to the second objective:

> To determine the epidemiology and effectiveness at the safety camera sites with special reference to different road users, RTC types and severity, before and after installation for the years 1997 to 2005

And research question:

> What are the epidemiological characteristics of RTCs that are prevented through safety camera enforcement?

4.2.1 Epidemiology of road traffic crashes in Strathclyde region vs. at safety camera sites

A total of 59,608 RTC records were obtained from STATS19 and of these 1,186 (2%) were RTCs that occurred at camera sites.

The variables that were significantly different (using chi-squared test) were severity of RTC (greater at camera sites before camera installation than in the rest of Strathclyde) and number of vehicles involved in RTC (more RTCs with multiple vehicles involved at camera sites than in the rest of Strathclyde). The remainder of variables tested were not significantly associated with camera sites compared to remainder of Strathclyde (i.e. whether crashes were junction related, number of casualties per RTC, type of weather/road surface/light conditions/day of week when RTC occurred, pedestrian RTC vs. vehicle only RTC).

4.2.1.1 Time trends in incidence of road traffic crashes

When we compared the average RTC rates between the first (1997-99) and last (2003-5) three-year periods, RTC incidence in the whole of Strathclyde region declined by 15% over the study period. The greatest proportional decrease (39%) was in serious RTCs. The trend gradients declined significantly for both slight and serious RTCs, while the decline in fatal RTCs was non-significant (Table 28).

Table 28 STATS19 recorded road traffic crash rates and trend gradient in Strathclyde per 100,000 population

	Three year averages			% Change from 1997-99		Trend gradient	p value
Severity	1997-99	2000-02	2003-05	2000-02	2003-05		
Fatal	4.6	4.3	4.3	-7%	-7%	-0.084	0.086
Serious	67.5	53.0	41.0	-22%	-39%	-4.328	0.000
Slight	244.4	230.5	222.5	-6%	-9%	-3.836	0.000
Total	316.6	287.7	267.7	-9%	-15%	-8.247	0.000

Trend gradient calculated using all years and linear regression

Fatal in all this analysis means police definition of dying within 30 days of RTC

Figure 13 STATS19 recorded road traffic crashes rates in Strathclyde per 100,000 population by year and severity

The linear-by-linear association test confirms that the downward trend at the camera sites was significantly different to the trend in the whole of Strathclyde.

The difference in the distribution of RTCs within each group over time (camera sites and remainder of Strathclyde) is shown in Figure 14. As no common denominator was available, the frequency distribution (% distribution of RTCs at sites vs. remainder of Strathclyde) is shown instead. Contrasting the first three-year average with the last, there was a 32% reduction in RTC incidence at camera sites compared to 16% in the remainder of Strathclyde.

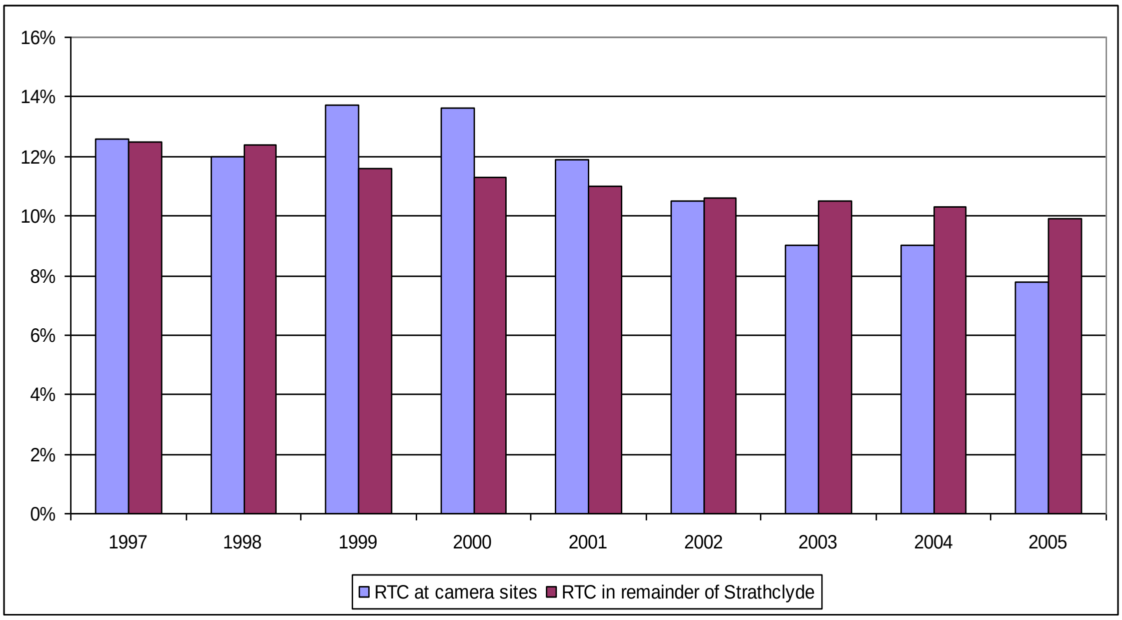


Figure 14 Frequency distribution of road traffic crashes at camera sites and the remainder of Strathclyde by year

4.2.2 Epidemiology of road traffic crashes at safety camera sites

To evaluate the impact of cameras on RTCs at camera sites, daily RTC rates and rate ratios were calculated. 72% of the RTCs at camera sites occurred before camera installation and 63% of days available for analysis were "before" days. In total, RTCs at camera sites declined by 31% (Table 29).

Table 29 Rate ratios and 95% confidence intervals of road traffic crash incidence reduction after camera installation

	Number of RTCs		Daily RTC rates		Rate ratio ('after' vs. 'before')		
	Before	After	Before	After	Rate ratio	95% CI lower	95% CI upper
RTCs at camera sites	854	332	0.0087	0.0060	0.69	0.61	0.78

4.2.2.1 Impact of cameras on road traffic crash epidemiology

To investigate whether cameras had a greater effect on some types of RTC than on others, we calculated daily "before" and "after" rates, rate ratios and 95% confidence intervals for the variables listed in Table 30 and Figure 15. All but one of the variables and subcategories show a significant reduction post-installation, but to varying degrees. Cameras appeared to contribute particularly to the reduction of more severe RTCs. Roads with many non-junction RTCs, RTCs with more than two casualties, single or multiple (more than two) vehicle RTCs and RTCs involving pedestrian injuries also appear to have particularly benefited from cameras, although the numbers were too small to produce significant results.

Table 30 Rate ratios and 95% confidence intervals of road traffic crash incidence reduction after camera installation by road traffic crash type

	Variable description	Number of RTCs		Daily RTC rates		Rate Ratio ('after' vs. 'before')		
		Before	After	Before	After	Rate ratio	95% CI lower	95% CI upper
Severity of RTC	KSI (fatal & serious)	212	57	0.0021	0.0010	0.48	0.36	0.64
	Slight	642	275	0.0065	0.0049	0.76	0.66	0.87
Vicinity of junction	Junction related	463	198	0.0047	0.0036	0.76	0.64	0.89
	Not junction related	391	134	0.0040	0.0024	0.61	0.50	0.74
Number of vehicles involved in RTC	One	318	111	0.0032	0.0020	0.62	0.50	0.77
	Two	444	193	0.0045	0.0035	0.77	0.65	0.91
	Three or more	92	28	0.0009	0.0005	0.54	0.35	0.82
Pedestrian vs. vehicle only RTC	Vehicle only RTCs	623	249	0.0063	0.0045	0.71	0.61	0.82
	Pedestrian RTCs	231	83	0.0023	0.0015	0.64	0.50	0.82
Number of casualties per RTC	One	657	253	0.0067	0.0045	0.68	0.59	0.79
	Two	127	59	0.0013	0.0011	0.82	0.62	1.12
	Three or more	70	20	0.0007	0.0004	0.51	0.31	0.83
Light conditions at site	Daylight	604	226	0.0061	0.0041	0.66	0.57	0.77
	Darkness	250	106	0.0025	0.0019	0.75	0.60	0.94

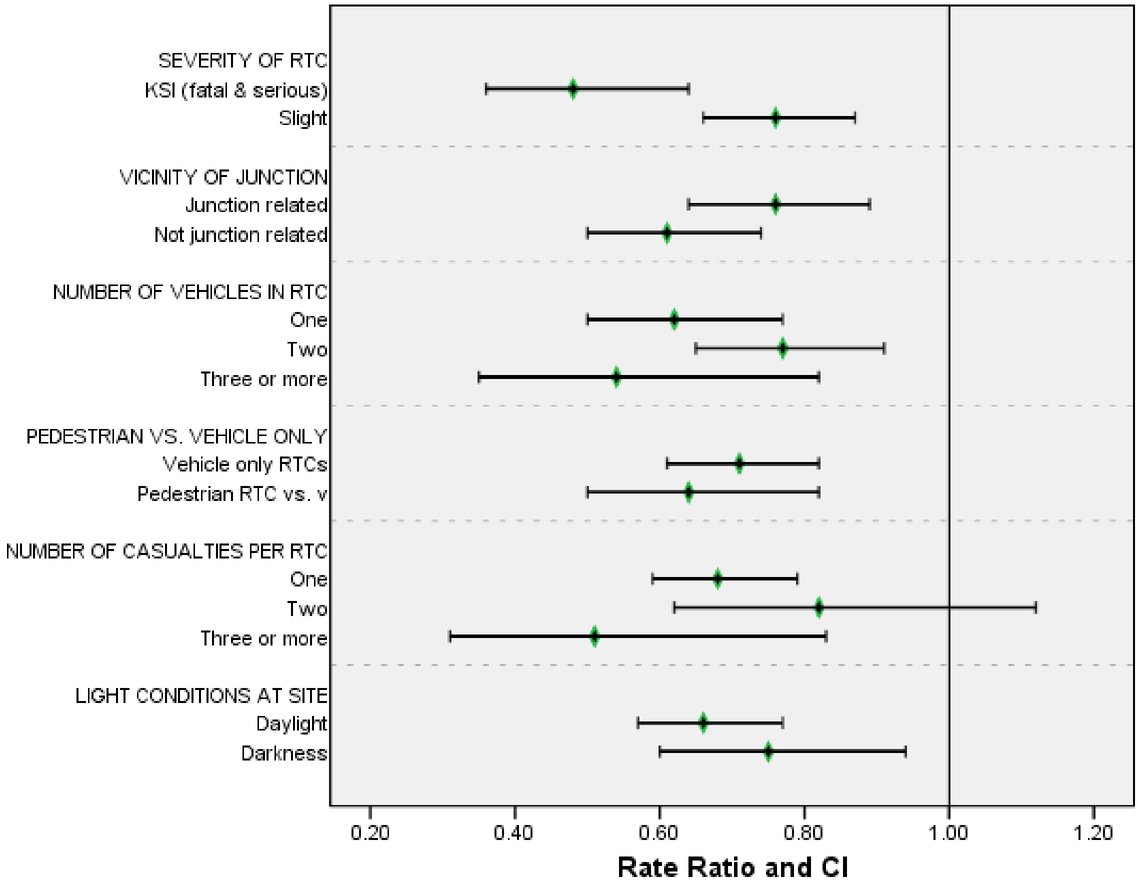


Figure 15 Rate ratios and 95% confidence intervals of road traffic crash incidence reduction after camera installation by road traffic crash type

4.2.2.2 Camera effect over time

The data reveal no diminishing effect of cameras on RTC incidence over time (Table 31), where the first year suggests a reduction of 34%, the second 1% and third 46%.

Table 31 Rate ratios and 95% confidence intervals of "before" and "after" road traffic crashes, grouped by year

Year after installation (No. of cameras)	Number of RTCs		Daily RTC rates		Rate ratio ('after' vs. 'before')		
	Before	After	Before	After	Rate ratio	95% CI lower	95% CI upper
1st year (35)	753	76	0.0093	0.0060	0.64	0.51	0.81
2nd year (29)	559	62	0.0086	0.0059	0.69	0.53	0.90
3rd year (14)	294	28	0.0103	0.0056	0.54	0.37	0.79

4.3 Cost impact of road traffic crashes

This part of the results is divided in to two sections. Firstly, the hospital cost impact of RTC casualties in the whole of Strathclyde region was evaluated. This included costs by injury type, road user, road context, SIMD, age and over time. Secondly, the cost impact of RTCs at camera sites was assessed. This comprised analysis of cost by casualty severity, road user, injury type, junction/non-junction, number of vehicles involved and RTC maximum cost.

The results presented in this section relates to the third objective:

> To estimate the economic burden of RTC hospital admissions in Strathclyde and at the "safety camera" sites before and after installation

And research question:

> What hospital admission costs are incurred by different types of injuries and casualties in Strathclyde and at safety camera sites?

4.3.1 Cost impact of road traffic crashes in Strathclyde region

The total cost of RTCs occurring in Strathclyde between 1997 and 2004 was nearly £58 million, of which surviving casualties accounted for over £53 million (Table 32). This equates to a total average cost of £7.3 million per year. In this analysis no 2005 data was utilised (or included as missing data.) and these comprised 959 linked records. Most tables also exclude all fatalities (956), but some include fatalities which incurred hospital costs (290).

Table 32 Mean and total costs (£) of hospital admissions by inpatient and day surgery

	Hospital admissions					
	Surviving casualties			Fatal casualties (within 1.5 y)		
Cost up to 1.5 years post RTC	Count	Mean cost	Total cost	Count	Mean cost	Total cost
Inpatient admissions	8,003	6,413	51,326,445	237	17,421	4,128,814
Day surgery admissions	1,954	1,067	2,085,339	109	1,298	141,521
Total casualties with admissions	8,822	6,054	53,411,784	290	14,725	4,270,335

4.3.1.1 Road traffic casualty cost by injury type

The data on surviving casualties, with a single injury diagnosis recorded, were analysed further to determine the cost impact of different types of injuries. Casualties with a single diagnosis comprised 60% of all surviving hospitalised casualties (5,337 out of 8,822).

The highest total cost (nearly £7 million) was incurred by head injuries, by far the most frequent single diagnosis in the data (36%, N 1,865). The highest mean costs (£12,241, Table 33) were incurred by injuries to the hip or thigh, at least double the cost of any other single injury. Hip and thigh injuries also, despite only comprising about 5% of single diagnosis casualties, reached a figure of nearly half the total of head injury costs (nearly £3 million).

Injuries to the knee/lower leg had relatively high mean and total costs (£6,218 and just over £5 million respectively).The lowest mean costs were incurred by injuries to other parts of the limbs (wrist/hand, elbow/forearm, shoulder/upper arm and ankle/foot).

Table 33 Mean and total costs (£) of (surviving) hospital admissions by single injury

Single injury diagnosis	Count	% of single injury	Mean cost	Total cost
Injuries to the head	1,865	36.4	3,645	6,798,251
Injuries to the knee and lower leg	840	16.4	6,218	5,223,390
Injuries to the hip and thigh	240	4.7	12,241	2,937,779
Injuries to the abdomen, lower back, lumbar spine	491	9.6	5,172	2,539,438
Injuries to the thorax	735	14.3	3,163	2,324,791
Injuries to the neck	311	6.1	4,357	1,354,896
Injuries to the shoulder and upper arm	213	4.2	3,010	641,143
Injuries to the elbow and forearm	240	4.7	2,135	512,489
Injuries to the ankle and foot	98	1.9	3,539	346,815
Injuries to the wrist and hand	95	1.9	1,933	183,648
Total	5,128	100	4,458	22,862,640
Missing data (not single injury)	4,650			

4.3.1.2 Road traffic casualty cost by road user and vehicle type: Strathclyde region

Nearly a quarter (22.1%) of police recorded injured pedestrians were admitted to hospital and/or died (2.3%, Table 34), while injured drivers or riders only had about half that incidence (10.5% and 1.3% respectively).

The total pedestrian hospital costs were also higher than those of drivers or riders (£26 million compared to £21 million) although the number of hospital admissions and fatalities among drivers and riders was about 20% more than that of pedestrians (4,213 admissions/deaths compared to 3,515).

The mean cost of hospitalised pedestrians was substantially higher than for other road users.

Table 34 Mean and total costs (£) of slight injuries, hospital admissions and fatalities by road user 1997-2004

Road user	Sight injuries		Hospital admissions				Fatalities (within 1.5 y)			
	Count	% of row count	Count	Mean cost	Total cost	% of row count	Count*	Mean cost**	Total cost	% of row count
Pedestrian	10,933	75.7	3,186	7,481	23,834,213	22.1	329	14,802	2,323,866	2.3
Driver or rider	31,501	88.2	3,760	5,217	19,614,413	10.5	453	13,509	1,161,736	1.3
Passenger	20,386	90.9	1,876	5,311	9,963,158	8.4	174	16,696	784,733	0.8
Total	62,820	86.5	8,822	6,054	53,411,784	12.2	956	14,725	4,270,335	1.3

*all fatalities
** mean cost of fatal with hospital admissions

Cars were by far the most common vehicle involved in police recorded hospitalised injury RTCs. The total costs of hospital admissions were £45.5 million (including both surviving and fatal casualties, not shown in table) with cars hitting pedestrians accounting for nearly half of this figure (£22.3 million of which £20.6 million was incurred by surviving casualties).

Pedestrian casualties incurred high mean hospital costs for all types of vehicle RTCs, but especially so when hit by a motorcycle/moped or pedal cycle (although numbers were small, Table 35).

For driver casualties, motorcycles/mopeds incurred the highest mean hospital cost (£6,687), while drivers of buses/minibuses and pedal cyclists had the lowest (£2,400 and £3,811 respectively). Passengers did not figure frequently in any of the casualty vehicle types apart from car RTCs where the mean costs incurred were very similar to drivers (£5,175 and £5,137 respectively).

Table 35 Mean and total costs (£) of (surviving) hospital admissions by road user and vehicle type

Vehicle type	Casualty class Driver or rider Count	Mean cost	Total cost	Vehicle or pillion passenger Count	Mean cost	Total cost	Pedestrian Count	Mean cost	Total cost
Car	2,637	5,137	13,547,534	1,638	5,175	8,475,992	2,777	7,422	20,611,906
Motorcycle or moped	520	6,687	3,477,204	37	4,307	159,353	38	8,804	334,536
Pedal cycle	355	3,811	1,353,004	1	7,554	7,554	9	11,369	102,320
Goods vehicle	178	5,128	912,863	53	4,546	240,945	134	7,644	1,024,305
Other vehicle	38	6,500	247,002	13	8,557	111,237	40	6,887	275,498
Bus or minibus	32	2,400	76,807	134	7,224	968,078	188	7,902	1,485,648
Total	3,760	5,217	19,614,413	1,876	5,311	9,963,158	3,186	7,481	23,834,213

4.3.1.3 Road traffic casualty cost by road context: Strathclyde region

Drivers and passengers in non-junction crashes had higher total and mean costs for surviving hospitalised casualties compared to junction RTCs (Table 36). Furthermore, the proportion of casualties that were fatal at non-junction sites was over double those at junction RTCs for these road users. Pedestrians, on the other hand, appeared to incur the same hospital costs and fatality rates, independent of whether the RTC occurred at a junction or not.

Table 36 Mean and total costs (£) of slight injuries, hospital admissions and fatalities by road user and vicinity of junction

	Road user	Sight injuries Count	% of row	Hospital admissions Count	Mean cost	Total cost	% of row	Fatalities (within 1.5 y) Count*	Mean cost**	Total cost	% of row
Not near junction	Driver or rider	14,121	84.8	2,205	5,510	12,148,603	13.2	319	11,789	636,619	1.9
	Passenger	8,999	87.7	1,147	5,835	6,693,309	11.2	112	13,912	292,150	1.1
	Pedestrian	5,802	74.8	1,778	7,306	12,989,795	22.9	181	15,460	1,252,268	2.3
At or near junction	Driver or rider	17,380	91.1	1,555	4,801	7,465,810	8.2	134	16,410	525,118	0.7
	Passenger	11,387	93.5	729	4,485	3,269,850	6.0	62	18,945	492,583	0.5
	Pedestrian	5,131	76.7	1,408	7,702	10,844,418	21.1	148	14,100	1,071,598	2.2
	Total	62,820	86.5	8,822	6,054	53,411,784	12.2	956	14,725	4,270,335	1.3

* all fatalities
** mean cost of fatal with hospital admissions

The speed of a vehicle has a large impact on casualty outcome in a RTC i.e. the higher the speed the poorer the outcome. The mean costs for surviving hospitalised drivers and passengers, however, were higher on 30 mph than 40-50 mph roads, while pedestrian casualties followed a clear pattern of higher speed equalling greater damage (mean hospital costs: £6,800, £11,000 and £24,000 for 30, 40-50 and 60-70 mph respectively, Table 37). The proportion of fatalities among pedestrians also reflect this relationship: at 30 mph, 2% of injured pedestrians had a fatal outcome, at 40-50 mph 7% and at 60-70 mph 16%. The large majority of pedestrian fatalities, however, occurred on 30 mph roads, generating over £22 million in total hospital costs.

Table 37 Mean and total costs (£) of slight injuries, hospital admissions and fatalities by road user and posted speed limit on road

	Road user	Sight injuries Count	% of row	Hospital admissions Count	Mean cost	Total cost	% of row	Fatalities (within 1.5 y) Count*	Mean cost**	Total cost	% of row
30 mph	Driver or rider	18,547	91.8	1,556	4,505	7,009,336	7.7	106	17,050	630,850	0.5
	Passenger	12,512	94.1	737	5,568	4,103,425	5.5	47	18,616	372,320	0.4
	Pedestrian	10,531	76.6	2,978	6,844	20,380,804	21.6	247	14,545	2,036,239	1.8
40-50 mph	Driver or rider	2,853	90.7	263	4,049	1,064,854	8.4	31	5,319	26,597	1.0
	Passenger	1,737	92.1	133	4,091	544,144	7.1	15	6,554	26,217	0.8
	Pedestrian	185	56.4	119	10,983	1,306,989	36.3	24	12,093	96,741	7.3
60-70 mph	Driver or rider	10,101	81.7	1,941	5,946	11,540,223	15.7	316	11,461	504,289	2.6
	Passenger	6,137	84.6	1,006	5,284	5,315,589	13.9	112	16,791	386,196	1.5
	Pedestrian	217	59.6	89	24,117	2,146,420	24.5	58	21,209	190,885	15.9
	Total	62,820	86.5	8,822	6,054	53,411,784	12.2	956	14,725	4,270,335	1.3

*all fatalities
** mean cost of fatal with hospital admissions

4.3.1.4 Road traffic casualty cost by Scottish Index of Multiple Deprivation: Strathclyde region

Driver mean hospital costs were highest for the most affluent population (SIMD 5, Table 38 and Figure 16), but in pedestrians this pattern was reversed (more deprived = higher mean cost). For passengers the mean costs of the most affluent population were only about half of those of the other SIMD groups.

Total costs could not be compared with any certainty as we did not calculate population rates, but pedestrians from the most deprived areas (SIMD 1) by far outnumbered the other pedestrian SIMD groups. The total costs of the SIMD 1 pedestrians were at least double those of any other pedestrian SIMD group (£13.4 million, including both fatal and surviving casualties). Indeed, the total cost of this group was more than the costs of all the other pedestrians combined (£12.6 million) and more than all passengers (£10.4 million), despite the total number of injured passengers (all SIMD and severity categories) being well over double that of pedestrians in SIMD 1 (12,698 injured passengers and 5,064 injured SIMD 1 pedestrians).

Table 38 Mean and total costs (£) of slight injuries, hospital admissions and fatalities by road user and SIMD

		Sight injuries		Hospital admissions				Fatal (within 1.5 y)			
	SIMD quintile	Count	% of row count	Count	Mean cost	Total cost	% of row count	Count	Mean cost	Total cost	% of row count
Driver or rider	1	5,631	83.8	1,001	4,899	4,903,589	14.9	87	19,262	443,016	1.3
	2	4,133	81.2	847	5,280	4,471,916	16.6	110	12,424	310,605	2.2
	3	3,180	79.7	723	4,881	3,528,994	18.1	89	10,515	147,203	2.2
	4	2,729	81.8	542	5,183	2,809,079	16.2	65	17,121	136,969	1.9
	5	2,716	82.5	506	6,624	3,351,559	15.4	69	8,552	119,727	2.1
Passenger	1	4,263	86.2	622	5,724	3,560,256	12.6	58	20,386	448,483	1.2
	2	2,535	85.1	409	6,202	2,536,765	13.7	34	12,141	109,271	1.1
	3	1,636	81.6	334	5,595	1,868,831	16.7	34	21,138	126,826	1.7
	4	1,220	83.8	220	5,321	1,170,625	15.1	16	9,489	37,956	1.1
	5	1,128	85.6	171	2,604	445,348	13.0	18	15,191	60,763	1.4
Pedestrian	1	3,244	64.1	1,666	7,350	12,245,757	32.9	154	14,141	1,117,124	3.0
	2	1,244	62.5	663	8,147	5,401,257	33.3	84	18,852	791,798	4.2
	3	722	63.7	361	7,770	2,805,083	31.9	50	11,862	260,953	4.4
	4	479	63.8	254	7,459	1,894,556	33.8	18	9,550	66,851	2.4
	5	424	65.3	205	6,283	1,287,986	31.6	20	12,449	87,140	3.1
Total		35,284	86.5	8,822	6,054	53,411,784	12.2	956	14,725	4,270,335	1.3
Missing		27,536									

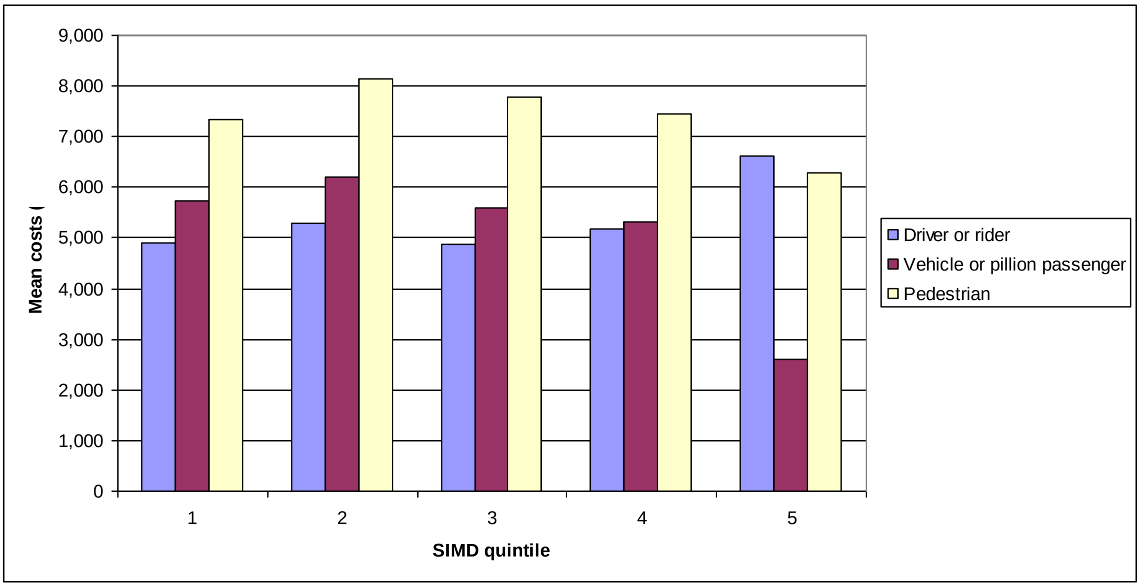


Figure 16 Mean hospital costs (£) by SIMD quintile (1=, most deprived, 5= most affluent) and road user

4.3.1.5 Road traffic casualty cost by age: Strathclyde region

A high proportion of young (0-14 year olds) and old (65+) STATS19 recorded casualties had hospital admissions (near 19% for each group, Table 39), but the youngest age group had the lowest mean cost and the oldest had the highest. As also shown in section 4.1.2.1, severity of RTC casualty was very dependent on age and the proportion of fatal outcomes increase with age from 0.6% in the youngest age group to 4% in age 65+.

The mean hospital costs of surviving casualties rose progressively with advancing age from £4,000 to nearly £11,000.

Since age-specific population rates were not calculated, total costs in the table should be interpreted with caution. The age group 65+, however, had a comparatively high total cost despite the relatively small number of admissions (hence the high mean). In total, the elderly (65+) age group incurred costs of £13.7 million, about double that of any other age category.

Table 39 Mean and total costs (£) of slight injuries, hospital admissions and fatalities by age

	Sight injuries		Hospital admissions				Fatal (within 1.5 y)			
Age group	Count	% of row count	Count	Mean cost	Total cost	% of row count	Count	Mean cost	Total cost	% of row count
0-14	8,761	80.5	2,057	4,043	8,316,282	18.9	61	8,103	218,775	0.6
15-24	14,732	88.2	1,775	4,225	7,500,176	10.6	204	3,384	131,957	1.2
25-34	13,419	90.3	1,279	5,983	7,651,804	8.6	155	11,831	283,941	1.0
35-44	10,763	89.7	1,099	6,311	6,935,906	9.2	135	7,014	119,233	1.1
45-54	6,624	87.1	877	6,692	5,868,531	11.5	107	20,637	474,641	1.4
55-64	4,130	84.7	680	8,660	5,888,687	13.9	65	22,907	572,673	1.3
65+	4,389	77.4	1,055	10,664	11,250,398	18.6	229	18,290	2,469,114	4.0
Total	62,818*	86.5	8,822	6,054	53,411,784	12.2	956	14,725	4,270,335	1.3

* 2 casualties with no age

4.3.1.6 Road traffic casualty cost over time: Strathclyde region

Costs over time were analysed using all the available admissions that were regarded as related to the RTC. This was for the purpose of comparing how the total costs were distributed over time.

Mean costs for the first six months of admissions increase slightly over the years from about £5,000 the first couple of years to around £6,000 for the last years and a similar pattern can be found for the 1.5 years admissions included post RTC.

The bulk of costs were associated with admissions the first six months after an RTC although the proportion of this bulk declined progressively as data on more years became available for including follow-up admissions. For RTCs occurring in 1997 only 71% of admissions occurred within six months and a further 5% within 1.5 years following the RTC. These proportions (naturally) increase and for RTCs occurring in 2004 (for which 1-2.5 years worth of admissions were available) 91% occurred the first six months.

Table 40 Mean and total costs (£) of, hospital admissions by time of road traffic crash

Year of RTC		Hospital admissions up to 6 months post RTC	Hospital admissions up to 1.5 years post RTC	Hospital admissions for the full available period post RTC	Max years of full available data
1997	Mean cost	5,084	5,467	7,147	9
	Total cost	5,932,547	6,380,072	8,340,429	
	Cumulative %	71%	76%	100%	
1998	Mean cost	4,363	4,763	5,717	8
	Total cost	4,808,022	5,248,404	6,299,905	
	Cumulative %	76%	83%	100%	
1999	Mean cost	5,304	5,846	6,958	7
	Total cost	5,818,561	6,413,069	7,633,199	
	Cumulative %	76%	84%	100%	
2000	Mean cost	5,513	5,867	6,833	6
	Total cost	6,036,783	6,424,866	7,481,681	
	Cumulative %	81%	86%	100%	
2001	Mean cost	5,626	5,915	6,630	5
	Total cost	6,549,096	6,884,524	7,716,926	
	Cumulative %	85%	89%	100%	
2002	Mean cost	5,033	5,616	6,089	4
	Total cost	5,476,265	6,110,563	6,625,109	
	Cumulative %	83%	92%	100%	
2003	Mean cost	6,478	6,878	7,132	3
	Total cost	6,386,819	6,781,679	7,032,189	
	Cumulative %	91%	96%	100%	
2004	Mean cost	5,638	6,099	6,228	2
	Total cost	5,508,304	5,959,080	6,085,009	
	Cumulative %	91%	98%	100%	

4.3.2 Cost impact of road traffic crashes at safety camera sites

Out of 1186 RTCs that were identified at the camera sites, 854 (72%) occurred before safety camera installation (Pre SCI), while 64% of days occurred Pre SCI. The daily rate of RTCs declined by 31% comparing before and after safety camera installation (Pre and Post SCI).

Table 41 Proportions of road traffic crashes and days Pre and Post SCI

	Pre SCI	Post SCI
RTC	854	332
% of row	72%	28%
Days	98,717	55,725
% of row	64%	36%
Daily RTC rate	0.0087	0.0060

There were 1,167 and 440 injured casualties respectively in the Pre SCI and Post SCI groups of RTCs. The mean casualty rate per RTC was 1.37 and 1.33. There appeared, however, to be a greater difference in the severity of casualties in the Pre SCI and Post SCI groups (Table 42), where 1.8% of casualties in the Pre SCI group were fatalities compared to 0.5% in the Post SCI group. There was also a smaller difference in the proportion of casualties admitted to hospital (11.9 Pre SCI and 10.5% Post SCI).

The mean costs for (surviving) casualties admitted to hospital were higher in the Pre SCI than in the Post SCI group (£6,200 and £4,742, respectively, Table 42). The mean costs for fatalities were not compared as there was only one casualty in the Post SCI group that incurred a hospital cost (the other casualty died before hospital admission) and that single hospital cost was relatively high, which further skewed the total mean cost.

Costs per day (for surviving hospital casualties) Pre SCI were over double those of the Post SCI group (£8.8 and £3.9 respectively).

The total cost per day was 36% less in the Post SCI group compared to Pre SCI.

Table 42 Total hospital admission cost up to 6 months post road traffic crash by injury severity

	Pre SCI				Post SCI			
	Count**	Mean cost	£ per day	Col %	Count	Mean cost	£ per day	Col %
Sight	1,007	.	.	86.3	392	.	.	89.1
Hospital admissions*	139	6,241	8.8	11.9	46	4,742	3.9	10.5
Fatal (within 6 months)	21	9,314	0.8	1.8	2	120,727	2.2	0.5
Total	1,167	6,408	9.5	100.0	440	7,210	6.1	100.0

*surviving casualties **count includes all casualties –not only the ones that incurred costs

4.3.2.1 Road traffic casualty cost by road user: safety camera sites

The overall mean casualty hospital cost declined by 24% (Table 43). The mean costs for drivers declined by 53%, while mean passenger costs actually increased by 51% (from £2,314 to £3,505) while pedestrian mean costs remained similar.

The daily cost declined by 55% in total (drivers 64%, passengers 14% and pedestrians 56%).

Table 43 Total hospital admission (survivors only) costs up to 6 months post road traffic crash, by road user

		Count	Mean cost	£ per day	% change from Pre SCI: In mean costs	In daily costs
Pre SCI	Driver or rider	44	6,327	2.8		
	Vehicle or pillion passenger	25	2,314	0.6		
	Pedestrian	70	7,589	5.4		
	Group Total	139	6,241	8.8		
Post SCI	Driver or rider	19	2,983	1.0	-53%	-64%
	Vehicle or pillion passenger	8	3,505	0.5	+51%	-14%
	Pedestrian	19	7,022	2.4	-7%	-56%
	Group Total	46	4,742	3.9	-24%	-55%

4.3.2.2 Road traffic casualty cost by injury type: safety camera sites

Mean costs declined for all injury groups apart from head/neck injuries (increased by 22%, Table 44). The highest means were found in lower limb injuries (£10,600 Pre SCI and £7,300 Post SCI). This group comprised of a high proportion of hip and thigh injuries, which commonly require relatively long hospital stay.

The daily costs declined in all injury categories, but especially lower limb injuries (-72%).

Table 44 Injury costs (surviving) hospitalised casualties Pre SCI and Post SCI

		Count	Mean cost	£ per day	% change from Pre SCI: mean costs	daily costs
Pre SCI	Lower limbs	56	10,602	6.01		
	Head/neck	43	4,307	1.88		
	Upper limbs	5	3,238	0.16		
	Abdomen, lower back, lumbar spine and thorax	29	2,120	0.62		
Post SCI	Lower limbs	13	7,285	1.70	-31%	-72%
	Head/neck	19	5,253	1.79	+22%	-5%
	Upper limbs	2	1,913	0.07	-41%	-58%
	Abdomen, lower back, lumbar spine and thorax	9	1,909	0.31	-10%	-50%

4.3.2.3 Cost by road traffic crashes: safety camera sites

Mean maximum cost per RTC was higher in the Pre SCI group, compared to Post SCI, for the hospital survivor group (£6,500 and £5,000 respectively, Table 45). The mean cost per day was over double in the Pre SCI hospital group compared to the Post SCI group (£8.6 vs. £3.8) –a reduction of 56%. .

Table 45 Costs by type of road traffic crash

RTC severity	Pre SCI				Post SCI			
	Count	Mean cost	£ per day	Col %	Count	Mean cost	£ per day	Col %
Slight injury only	706	.		82.7	288	.		86.7
Hospitalised survivors	129	6,548	8.6	15.1	43	4,962	3.8	13.0
Fatal with hospital stay	8	9,314	0.8	0.9	1	120,727	2.2	0.3
Fatal only	11	.		1.3		.		
Total	854	6,709	9.3	100.0	332	7,593	6.0	100.0

4.3.2.4 Cost by type of road traffic crash at junction / non-junction: safety camera sites

Mean (max) costs per non-junction RTC was higher in the Pre SCI group compared to Post SCI –this cost declined by over half. Mean cost per day, for the same types of RTC, declined by 72%. Junction RTCs, on the other hand, had a slight increase (+15%, Table 46) while the mean cost per day declined by about one third.

Table 46 Costs by junction / non-junction type of road traffic crash, hospitalised survivors only

					% change from Pre SCI	
		Count	Mean	£ per day	Mean costs	Daily costs
Pre SCI	Not near junction	63	7,744	4.94		
	At or near junction*	66	5,406	3.61		
Post SCI	Not near junction	21	3,624	1.37	-53%	-72%
	At or near junction*	22	6,240	2.46	+15%	-32%

*within 20 metres of junction

4.3.2.5 Cost by type of road traffic crash and number of vehicles involved: safety camera sties

The mean cost of single vehicle RTCs declined little, but the daily cost of these declined by 53% (Table 47). The costs of two vehicle RTCs, on the other hand, declined substantially in both categories (-57% for mean cost and -65% for daily costs). The costs for multiple vehicles (three or more) actually increased slightly in the mean costs, but declined in daily cost (NB the numbers in this category were fairly small).

Table 47 Cost by number of vehicles involved in road traffic crash, hospitalised survivors only

		Count	Mean	£ per day	% change from Pre SCI mean costs	% change from Pre SCI daily costs
Pre SCI	Single vehicle	84	6,625	5.64		
	Two vehicles	35	7,355	2.61		
	Three or more vehicles	10	3,078	0.31		
Post SCI	Single vehicle	23	6,475	2.67	-2%	-53%
	Two vehicles	16	3,149	0.90	-57%	-65%
	Three or more vehicles	4	3,516	0.25	+14%	-19%

4.4 Summary of Chapter 4

- The frequency of RTC casualties declined significantly over the study period (approximately 18-21%).

- Males were more likely than females to have a fatal outcome of an RTC injury. Young people constituted the largest casualty group although they had a low fatality rate. Old people were more likely to suffer severe or fatal injuries.

- Less protected road users (including pedal cyclists, pedestrians and motorbike/moped occupants) had more severe and fatal injuries. Pedestrians and pedal cyclists were most likely to suffer head injuries, while car occupants more frequently incurred injuries to the thorax and abdomen/lower back/lumbar spine.

- Police RTC records of serious injuries appears underreported i.e. 45% of hospitalised casualties were not recorded by police. The following RTC casualty characteristics were significantly associated with underreporting: no third party involvement, age (older age), year (casualties from earlier years), vehicle occupant (especially pedal cyclist), length of stay (day cases) and gender (females).

- Seriously injured STATS19 casualties also declined in frequency more than the SMR01 would indicate (38% and 21% respectively). At the same time linked

SMR01 casualties that were coded slight by the police increased with 5%, while linked SMR01 casualties coded serious declined 27%.

- RTCs at safety camera sites comprised 2% of all RTCs in Strathclyde region and the RTC epidemiology at camera sites before camera installation did not differ significantly from the remainder of Strathclyde region (apart from having more severe injuries and multiple vehicle RTCs).

- Compared to the rest of Strathclyde, there was a significantly greater downward linear time trend at the camera sites.

- Camera effect on RTCs over time appears stable and cameras appear to be effective in reducing RTCs with serious or fatal outcome, as well as multiple-vehicle and non-junction RTCs.

- The total inpatient costs (excluding unlinked SMR01 records) were conservatively estimated to be £53 million over the study period which equates a yearly average of £7.3 million.

- Injuries to the head and to the lower extremities incurred the highest costs (28% and 34% of total costs respectively). Occupants of motorbikes or mopeds incurred the highest mean costs. Pedestrian, constituting 36% of casualties incurred 44% of total costs.

- Casualties from deprived areas, and pedestrians in particular, incurred higher mean hospital costs than other road user groups. Drivers from the most affluent SIMD areas incurred the highest mean cost for drivers.

- Fatality rates and mean costs increased with age.

- 71% of hospital admission costs were incurred within the first six months following an RTC and a further 5% in the following year (for RTCs occurring in 1997).

- The mean costs for (surviving) casualties admitted to hospital declined by 24% Post SCI (£6,200 vs. £4,742) and the mean daily cost declined by 55% i.e. costs per day Pre SCI were £8.8 and Post SCI £3.9.

- Daily costs for pedestrian injuries declined by 56% comparing Pre and Post SCI and, in terms of injuries, the daily costs appear to have declined most for lower limbs (-72%).

- Comparing Pre and Post SCI, daily costs for non-junction RTCs and RTCs involving two vehicles declined by 72% and 65% respectively and mean costs declined 53% and 57% respectively.

CHAPTER 5. DISCUSSION

Contents of Chapter 5

5.1 Main findings

The presentation of this section follows the order of the rest of this document beginning with the epidemiology of RTCs in Strathclyde region, which is here followed by a separate section on accuracy of police recording. The results from analysis of cost implication are divided in to two parts (whole of Strathclyde and at safety camera sites) impact.

5.1.1 Epidemiology of road traffic injuries in Strathclyde region

Over the years 1997 to 2005 estimates suggests that nearly 89,000 people were injured on Strathclyde roads, which constitutes about 4% of Strathclyde's total population of 2.3 million. RTC injuries have, however, declined approximately 18-21% over the study period.

Young people constituted the largest casualty group (23%) but they had a low fatality rate (0.6% of casualties died within 1.5 years). By contrast,, people aged 65 or over had a low proportion of casualties (8%), but were more likely to suffer severe or fatal injuries (4% of casualties died within 1.5 years).

A higher proportion of police recorded male casualties were admitted to hospital than females and there were more male casualties in total. Males were also more likely than females to have a fatal outcome of an RTC injury.

In terms of deprivation, 38% of casualties were from the fifth most deprived areas, while only 12% were from the most affluent areas. No pattern in terms of deprivation relating to fatality risk was found.

Less protected road users, including pedal cyclists, pedestrians and motorbike/moped occupants were more likely to sustain severe injuries compared to car occupants. Motorbike and moped occupants were also most likely to have a fatal outcome.

Head injuries, which were the most common injury of total admitted casualties (44%), were most frequently suffered by pedestrians and pedal cyclists, while car occupants more frequently incurred injuries to the thorax and abdomen/lower back/lumbar spine.

5.1.2 Accuracy of police reported road traffic casualties

Over the study period police road casualty data appeared to underreport; 45% of hospitalised casualties were not recorded by police. The following RTC casualty characteristics were significantly associated with underreporting: no third party involvement, age (progressively higher risk with older age), year (casualties from earlier years appeared to be more under-recorded), type of road user (especially pedal cyclist), length of stay (day cases were less likely to be recorded by police) and gender (females were less likely to be recorded by the police).

Looking at STATS19 and SMR01 separately suggests that casualties coded as seriously injured in STATS19 declined in frequency more than the SMR01 RTC casualties (38% and 21% respectively). The analysis of the linked STATS19-SMR01 data showed that, while linked SMR01 casualties coded *serious* declined 27%, linked SMR01 casualties that were coded *slight* by the police increased by 5% over time. Head injuries were increasingly coded as slight (from 35% to 50% of head injury cases) and less often coded as serious over time. At the same time, mean hospital length of stay increased for this group indicating that head injuries were unlikely to have become less severe. A similar pattern was found in neck, thorax and abdominal/lower back/lumbar spine injuries.

5.1.3 Epidemiological impact of safety cameras

A total of 59,608 RTC records were obtained for Strathclyde region (STATS19) and of these 1,186 (2%) occurred at safety camera sites. The RTC epidemiology at camera sites before camera installation did not differ significantly from the remainder of Strathclyde region (apart from having more severe injuries and multiple vehicle RTCs).

There was a significantly greater downward linear time trend at the camera sites compared to the rest of Strathclyde (32% vs. 16% respectively).

Cameras appeared to be effective in reducing RTCs with serious or fatal outcome, as well as multiple-vehicle and non-junction RTCs and the camera effect on RTCs over time appeared stable.

5.1.4 Cost of road traffic crashes in Strathclyde region

The total inpatient costs (excluding unlinked SMR01 records) were conservatively estimated to be £7.3 million yearly (£58 million in total over 8 years). The highest costs were incurred by injuries to the head and to the lower extremities (28% and 34% of total costs respectively).). The highest mean costs (£12,241), which were at least double the cost of any other single injury, were incurred by injuries to the hip or thigh.

Although constituting only 36% of casualties, pedestrian RTCs incurred 44% of total costs, while the highest mean costs were incurred by occupants of motorbikes or mopeds. Costs incurred by pedestrians from the most deprived areas were more than the costs of all the other pedestrians combined. The highest mean cost for drivers was for the most affluent SIMD group while lowest for the passengers in the same group.

Speed had a great impact on pedestrian casualties with mean hospital costs of surviving casualties of £6,800 if hit on a 30 mph road, £11,000 on 40-50 mph road and £24,000 on 60-70 mph road. This was also reflected in fatalities, where 2%, 7% and 16% of pedestrian casualties were killed on 30, at 40-50 mph and at 60-70 mph respectively. The large majority of pedestrian fatalities, however, occurred on 30 mph roads, generating over £22 million in total hospital costs (38%).

Mean costs and fatality rates increase by age; the mean hospital costs of surviving casualties rose progressively with advancing age from £4,000 to nearly £11,000 and fatality rates increased from 0.6% to 4%.

For RTCs occurring in 1997 (the group with the longest follow-up period), 71% of hospital admission costs were incurred within the first six months following an RTC and a further 5% in the following year.

5.1.5 Cost of road traffic crashes at safety camera sites

Of all casualties before safety camera installation (Pre SCI), 11.9% were hospitalised and 1.8% were fatal, while 10.5% of casualties after safety camera installation (Post SCI) were hospitalised and 0.5% fatal.

The mean costs for (surviving) casualties admitted to hospital declined by 24% after safety camera installation (£6,200 Pre SCI and £4,742 in the Post SCI group) and the daily cost declined by 55% i.e. costs per day (for surviving hospital casualties) Pre SCI were £8.8 and £3.9 Post SCI.

Daily cost reductions were most marked for pedestrian injuries (56%), lower limb injuries (72%), casualties injured in non-junction RTCs (72%) and two vehicle RTCs (65%).

5.2 Interpretation of results

This section comprises the main findings in light of other research and an interpretation of what these may mean. The section follows the same structure as the section "main results" 5.1 and endeavours to refer to all findings presented there.

5.2.1 Epidemiology of road traffic casualties in Strathclyde region

A reduction in RTC frequency is currently expected in high-income countries [15]. This study is in line with those predictions and confirms that there has been a significant general decline in RTC casualties over the nine year study period. Comparing the first three years with the last indicates a reduction of 18% in all STATS19, 38% in killed and seriously injured (KSI) STATS19 and 21% in SMR01 records. The possible reasons for the difference in KSI and SMR01 are discussed further later in this section.

Similar to other studies [27,33,83] the results showed that young people made up the largest proportion of casualties but have a low fatality rate. Older casualties, on the other hand, were more likely to sustain more severe injuries that required hospitalisation or resulted in fatalities.

More males than females had a fatal outcome of an RTC injury which both confirms [3] and contradicts published results [83,84]. One study found that especially females aged 20-35 would be more at risk of a fatal outcome compared to males while findings presented here show the opposite, but this could be due to study design e.g. they were estimating risks including controlling for seatbelt use etc while this study suggests the proportions of fatalities of injured casualties (i.e. the risk of a fatal outcome when e.g. not wearing seatbelt may be higher for females, but perhaps more females wear seatbelts hence resulting in more females than males surviving).

Similar to previous findings [87], severe injuries appeared to be more likely for less protected road users i.e. pedal cyclists, pedestrians and occupants of motorbikes and mopeds. Occupants of motorbikes and mopeds were also at highest risk of dying, probably reflecting a combination of high speed and being relatively unprotected.

Type of road user was also correlated with injury type, where head injuries were common among pedestrians and pedal cyclists and knee and lower leg injuries sustained foremost by pedestrians and occupants of motorbikes/mopeds. Car occupants, on the other hand were more likely to suffer injuries to the thorax and abdomen/lower back/lumbar spine. This is in line with other research [34,88,90,91] and is likely to reflect different circumstances in terms of speed and protection.

Collisions produced, on average, less severe injuries than non-collisions (both in terms of hospitalised and fatal casualties), but these results may vary by, for example, road user. Deprivation appeared to have had no effect on severity at this level of descriptive analysis, but is discussed further in relation to road user in Results section 4.3.1.4 and Discussion section 5.2.4.

5.2.2 Accuracy of police reported road traffic casualties

Underreporting of road traffic casualties in police records has been well documented (see further section 1.4) and relying only on police data of road traffic crashes may therefore be misleading [106-110]. A specific cause for concern is the reporting of casualty severity by police forces and it is thought that injuries labelled as serious are particularly underreported. For that reason, part of the general epidemiological analysis of the study was undertaken to investigate the extent of possible underreporting of casualties due to road traffic crashes (RTCs) in Strathclyde region.

The results suggest a consistent underreporting in police road casualty data of around 45%. This is a similar figure to that reported in previous studies linking emergency department or hospital data with STATS19 data [103,118,131].

There are numerous possible reasons why a proportion of total casualties are unrecorded in STATS19 by the police. For example, when only the driver is injured and the only damage caused is to their vehicle, there is no legal requirement to report an RTC. Underreporting, however, seems to occur particularly apply in RTCs involving motorcycles or pedal cycles when no other vehicles are involved. This could be because road users may regard police reports as being necessary only when insurance claims arise. This hypothesis is consistent both with the findings in this study and those of other studies [104,105,109,115,116]. Additionally, the results showed that age, gender, year of RTC and length of stay in hospital were significantly associated with underreporting. Road users driving under the influence of alcohol or drugs, driving stolen vehicles or driving with no insurance, driving licence or MOT (roadworthiness certificate) were also less likely to bring their RTC to the attention of the police, in particular if no other vehicle was involved. Casualties who leave the RTC site without giving their details to police or other people in the incident are not recorded. In theory police forces should update the severities of casualties on the reports but in practise do not always do so. There appears to be no system for healthcare professionals to update police officers about changes in severity e.g. the police may not be aware that a casualty has subsequently been admitted to a ward and therefore should be labelled as "serious". Lastly, there may be a recording problem with patients admitted to hospital that fraudulently claim to have been involved in an RTC or exaggerate the injury symptoms, possibly to obtain compensation or to obscure the real reason for their injuries.

As matching links of casualties from neighbouring health boards also were included (4%, i.e. 444 out of 10,005 hospital admissions – excluding immediate deaths), there would also be a proportion of unlinked SMR01 records that had a matching STATS19 record in a neighbouring police force too. Consequently, if an equal number of SMR01 records in Strathclyde matched a STATS19 elsewhere, the actual proportion of RTC SMR01 records that were not recorded by the police would be 43% rather than 45%.

In terms of casualty severity, these results are in agreement with those of Gill et al [114] implying there has been an increase over time in the underreporting by the police of serious casualties. Seriously injured STATS19 casualties declined in frequency more than the SMR01 would indicate. There are several potential explanations for this (of which some also were highlighted by the Department for Transport [186]).

Firstly, there may have occurred a true, disproportionate fall in the number of serious casualties caused by RTCs, but as the reduction was not reflected in the number of fatal injuries or total injuries in SMR01 this seems improbable. Alternatively, public reporting of serious RTCs (as in public reporting to the police) or the proportion of less severe casualties being treated in emergency departments may have declined. There is, however, little evidence in favour of either explanation. Hospital admission policies, such as a rise over time in hospital admissions of less severe road casualties, may have occurred as there was some evidence of an increase in A&E admissions in Glasgow in earlier years [187]. Hospital reporting of casualties may have changed over time but the same reporting standards have been used in Scotland for decades and the completeness of SMR data are audited regularly in terms of coding and accuracy with consistent results over time [188].

Perhaps the most likely explanation is that some types of casualty, formerly recorded by the police as severe, were in the later study years recorded as slight (i.e. a shift in police judgement of casualty severity). In the light of the length of stay analysis these casualties may, to a large extent, be those with a head or neck injury. The hospitalised casualties with injuries to hand/wrist or ankle/foot also seem more likely to have been coded slight in later years.

5.2.3 Epidemiological impact of safety cameras

As indicated in section 1.7.3, previous evaluations of speed cameras have found that they contribute to reducing the incidence of RTCs [150-156], fatalities and injuries[158-160], although so far the evidence is not conclusive [161]. There appear to be no studies that have reported the epidemiological impact or the type of crashes that are influenced by cameras. Such information could help in the future deployment of cameras where they are likely to exert the greatest effect on RTC rates.

This component of the study was designed to compare the pattern and types of RTCs before and after the installation of the cameras in the Strathclyde region and to quantify their effectiveness in reducing the incidence and severity of associated casualties.

Analysis included a large-scale epidemiological evaluation of the impact of safety cameras on the incidence, severity and type of RTCs in a high-risk region of the United Kingdom for fatal and serious road casualties [16]. The findings, in keeping with those of others [154,155,189], suggest that safety cameras have contributed a substantial reduction in the incidence of RTCs and especially of serious injury RTCs [158,159]. The results of the present study show a significantly greater downward linear time trend at the camera sites compared to the rest of Strathclyde. The findings have, in addition, enhanced understanding of which types of crashes the cameras have impacted most upon, and where cameras might be most effectively located in the future.

Before camera installation, the RTC epidemiology at camera sites did not differ significantly from the remainder of Strathclyde region. The main difference was that camera sites had, overall, more RTCs in which someone was killed or seriously injured. This confirms that the selection method of sites was related to RTC severity. There also appeared to be more multiple vehicle RTCs (three or more vehicles) at camera sites Pre SCI than the remainder of Strathclyde.

The findings indicate that cameras were effective in reducing the incidence of fatal and serious RTCs at camera sites. This was especially true with RTCs involving multiple casualties and vehicles. Cameras also appeared to have a greater effect on non-junction RTCs than on those occurring at junctions. Somewhat counterintuitively, the effectiveness of cameras in reducing RTC rates did not appear to diminish over time.

Although the installation criteria based on speed and severity of RTCs seem appropriate and effective, the addition of other indicators (e.g. rates of non-junction and multiple vehicle RTCs on sites) might aid the future selection of camera sites and enhance the impact of cameras further.

5.2.4 Cost of road traffic crashes in Strathclyde region

As discussed in section 1.5, little is known about the long-term health and economic consequences of RTCs, and the financial costs are probably greatly underestimated [190].

The purpose of this part of the study was to provide an economic analysis of the costs attributable to hospitable admissions due to road traffic crashes in the Strathclyde region of Scotland.

The total cost of inpatient and day surgery treatment following RTC in Strathclyde police area was conservatively estimated at £7.3 million per year (excluding the unlinked SMR01 records).

Extremely high costs were incurred by injuries to the lower extremities (hip/thigh and knee/lower leg) and head injuries, compared to other injuries (34% and 28% of total costs respectively), which is consistent with estimates from Australia (33% and 27% respectively) [136] and the USA [137].

Pedestrians are a vulnerable group of road users and, although only constituting 36% of hospitalised RTC casualties (and 20% of total injured casualties), they incurred 44% of total hospital costs (for survivors). By contrast, a study from New Zeeland showed that pedestrians, comprising 10% of hospitalised RTC casualties, incurred 18% of total costs [138]. In the study, fatality rates for pedestrians were about double those of other injured road users (2.3% compared to 1.3% of drivers/riders and 0.8% of passengers).

Unsurprisingly, drivers of motorcycles/mopeds had the highest mean cost, probably reflecting the speed and vulnerability of these road users.

Both posted speed limit and junction context had an effect on RTC outcome, but this varied by type of road user. All road users, but especially pedestrians, had increasingly poorer outcomes with higher posted speed limits (with higher rates of fatal results). Predictably, non-junction RTCs were worse for drivers and passengers than junction RTCs, but appeared to make no difference for pedestrian casualties.

Casualties from deprived areas, and pedestrians in particular, incurred higher mean hospital costs reflecting more severe injuries. The mean cost for drivers was highest for the most affluent SIMD group while lowest for the passengers in the same group. It is possible that there is a varying degree of utilisation of passenger seatbelt and child car seats in different SIMD groups. In future analyses, exploring the interactions between age, gender (e.g. young male driver) and deprivation variables together with numbers of casualties in a vehicle (e.g. whole family or single driver injury) might yield further insights into this finding.

In terms of age, the youngest and oldest groups had the highest admission rates, possibly reflecting their predominance as pedestrians. The vulnerability to injury by age is revealed by both the mean hospital costs and fatality rates, the highest of which was found in the oldest age group.

Only 71% of hospital admission costs were incurred within the first six months following a RTC (for RTCs occurring in 1997) and a further 5% in the following year. The remaining costs arise from admissions for the period between 1.5 and nine years post RTC. It may therefore be reasonable to increase the estimate of the full hospital costs accordingly.

The Department for Transport [134] has estimated a cost of serious injury of about £155,000, including medical/ambulance costs of £11,000 (for 2004). The estimate for hospital costs was only £6,000 – only about 4% of the total estimated costs.

In summary, the results show the uneven burden of suffering and costs of RTCs with the most costly RTCs occur in areas with high levels of deprivation, a history of pedestrian RTCs and/or elderly and children, areas with many non-junction RTCs and 30 mph roads.

5.2.5 Cost of road traffic crashes at safety camera sites

The mean costs and costs per day appeared to decline in most categories for both casualties and RTCs. The daily hospital cost for the sites declined by over half Post SCI.

There also appears to have been a shift in severity in the proportions so that of all injured in the Post SCI group, 11% were hospitalised or fatal while this proportion was 14% in the Pre SCI group i.e. casualties were more likely to be severely or fatally injured Pre SCI than Post SCI.

There appears to have been a reduction in pedestrian hospitalised injuries (for which the daily cost declined by 56%) although the mean cost for an hospitalised pedestrian appeared similar to Pre SCI. The overall mean casualty hospital cost for casualties declined by 24% for all road users, suggesting that the admitted casualties were less severely injured (shorter length of stay and, as a result, lower cost).

The mean costs appears to have declined most for lower limbs (and upper limbs, but these were very small numbers) indicating that perhaps cameras aid in reducing the severity of crashes causing these type of injuries. The cost per day was also greatly reduced for the upper limb category.

In line with previous findings, safety cameras appeared to have a greater impact on non-junction RTCs compared to junction RTCs. As the mean cost for hospitalised (surviving) casualties declined by over 50% it is possible that cameras encouraged slower speeds that in turn resulted in fewer severe injuries. The impact of speed in relation to injury severity is well documented [51,83,92,93] i.e. the higher the speed the more severe injuries. As the daily costs also declined (-72% for non-junction crashes), this too may reflect lower speeds and fewer RTCs.

The costs of hospitalisation in RTCs with two vehicles involved declined both in mean cost per RTC and cost per day. This could indicate that these types of crashes were both less severe and less frequent Post SCI.

The Department for Transport (DfT) [134] has estimated a cost of serious injury of about £155 thousand, including medical/ambulance costs of £11 thousand (for 2004). The mean casualty hospital costs in this study were estimated at only £6 thousand Pre SCI and £5 thousand Post SCI – about 3-4% of the DfT total estimated costs. If a rough estimate was made using DfTs approximation, the cameras may have contributed to the savings as follows: 139 seriously injured casualties (hospitalised) in the Pre SCI period would cost £21,545,000 (applying DfT costing estimate) over 98,717 days (= daily rate £218.5) and in the Post SCI period 46 seriously injured would cost £7,130,000 over 55,725 days (= daily rate £127.9). If the daily cost rate of the casualties injured during Post SCI period was the same as for the Pre SCI period, the total costs would have been 12,161,989 for that period, which in turn is a saving of £5,031,989. This is considering the limited Post SCI period only and no fatal or slight injury costs.

Estimating cost-benefits of safety cameras require further investigation, particularly into the additional costs of slight injuries and surrounding costs incurred by RTC (these are thought to be substantial, see further strengths and weaknesses). However, given that the mean costs of crashes were reduced by over half for hospitalised casualties and over a third for total casualties, it is possible that cameras are cost-beneficial, appearing to reduce both the severity and frequency of RTCs. These results, together with previous findings that indicate that cameras do not lose effect over time, may be useful indicators for further econometric analyses.

5.3 Strengths and weaknesses of study

The section begins with strengths including validity of data sources and linkage discussing the two main sources of data (STATS19 and SMR01) and the rate of false positive and false negative as calculated by ISD. This is followed by a discussion of the merits of the sample size and follow-up admissions. The section ends with a discussion of weaknesses including regression to the mean.

5.3.1 Strengths

The study is overall relatively unique and considering the difficulties incurred in the first years of study the achievements are substantial. There is, however, considerable scope for continuing analysis with the data and this is discussed further in section 5.6.1.

5.3.1.1 Validity of data sources and linkage

The two main data sources utilised in this study are problematic when analysed separately. The linked database, however, provides a much more solid basis for analysis. STATS19 has been utilised as a recording system in its current format since 1979 and nearly all road traffic crash statistics are derived from this source. STATS19 is, however, known to underascertain some categories of RTCs, mainly those associated with injuries involving pedestrians, motorcyclists and pedal cyclists [115,116], a finding that was confirmed in this study. Additionally, the reliability of police severity judgement is questionable. Utilising linked hospital and police RTC data is much preferable in analysing RTCs as the SMR01 system h is one of the first and most complete national health data sets in the world [171].

ISD had previously performed several linkages and the method of linkage used had in the past been shown to have 3% false positive and 3% false negative rates [183]. The linkage used a range of variables for matching and, according to ISD, crude estimates indicate that the false negative rate was 2.6% - i.e. 2.6% (1,802) of the unlinked STATS19 records were missed links (i.e. should have been linked). On the other hand, a crude estimate of the false positive rate was 15.6% - i.e. 15.6% (1,607) of the linked STATS19 records were false positives (i.e. should not have been linked). As a result, the number of missed linked records was nearly compensated for by the number of incorrectly linked records.

5.3.1.2 Size of sample and follow-up admissions

The data included the full (recorded) RTC population of Strathclyde region and the study period was extensive, which together enhanced statistical power.

An unusual feature if the linked database was its inclusion of follow-up admissions. This especially improved the cost analysis, but also provided a greater understanding of the severity of RTC in terms of total length of hospital stay and how hospital admissions, related to the RTC, continued over many years.

5.3.1.3 Regression towards the mean

Among the advantages of the relatively long study period of is that regression towards the mean (RTM) and random fluctuations should have been The time periods before camera installation ranged from 2 to 7 years, depending on when the cameras were installed. Thus any random large peaks in RTCs should have been smoothed out. RTM could, however, still play a role, but probably not sufficient to invalidate the findings that cameras are effective in reducing RTC.

5.3.2 Weaknesses

5.3.2.1 Before and after study

The foremost weakness of this study is that it used a before-and after evaluation design rather than the more robust methodology of a randomised controlled trial (RCT). An RCT is, however, difficult to perform in the field of public policy and was not an option at the time this study was initiated, particularly as the cameras were mostly already installed. Before and after studies may suffer from several problems such as data artefacts (such as changing classification of severity), statistical error (due in part to small sample sizes), bias (e.g. the police expect cameras to be effective) or confounding variables (such as safer vehicles or better designed roads).

5.3.2.2 Retrieving the data

A key weakness of this study was that the procedure to attain the linked data was rather prolonged and the author faced several difficulties in achieving this. The consequence was that some analyses had to commence using STATS19 only. This especially affected the evaluation of safety cameras.

There were limited data available on RTCs and its consequences. No routine data from emergency departments currently exist, nor records from primary care or outpatient hospital care. Additionally, data from social security, employers or insurances would be desirable in order to provide an insight in to sick leave and economic consequences.

5.3.2.3 Validity of data sources and linkage

Although the method utilised for linkage previously has shown to have 3% false positive and 3% false negative rates [183], this linkage may, due to the limited identifying information available, , not have achieved such accuracy. Thorough clerical checking of a large sample of best matching pairs at a wide range of probability weights was, however, completed by ISD.

There was also a potential bias in that matching links of casualties from neighbouring health boards was performed. Hence, there might have been a proportion of unlinked SMR01 records that had a matching STATS19 record in a neighbouring police force (but not linked in the study). Consequently, the estimated underrecording was likely to be 43% rather than 45% (see section 5.2.2).

There may have been errors relating to the decision process of including follow-up admissions as there was no way of knowing whether or not an admission was related to the initial RTC. The inclusion period, however, was limited to 1.5 years post RTC for cost and LoS analysis and care was taken when including admissions beyond six months post RTC i.e. only admissions close in time or related statistically to the injury at admission were included (see further section 3.4.2.2).

5.3.2.4 Errors related to analyses and results

In analysing costs and safety cameras, the data were not population based. Comparing the mean costs, however, provides reasonable estimates of the severity and cost and for the camera analyses daily rates were utilised instead.

All cost estimates in the study are likely to be extremely conservative for several reasons. Firstly, the costs presented were only incurred by acute hospital treatment; no outpatient, GP, ambulance or other health service resources were included. Large costs are also likely to have been incurred by loss of work (lost output), property damage, insurance and human costs, none of which were accounted for. Secondly, most of the analysis was limited to the first 1.5 years admissions post-RTC, for ease of comparison (probably including less than 76% of hospital costs, see results section "costs over time"). Lastly, unlinked SMR01 RTCs were not included as data on follow-up admissions were unavailable. As they comprised 45% of total traffic related hospital admissions, the costs presented here may therefore be substantially underestimated.

The safety camera cost analysis was limited to include only the first six months' admissions post-RTC, which means some acute costs were not included. The number of hospitalised casualties and RTCs in this part of analysis is not very high and some random effects could possibly have occurred e.g. regression towards the mean. However, long term means (daily rates of injury costs over several years) were utilised so the impact of RTM should have been minimised [154], as discussed earlier in this section.

5.4 Implications

The structure follows a similar pattern to previous section beginning with epidemiological findings (point 1) followed by accuracy of data (point 2-3), safety camera impact (4-5) and cost implications (6-7). The section ends with a suggestion as to how all analyses could be improved: routinely linking police and hospital records by adding geographical information to SMR01 (point 8).

1. Estimates show that about 89,000 people were injured on Strathclyde's roads over a nine year period and of these about 22% (over 19,000) were fatal casualties or casualties that required hospital admission. The results show that, in line with previous findings, young people make up the largest proportion of total casualties while older casualties were more likely to die from a road traffic crash. Furthermore, less protected road users were more likely to suffer severe injuries (especially occupants of mopeds and motorcyclists) and head injuries were more common among pedestrians and pedal cyclists. Although a decline of about 18-21% occurred over the study period the results should inform policy makers that road traffic crashes continue to play a major role in disability and premature death and should remain a high priority. Insights from the study could further help direct resources towards the most vulnerable in traffic: older and younger people, deprived areas and pedestrians.

2. There has been a considerable decline in seriously injured casualties according to police reports, but hospital records did not show the same reduction. The results from this study show that the decline in serious injuries probably was caused by an increasing tendency, over time, for police officers to report injuries as slight rather than serious. These findings have implications for road safety policy in Scotland, and perhaps the UK as a whole, and should inform the future collection, interpretation and utilisation of road casualty statistics. In particular, government should re-assess the current achievements against the national targets for 2010 (see section 1.6 for details) which are based solely on police STATS19 data [191]. Additionally, the national safety camera programme also relies heavily on the completeness and accuracy of police data - especially fatal and seriously coded

RTCs - in order to site cameras at casualty “blackspots”. An overhaul of police RTC recording practices is needed.

3. Nearly half of all road traffic casualties that are admitted to hospital are not recorded by police. This means that there are thousands of injuries potentially missing from the databases of the police, local authorities and trunk-route operators who rely on STATS19 information to target dangerous sites for remedial measures such as new road layouts or traffic calming. There are some RTC casualty categories that are more likely than others to be missed by police including situations where no other people were involved in the incident, pedal cyclists and motorbike occupants or older people and females. Missing these road users could have implications for the targeting of road safety education by public agencies and road safety groups. It is very important to take these findings into account in various situations, but especially when updating national statistics and assessing achievement of national targets (as also discussed in the previous section). Finally, the Government’s estimates of the total cost to society of not preventing RTCs will need to be radically revised [16,191].

4. Safety cameras have been installed over several years to remedy RTC prone stretches of road. There have been many studies showing that speed cameras probably contribute in reducing the incidence and severity of RTCs. The results from this study support earlier findings with the addition that the effect is sustained over time. Consequently, safety cameras should continue to play a major part in RTC prevention policies and expansion should be considered.

5. Safety cameras are one of several initiatives to reduce road traffic crashes and are placed on stretches of roads with a history of many RTCs. In order to achieve the most RTC reduction from the cameras, site selection criteria are based on average speeds and incidence and severity of RTCs. This study supports these selection

criteria in that the cameras appeared to be effective both in reducing frequency and severity of RTCs. The results also suggest that cameras may be effective in reducing crashes that are not in the vicinity of a junction and crashes that involves more than two vehicles. Using this information when selecting camera sites may therefore enhance the impact of cameras further. It could be taken into account at the next revision of safety camera regulations or could be considered, more informally, as additional selection criteria should there be too many sites qualifying for a safety camera.

6. The most costly RTCs occurred in areas with a history of pedestrian RTCs and/or elderly and child casualties, high levels of deprivation, areas with many non-junction RTCs and 30 mph roads. Pedestrian casualties hit on 30mph roads made up about 40% of total hospital costs (over £22 million); over half of this (£12 million) was incurred by (pedestrian) casualties from the most deprived areas; two thirds of these costs (£8 million) were sustained by the youngest and oldest casualty age-groups. Consequently, considering cost impact and size of different road casualty groups it would be advisable to evaluate current policies and practices in pedestrian traffic injury prevention, particularly in deprived areas with large elderly and child populations. Using a fuller data set (as suggested in the next paragraph) in detecting traffic injury black-spots, could aid in identifying where, geographically, current gaps in road safety exist.

7. The results indicate that cameras are cost-effective and that (up to the end of this study) may have saved over £5 million using a calculation based on Department of Transports estimates. The Safety Camera Partnership should utilise these findings further weighing camera costs against the calculated savings in a cost-benefit evaluation.

8. To further improve the quality of information relating to road casualties, the first step would be to assess current police recording practices. Thereafter, the feasibility of routinely linking road casualty data derived from police and hospitalisation databases should be assessed. This could progress by adding geographical information to RTC hospital data (which should be feasible during a casualty's hospital stay). Knowing where all RTCs occurred would both enhance the quality of the linkage between police and hospital data and identify where hospitalised RTC casualties (that were not reported to or by the police) took place. Finally, the database could be updated over time with follow-up hospital admissions linked to the initial admission (by, for example, using the suggested method of inclusion). This would allow for costs to be routinely attached in a similar manner as for this study. The ideal would, obviously, be to also include RTC and emergency information in such a database, but to date s no routinely collected emergency department data are available. Consequently, by only adding geographical information to the hospital RTC casualty records there is potential to achieve a more or less complete RTC database and to utilise it in a variety of settings - from informing road safety policies to locating and evaluating interventions.

5.5 <u>Unanswered questions</u>

Questions relating to the RTC epidemiology:

1. What are the consequences of slight and serious RTC injuries, including analysis of long-term effects (including analysis of primary care data)?

Questions related to the accuracy of police recording:

1. Why would the police judgement of casualty severity change over time? This question requires an answer in order to find a remedy to the problem.

2. What are the implications, of police underreporting severe casualties, on the national targets for casualty reduction?

Questions concerning prevention of speed related RTCs:

1. What are the differences between speed cameras and other traffic calming measures in preventing casualties?

2. What are the characteristics of a speed related crash?

3. Are the primary causation factors reliable and can they be utilised in further research?

Questions relating to cost:

1. Where are the sites/areas with the most costly RTCs and where are sites with the highest total costs (adding RTCs in vicinity)?

2. What are the cost benefits of speed cameras, including a full cost analysis of RTC consequences?

5.6 Suggestions for further research

This section is divided in to two parts, namely further research that could extend and/or enhance this study (including addressing weaknesses identified) and secondly, other more general research that could aid in filling the gaps as identified by the unanswered questions.

5.6.1 Suggestions for continuing research on the linked data

5.6.1.1 Study setting

Although the study setting of Strathclyde region includes about one third of Scotland's population it would be sensible to extend a study of this type to the whole of Scotland and this could probably be achieved without too much effort (especially drawing on the experience and expertise from this study). This would provide a source for a full Scottish investigation and supply a data set of use for many types of research in the road traffic crash field.

5.6.1.2 Data sources and linkage

As discussed above, extending the study would aid in an even fuller evaluation. ISD holds all Scotland's SMR01 data and linkage would not have to be restricted by council areas. The Strathclyde Safety Camera Partnership has an ongoing collaboration with the remainder of Scotland, hence retrieving information on other speed cameras would be possible. Retrieving STATS19 including postcodes from every police force in Scotland could prove more difficult. Overall, newer data could be included, which means that a higher level of accuracy of linkage can be expected as more postcodes are available (in STATS19).

It would be desirable to achieve a fuller analysis of thecost implications, even if just by attaching follow-up admissions to the unlinked SMR01 records. DfT costing methodology could be used further including the total estimates and fatal "willingness to pay" cost estimates.

Identifying control sites for the safety cameras would be helpful for a more detailed evaluation of camera effects. This could be achieved through using sites that were part of the selection process but did not qualify for a camera). The "control" sites could be matched in tome time with installation of the "real" safety camera sites (for before after analysis). These sites would provide a satisfactory control group, although not a substitute for a randomised design.

5.6.1.3 Analyses

Analytical approaches could follow more closely a weighting strategy method as developed by Hess & Polak [154] where RTC numbers at camera sites could be "detrended" and "deseasonalised".

Continuing analysis of what effect cameras have on different types of RTCs, injuries and costs, could create a basis for evaluating future widespread impact of safety cameras.

Geographical analysis of RTCs could be performed taking account of cost or other parameters of interest e.g. child casualties. Additionally, it would perhaps be useful to map where, in terms of deprivation, RTCs occur.

5.6.2 Suggestions for other research

There is a range of research that could complement the current study. Here are a few examples that would cover some of the current gaps in road traffic injury research.

5.6.2.1 Epidemiology of road traffic crashes in Strathclyde

Road traffic crashes will continue to be a major burden for the foreseeable future and even though we have come a long way in preventing RTC injuries in the developed world with a steady decline over time, RTCs will continue to increase rapidly in the developing world [1,15]. The RTC injuries investigated is usually only the more serious cases, but these are only a small proportion of total injuries and it would be of great use to add understanding of less serious injuries, as these also have a large impact on human suffering and cost to society.

It is of great importance to continue to support and pursue research into why and to whom RTC happens in order to develop and test appropriate countermeasures.

5.6.2.2 Accuracy of police reported casualties

In the light of the findings from this study there is an urgent need to investigate police judgement of injury severity over time, perhaps using a combination of quantitative and qualitative methods. Additionally, as it appears that the police are not informed of 45% of hospitalised RTC casualties. Research is indicated on to why this is and how it might be remedied. For example, determining the geographical location of the hospitalised casualties that are "missing" in STATS19 would greatly aid in both locating safety cameras and enhance the evaluation of these.

5.6.2.3 Impact of safety cameras

"Primary causation factors" for RTCs in STATS19 have recently been updated and an evaluation of these is required, with special attention to the reliability and usability of the speed related factors. If these turns out to be reliable they could be utilised in future studies of safety cameras.

There is little evidence about the efficacy of speed cameras compared to other types of RTC prevention but this would be useful in deciding on the deployment of preventative measures in the future.

5.6.2.4 Cost of road traffic crashes

The cost of road traffic crashes needs to be expanded to include slight injuries as well as serious because, even though hospitalised casualties have longer disability, the majority of the disability burden is carried by non-hospitalised casualties [74]. It would therefore be desirable to include primary care, hospital outpatient care and social services in national data collection, in a similar manner to the SMR01 and STATS19 recording. In a further step, surveys could be undertaken on sub-samples (e.g. RTC casualties from safety camera sites) in order to assess hitherto unmeasured additional costs to the individual.

5.7 Summary of Chapter 5

This chapter summarises the main findings, interpretation of results, strengths and weaknesses, implications, unanswered questions and suggestions for further research by research strand i.e. epidemiology of road traffic casualties in Strathclyde, accuracy of police reported road traffic crashes, epidemiological impact of safety cameras, cost impact of RTCs in Strathclyde and cost impact of RTCs at safety camera sites.

5.7.1 Epidemiology of road traffic casualties in Strathclyde

- Main results: Young people made up the largest proportion of total casualties, older casualties were more likely to die from an RTC, less protected road users suffered more severe injuries, head injuries were more common among pedestrians and pedal cyclists, while car occupants more often suffered injuries to the thorax and abdomen/lower back/lumbar spine.

- Interpretation: Overall, findings were in line with previous research. Older casualties were more likely to have a worse outcome of RTC because of frailty while younger casualties were protected by their health. Less protected road users were more likely to suffer severe injuries.

- Strengths and weaknesses: The study had a long study period and a large sample, but the linkage may not have been completely robust hence some associations may have been missed.

- Implications: The results should inform policy makers that road traffic crashes continue to play a major role in disability and premature death.

- Unanswered questions: What are the RTC consequences of slight and serious injuries, including analysis of long-term effects (including analysis of primary care data)?

- Suggestion for further research: Adding understanding of less serious injuries would be desirable. Further extending the current study to include all of Scotland and up to date records would be feasible and useful.

5.7.2 Accuracy of police reported road traffic casualties

- Main results: About 45% of hospitalised RTC casualties were not reported in police records. Underreporting was mainly associated with no third party involvement and type of road user (especially pedal cyclists). Casualties coded as seriously injured in STATS19 declined in frequency more than the SMR01 RTC casualties.

- Interpretation: Underreporting of RTC casualties in police records is well known, as is the decline in serious injuries reported by police, and findings from this study support this. Additionally, findings show that there has been an increase in casualties coded slight. Hence there may have been a shift in police judgement of severity over time (for alternative explanations see section 5.2.2 for details).

- Strengths and weaknesses: The study period and sample size were large and provided good statistical power in detecting linear trends etc.

- Implications: Re-assessing the current achievements against the national targets for 2010 (based on STATS19) is necessary. Additionally, the national safety camera programme also relies heavily on the completeness and accuracy of police data in order to site cameras at casualty "blackspots."

- Unanswered questions: Why would the police judgement of casualty severity change over time and what are the implications of police underreporting of severe casualties on the national targets for casualty reduction?

- Suggestion for further research: Investigation of police changing judgement of injury severity over time and why the police are not informed of 45% of hospitalised RTC casualties.

5.7.3 Epidemiological impact of safety cameras

- Main results: Safety cameras appeared to have contributed to a substantial reduction in the incidence of RTCs and especially of serious injury RTCs. Cameras appeared to have impacted most upon non-junction and multiple vehicle crashes, and the reduction were sustained over time.

- Interpretation: Findings were mostly in line with previous research with the addition of what type of crashes cameras are most effective in preventing and that effect appeared sustained over time.

- Strengths and weaknesses: The main weakness of this study was that it did not include a randomised controlled trial and a before and after study design was used instead. It included a relatively long time period (which should minimise the risk of regression towards the mean) and sample size and controlled the RTCs at camera sites against the remainder of Strathclyde region.

- Implications: Safety cameras should continue to play a major part in RTC prevention policies and expansion should be considered.

- Unanswered questions: What are the differences between speed cameras and other traffic calming measures in preventing casualties and costs (including cost-benefit analysis)? What is the characteristics of a speed related crash -are the primary causation factors reliable and can they be utilised in further research?

- Suggestion for further research: A randomised controlled trial of speed cameras and comparing speed cameras with other types of prevention is needed. Determining the geographical location of the hospitalised casualties that are "missing" in STATS19 would aid in both locating safety cameras and enhance the evaluation of these.

5.7.4 Cost impact of road traffic crashes in Strathclyde

- Main results: The total estimated inpatient costs were (conservatively) £7.3 million yearly. The highest costs were incurred by head injuries and injuries to the lower extremities. Hip or thigh injuries incurred the highest mean costs. Pedestrian casualties on 30mph roads incurred a cost of £22 million (40% of total costs); of these £12 million was borne by casualties from the most deprived SIMD quintile

(20% of casualties), of which £8 million was incurred by the youngest and oldest age-groups.

- Interpretation: The results indicate the uneven burden of suffering and costs of RTCs with the most costly RTCs occur in areas with high levels of deprivation, a history of pedestrian RTCs and/or elderly and children, areas with many non-junction RTCs and 30 mph roads.

- Strengths and weaknesses: All cost estimates are likely to be extremely conservative: only costs incurred by acute hospital treatment were included; analysis was limited to include only the first 1.5 years admissions and unlinked SMR01 RTCs were not included as data on follow-up admissions were unavailable.

- Implications: In view of cost impact and size of different road casualty groups it would be desirable to evaluate current policies and practices in pedestrian traffic injury prevention, particularly in deprived areas with high elderly and child populations.

- Unanswered questions: Where are the sites/areas with the most costly RTCs and where are sites with the highest total costs (adding RTCs in vicinity)?

- Suggestion of further research: The cost of road traffic crashes needs to be substantiated with slight injuries as the largest disability burden is carried by non-hospitalised casualties. Including primary care, hospital outpatient care and social services in national data collection would be desirable.

5.7.5 Cost impact of road traffic crashes at safety camera sites

- Main results: Safety cameras in Strathclyde may so far have contributed to a saving of over £5 million and costs per day pre safety camera installation were over double that of the post safety camera installation (£8.8 and £3.9 respectively). Daily cost of non-junction crashes declined with 72%.

- Interpretation: The impact of speed in relation to injury severity is well documented (higher speeds = more severe injuries). As the daily costs declined with 72% for non-junction crashes (i.e. RTCs unaffected by slow speeds required at junctions) this may reflect that safety cameras result in lower speeds and fewer RTCs.

- Strengths and weaknesses: This part of cost analysis was limited to incorporate only the first 6 months admissions post-RTC, hence some acute costs were unaccounted for. The low frequency of hospitalised casualties and RTCs in this analysis may cause some random effects such as regression towards the mean. However, long term means were utilised, so the impact of RTM should be minimised.

- Implications: Safety cameras appear cost-effective and the safety camera partnership should utilise these findings further weighing camera costs against the calculated savings in a cost-benefit evaluation.

- Unanswered questions: What are the cost benefits of speed cameras, including full cost analysis of RTC consequences?

- Suggestion of further research: Including information on primary care, hospital outpatient care and social services through e.g. completing a survey of RTC population on camera sites in order to assess additional costs to the individual.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

Contents of Chapter 6

6.1 Conclusions

1. Young people were the largest group of casualties although they had a low fatality rate. Severity of injury was progressively worse with advancing age and males were more likely to suffer a fatal injury compared to females.

2. Unprotected road users were more likely to sustain severe injuries and head injuries were most commonly suffered by pedal cyclists and pedestrians. Motorcycle/moped occupants were most likely to have a fatal outcome.

3. There has been a general decline in road traffic crashes in Strathclyde region of approximately 18% over the years (comparing the first three years with the last three). Fatalities declined by 7%. Police fatal and serious injuries declined 40% while hospital injuries declined 21%.

4. Although police records indicate that serious injuries declined much more than hospital admissions, a general decline in the completeness of STATS19 is unlikely to have occurred. There appears, however, to have been an increasing tendency over time for police officers to report injuries as slight rather than serious.

5. 45% of hospitalised casualties were not recorded by police. Likelihood of RTC casualty not being recorded by police was associated with no third party involvement, higher age, earlier year of recording, road user (especially pedal cyclists and motorbike/moped occupants), shorter length of hospital stay and females.

6. The evaluation of safety cameras strongly suggests that they were effective in reducing both road casualty incidence and severity and that the reduction in incidence was sustained over time. Cameras thus fulfil an important public health,

as well as law enforcement, function and should continue to play a central role in traffic calming.

7. Cameras appeared effective in reducing RTCs that were not near a junction and/or multiple vehicle RTCs, as well as serious and fatal injury RTCs.

8. The study indicates that the most costly RTCs occured in areas with high levels of deprivation, a history of pedestrian RTCs and/or elderly and children, areas with many non-junction RTCs and 30 mph roads. Pedestrian casualties occurring on 30mph roads made up about 40% of total hospital costs for the period (over £22 million); over half of this (£12 million) was incurred by (pedestrian) casualties from the most deprived SIMD quintile; two thirds of these costs (£8 million) were in the youngest and oldest age-groups.

9. Safety cameras in Strathclyde may so far have contributed to a saving of over £5 million and hospital admission costs per day (for surviving hospital casualties) Pre SCI were over double that of the Post SCI (£8.8 and £3.9 respectively).

10. Linking police and hospital RTC records provides a more comprehensive source for road traffic analysis, both in terms of evaluating time trends and national targets or investigating areas in need of remedial treatment, than any of the sources separately.

6.2 Recommendations

The recommendations are subdivided by professional area of interest i.e. scientists, practitioner and policy makers.

6.2.1 Recommendations for scientists

1. Epidemiological evaluations, similar to this study, with the addition of information from emergency departments, primary care, hospital outpatient care and social security, are required.

2. Further evaluation, probably using qualitative method of study, considering underlying reasons of police severity judgement, is urgently warranted.

3. Evaluation of the relatively new recording of primary causation factors (in STATS19) is required, with special attention to the reliability and usability of the speed related factors.

4. A cost-benefit evaluation using the findings from this study could be performed by the Safety Camera Partnership.

5. A randomised controlled trial of speed cameras or, as a second choice, a quasi-RCT is needed (see section 5.6.1.2).

6. Studies comparing speed cameras with other preventive measures is required, especially evaluations of different types of cameras in varying contexts.

6.2.2 Recommendations for practitioners

1. It would be worthwhile to examine and revise current practices for updating police STATS19 records with hospital admission information.

2. Safety camera installation criteria based on speed and severity of RTCs appears to be effective, but adding further criteria (e.g. rates of non-junction and multiple vehicle RTCs on sites) may enhance the impact of cameras further.

3. It is advisable to evaluate current policies and practices in pedestrian traffic injury prevention, particularly in deprived areas with high elderly and child populations.

4. Using a fuller data set (as in this study) in detecting traffic injury black-spots could aid in identifying where, geographically, current gaps in road safety exists.

6.2.3 Recommendations for policy makers

1. Continuing to battle road traffic crashes is of utmost importance and, although casualty rates in Scotland are comparatively low, policy makers should not be complacent. This should remain high priority in policy making.

2. It is of great importance that the achievements to date, towards the national targets for road traffic crash reduction for 2010, are re-examined in the light of this study (see section 5.2.2).

3. Supporting further research in this field is required. This study has provided a solid platform to continue building on (especially the linked data, see section 5.6.1)

4. Routinely linking hospital and police data should be considered and adding geographical information to the hospital RTC records would greatly enhance research (see section 5.4).

5. An evaluation of expanding routinely collected RTC casualty information to include emergency departments and primary care should be done.

6.3 Summary of chapter 6

- RTC injury incidence in Strathclyde declined over the study period.

- Young and elderly people, as well as unprotected road users, carry a disproportionately great RTC injury burden.

- Many hospitalised RTC casualties were not recorded by police and there appears to have been an increasing tendency over time for police officers to report injuries as slight rather than serious. National (UK) statistics of RTCs should be interpreted with caution in the light of these findings and routinely linking police and hospital data would enhance the quality of RTC casualty statistics.

- The study indicates that the most costly RTCs occur in areas with high levels of deprivation, a history of pedestrian RTCs, elderly and child casualties, roads with many non-junction RTCs and 30 mph speed limits.

- Safety cameras appear effective in reducing both road casualty incidence and severity and the reduction in incidence is sustained over time. Additionally, safety cameras in Strathclyde may have contributed to a saving of over £5 million. Cameras thus fulfil an important public health, as well as law enforcement, function and should continue to play a central role in traffic calming. Studies comparing speed cameras with other preventive measures are required, as are randomised controlled trials where feasible.

- This study has demonstrated the value of utilising multiple data sources in the road traffic injury field.

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APPENDIX

Contents of appendix

I. Published paper

An evaluation of police reporting of road casualties.

Jeffrey S, Stone DH, Blamey A, Clark D, Cooper C, Dickson K, Mackenzie M, Major K.

Inj Prev. 2009 Feb;15(1):13-8.

II. Stats19 data guide

Data Guide

The Department of the Environment, Transport and the Regions (DETR)

Road Accident Data - GB

Variables and Values and Export Record Layouts

December 1999

Record Layouts

Accident Records

Variable	Character Position	Integer /Alpha	Variable Label
ACCYR	1 - 4	(I)	Accident Year (YYYY)
ACCREF	5 - 13	(A)	Accident Ref. No.
1.2	20 - 21	(I)	Police Force Code
A3	22	(I)	Accident Severity
1.5	23 - 25	(I)	No. of Vehicles
1.6	26 - 28	(I)	No. of Casualties
ACCDAY	29 - 30	(I)	Accident Day
ACCMTH	31 - 32	(I)	Accident Month
A7	33	(I)	Day of Week
A8H	34 - 35	(I)	Hour of Accident
A8M	36 - 37	(I)	Minute of Accident
1.10	38 - 40	(I)	Local Authority
A10	41 - 45	(I)	Location - Easting
A11	46 - 50	(I)	Location - Northing
1.12	51	(I)	1st Road Class
1.13	52 - 55	(I)	1st Road Number
1.14	56	(I)	Road Type
1.15	57 - 59	(I)	Speed Limit
1.16	60 - 61	(I)	Junction Detail
1.17	62	(I)	Junction Control
1.18	63	(I)	2nd Road Class
1.19	64 - 67	(I)	2nd Road Number
1.20A	68	(I)	Pedestrian Crossing - Human Control
1.20B	69	(I)	Pedestrian Crossing- Physical Facilities
1.21	70	(I)	Light Conditions
1.22	71	(I)	Weather Conditions
1.23	72	(I)	Road Surface Conditions
1.24	73	(I)	Special Conditions at Site
1.25	74	(I)	Carriageway Hazards
1.26	75	(I)	Place Accident Reported

Vehicle Records

Variable	Character Position	Integer /Alpha	Variable Label
ACCYR	1 - 4	(I)	Accident Year (YYYY)
ACCREF	5 - 13	(A)	Accident Ref. No.
2.4	14 - 16	(I)	Vehicle Ref. No.
2.5	20 - 22	(I)	Vehicle Type
2.6	23	(I)	Towing and Articulation
2.7	24 - 25	(I)	Vehicle Manoeuvre
V7	26	(I)	Compass Point - From
V8	27	(I)	Compass Point - To
2.9A	28	(I)	Vehicle Location - Road
2.9B	29 - 30	(I)	Vehicle Location - Restricted Lane/Away from Main Carriageway
2.10	31	(I)	Junction Location At Impact
2.11	32	(I)	Skidding/Overturning
2.12	33 - 34	(I)	Hit Object In Carriageway
2.13	35	(I)	Vehicle Leaving Carriageway
2.14	36 - 37	(I)	Hit Object off Carriageway
V15	38	(A)	Vehicle Prefix/Suffix Letter
2.16	39	(I)	1st Point of Impact
2.17	40 - 42	(I)	Other Vehicle Hit-Ref No.
V24	43 - 44	(I)	Combined Damage
V25	45	(I)	Roof/Underside Damage
2.21	46	(I)	Sex of Driver
2.22	47 - 48	(I)	Age of Driver
2.23	49	(I)	Breath Test
2.24	50	(I)	Hit and Run

Casualty Records

Variable	Character Position	Integer /Alpha	Variable Label
ACCYR	1 - 4	(I)	Accident Year (YYYY)
ACCREF	5 - 13	(A)	Accident Ref. No.
3.4	14 - 16	(I)	Vehicle Ref. No.
3.5	17 - 19	(I)	Casualty Ref. No.
3.6	20	(I)	Casualty Class
3.7	21	(I)	Sex of Casualty
3.8	22 - 23	(I)	Age of Casualty
3.9	24	(I)	Severity of Casualty
3.10	25 - 26	(I)	Pedestrian Location
3.11	27	(I)	Pedestrian Movement
3.12	28	(I)	Pedestrian Direction
3.13	29	(I)	School Pupil
C13	30	(I)	Seat Belt Usage (1979 - 1993)
3.15	31	(I)	Car Passenger
3.16	32	(I)	Bus or Coach Passenger
C16	33 - 35	(I)	Casualty Type

III. Scottish Morbidity Records 01 and General records office Scotland mortality codes

LINKED SMR1/SMR4/SOCRATES/GRO DEATH CATALOG **01B**

COPPISH SMR01 Discharges April 1997 onwards (Linked Catalog Layout)

File Source: **ASCII (SDF)**
File Location: **Unix Server: \\zippy/conf/linkage**
Contact: **Kevin McInneny, James Boyd**

Position From	Position To	Field Name	Size	Description/Format/Values
1	8	Personal Identifier	8	Link number
9	16	Date of admission	8	CCYYMMDD
17	24	Date of discharge	8	CCYYMMDD
25	27	Record type	3	01B = SMR01 record 1997 Q2 onwards
28	35	Accession number	8	Numeric
36	43	Unique record identifier	8	Numeric
44	47	Surname soundex code	4	Alpha-numeric in the format ANNN
48	51	Maiden name soundex code	4	Alpha-numeric in the format ANNN
52	55	Common unit code	4	Integer
56	61	One pass link weight (score)	6	Real number
62	62	Sort marker	1	
63	70	Date of linkage	8	CCYYMMDD
71	78	Date last amended	8	CCYYMMDD
79	81	Continuous inpatient stay	3	
82	82	Summarised admission code	1	
83	83	Summarised discharge code	1	
84	100	**Filler**	17	Reserved for future MRL use
101	105	Sending location	5	Alpha-numeric in the format ANNNA
106	116	Episode record key	11	
		Patient ID Data :-		
117	136	Surname	20	
137	156	1st forename	20	
157	176	2nd forename	20	
177	196	Previous surname	20	
197	204	Date of birth	8	CCYYMMDD
205	205	Sex	1	1=male, 2=female
206	206	Marital status	1	
207	216	CI/CHI number	10	
217	226	NHS number	10	
227	230	Health records system identifier	4	
231	240	Patient identifier	10	Case reference number - Alpha numeric
241	250	Alternative case reference number	10	
251	258	Postcode	8	
259	260	Ethnic group	2	
261	266	GP practice code	6	
267	274	Referring GP/GDP GMC number	8	Can be alpha numeric
		Episode Management Data :-		
275	284	Care package identifier	10	
285	289	Location	5	Alpha-numeric in the format ANNNA
290	292	Specialty	3	
293	293	Specialty local code	1	
294	295	Significant facility	2	Alpha numeric
296	298	Clinical facility – start	3	Alpha numeric
299	301	Clinical facility – end	3	
302	309	Consultant/HCP responsible for care	8	Can be alpha numeric

Page 1 of 3

Position From	Position To	Field Name	Size	Description/Format/Values
310	310	Manage of patient	1	
311	311	Patient category	1	
312	316	Provider code	5	Code in the format AAANN
317	321	Purchaser code	5	
322	327	Serial number	6	
328	333	GP referral letter number	6	Numeric
334	334	Waiting list guarantee exception code	1	
335	342	Waiting list date	8	CCYYMMDD
343	350	Admission date	8	CCYYMMDD
351	351	Waiting list type	1	
352	353	Admission type	2	
354	355	Admission reason	2	Alpha numeric
356	357	Admission/transfer from	2	Alpha numeric
358	362	Admission/transfer from – location	5	Alpha-numeric in the format ANNNA
363	370	Ready for discharge date	8	CCYYMMDD
371	378	Discharge date	8	CCYYMMDD
379	380	Discharge type	2	
381	382	Discharge/transfer to	2	Alpha numeric
383	387	Discharge/transfer to – location	5	Alpha-numeric in the format ANNNA
General Clinical Data:-				
388	393	Main condition	6	ICD10
394	399	Other condition 1	6	ICD10
400	405	Other condition 2	6	ICD10
406	411	Other condition 3	6	ICD10
412	417	Other condition 4	6	ICD10
418	423	Other condition 5	6	ICD10
424	427	Main operation - A	4	OPCS4
428	431	Main operation - B	4	OPCS4
432	439	Date of main operation	8	CCYYMMDD
440	447	Clinician responsible for main operation	8	Can be alpha numeric
448	451	Other operation 1 - A	4	OPCS4
452	455	Other operation 1 - b	4	OPCS4
456	463	Date of other operation 1	8	CCYYMMDD
464	471	Clinician - other operation 1	8	Can be alpha numeric
472	475	Other operation 2 - A	4	OPCS4
476	479	Other operation 2 - B	4	OPCS4
480	487	Date of other operation 2	8	CCYYMMDD
488	495	Clinician - other operation 2	8	Can be alpha numeric
496	499	Other operation 3 - A	4	OPCS4
500	503	Other operation 3 - B	4	OPCS4
504	511	Date of other operation 3	8	CCYYMMDD
512	519	Clinician - other operation 3	8	Can be alpha numeric
520	549	**Filler**	520	
Additional back-mapped fields :-				
550	550	Inpatient/day case marker	1	Alpha numeric
551	552	Old specialty code	2	
553	553	Old type of admission code	1	
554	554	Deprivation category 5	1	
555	555	Deprivation category 7	1	
556	557	Numeric health board code	2	
558	558	Waiting time code	1	

Position From	Position To	Field Name	Size	Description/Format/Values
559	565	7 character postcode	7	Postal Sector 559-563
		Derived Data :-		
566	566	HB of residence cypher	1	Character
567	568	Local Government District	2	
569	578	Grid reference	10	
579	579	Catchment area	1	
580	581	Local Government Region	2	
582	584	Ward code	3	
585	586	New town code	2	
587	587	Urban/Rural code	1	
588	592	Pop locality	5	
593	598	Enumeration district	6	
599	600	Local council area	2	
601	602	Parliamentary constituency	2	
603	605	Age in years	3	
606	609	Age in months	4	
610	614	Days waiting	5	
615	619	Length of stay	5	
620	622	HRG	3	
623	623	Postcode query ind	1	
624	624	Error flag	1	0 = No, 1 = Yes
625	625	Query flag	1	0 = No, 1 = Yes, 2 = Amended
		Processing History :-		
626	631	Batch number	6	
632	635	Batch sequence number	4	
636	641	Version number	6	
642	649	Date record inserted	8	CCYYMMDD
650	657	Date last amended	8	CCYYMMDD
658	658	Delete flag	1	
659	659	Accredited flag	1	
660	660	Processing site	1	
661	665	Input provider	5	
666	671	Date (of discharge)	6	MMCCYY

IV. ICD 10 codes

ICD 10 injury codes and external codes utilized in the study
Retrieved from WHO website:
http://apps.who.int/classifications/apps/icd/icd10online/

Injury, poisoning and certain other consequences of external causes
(S00-T98)

S00-S09 Injuries to the head
S10-S19 Injuries to the neck
S20-S29 Injuries to the thorax
S30-S39 Injuries to the abdomen, lower back, lumbar spine and pelvis
S40-S49 Injuries to the shoulder and upper arm
S50-S59 Injuries to the elbow and forearm
S60-S69 Injuries to the wrist and hand
S70-S79 Injuries to the hip and thigh
S80-S89 Injuries to the knee and lower leg
S90-S99 Injuries to the ankle and foot
T00-T07 Injuries involving multiple body regions
T08-T14 Injuries to unspecified part of trunk, limb or body region

External causes of morbidity and mortality
(V01-Y98)

- V01-X59 Accidents
  - V01-V99 Transport accidents
    - V01-V09 Pedestrian injured in transport accident
    - V10-V19 Pedal cyclist injured in transport accident
    - V20-V29 Motorcycle rider injured in transport accident
    - V30-V39 Occupant of three-wheeled motor vehicle injured in transport accident
    - V40-V49 Car occupant injured in transport accident
    - V50-V59 Occupant of pick-up truck or van injured in transport accident
    - V60-V69 Occupant of heavy transport vehicle injured in transport accident
    - V70-V79 Bus occupant injured in transport accident
    - V80-V89 Other land transport accidents
    - V90-V94 Water transport accidents
    - V95-V97 Air and space transport accidents
    - V98-V99 Other and unspecified transport accidents

V. The Scottish record linkage system

Selected parts of the paper on The Scottish Record Linkage System. No author is stated, but the full paper is online at

http://www.isdscotland.org/isd/files/The%20Scottish%20Record%20Linkage%20System.doc

THE CURRENT PROJECT

It was envisioned that the creation of the national linked data sets would be carried out purely by automated algorithms with no clerical checking or intervention involved. After linkage of five years of data in the main linked data set it was found that the false positive rate in the larger groups of records was beginning to creep up beyond the 1% level felt to be acceptable for the statistical and management purposes for which the data sets are used. Limited clerical checking has been subsequently used to break up falsely linked groups. This has served to keep both the false positive and false negative rates at below three per cent. More extensive clerical checking is used for specialised purposes such as the linking of death records to the Scottish Cancer Registry to enable accurate survival analysis for example.

METHODS OF LINKING

In a world with perfect recording of identifying information and unchanging personal circumstances, all that would be necessary to link records would be the sorting of the records to be matched by personal identifiers. In the real world of data however, for each of the core items of identifying information used to link the records (surname, initial, year, month and day of birth), there may be a discrepancy rate of up to 3% in pairs of records belonging to the same person. Thus exact matching using these items could miss up to 15 % of true links.

To allow for the imperfections of the data, the system uses methods of probability matching which have been developed and refined in Canada 3 , Oxford 4 and Scotland 5 itself over the last thirty years. Despite the size of the data sets, linking the records consists of carrying out the same basic operation over and over again. This operation is the comparison of two records and the decision as to whether they belong to the same individual.

THE ELEMENTS OF LINKAGE.

1. 1. Bringing pairs of records together for comparison. How do we bring the most effective subset of pairs of records together for comparison? It is usually impossible to carry out probability matching on all pairs of records involved in a linkage. Usually only a subset are compared, those which share a minimum level of identifying information. This has been traditionally achieved by sorting the files into 'blocks' or 'pockets' within which paired comparisons are carried out e.g. soundex, date of birth etc. (Gill and Baldwin, 1987).

2. 2. Calculating probability weights. How do we assess the relative likelihood that pairs of records belong to the same person? This lies at the heart of probability matching and has probably been the main focus of much of record linkage literature (Newcombe, 1988).

3. 3. Making the linkage decision. How do we convert the probability weights representing relative odds into absolute odds which will support the linkage decision? The wide variety of linkages undertaken has been particularly important in moving forward understanding in this area.

1. Blocking

In an ideal world with infinite computing power we would carry out probability matching between every pair of records in order to determine whether they belong to the same person. At present this is realistically beyond current computing capacities and would be enormously wasteful even if it were possible. It is necessary to cut down in some way the number of pair comparisons which are made in a given linkage. Instead of comparing all pairs of records we compare only those records which have some minimum level of agreement in identifying items ('blocking' the records).

In the linkages carried out at ISD we tend to compare only those pairs of records between which there is agreement on:

Soundex/NYSIIS code, first initial and sex (Block A)

or All elements of date of birth (day, month, year) (Block B)

Thus records will not be compared if they disagree on one or more of the first set of blocking items and also disagree on one or more of the second set of blocking items. It is of course possible that two records belonging to the same person will disagree on for example, first initial and also date of birth. Experience shows that the proportion of true links thus lost because of blocking is less than 0.5%.

2. Probability Weights

Our approach to the calculation of probability weights has been relatively conventional and can be quickly summarised. A concern has been to avoid over-elaboration and over complexity in the algorithms which calculate the weights. Beyond a certain level increasing refinement of the weight calculation routines tends to involve diminishing returns.

For the internal linking of hospital discharge (SMR1) records across Scotland we have available the patient's surname (plus sometimes maiden name), forename, sex and date of birth. We also have postcode of residence. For records within the same hospital (or sometimes the same Health Board) the hospital assigned case reference number can be used. In addition positive weights can be assigned for correspondence of the date of discharge on one record with the date of admission on another. Surnames are compressed using the Soundex/NYSIIS name compression algorithms (Newcombe, 1988) with additional scoring assigned for more detailed levels of agreement and disagreement. Wherever possible specific weights relating to degrees of agreement and disagreement are used. Soundex and related name compression algorithms overcome some of the problems associated with misspelling of names and variant spellings.

Blocking allows subsets of the records to be efficiently brought together for comparison. Finally and most importantly probability matching allows mathematically precise assessment of the implications of the levels of agreement and disagreement between records.

Probability matching

Two very simple and common sense principles underlie probability matching:

A. A. Every time an item of identifying information is the same on the two records, the probability that they apply to the same person is increased.

B. B. Every time that an item of identifying information differs between two records, the probability that they apply to the same person is usually decreased.

Whatever kind of matching we are doing, whether linking records within a file or linking records between files, we are looking at pairs of records and trying to decide whether they belong to the same person or don't belong to the same person. We are trying to divide the pairs into two classes - which are more generally referred to as 'truly linked' or 'truly unlinked', i.e. in our case belonging to the same person or not belonging to the same person.

The common core of identifying items are as follows:

1. 1. Surname

2. 2. First initial (also full forename and second initial if available)

3. 3. Sex

4. 4. Year, month and day of birth

5. 5. Postcode.

In principle, any items whose level of agreement or disagreement influences the probability that two records do or do not belong to the same person can be used by the computer algorithm. However, items should be statistically independent as far as possible.

Every time we compare an item of identifying information between two records we obtain what can be called an outcome. In the first instance this is either agreement or disagreement.

For every outcome we ask the same two questions.

1. 1. How often is this outcome likely to occur if the two records really do belong to the same person (are truly linked)?

2. 2. How often is this outcome likely to occur if the two records really don't belong the same person (are truly unlinked)?

The ratio between these two probabilities or odds is what is called an odds ratio - this is a measure of how much that particular outcome has increased or decreased the chances that the two records belong to the same individual. Odds can be awkward to handle so probability matching tends to use binit weights instead. The binit weight is the odds expressed as a logarithm to base 2.

The linkage methodology is aimed at squeezing the maximum amount of discrimination from the available identifying information. Thus the distribution of probability scores differs for each kind of linkage. The threshold (or score at which the decision to link is made) is determined by clerical checking of a sample of pairs for each type of link.

The odds ratio: an example

Suppose we have two records, and we are comparing their first initials. We find that they both have first initial 'J'. We want to calculate an odds ratio which will tell us what effect this outcome - agreement of first initial 'J' - has on the chances that the records belong to the same person.

If both records belong to the same person how often will one record have the initial 'J'? In a perfect world with perfect data the answer would be always - the probability would be one, or in percentage terms, 100%. However, there are often going to be discrepancies in identifying information between records applying to the same person. If we estimate that the first initial is likely to disagree 3% of the time on records applying to the same person, then it will agree 97% of the time. So on the top line of our odds ratio we have a figure of 97%.

Next we look to the bottom line of the odds ratio. How often are we going to get agreement on the initial 'J' among pairs of records which do not belong to the same person? The answer quite simply depends upon how common that first initial is. If 20% of all first initials are 'J', then if we take any record with first initial 'J' and compare it with all the other records, then 20% of the time the record it is compared with will have first initial 'J'. So the bottom line of the odds ratio is 20%. The odds ratio then is 97%/20% or 4.85.

So agreement of first initial 'J' has improved our chances that the records belong to the same person by 4.85 to one.

What if the first initial disagrees? Again we compare the outcome among pairs of records which do belong to the same person against pairs of records which do not.

The top line of the odds ratio is 3% (if you take all records with initial 'J', then 3% of the time - even among records belonging to the same person - the other record will have a different initial.) For the bottom line, we want to know how often the first initial disagrees when the records do not belong to the same person. For illustration we can take the initial as disagreeing 92.5% of the time among records not belonging to the same person. So for disagreement of first initial we have an odds ration of 3%/92.5% or 1 to 32. So disagreement of first initial has reduced the chances that the records belong to the same person by 32 to 1.

So we now have a quantitative estimate of how much an agreement on first initial 'J' has improved our chances that we are looking at records belonging to the same person. Similarly we have a quantitative estimate of how much a disagreement on first initial has reduced the chances that the records relate to the same person.

We can now give an example of how the odds ratios deriving from comparison of individual identifying items can be combined to give odds for the overall comparison of the two records.

Suppose we have two records each with the identifying information:

Male J Thompson born 15 05 1932

Male J Thompson born 05 05 1932

The odds associated with these comparisons are as follows:

				Binit
Sex				
Agreement: odds ratio	99.5%/50%	=	1.99	+0.99
First initial				
Agreement: odds ratio	97%/20%	=	4.85	+2.28
Surname				
Agreement: odds ratio	97%/0.8%	=	121.25	+6.92
Day of birth				
Agreement: odds ratio	3%/92%=	0.0326	-4.94	
Month of birth				
Agreement: odds ratio	97%/8.3%	=	11.7	+3.55
Year of birth				
Agreement: odds ratio	97%/1.4%	=	70.0	+6.13

How much have all these comparisons of identifying information improved the chances that these two records really apply to the same person? You combine odds by multiplying them:

1.99 x 4.85 x 121.25 x 0.0326 x 11.7 x 70 = 31,245 to 1.

So the comparisons have increased the likelihood that the two records belong to the same person by 31,245 to 1. However, that does not mean that it is a certainty. Our files have millions of records on millions of individuals. It is not inconceivable that there is more than one male J. Thompson born on the 14th or 15th of May 1932. That is why the procedure is known as probability matching - there are never any certainties. And since there are no certainties, we still have to make a decision as to whether or not the records do apply to the same person.

Binit weights

Odds like 31,245 to 1 are rather awkward to handle. Probability matching tends to use instead what are called binit weights. So far we have talked about odds ratios e.g. the odds ratio for agreement on initial 'j' is 4.85 to 1. The binit weight is this number expressed as a logarithm to base 2.

In this context, the most useful thing about logarithms in general, or binit weights in particular, is that they can be added together. Adding together the binit weights is the same as multiplying the odds ratios. So our overall improvement in the chances that the records belong to the same person of 31,245 to 1 is equivalent to a binit weight of 14.93.

The essence of record linkage is to calculate the overall binit weight for each pair of records. High binit weights mean that the records are likely to belong to the same person. Low binit weights (which reflect odds against) mean that the records are unlikely to belong to the same person.

Soundex/NYSIIS codes

Surnames are changed to a coded format in order to overcome the effects of most discrepancies in the spelling. First the NYSIIS (New York State Intelligence Information System) name compression algorithm is applied. This carries out such tasks as bringing together commonly confused letter groups like 'ch' and 'gh' or 'sh' and 'sch' as well as removing vowels. The surnames are then Soundexed 6 , which involves giving the same code to similar sounding non-initial constants. The resulting compression and soundex codes are assigned different weights for agreement depending upon their frequency in the population.

3. Decision-making

Binit weights present us with a mathematical expression of the extent to which the available identifying information increases or decreases the chances that two records belong together. These however are only relative odds. They allow us to rank order the pairs of records in order of likelihood. They are not absolute odds. Such absolute odds depend upon various factors such as the size of the data sets involved. Methods of calculating such absolute odds are available but they are usually based on rather speculative assumptions. It is much safer to base the decision on which records belong together on a match weight threshold based on empirical inspection. In other words we compare records, calculate relative odds for each pair and look at a selection of odds before deciding on the cut off point for accepting matches.

When the frequencies of pairs of records with given values of the binit weight are graphed, a bimetal pattern usually emerges (see IARC report No.32 - Automated Data Collection in Cancer Registrations). The group of pairs of records with high binit weights can be taken as matches (as belonging to the same person). The group with low binit weights can be regarded as non-matches. It is the group in between which cause problems.

The crucial step is to identify a threshold above which pairs will be taken as linking, and below which the pairs will not be accepted as linking.

This threshold is usually determined by clerical inspection of a sample of pairs of records. The threshold is usually set at the 50/50 point. In other words, at the threshold it is a fifty-fifty bet as to whether the pair of records belongs to the same person. Above the threshold it is more likely than not that they do belong to the same person. Below the threshold it is more likely than not that they do not belong to the same person.

Once a threshold in terms of the binit weight has been set, the computer can be allowed to make the decisions as to whether records belong together. In practice the development of match weights and the setting of the threshold is an iterative process with results depending on the precise characteristics of the data sets involved.

Tuning the linkages

Tuning the linkages, either in terms of adjusting the weights for particular comparisons or by adjusting the match threshold is an iterative process.

All linkages are different and the quality of the linkage is best ensured by taking careful account of the precise properties of the data sets involved and the different problems which emerge in linking two particular data sets.

The linkage threshold is established or confirmed by inspecting the pairs output file and thereby establishing the weight above which it is more likely than not that a pair of records belong to the same person and below which it is more likely than not that the pair of records do not belong to the same person. This threshold is often confirmed in terms of the graph of the frequency of the outcome weights for a particular linkage. The 50/50 threshold (the weight at which it is evens whether records do or do not belong together) often corresponds to the low point of the trough in the frequency counts.

QUALITY OF LINKAGE

The linkage system has been automated as much as possible. The probability matching algorithm alone makes the decision as to whether records belong together. Clerical monitoring shows that on a pair-wise basis, both the false positive rate (the proportion of pairs which are incorrectly linked) and the false negative rate (the proportion of pairs which the system fails to link) are around three per cent.

As the data set has expanded the number of patient record sets with large numbers of records has grown. In order to construct a patient record set with 10 records, up to 45 pair comparisons will have been carried out, each comparison contributing its own possibility of a false positive link. Thus larger groups of records are more likely to be false positive. Some of the more important groups moreover tend to be the larger groups. Patient record sets containing cancer registrations tend to have more records than average have thus have a relatively high error rate. For this reason, groups of records where there is an obvious error such as two death records or a hospital admission following death have been targeted for clerical correction. Such errors will help to keep the overall false positive and false negative rates close to one percent.

By using such a focused approach to clerical checking we are intending to achieve the advantages of the quality of a fully clerically checked system without the massive investment of time and expense which such a system would involve.

ESTIMATION OF FALSE POSITIVE RATES (QUOTE FROM MR DAVID CLARK ANALYST AT ICD):

Essentially what I did was break down the cohort into the various matching standards and within this (probability weights as generated by the linkage)and sampled the matching pairs and tried to decide as best as I could from all the available information (e.g. Age, sex, dates, postcode, council area, hospital of treatment, diagnosis codes, severity, casualty class, whether there were rival potential matches or not) whether I thought the match was good, bad or undecided. This is a very subjective process. I scored 2 for good, 1 for undecided, 0 for bad. I then calculated a "probability" for each category e.g. if there were 20 cases sampled at a particular score and 10 were good, 5 were bad, 5 were unsure the probability of a good link for this group of links was 25/40= 67.5%. If there were 200 links in total for this group then could estimate 135 good links and 65 bad links. I then summed up the total over all the categories of links to get the total estimated good and bad links. Likewise I sampled below the linkage threshold to find the number of estimated good and bad missed links.

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VI. Follow-up diagnosis significantly related to a 1st single injury

P values were calculated using chi square and criteria for inclusion for further analysis were that no more than 1 cell can have an expected count of <5 and a significant p value of <0.2. A total of 41 follow-up diagnoses (FUD) were considered significantly related to one or more injuries. The specific injury that was related to a FUD were identified by analysing the proportions of these in relation to all injury categories and the FUD that have more than 30% over the expected proportion of FUD were considered statistically related (e.g. the follow-up diagnosis "cerebrovascular diseases had a p value of 0.09 (i.e. statistically related to one or more of the 1st diagnoses) and casualties with injuries to the thorax, 13% of total casualties, had 21% of this diagnose i.e. 62% over the expected rate). Two diagnoses had no injury with >30% FUD, but the injury closest to >30% were identified in these cases (highlighted in *italic*).

In summary the following correlations were found (the % next to the injury is the proportion of casualties with that particular injury and the % next to FUD is the proportion of casualties with that FUD previously having that injury, see also table):

⇒ Injuries to the head (34%)
- Accidental exposure to other and unspecified factors (53%)
- Assault (48%)
- Diseases of oral cavity, salivary glands and jaws (49%)
- Mental and behavioural disorders due to psychoactive substance use (46%)
- Persons encountering health services for examination and investigation (44%)

⇒ Injuries to the neck (6%)
- Assault (8%)
- Benign neoplasms (10%)
- Diseases of oesophagus, stomach and duodenum (13%)
- Diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified (13%)
- Hernia (10%)
- Hypertensive diseases (9%)
- Ischaemic heart diseases 10%)
- Noninflammatory disorders of female genital tract (11%)
- Other diseases of intestines (10%)
- Other diseases of the digestive system (14%)
- Other diseases of urinary system (11%)
- Other disorders of the skin and subcutaneous tissue (10%)
- Persons encountering health services in circumstances related to reproduction (13%)
- Symptoms and signs involving the circulatory and respiratory systems (12%)
- Symptoms and signs involving the digestive system and abdomen (11%)

⇒ Injuries to the upper limbs (11%)
- Arthrosis (19%)
- Disorders of bone density and structure (22%)
- Other disorders of the skin and subcutaneous tissue (16%)

⇒ Injuries to the thorax (13%)
- Bacterial agents resistant to antibiotics (19%)
- Bacterial, viral and other infectious agents (21%)
- Benign neoplasms (24%)
- Cerebrovascular diseases (21%)
- Diabetes mellitus (24%)

    - Diseases of oesophagus, stomach and duodenum (20%)
    - Disorders of gallbladder, biliary tract and pancreas (19%)
    - Disorders of lens (28%)
    - Hernia (27%)
    - Hypertensive diseases (23%)
    - Ischaemic heart diseases (22%)
    - Malignant neoplasms, stated or presumed to be primary, of specified sites, except of lymphoid, haematopoietic and related tissue (28%)
    - Metabolic disorders (17%)
    - Other and unspecified disorders of the circulatory system (19%)
    - Other diseases of intestines (23%)
    - Other diseases of the digestive system (18%)
    - Other diseases of urinary system (20%)
    - Other dorsopathies (21%)
    - Other forms of heart disease (26%)
    - Renal failure (20%)
    - Symptoms and signs involving the circulatory and respiratory systems (23%)
    - Symptoms and signs involving the nervous and musculoskeletal systems (17%)
    - Symptoms and signs involving the urinary system (26%)

⇒ Injuries to the abdomen, lower back, lumbar spine (9%)

    - Disorders of gallbladder, biliary tract and pancreas (19%)
    - Malignant neoplasms, stated or presumed to be primary, of specified sites, except of lymphoid, haematopoietic and related tissue (13%)
    - Noninflammatory disorders of female genital tract (20%)
    - Other dorsopathies (16%)
    - Persons encountering health services in circumstances related to reproduction (18%)
    - Symptoms and signs involving the digestive system and abdomen (14%)
    - Symptoms and signs involving the urinary system (14%)

⇒ Injuries to the lower limbs (26%)

    - Bacterial, viral and other infectious agents (37%)
    - Complications of surgical and medical care, not elsewhere classified (46%)
    - Disorders of bone density and structure (60%)
    - Falls (31%)
    - Other disorders of the skin and subcutaneous tissue (35%)
    - Other joint disorders (40%)
    - Other soft tissue disorders (36%)
    - Persons encountering health services for specific procedures and health care (49%)
    - Renal failure (45%)
    - Surgical and other medical procedures as the cause of abnormal reaction of the patient, or of later complication, without mention of misadventure at the time of the procedure (44%)
    - Symptoms and signs involving the nervous and musculoskeletal systems (35%)

Some correlations may be obvious such as injuries to the lower limbs and the FUD "other joint disorders" and injuries to the thorax which is correlated to "ischaemic heart diseases", while others are more questionable. Injuries to the neck, for example appears to have a large number of related FUD including several diagnoses of the abdominal region (reproductive, digestive, intestines etc) –could this possibly be related to neck injuries resulting in paralysis? Some of the significantly related FUDs are few in numbers e.g. "arthrosis" N=59, but seeing as the p value is relatively low and that casualties with injuries to the upper limbs suffer this FUD about 70% more than the expected rate it is reasonable to include this in the FAD 'selection criteria'.

ICD-10 code	ICD-10 description	P	# Cells w expected count of less than 5	Injuries to the head (34%)		Injuries to the neck (6.2%)		Injuries to the upper limbs (11%)		Injuries to the thorax (13%)		Injuries to the abdomen, lower back, lumbar spine (9%)		Injuries to the lower limbs (26%)		Total
				Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Sum
X58-X59	**Accidental exposure to other and unspecified factors**	0.000	0	**53.3**	80	6.0	9	10.7	16	2.7	4	5.3	8	22.0	33	150
M15-M19	**Arthrosis**	0.130	1	20.3	12	3.4	2	**18.6**	11	16.9	10	11.9	7	28.8	17	59
X85-Y09	**Assault**	0.006	0	**48.0**	59	**8.1**	10	12.2	15	6.5	8	7.3	9	17.9	22	123
U80-U89	**Bacterial agents resistant to antibiotics**	0.011	0	30.1	112	7.0	26	10.5	39	**19.4**	72	8.9	33	24.2	90	372
B95-B97	**Bacterial, viral and other infectious agents**	0.031	1	20.0	14	5.7	4	10.0	7	**21.4**	15	5.7	4	**37.1**	26	70
D10-D36	**Benign neoplasms**	0.005	0	21.0	21	**10.0**	10	11.0	11	**24.0**	24	8.0	8	26.0	26	100
I60-I69	**Cerebrovascular diseases**	0.090	0	33.1	44	7.5	10	8.3	11	**21.1**	28	6.0	8	24.1	32	133
T80-T88	**Complications of surgical and medical care, not elsewhere classified**	0.000	0	22.4	34	7.2	11	9.9	15	5.9	9	8.6	13	**46.1**	70	152
E10-E14	**Diabetes mellitus**	0.013	0	24.0	24	7.0	7	7.0	7	**24.0**	24	12.0	12	26.0	26	100
K20-K31	**Diseases of oesophagus, stomach and duodenum**	0.000	0	25.8	59	**13.1**	30	9.6	22	**19.7**	45	10.5	24	21.4	49	229
K00-K14	**Diseases of oral cavity, salivary glands and jaws**	0.000	0	**48.6**	70	4.2	6	8.3	12	4.2	6	4.2	6	30.6	44	144
I80-I89	**Diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified**	0.042	0	28.2	33	**12.8**	15	10.3	12	14.5	17	12.0	14	22.2	26	117
M80-M85	**Disorders of bone density and structure**	0.000	0	8.3	8	2.1	2	**21.9**	21	6.3	6	1.0	1	**60.4**	58	96
K80-K87	**Disorders of gallbladder, biliary tract and pancreas**	0.027	1	23.8	15	6.3	4	14.3	9	**19.0**	12	**19.0**	12	17.5	11	63

ICD-10 code	ICD-10 description	P	# Cells w expected count of less than 5	Injuries to the head (34%)		Injuries to the neck (6.2%)		Injuries to the upper limbs (11%)		Injuries to the thorax (13%)		Injuries to the abdomen, lower back, lumbar spine (9%)		Injuries to the lower limbs (26%)		Total
				Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Sum
H25-H28	**Disorders of lens**	0.000	0	22.8	21	1.1	1	7.6	7	**28.3**	26	7.6	7	32.6	30	92
W00-W19	**Falls**	0.070	0	34.6	112	3.7	12	12.3	40	11.1	36	7.4	24	*30.9*	100	324
K40-K46	**Hernia**	0.000	0	20.5	26	**10.2**	13	7.1	9	**26.8**	34	11.8	15	23.6	30	127
I10-I15	**Hypertensive diseases**	0.000	0	21.6	33	**9.2**	14	7.8	12	**22.9**	35	9.2	14	29.4	45	153
I20-I25	**Ischaemic heart diseases**	0.000	0	22.1	53	**10.0**	24	8.3	20	**22.1**	53	10.8	26	26.7	64	240
C81-C96	**Malignant neoplasms, stated or presumed to be primary, of specified sites, except of lymphoid, haematopoietic and related tissue**	0.000	0	25.7	38	2.7	4	10.1	15	**27.7**	41	**12.8**	19	20.9	31	148
F10-F19	**Mental and behavioural disorders due to psychoactive substance use**	0.000	0	**46.2**	104	4.0	9	12.9	29	7.1	16	6.2	14	23.6	53	225
E70-E90	**Metabolic disorders**	0.100	0	41.3	43	6.7	7	6.7	7	**17.3**	18	11.5	12	16.3	17	104
N80-N98	**Noninflammatory disorders of female genital tract**	0.000	0	33.6	42	**11.2**	14	11.2	14	12.8	16	**20.0**	25	11.2	14	125
I95-I99	**Other and unspecified disorders of the circulatory system**	0.000	0	30.1	157	6.3	33	9.4	49	**19.3**	101	7.5	39	27.4	143	522
K55-K63	**Other diseases of intestines**	0.000	0	24.3	60	**9.7**	24	9.3	23	**23.1**	57	10.9	27	22.7	56	247
K90-K93	**Other diseases of the digestive system**	0.054	1	35.6	26	**13.7**	10	6.8	5	**17.8**	13	6.8	5	19.2	14	73
N30-N39	**Other diseases of urinary system**	0.003	0	23.9	38	**11.3**	18	10.1	16	**19.5**	31	7.5	12	27.7	44	159
L80-L99	**Other disorders of the skin and subcutaneous tissue**	0.015	0	30.5	25	**9.8**	8	**15.9**	13	6.1	5	2.4	2	**35.4**	29	82
M50-M54	**Other dorsopathies**	0.109	1	25.0	17	7.4	5	10.3	7	**20.6**	14	**16.2**	11	20.6	14	68

ICD-10 code	ICD-10 description	P	# Cells w expected count of less than 5	Injuries to the head (34%)		Injuries to the neck (6.2%)		Injuries to the upper limbs (11%)		Injuries to the thorax (13%)		Injuries to the abdomen, lower back, lumbar spine (9%)		Injuries to the lower limbs (26%)		Total
				Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Row %	Sum	Sum
I30-I52	**Other forms of heart disease**	0.000	0	22.3	39	4.6	8	7.4	13	**25.7**	45	9.7	17	30.3	53	175
M20-M25	**Other joint disorders**	0.012	0	24.8	28	7.1	8	12.4	14	8.0	9	8.0	9	**39.8**	45	113
M70-M79	**Other soft tissue disorders**	0.104	0	23.9	28	6.8	8	12.8	15	11.1	13	9.4	11	**35.9**	42	117
Z00-Z13	**Persons encountering health services for examination and investigation**	0.002	0	*44.0*	103	5.6	13	9.8	23	14.5	34	10.7	25	15.4	36	234
Z40-Z54	**Persons encountering health services for specific procedures and health care**	0.000	0	19.1	110	3.3	19	13.7	79	7.5	43	7.8	45	**48.5**	279	575
Z30-Z39	**Persons encountering health services in circumstances related to reproduction**	0.041	1	28.6	16	**12.5**	7	14.3	8	10.7	6	**17.9**	10	16.1	9	56
N17-N19	**Renal failure**	0.002	1	25.0	15	3.3	2	1.7	1	**20.0**	12	5.0	3	**45.0**	27	60
Y83-Y84	**Surgical and other medical procedures as the cause of abnormal reaction of the patient, or of later complication, without mention of misadventure at the time of the procedure**	0.000	0	24.5	36	6.8	10	8.8	13	8.2	12	7.5	11	**44.2**	65	147
R00-R09	**Symptoms and signs involving the circulatory and respiratory systems**	0.000	0	25.8	66	**11.7**	30	10.2	26	**22.7**	58	8.2	21	21.5	55	256
R10-R19	**Symptoms and signs involving the digestive system and abdomen**	0.000	0	29.0	93	**10.6**	34	12.5	40	16.2	52	**14.3**	46	17.4	56	321
R25-R29	**Symptoms and signs involving the nervous and musculoskeletal systems**	0.086	0	18.5	15	7.4	6	12.3	10	**17.3**	14	9.9	8	**34.6**	28	81
R30-R39	**Symptoms and signs involving the urinary system**	0.000	0	28.0	33	5.9	7	5.9	7	**26.3**	31	**13.6**	16	20.3	24	118
	All injuries			34.2	1112	6.2	203	11.0	359	13.3	432	9.3	303	26.0	847	

VII. Weighted mean cost by speciality

		Inpatient	Day case
General Surgery	01	510.11	624.81
Orthopaedic Surgery	02	599.67	936.29
ENT	03	894.95	783.81
Ophthalmology	04	1092.17	798.76
Urology	05	555.69	506.88
Neurosurgery	06	625.61	2208.63
Cardiothoracic Surgery	07	1013.57	No daycase data
Plastic Surgery	08	828.17	695.33
Orthodontics/Paediatric Dentistry	11		
Oral Surgery/Medicine	12		
General Medicine	16	328.84	426.77
Cardiology	17	830.55	1169.82
Metabolic Diseases	18		
Neurology	19	692.19	1350.11
Gastroenterology	21	455.19	561.48
Dermatology	23	231.01	142.02
Nephrology	24	546.48	799.56
Rheumatology	25	607.63	583.11
Rehabilitation Medicine	26	217.39	562.92
Respiratory Medicine	28	427.76	445.15
Communicable Diseases	31	396.43	4755.88
Diagnostic Radiology	33		
Radiotherapy	34	106.95	573.25
Homeopathy	36		
Medical Oncology	37	2723.72	647.94
Spinal Paralysis	38	338.10	513.77
Surgical Paediatrics	39	794.97	1095.63
Medical Paediatrics	40	754.08	750.56
Pain Control	41		
Gynaecology	42	704.04	711.87
Intensive Therapy Unit	48		
Accident & Emergency	49	809.08	no info
Geriatric Assessment	50	222.36	no info
Young Chronic Sick	52		
Haematology	62	499.05	349.46
Gp (Ex. Obstetrics)	73	274.95	189.72
Other Acute	98		896.42