

**Transport Research Laboratory**



# **Enhanced medical engineering link**

**by D C Richards, R E Cookson, and R W Cuerden**

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by **D C Richards, R E Cookson, and R W Cuerden (TRL)**

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	<b>Name</b>	<b>Date Approved</b>
<b>Project Manager</b>	Rebecca Cookson	05/01/09
<b>Technical Referee</b>	Roy Minton	05/01/09

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## Executive summary

Road safety is a public health concern in which many organisations have an active interest, such as hospitals, vehicle manufacturers, and the Police. Each of these organisations can bring different areas of expertise to bear on the problem of road traffic accidents, and there are benefits to be had by combining their efforts, sharing skills and information to achieve their common goal of improving road safety.

This project has explored the methodology and benefits of a 'medical engineering link' between medical professionals and vehicle engineers. This has been done by bringing together two institutions: TRL, which has significant experience in accident research and vehicle safety design; and the Helicopter Emergency Medical Service (HEMS), which has been treating seriously injured road traffic casualties for the last 20 years.

The two organisations have worked together to investigate the causes of pedestrian injuries in accidents involving new cars, with TRL sharing their expertise of injury causation, and HEMS sharing their expertise on the consequences of the injuries. The HEMS team also provided TRL with the data they have recorded on pedestrian casualties from 2000-2007. This enabled TRL to explore the data and determine the useful information which could be deduced from it, for the benefit of both the vehicle engineering and medical community. It is clear that some relatively simple alterations to the HEMS data, such as photographs of the vehicle damage, would improve the data with respect to engineering content.

Analysis of the years of working life lost due to traffic accidents (as recorded by the Police STATS19 records and the Office for National Statistics mortality statistics) displays the size of the road safety problem: with the exception of ischaemic heart diseases, road traffic injuries are the leading cause of years of working life lost in England and Wales. This is principally because of the large number of young people who are killed in traffic accidents compared to the generally older age profile of those who succumb to most other diseases.

Amongst other analysis, the cost of pedestrian injuries was investigated using the HEMS data and a model based on the number of days spent in intensive care and/or on the ward. This explored how the medical data collected by HEMS could be used to provide information which is useful to both the medical and vehicle safety design/legislation communities.

Following the creation of the link between TRL and HEMS, and the exploration of its possible benefits, a methodology has been proposed for developing the medical engineering link in the future. This could involve a combination of different data sources: the Police STATS19 records of accidents; the Hospital Episode Statistics (HES), containing details of the injury and treatment of road traffic casualties admitted to hospital; in-depth accident studies, such as those based at TRL; Police accident investigator reports; and enhanced data collected by the HEMS with a supporting research team.

The continuing development of these links would lead to an on-going study, which could answer the questions and provide continual feedback to all the stakeholders in road safety, including the Police, vehicle engineers, public health professionals, and the government.



# 1 Introduction

Road safety is a public health concern in which many organisations have an active interest, such as hospitals, vehicle manufacturers, and the Police. Each of these organisations can bring different areas of expertise to bear on the problem of road traffic accidents, and there are benefits to be had by combining their efforts, sharing skills and information to achieve their common goal of improving road safety. The purpose of this project is to explore how a link could be made between different organisations, and how this could be used to address the problem of road safety.

## 1.1 Size of the road safety problem

In 2007, there were 2,946 deaths on Britain's roads. In addition to these fatalities, there were 27,774 seriously injured and 217,060 slightly injured casualties (Department for Transport, 2008). Although this was a reduction on previous years, it still cost the country a large amount of money: the Department for Transport estimated the societal cost of these casualties in 2007 as £13.8 billion (Department for Transport, 2008). Despite this, the amount of attention given to road safety is relatively small compared to other public health campaigns such as the recent "5-a-day" healthy eating campaign. Part of this project will exhibit the relative importance of road traffic casualties compared to other public health issues (see section 3.1).

## 1.2 Monitoring the problem

There is large number of bodies that monitor the impact of road traffic casualties, who are not necessarily benefitting from the best evidence available. These include local authorities, the Police, vehicle engineers, public health professionals, and the government, who all have an active interest in road safety. If all these organisations shared their knowledge, they would all benefit from the best body of information possible.

The government monitors progress towards the targets it has set on the number of people injured on the roads, using accident data collected by the Police (the so-called STATS19 records). In 2000, the government targets for 2010 were set as a reduction in the number of killed and seriously injured casualties by 40%, a reduction in the number of children killed or seriously injured by 50%, and a reduction in the number of slight casualties by 10% compared to the 1994-98 average (Department for Transport, 2008).

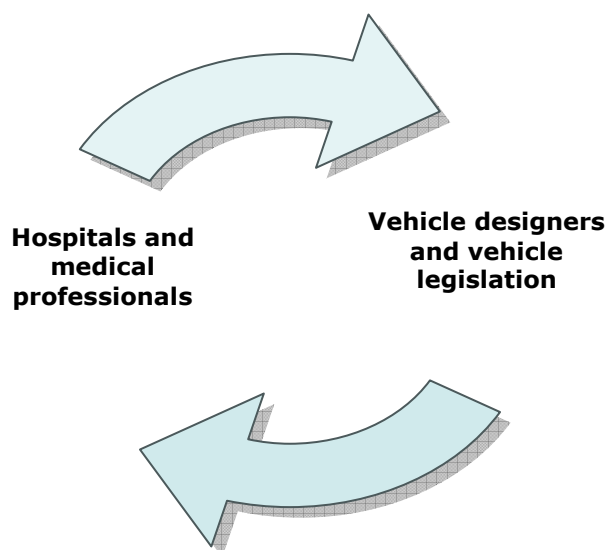
Local authorities are required to set up local strategies to reduce the number of road accidents in their area, and these are often based around the "4 E's" of engineering, enforcement, education, and environment.

National Health Service (NHS) trusts need to know the likely numbers and types of road traffic injuries, so they can allocate resources appropriately, and develop strategies for diagnosis and treatment of those injuries. Some centres see many cases of road accident trauma, and others far fewer, so it is important to share good practice between different centres.

Vehicle engineers, including government or EU legislators, need to link injury epidemiology to vehicle design, so they can decide exactly how vehicle designs need to be improved.

Combining and correlating information by better sharing of knowledge between these and other stakeholders who monitor road safety would be of benefit to each individual organisation. For example, Figure 1-1 shows the feedback loop between hospitals/medical professionals and vehicle designers/vehicle legislation. Through the medical engineering link, the medical professionals will inform new vehicle legislation depending on the types of injuries they see as a problem in the real world. The vehicle

designers will then design countermeasures, and the medical professionals will be able to tell them whether the countermeasures have reduced the problem, or if they have created new problems. This process is the feedback loop.

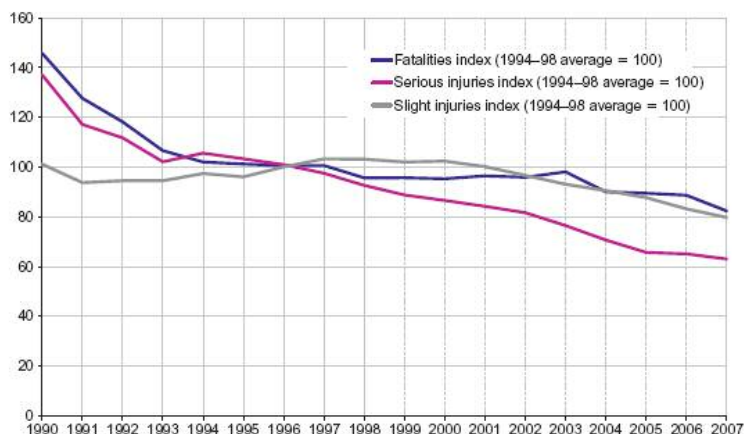


**Figure 1-1. Feedback loop**

### **1.3 Determining costs and benefits of interventions**

For any potential intervention with the intent to improve road safety, the costs and benefits need to be carefully considered. For example, when introducing a new speed management scheme, or vehicle engineering countermeasure, the target of the intervention must be taken into account to determine the possible benefit. Will it target the people most vulnerable in this type of accident or the people who are in this type of accident more frequently? Will it have different effects for different levels of injury severity? Will it take into account impairment and/or treatment costs?

These sorts of questions cannot be answered using one source of information alone. There are also questions at the national level which require a more holistic approach. For example, Figure 1-2 shows how the number of road accident casualties has fallen in recent years. This figure shows that the number of serious casualties has gone down proportionately more than the number of fatalities. However, serious casualties range from a simple broken bone to life-threatening injuries with long term impairment, or even death more than 30 days after the incident. It is possible that the number of "more serious" serious casualties is dropping at a similar rate to the number of fatalities, and that it is actually a reduction in the "less serious" serious casualties which accounts for most of the reduction in serious casualties.



**Figure 1-2. Reduction in road accident casualties (Department for Transport, 2008)**

While this fall in the number of serious casualties will mean that the government targets for the reduction in road traffic casualties are met, they may overestimate the effect on the health service. If the number of casualties with the “more serious” serious injuries is not falling as quickly, the reduction in the cost to the hospitals of treating these casualties will not be as great as Figure 1-2 might suggest. Comparisons of STATS19 with hospital data also suggest that there is a large amount of under-reporting of serious casualties in the Police data (Goldacre, Gill, & Yeates, 2006; Department for Transport, 2008).

Other approaches may also lead to different estimates of the cost of road traffic injuries. For example some injuries, which may not be very serious in terms of threat to life, may cause life-long impairment or require a large number of costly operations. Some injuries may affect different portions of the population differently; for example an older person may require a much longer stay in hospital and more aftercare for a particular injury than a younger person would. Taking differences like this into account may drastically affect the perceived benefits of a countermeasure.

#### 1.4 Focus of this project

The focus of this project is to present how TRL and hospitals, both interested in injury prevention, can combine their efforts. Examples are given of what can be achieved when this happens. TRL has a history of work in injury prevention, including developing crash test dummies, working with the EuroNCAP testing programme, identifying the dangers of using mobile phones while driving, and many more accident, behavioural, and vehicle design studies. Hospitals have a great interest in all public health issues, including road traffic accidents. By bringing these two together, we can improve the wider understanding of injury mechanisms, and the epidemiology of prioritising injuries for prevention or reduction. In addition to this, medical information from another source (mortality statistics) will be used to present the size of the road safety problem in relation to other public health issues.

In order to test the possibilities of an enhanced medical engineering link, this project has chosen to focus on pedestrian road traffic casualties. Compared to car occupants, the injury epidemiology and characteristics of pedestrians are less well understood, because of the lack of large pedestrian-focused accident studies. In addition to this, recent European pedestrian regulations (European Parliament, 2003) have meant that the design of cars has changed, so it is important to investigate the characteristics of pedestrian impacts with these newer cars.

Using the link developed for this project, the medical and engineering professions would be able to work together to improve their knowledge of the engineering and medical factors relating to pedestrian accidents. Examples will be given of the sort of research that can be performed when institutions such as TRL and the NHS work together.

## 2 Methodology

The ultimate aim of an enhanced medical engineering link is to persuade all the people who have an interest in road safety to work together to combine their resources and experiences to prevent trauma, and improve the management and treatment of trauma. This could be expanded to include medical professionals, public health professionals, engineers, criminologists, sociologists, physicists, psychologists, and many others. This would lead to a robust and reliable spine of information and interconnected data sources across all these disciplines. This could provide the base for all research related to public health and road safety and, once created, it would reduce the time and expense required to set up road safety studies of all types. More importantly, it would enable future prevention and mitigation countermeasures to be developed.

This project has explored the methodology of creating such a link, by working with the Helicopter Emergency Medical Service (HEMS) to create a medical-engineering link between the clinicians at HEMS and the accident researchers and vehicle engineers at TRL. This included establishing a link between the two organisations, and then finding a topic on which the two organisations could work together to investigate the benefits of the link.

The topic chosen was pedestrian accidents, and the costs and causes of pedestrian injuries. The HEMS team records details of all their missions, so once TRL had applied for the appropriate research and ethical approval from the NHS, this data was made available for analysis.

In addition to the information from HEMS, this study takes a number of different sources of information to explore the methodology of combining the knowledge of different organizations. These include government statistics (mortality figures), hospitals (HEMS and HES), the Police (STATS19 and fatal files), post-mortems, and the knowledge obtained from the in-depth research studies undertaken at TRL.

### 2.1 Helicopter Emergency Medical Service (HEMS)

A report was produced in the 1980s by the Royal College of Surgeons which documented cases of patients dying unnecessarily because of the delay in receiving prompt and appropriate medical care. London's Air Ambulance was established to address the findings of this report and to find a way to respond quickly in London's increasingly congested roads. London's Air Ambulance began operations in 1989 from a temporary base at Biggin Hill Airport and in 1990 moved to a permanent base in central London. This was at the Royal London hospital, which was successful in its bid due to being the only multidisciplinary hospital with a site where it would be safe to build a rooftop helipad. The Helicopter Emergency Medical Service (HEMS) began to fly from the rooftop at the Royal London on 30 August 1990 and to date has flown over 17,000 missions.

Two trauma teams are available to attend major trauma incidents seven days a week from 7 am to sunset. At night the poor visibility makes flying around the city dangerous, so rapid response cars are used instead. These cars can also be used if the emergency occurs whilst the helicopter is away on another mission.

HEMS primarily deals with major trauma accidents of all varieties including serious road traffic accidents. The patient is then seen as quickly as possible by a specialist trauma doctor and paramedic team to provide the greatest chance of survival. The paramedic team at the London Ambulance Service control room decides which of the 3,500 calls they receive a day are appropriate for the HEMS to attend. The paramedic team can also request for HEMS to attend if they require further medical resources in the field. The helicopter's medical team are equipped with a substantial range of drugs, emergency surgical kits, monitors and other equipment so that they can begin treatment immediately. A doctor is part of the HEMS team and is able to perform life saving medical procedures that a paramedic is sometimes not qualified to undertake. They can

also take the patients to the hospital best suited for the patient's needs rather than the closest A&E department.

### **2.1.1 Establishing a link with HEMS**

Due to previous work involving the accident research group at TRL, links with two doctors at the Royal London Hospital were already established. These were a Consultant in Emergency Medicine for Barts and The London NHS Trust, and the clinical director of HEMS.

These professionals were contacted to discuss what data TRL would be able to access and what they thought accident researchers could offer the medical professional and vice versa in terms of knowledge and data. Through them, links were made with the Patient Development Sister for HEMS, who works on the data collection for the HEMS database, and who provided us with the data required for analysis, as well as answering many queries.

The clinical director of HEMS was involved at later stages for workshops and injury causation analysis and further information. TRL were also invited to the HEMS clinical governance days and "Discuss & Debrief" afternoons in which the HEMS team went through the RTAs they attended that week, what they saw, and what treatment they gave, whilst asking TRL's opinions on the accident and what may have happened.

Through these links with the HEMS team it was possible to carry out the work in this project.

### **2.1.2 HEMS dispatch criteria**

There are a number of criteria which determine whether an emergency call is appropriate for the HEMS. For pedestrian accidents, there would be immediate dispatch (in less than three minutes) if the pedestrian was trapped underneath a vehicle, had received traumatic amputation above the wrist or ankle, or was involved in a collision which already contained a confirmed fatality. The HEMS team would also be dispatched immediately if requested to do so by another crew or emergency service.

If the details of the incident do not meet the criteria for immediate dispatch, then the calls are "interrogated", to determine whether the call is appropriate for HEMS. This leads to an "interrogation dispatch" in less than seven minutes. The calls are interrogated to determine whether there is any loss of consciousness, airway compromise, breathing difficulties, head/spinal/chest/abdomen/pelvic/limb injuries, or burns/scalds covering the body surface. The result of this interrogation is a decision as to whether the call is appropriate for the HEMS.

### **2.1.3 Collecting the data**

The HEMS team collect a large amount of data on each mission, regardless of outcome, method of transport, or the hospital where the casualty is treated. This data is stored in a database, with a graphical user interface which can be used to enter and display data.

The data includes:

- Details of the casualty, including name, address, age, gender, and whether they survived or where they died;
- Details of the incident, including the date, time of the 999 call, time of HEMS activation and arrival on the scene;
- Details of the doctors and paramedics on duty, whether they travelled to the scene by helicopter or fast response vehicle, and the mode of transport to hospital;

- Details of the observations at the scene, including the type of incident, and measurements of blood pressure, heart rate, and Glasgow Coma Scale of the casualty;
- Details of the medical interventions carried out pre-hospital and in the accident and emergency department;
- Details of the operations and procedures carried out on the patient;
- Details of the injuries received by the patient, coded using the International Classification of Disease 9 (ICD-9), as well as the AIS injury severity score for each injury;
- The duration of stay of the patient on the ward and in intensive care.

#### **2.1.4 Gaining access to the data**

The process of gaining access to the HEMS data was as follows.

1. An application for provisional research and development approval was submitted to the Barts and The London NHS Trust Research and Development office. 'Barts and The London NHS Trust' is the NHS trust which governs The Royal London Hospital, in addition to St Bartholomew's Hospital and The London Chest Hospital. The application included: a "Data Protection Act Research Form", containing the purpose of the research, who would be using the data, and how it would be stored; a copy of the research proposal; and a letter stating that the study would be exploratory, using secondary data analysis, and would not include contact with patients or have any effect on the treatment they would receive. This letter explained that the study would be classified as an "audit" rather than medical research, which ensured that the proposal could be fast-tracked through the approval process.
2. Once provisional research and development approval was given, The East London and The City Research Ethics Committee was contacted for an ethical opinion, which was required before final approval could be given by the Barts and the London NHS Trust. Because the study was classified as an "audit" rather than medical research, full ethical approval was not required, and the study was successfully registered with the Clinical Effectiveness Unit.
3. Once the study was registered with the Clinical Effectiveness Unit, this information was passed onto the Research and Development Office, who then could give final research and development approval.

Details of the approval process are given on the Barts and The London NHS Trust website: [http://www.bartsandthelondon.nhs.uk/research/the\\_approval\\_process.asp](http://www.bartsandthelondon.nhs.uk/research/the_approval_process.asp). For this study, TRL produced the required documents, and the approval process was initiated and followed up by the HEMS team. From beginning to end, the approval process took approximately two months to complete.

The data was supplied to TRL via email in the form of password protected Excel spreadsheets (one for each year of data). The data was combined into a password protected Access file, which was stored on the TRL network. For analysis purposes, the data was also converted into an SPSS file, which was stored and analysed locally on two password-protected computers. In this way, no one had access to the data apart from the two TRL researchers working on the project.

The following data was made available to TRL, for pedestrians recorded in the HEMS database from 2000-2007. This is split into data stored at the casualty and injury level.

- **Casualty level**

- HEMS casualty number
- Incident date
- Time of 999 call
- Incident code ("814.7" for all cases)
- Incident description ("Motor vehicle traffic accident involving collision with pedestrian" for all cases)
- Age of pedestrian
- Gender of pedestrian
- Team arrived by (fast response vehicle/helicopter/other)
- Mode of transport to hospital (helicopter – HEMS/helicopter – other/London Ambulance Service/other)
- Patient destination ("Royal London Hospital" for all cases)
- Outcome (Lived, or died in Accident & Emergency/Intensive Care Unit/Other hospital/Theatre/Ward)
- Total number of days in intensive care unit
- Total number of days on ward
- Total number of days in Royal London Hospital
- **Injury level**
  - ICD9 code
  - ICD9 description
  - Abbreviated Injury Scale 1990 severity score
  - Abbreviated Injury Scale 1990 body region

The other variables present in the HEMS database were either incompletely coded, or were not available because they could be used to identify the patient / doctors involved. In total, the HEMS data consisted of 746 pedestrians struck by motor vehicles, with 2,974 injuries received in total. Of the 746 pedestrians, 616 survived (83%).

### **2.1.5 Other data collected and stored by HEMS**

HEMS collects other information, which was not made available to TRL in this project, about the casualties and accidents which they attend. This information can be analysed by the HEMS team itself, or could be used in an enhanced medical engineering link in the future if the appropriate ethical considerations were met. The following list is not exhaustive, but presents the additional information collected by HEMS which may be relevant to a medical engineering link.

Details of each mission are recorded, including the exact times of the 999 call, the HEMS activation, and the arrival and departure times of the HEMS team on the scene. The casualty's vital statistics such as blood pressure and heart rate are recorded at the scene, as well as notes and observations of the scene and the condition of the patient.

The interventions (for example, the drugs given to the patient) pre-hospital and in accident and emergency are recorded with precise quantities, as well as the number and types of diagnostic scans. Observations of the patient's vital statistics are also recorded in accident and emergency. In addition, the HEMS system records details of the operations and procedures which were performed on the patient during their stay in hospital. These details include the duration of the operation, and the surgeon and

anaesthetist who performed it. Procedures are recorded using the NHS Classifications Service OPCS classification of interventions and procedures

Although it is not frequently recorded, the HEMS system has the capability to record the functional independence measure (FIM). This is a measure of how incapacitating the injuries received are to the patient, and measures how the patient's quality of life has decreased due to their injuries.

HEMS sometimes take photographs of the accident scene, but this is not done for every case, and the photographs that are taken are often not linked to their respective cases in the databases. However, for the TRL-HEMS workshop, the HEMS team took photographs of the vehicles involved in the pedestrian accidents they attended, so the causes of injury could be discussed. So, although they do not take these photographs routinely, it would be possible in the future for such photographs to be taken for every accident they attend.

While none of this information could be used in this current project, it could potentially be used in the future.

## **2.2 Other sources of data**

### **2.2.1 Mortality statistics**

The causes of death in the UK are summarised by the Office for National statistics each year in the "Mortality statistics" publications, the most recent of which (at the time of writing) summarised the causes of deaths registered in 2006 (Office for National Statistics, 2008). The causes of death are recorded using the International Classification of Disease version 10 (ICD-10) system.

The majority of deaths are registered within five days of the date of death, but there are circumstances in which this time is lengthened. This includes deaths which are investigated by a coroner, and where a coroner's inquest is required. This includes all deaths which were not due to natural causes, which will include all deaths due to traffic accidents. This means that the number of road traffic deaths *registered* in a year can be different to the number of deaths which occurred in the year, because some of them will be registered in the following year.

### **2.2.2 Hospital Episode Statistics (HES)**

Hospital Episode Statistics are compiled by the Department of Health and record details of all hospital admissions, finished consultant episodes and hospital discharges for England. Data of this type has been collected since 1989, with its main purpose being to ensure correct funding of hospitals from their Primary Care Trust (Department for Transport, 2007). HES contains data such as age, sex, dates of admission and discharge, diagnoses, operations and procedures, place of residence and ethnicity, with approximately 12 million new records being added each year. Information regarding the diagnosis of injury and its causation is coded using the International Classification of Diseases (ICD), of which the latest version ICD-10 has been used since 1995. Injuries sustained in road traffic accidents can easily be identified when coded in this way. It should be noted that HES do not include details of any casualties treated in A&E that are not subsequently admitted to hospital (Department for Transport, 2006b).

The HES data used in this report is taken from an as-yet unpublished report for the Transport Research Foundation (Cookson, Richards, Chislett, and Cuerden, 2008).

### **2.2.3     *STATS19***

STATS19 is, in principle, the national database in which all traffic accidents that result in injury to at least one person are recorded, although it is acknowledged that a few injury accidents are missing from the database, and a few non-injury accidents are included. The database primarily records information on where the accident took place, when the accident occurred, the conditions at the time and location of the accident, details of the vehicles involved, and information about the casualties. Approximately 50 pieces of information are collected for each accident (Department for Transport 2007).

The accidents that are recorded in STATS19 are summarised annually in the Department for Transport "Road Casualties Great Britain" series. TRL also has access to the STATS19 database itself.

### **2.2.4     *Police fatal files***

Police fatal file accident reports are recognised as an important source of information for accident research. They can provide detailed information on the events leading up to an accident, as well as giving details of driver errors and/or vehicle defects which may have contributed to the accident and to the injuries that resulted in the fatality.

These fatal accident reports cost a great deal to produce both in terms of Police and pathologists' time. The reports are produced, even where no criminal prosecution is envisaged, for presentation in evidence at the Coroner's inquest.

In 1992, TRL was commissioned by the Department for Transport (DfT) to set up and manage the Police fatal road traffic accident reports project. The purpose of this project was to institute a scheme whereby Police forces in England and Wales would routinely send fatal road traffic accident reports to TRL when they were no longer of use for legal purposes.

The fatal reports provide a unique insight into how and why fatal accidents occur and the detailed information contained within them is not available from any other source. The reports provide a unique opportunity to learn from these tragic accidents, so that we can work towards reducing the number of fatal accidents which occur in the UK and in the rest of the world. The current archive contains over 34,000 Police fatal accident reports.

Each report is given a unique TRL number which is linked to its corresponding STATS19 number. By linking each fatal accident to its STATS19 number, groups of accidents, which meet certain criteria, can be quickly identified. These accident reports can then be retrieved from the central archive, so that further details of the accident can be obtained and analysed. For this project, STATS19 was analysed to provide a list of fatal pedestrian accidents involving cars registered after 2000, and the fatal file archive was interrogated to find and extract any of these files held at TRL. Only those files which contained photographs of vehicle damage and a post-mortem report were used, since the aim of looking at the files was to associate the damage on the vehicles to the injuries the pedestrians received.

Post-mortems are ordered by the coroner for road traffic fatalities. The post-mortems are carried out by pathologists, who will record the details of the internal and external injuries received by the casualty. These details are put into a report, which will include what the pathologist considered to be the cause of death. These reports are often included in the Police fatal files. For this project, the post mortems were coded into AIS 2005 codes (see section 2.2.5.2 for an explanation of the AIS coding system).

### **2.2.5     *Recording injuries***

Many of these different sources of data use different methods of recording injuries and causes of injuries. The mortality statistics and HES both use ICD-10 to record the cause of injury, and HES also uses it to record the individual injuries. The HEMS data uses the

older ICD-9 system to record injuries. STATS19 does not record individual injuries, but does give each casualty an injury severity of "slight", "serious" or "fatal". The post mortems describe injuries, and for this project these descriptions have been translated using the Abbreviated Injury Scale.

It is important to know exactly how these different methods of recording injuries relate to each other. The following section explores each method in turn.

#### 2.2.5.1 ICD

The International Statistical Classification of Diseases and Related Health Problems, Ninth Revision (ICD-9) is used to record the injuries in the HEMS database. This is a coding system developed by the World Health Organisation in 1975 (World Health Organization, 2008), where each possible injury has a unique four character ICD-9 code associated with it. There are dictionaries of ICD-9 codes freely available on the internet (ICD9, 2008). This code describes what the injury is, but does not include a measure of the severity of the injury. The HEMS team actually use AIS to give a measure of the severity of each injury.

The Tenth revision of the ICD was developed in 1989. The major difference between ICD-9 and ICD-10 is that the codes changed from numeric to alphanumeric in ICD-10, enabling a far greater number of codes to be assigned (World Health Organization, 1992). This has been used to record the injuries in HES since 1995.

#### 2.2.5.2 AIS

The severity of the injuries is recorded by the HEMS team using the abbreviated injury scale (AIS). This was also used to record the injuries from the post mortems in the Police fatal files. The AIS scores in HEMS are recorded using the 1990 revision of AIS, while the post-mortems were recorded using the 2005 revision.

In the AIS system, each injury description is assigned a unique six digit numerical code in addition to the AIS severity score. The AIS severity score is a consensus-derived anatomically-based system that classifies individual injuries by body region on a six point ordinal severity scale ranging from AIS 1 (minor) to AIS 6 (currently untreatable), shown in Table 2-1 (Association for the Advancement of Automotive Medicine, 1990).

**Table 2-1. Possible values of AIS**

<b>AIS Score</b>	<b>Description</b>
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum
9	Unknown

MAIS denotes the maximum AIS score of all injuries sustained by a particular occupant. It is a single number that attempts to describe the seriousness of the injuries suffered by that occupant.

It is well recognised that casualties with multiple injuries have a more difficult and challenging recovery period and indeed a higher mortality rate. A better measure for the assessment of multiple injuries is the ISS (Injury Severity Score). The ISS is the sum of the squares of the three highest AIS codes in each of the three most severely injured ISS body regions. The six body regions used for ISS are:

- Head or neck
- Face
- Chest
- Abdominal or pelvic contents
- Extremities or pelvic girdle
- External

Because AIS gives each injury a severity score, and the severity of each casualty can be easily calculated (using the maximum severity score or ISS), AIS is very useful in accident research, much more so than ICD.

### 2.2.5.3 *Fatal, serious and slight*

Although the Police do not record individual injuries, they do record an overall severity for each casualty of slight, serious and fatal. The definitions of these are given in the STATS20 manual (Department for Transport, 2004). This states the following:

'Fatal' injury includes only those cases where death occurs in less than 30 days as a result of the accident. 'Fatal' does not include death from **natural causes or suicide**.

Examples of 'Serious' injury are:

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  
Injuries to casualties who die 30 or more days after the accident from injuries sustained in that accident.

Examples of 'Slight' injury are:

Sprains, not necessarily requiring medical treatment  
Neck whiplash injury  
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).

It is important to know the precise definition of a "serious" injury, because government targets are based on the reduction of the number of fatally and seriously injured casualties. These definitions also help to explain the relationship between the Police STATS19 data and the hospitals. Because seriously injured casualties include those who are an in-patient in hospital, this means that every road traffic casualty who is recorded

as being an in-patient in hospital data should be present as a serious (or fatal) casualty in the Police STATS19 data.

## **2.3 Workshops**

A number of workshops and meetings were held both within TRL and with the HEMS team in order to gain and share knowledge of pedestrian accidents, their injuries, and previous research. The discussions of these meetings are covered in this section.

### **2.3.1 TRL pedestrian workshop**

One of the workshops was held at TRL involving various experts in different areas of pedestrian accident research in order to gain an insight into the work already carried out on pedestrian accidents and areas of particular interest.

In this workshop the first part involved an expert who has worked on pedestrian safety and the development of pedestrian test procedures since 1988. This work on pedestrian safety has included development of impactors (test devices), development of test procedures, analysis of accident data, cost benefit studies, and the production of pedestrian impactors for sale. He informed the project team members of the different testing procedures vehicles undergo related to pedestrians in the UK and worldwide. This included legform and headform tests and the various changes and consultations that are occurring in these areas. For example, with the headform tests for children, where the headform is fired into the bonnet and the level of injury to the head is measured, there are discussions taking place on whether a headform of 2.5 kg or 3.5 kg should be used.

Also present was an expert with vast experience in the areas of biomechanics and injury prevention for those involved in road traffic accidents. He shared his knowledge of mechanisms of injury to pedestrians, particularly work he had carried out in looking at the rotational and linear acceleration aspects of head injuries. It was suggested here that looking at the types of injury pedestrians receive compared to the shape of the vehicles could be interesting along with a focus on pelvic and joint injuries, which are areas in which little work has been done previously. Also the concept of the motion of the pedestrian was brought out to be of interest, such as which direction the pedestrian was facing at the time of impact, which leg was bearing the load of the pedestrian at the time of impact and relating these factors to the injuries further up the body.

Following this was the lead engineer in the development of the TRL SensorLeg™ that is used by many companies to test the injuries received by legs in pedestrian impacts. This is the most human-like leg available and is modelled on a 50<sup>th</sup> percentile male, simulating human muscle shape, flesh density and bone fracture. It will enable vehicle and component developers to test accurately and evaluate new active safety pedestrian systems (e.g. pop-up bonnets) which are designed to reduce head injury in the event of a pedestrian impact. He also commented on the different regions of the leg that receive injuries and which parts of the car were found to be causing these injuries.

### **2.3.2 TRL-HEMS workshops**

Many meetings were held between members of the TRL and HEMS teams for a transfer of knowledge between the different groups. For example, the HEMS team, whilst having a great and in-depth knowledge of the injuries and treatments of the injuries, had much less appreciation of the mechanisms of the accidents and relating the injuries received to the areas of contact of pedestrians on the vehicles. The TRL team were the opposite, with expertise on accidents, their mechanisms and contact of pedestrians on the vehicles, but limited knowledge of injuries and their associated treatment. Due to the expertise of these people and thus their high utilisation in their areas, setting up workshops with many people was difficult in itself.

The largest workshop held was that to look at some case studies of fatal files, in order for TRL to gain knowledge of injuries and the types of mechanisms that could have caused them, and for the HEMS team to share with TRL some of the accidents they have been to, what they found at the scene, and what we thought had happened in the accidents. See section 3.4.1 for details of some of these case studies.

## **2.4 Analysis**

The following sections give an outline of the methods by which the analysis of pedestrian accident data was carried out.

### **2.4.1 Size of the road safety problem**

There are a variety of different ways of quantifying the relative effect of road traffic accidents compared to other sources of injury. One such method calculates the “years of life lost” for fatalities, by determining the difference between the age at death, and the life expectancy for a person at that age. A variation of this is the “years of working life lost”, which provides a simple way of ranking causes of death by their economic effect on the country. For this project the years of working life lost were calculated by summing the number of years lost between the ages of 15 and 64. The results of this analysis are in section 3.1.

### **2.4.2 HEMS and national data**

The pedestrian casualties recorded in HEMS are a subset of the pedestrian casualties recorded nationally. The accidents all occurred in London or the surrounding area, and because of the HEMS dispatch criteria (discussed in section 2.1.2) they are likely to be more seriously injured compared to the national population of pedestrian casualties. This project explores the possible biases in the HEMS dataset by combining it to two national datasets of pedestrian casualties: the Police STATS19 database and the Hospital Episode Statistics (see section 3.2). Only those pedestrians in STATS19 who were seriously injured or killed are included in this analysis. The HES data includes all pedestrian casualties contained in HES from April 1998 to March 2007 in England (Cookson et al., 2008).

### **2.4.3 Cost of pedestrian injuries**

The information recorded in HEMS of the length of time casualties remain in hospital was used to estimate the cost of pedestrian casualties. The Intensive Care Society stated that the cost to the hospital of a day in an ICU is approximately six times that of a day spent on a ward (Intensive Care Society, 2008). Christensen, Ridley, Lecky, Munro, and Morris (2008) cited the Department of Health statistics (Department of Health, 2005) which said that the mean cost per patient per day on a general ward was £281, and the mean cost per patient per day in a critical care unit was £1,328 (approximately 4.7 times more costly than the ward). The information in the HEMS database included the number of days spent by each patient on the ward and in the ICU, so these values were used to calculate a cost of each patient to the hospital.

It should be noted that this cost only accounted for the length of time each pedestrian was in hospital, and did not account for, e.g. the differing costs of the operations and procedures carried out during their stay. This was partially because details of the operations could not be provided by the HEMS for this study, but also because the length of stay in hospital made up a large proportion of the cost for each patient. In a study of blunt trauma patients, Christensen et al. (2008) calculated that approximately 75% of

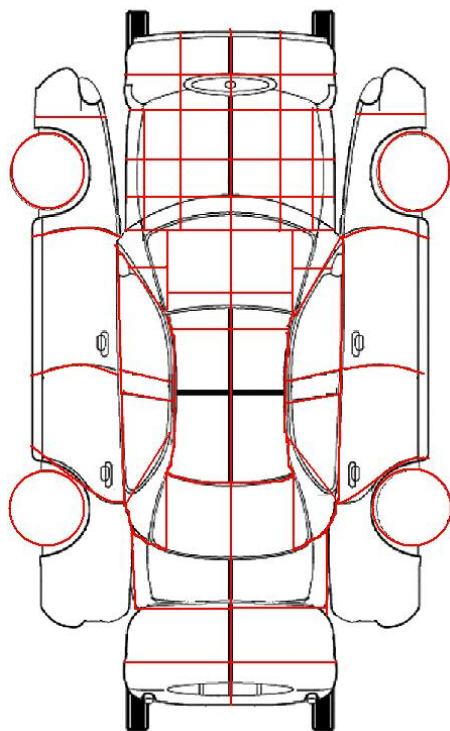
the total costs were accounted for by the length of stay in hospital. This analysis can be seen in section 3.3.

#### **2.4.4 Fatal files**

Police fatal files were examined to investigate the causes of pedestrian injuries. In order to select relevant fatal files from the archive, analysis was carried out on the STATS19 database to identify pedestrian collisions involving cars registered in 2000 or newer. From this analysis, 1008 pedestrian collisions were identified, 211 of which were in the fatal file archive. Out of the 70 cases extracted, 34 were found to have good photographs of the damage and post mortems, which were required for the analysis. This resulted in 34 vehicles which struck 34 pedestrians who had a total of 583 injuries coded (an average of 17 per pedestrian). It should be noted that some post mortems available included much more detail than others depending on the type of report; therefore, the number of injuries which could be AIS coded per person varied greatly. Also in some cases the body was not be examined in as much detail, for example, in one case the brain was not examined in order to avoid further distress to the families.

The information from the Police fatal files was recorded using a number of different forms, which were created for this project. These forms collected data about the accident, the vehicles involved, the damage on the vehicles, the drivers and pedestrians, the injuries received by the pedestrians, and the causes of those injuries.

For the analysis, the forms were put together and the results punched into a database. The vehicles involved in collisions with pedestrians were split into 70 zones, shown in Figure 2-1. The AIS 2+ injuries received by each pedestrian were attributed to the various zones on the vehicle that were damaged or to other causation factors such as acceleration injuries, or secondary impacts with the ground or other objects. If two or more injuries to a body region were due to the same zone on the vehicle, the zone was counted only once as having caused an injury in that accident.



**Figure 2-1. Location of zones on the vehicle**

The discussions in the workshops held with HEMS on the fatal files were used in order to guide some of the analysis carried out on the data. The key findings from the analysis of the fatal files can be seen in section 3.4.

### 3 Key findings

Using the information received from HEMS and the discussions with the HEMS team on injuries and their causations, various aspects of pedestrian collisions were investigated to show what could be done with the data, and the key findings from this analysis are presented in this section. This includes examples of analysis using sources of medical data in addition to the HEMS data, such as mortality statistics, national Hospital Episode Statistics, and Police fatal files.

#### 3.1 Size of the road safety problem

Table 3-1 shows causes of death in England and Wales ranked by the years of working life lost due to these causes in 2006. This table was obtained from the Office for National Statistics (ONS) "Mortality Statistics" publications (Office for National Statistics, 2008). This publication records the deaths which were registered in 2006. Table 3-1 also contains an estimate of the years of working life lost using data in Road Casualties Great Britain (RCGB) (Department for Transport 2007).

**Table 3-1. Causes of death in England and Wales in 2006**

Cause	Number of deaths	Years of working life lost (2006) (thousands)
Ischaemic heart diseases	82,619	99
Land transport accidents (from ONS)	2,990	78
Road traffic accidents (from RCGB)	2,858	75
Diseases of the liver	7,281	69
Intentional self-harm	3,331	64
Malignant neoplasm of trachea, bronchus and lung	29,332	49
Malignant neoplasm of breast	11,011	43
Cerebrovascular diseases	48,389	36
Accidental poisoning by and exposure to noxious substances	1,072	26
Malignant neoplasm of colon, rectum and anus	14,022	25
Malignant neoplasm of brain	3,112	24
Mental and behavioural disorders due to psychoactive substance abuse (excludes alcohol and tobacco)	739	23
Pneumonia and influenza	28,691	20
Leukaemia	3,859	15
Malignant neoplasm of oesophagus	6,495	13
Malignant neoplasm of pancreas	6,584	11
Non-Hodgkin's lymphoma	3,987	11

Diabetes mellitus	5,490	10
Malignant neoplasm of ovary	3,799	10
Malignant neoplasm of kidney, except renal pelvis	3,102	9
Malignant melanoma of skin	1,649	9
Malignant neoplasm of stomach	4,562	8
Malignant neoplasm of cervix uterii	831	7
Malignant neoplasm of liver and intrahepatic bile ducts	2,664	6
Asthma and status asthmaticus	1,082	6
Multiple sclerosis	933	6
Motor neuron disease	1,655	4
Meningococcal infection and meningitis	216	4
Malignant neoplasm of prostate	9,057	3
Malignant neoplasm of bladder	4,304	3
Multiple myeloma and malignant plasma cell neoplasms	2,301	3
Duodenal ulcer	1,799	3
Tuberculosis, including sequelae	432	2
Bronchitis	230	0
All causes, all ages	502,599	1,262

The method used to calculate the years of working life lost is described in Office for National Statistics (2008). Using the number and age of casualties given in RCGB, the years of working life lost due to road casualties in Great Britain was estimated as 82,850 in 2006. Assuming that the age distribution of casualties in Scotland in 2006 was the same as that in England and Wales, it was estimated from RCBG that the years of working life lost in England and Wales due to road accidents was 74,648. These values are shown in Table 3-1. While a more accurate estimate could be made using STATS19 data instead of data published in tables in RCGB, it is unlikely that this would alter the estimate by a large amount.

In 2006 "land transport accidents" and road traffic accidents were the second largest cause of years of working life lost. The reason that these accidents ranked so highly was that the average age of people killed in road accidents was much lower than that for most other causes. For example, the average age of men killed in land transport accidents in 2006 was 39, and for women it was 48. This compares to a mean age of death for ischaemic heart diseases of 75 for men and 82 for women.

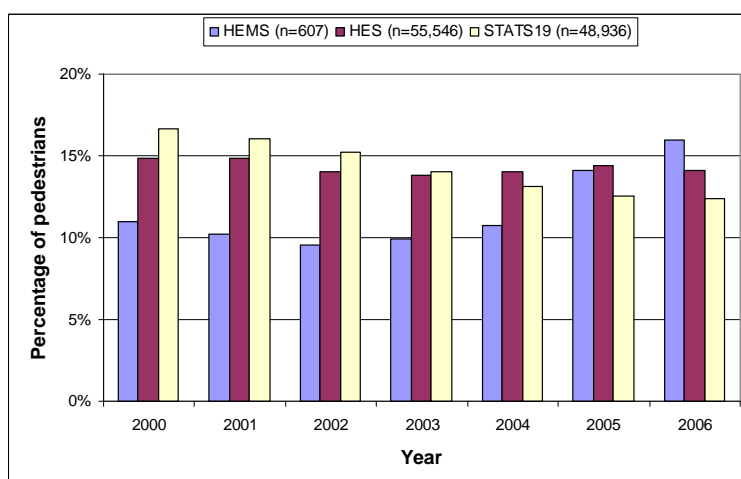
It should be noted that different ways of grouping causes of death would affect where they appear in this ranking. For example, if all cancers (malignant neoplasms) were grouped together as one cause, they would appear at the top of the list. Different methods of grouping causes of death have their own benefits, and have been discussed by Griffiths, Rooney, and Brock (2005). The grouping used in the "years of life lost" tables by the Office of National Statistics splits cancers and causes of accidents, and it is these tables which have been used to produce Table 3-1.

The “land transport” category does not only include traffic accidents, although the vast majority of these accidents were traffic accidents. The majority of the land transport accidents which were not traffic accidents occurred off the public highway, such as in car parks and building sites. There were also some accidents where it was not specified whether they were traffic or non-traffic accidents. In addition, there were some accidents where the transport involved was not road transport. This included 48 deaths involving trains.

### 3.2 Relationship of HEMS to national data

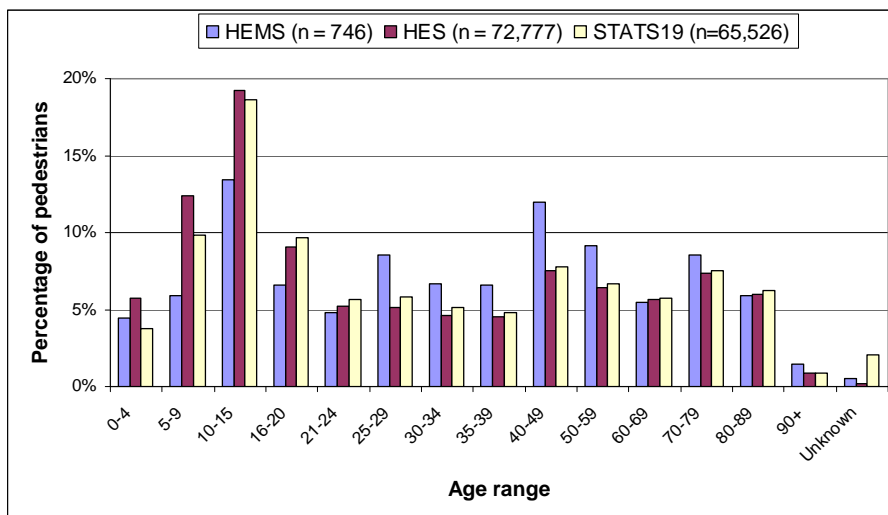
Figure 3-1 shows the variation of the number of casualties recorded in HEMS, HES and STATS19 from 2000-2006. This figure shows that the number of casualties recorded in HEMS has increased over time, while the number of casualties recorded in HES has remained relatively constant and the number of casualties recorded in STATS19 has reduced.

The difference between the number of road casualties recorded by the Police in STATS19 and the hospitals in HES is well documented (Goldacre, Gill, & Yeates, 2006; Department for Transport, 2008).



**Figure 3-1. Proportion of casualties in HEMS, HES and STATS19 by year of accident**

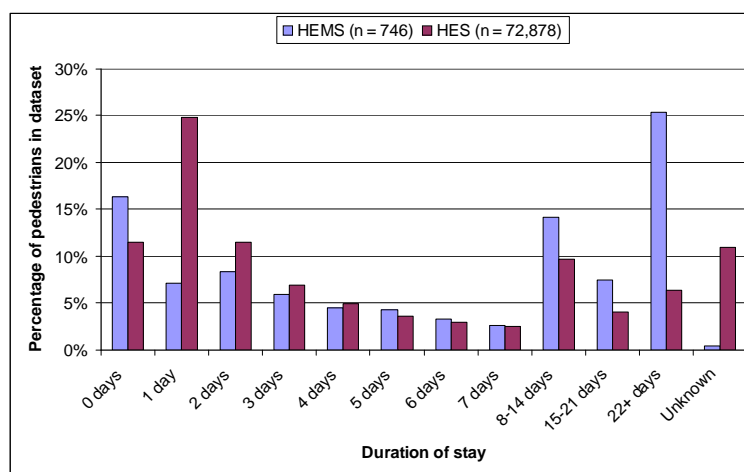
Figure 3-2 shows the distribution of age in the three datasets. Broadly the distributions were similar, although HEMS had proportionally fewer 5-15 year olds, and proportionally more 25-59 year olds.



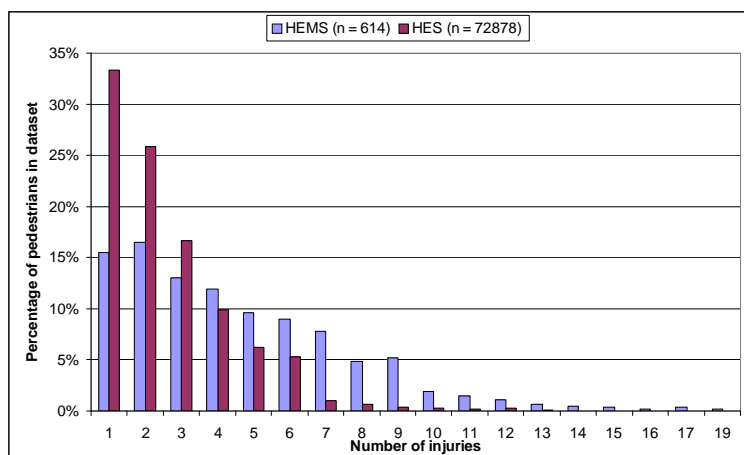
**Figure 3-2. Age distribution of pedestrian casualties in HEMS, HES and STATS19**

Comparison of gender showed that all the datasets had a similar proportion of males (~60%) to females (~40%), and that the age distribution of males and females reflected the age distribution of all the casualties.

Figure 3-3 and Figure 3-4 provide evidence that the pedestrian casualties in the HEMS dataset are more severely injured than those recorded nationally in the HES dataset. These figures show that pedestrians in HEMS were more likely to stay in hospital for a longer duration, and were more likely to receive a greater number of injuries. It should be noted that the step reduction in the number of pedestrians in HES with seven or more injuries recorded was because until 2002, only six injuries could be recorded per person in HES. Currently HES can record up to 14 injuries per person. There is no such limit in the HEMS database.



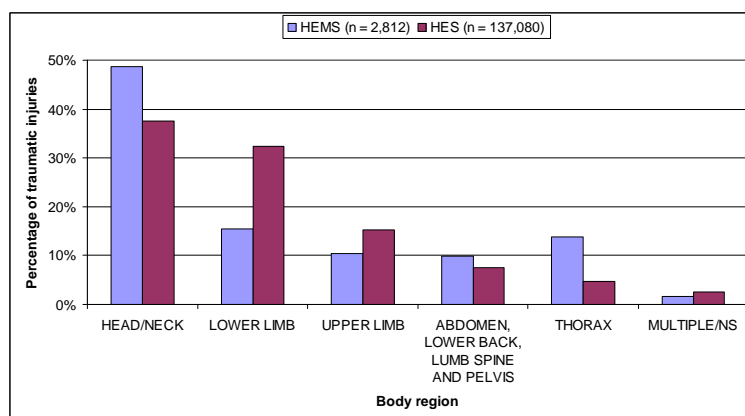
**Figure 3-3. Duration of stay of pedestrians in HEMS and HES**



**Figure 3-4. Number of recorded injuries for pedestrians in HEMS and HES**

Figure 3-5 shows the distribution of injuries sustained by the pedestrians in the two datasets, split by body region. Only the traumatic injuries, which could have been caused by the accident, were included. This excluded pre-existing diseases and complications due to surgery, which were recorded in the datasets but not included in this figure.

The HEMS dataset had a greater proportion of head and thorax injuries compared to the HES dataset. Injuries to these areas are likely to be more life-threatening than injuries to the limbs, again showing that the HEMS dataset is biased towards more seriously injured pedestrians.



**Figure 3-5. Distribution of injuries in HEMS and HES.**

It should be noted that the two databases use different versions of the International Classification of Disease coding system. The HEMS database uses the ninth revision (ICD-9), while the HES database uses the tenth revision (ICD-10). The major difference between ICD-9 and ICD-10 is that the codes changed from numeric to alphanumeric in ICD-10, enabling a far greater number of codes to be assigned (World Health Organization, 1992). Despite these changes in the coding system, the same injury regions can be defined in both versions. One possible effect this may have on the comparison here is that the most frequent codes in HEMS may make up a larger proportion of the codes in the dataset compared to HES, because there are a greater number of possible ICD codes in HES.

Table 3-2 and Table 3-3 show the most frequent injuries recorded in the HEMS and HES datasets respectively. The most frequent injuries to pedestrians in the HEMS dataset were dominated by head injuries, which made up seven of the ten most frequent injuries. No leg injuries appeared in the ten most frequent injuries in the HEMS dataset, in contrast to HES, where four of the ten most frequent injuries were fractures of the lower leg. There were also four types of head injuries in the ten most frequent injuries in the HES dataset. The differing proportion of head and leg injuries in the top ten most frequent injuries reflected the distribution of the injuries in the two datasets shown in Figure 3-5.

**Table 3-2. Most frequent injuries in HEMS dataset**

<b>ICD9 injury description</b>	<b>Number of pedestrian injuries</b>	<b>% of injuries</b>
Cerebral contusion closed	188	6.7%
Face wound open without complication	154	5.5%
Generalized SAH IVH*	145	5.2%
Fracture of ribs closed	137	4.9%
Scalp without mention of complication	133	4.7%
Fracture of base of skull, closed with intracranial injury	116	4.1%
Cerebral subdural haematoma	98	3.5%
Injury to lung without wound into thorax	84	3.0%
Pneumothorax, without wound into thorax	80	2.8%
Fracture of malar and maxillary bones closed	67	2.4%
Total	2812	-

\* Generalized subarachnoid haemorrhage and intraventricular haemorrhage

**Table 3-3. Most frequent injuries in HES dataset**

<b>ICD10 injury description</b>	<b>Number of pedestrian injuries</b>	<b>% of injuries</b>
Unspecified injury of head	11410	8.2%
Fracture of shaft of tibia	8488	6.1%
Open wounds of other part of head	4417	3.2%
Superficial injury of other parts of head	4125	3.0%
Fracture of upper end of tibia	3983	2.9%
Fracture of lower end of tibia	3923	2.8%
Open wound of scalp	3516	2.5%
Fracture of pubis	2946	2.1%

Fracture of upper end of humerus	2497	1.8%
Fractures of other parts of lower leg	2327	1.7%
Fracture of clavicle	2303	1.7%
Total	139308	-

In summary, there is evidence that the HEMS dataset contains a greater proportion of pedestrians with serious injuries than the HES dataset, which covers all pedestrian admissions in England. Pedestrians in the HEMS dataset tend to have a longer stay in hospital, more injuries, and more head and thorax injuries than the pedestrians in the HES dataset. This reflects the policy of the Helicopter Emergency Medical Service, which is more likely to pick up pedestrians with serious and life-threatening injuries.

The distribution of the age of pedestrians is also different in HES and HEMS. The latter has a smaller proportion of children aged from 5-15, and a larger proportion of female pedestrians between the ages of 21-59.

These differences need to be borne in mind for the following sections.

### 3.3 Cost of pedestrian injuries

Table 3-4 shows the total number of days spent on a ward and in ICU and the total cost for all the pedestrians in the HEMS dataset. It also shows the annual cost, which was calculated by dividing the total cost by eight (the number of years covered by the HEMS dataset).

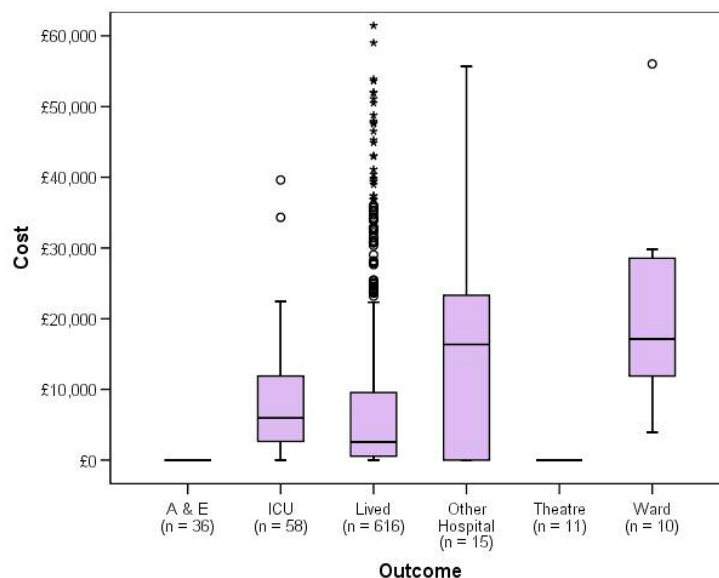
**Table 3-4. Summary of costs for HEMS dataset**

Number of pedestrians	746
Total days on ward	12,009
Total days in ICU	2,634
Total cost	£6,853,252.80
Annual cost	£856,656.60
Mean cost per patient	£9,186.67

Figure 3-6 shows the distribution of the costs of the pedestrian casualties to the hospital, by their outcome: whether they survived, or where they died. The central horizontal line within the bars gives the median cost, and the bars themselves give the upper and lower quartiles. The lines extending from the bars contain approximately 99% of the pedestrians. The circles and stars outside these lines are outliers. All the pedestrians who died in accident and emergency (A&E) or in theatre did so within a day of admission, which means that the annual cost for these pedestrians was zero.

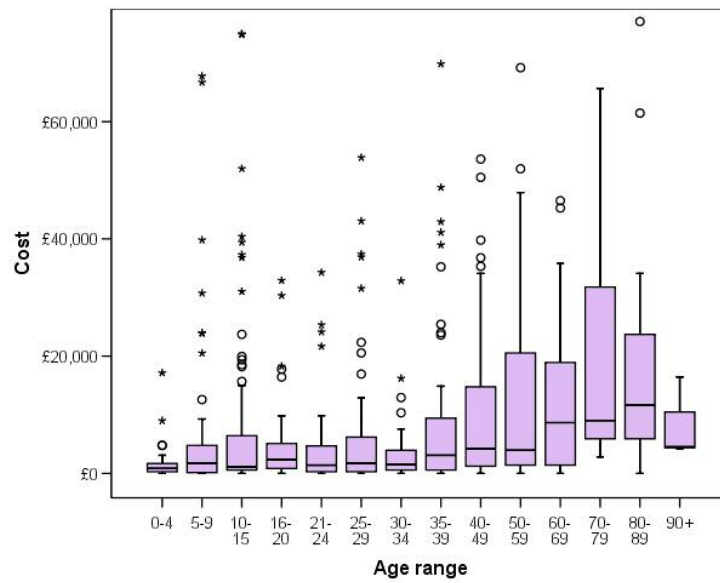
The annual cost of the pedestrians for each outcome was calculated by summing the cost of each individual pedestrian with a given outcome, then dividing by the number of years covered by the HEMS data. The annual cost for pedestrians who died in intensive care was £89,639.00, for those who died on the ward it was £25,890.64, and for those who died in another hospital it was £28,539.06. The annual cost of the pedestrians who survived was £712,587.90.

This cost model, based on the duration of stay in hospital, does not include any additional cost relating to the death of a patient. For this reason, the costs calculated from this point on will only include those pedestrians who survived.

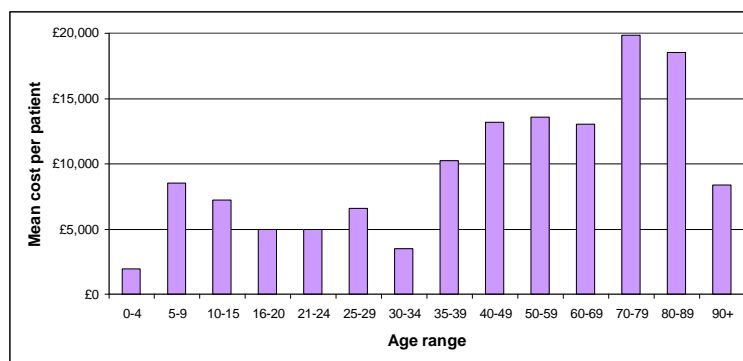


**Figure 3-6. Cost of pedestrian casualties by outcome**

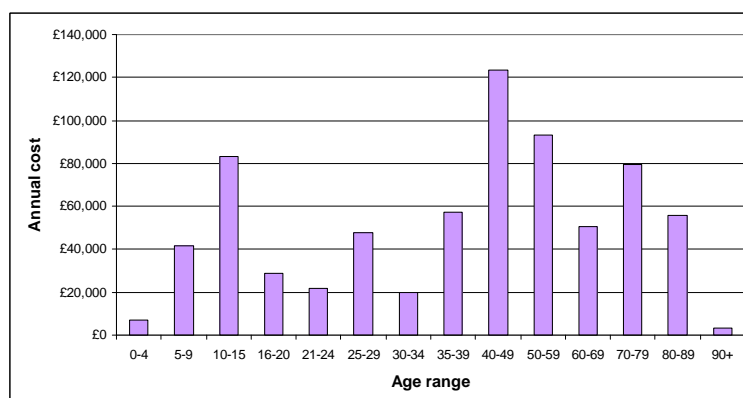
Figure 3-7, Figure 3-8 and Figure 3-9 show the relationship between the age of the pedestrian casualties and their cost to the hospital, for surviving pedestrians only. Figure 3-7 shows how the distribution of cost to the hospital of pedestrian casualties varied with age. For older casualties, the range of cost to the hospital was much greater than for younger casualties. Figure 3-8 shows that the mean cost to the hospital was also greater for these older pedestrians. Figure 3-9 shows that the annual cost of elderly pedestrians to the hospital was greatest, but also that the annual cost of pedestrian casualties aged 10-15 was relatively high. Although these young pedestrians had a relatively low average cost, they were relatively high in frequency, and account for a large proportion of the cost of all pedestrian casualties.



**Figure 3-7. Cost of pedestrian casualties by age range (surviving pedestrians only)**



**Figure 3-8. Mean cost per patient by age range (surviving pedestrians only)**



**Figure 3-9. Annual cost of pedestrians in HEMS by age range (surviving pedestrians only)**

Table 3-5 lists the 20 injuries associated with the largest annual cost to the hospital. These included injuries with a severity of AIS 2 or greater, and which were received by surviving pedestrians. The annual cost of each injury was calculated by summing the cost of each patient who received that injury, regardless of what other injuries they had.

**Table 3-5. ICD9 descriptions of the 20 AIS 2+ injuries with the highest annual cost, surviving pedestrians only.**

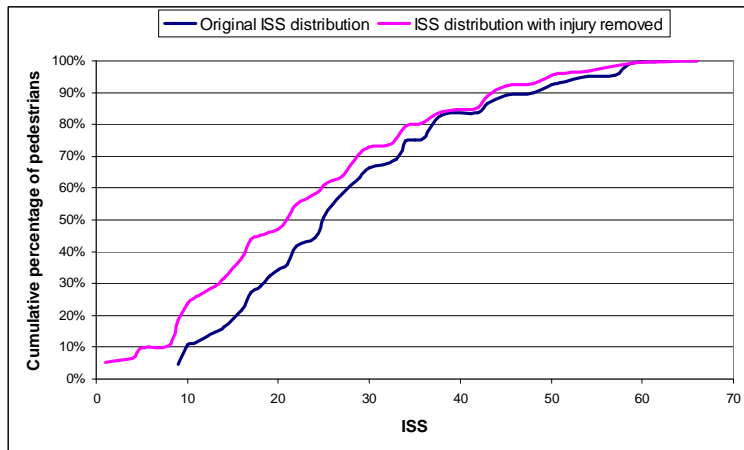
ICD9 code	ICD9 description	Annual cost
851	Cerebral contusion closed	£223,644.39
852.05	Generalized SAH IVH*	£197,135.55
852.04	Cerebral subdural haematoma	£147,423.14
807	Fracture of ribs closed	£127,802.31
860	Pneumothorax, without wound into thorax	£108,336.04
802.4	Fracture of malar and maxillary bones closed	£98,578.31
861.2	Injury to lung without wound into thorax	£88,132.14
801.1	Fracture of base of skull, closed with intracranial injury	£85,202.71
808.2	Fracture of pelvis, pubis closed	£82,431.35
810	Fracture of clavicle, closed	£77,503.31
802.8	Fracture of other facial bones, closed	£76,382.83
805	fracture of cervical spine closed	£74,802.20
811	Fracture of scapula, closed	£71,640.95
864	Injury to liver without wound into cavity	£56,965.73
823.1	Fracture of tibia and fibula, unspecified part, open	£56,898.99
823	Fracture of tibia and fibula, unspecified part, closed	£49,873.99
808.4	Fracture of pelvis, specified part, closed	£46,480.91
808	Fracture of pelvis, acetabulum, closed	£46,235.04
805.2	Fracture of vertebral column without spinal cord lesion, dorsal closed	£45,760.85
802.2	Fracture of mandible closed	£44,664.95

\* Generalized subarachnoid haemorrhage and intraventricular haemorrhage

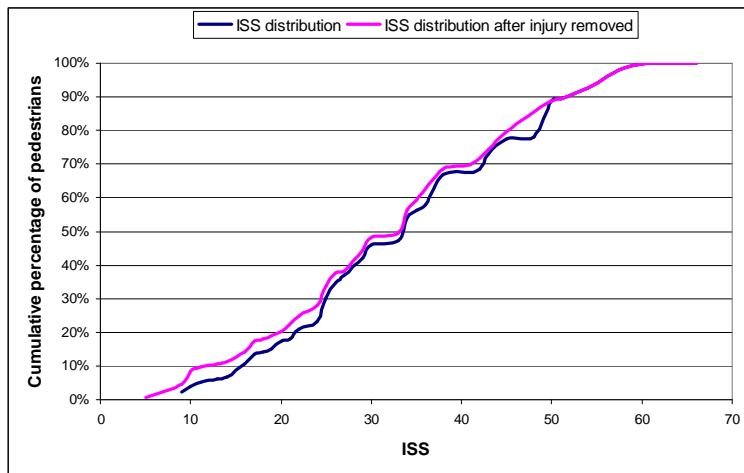
Once the most costly injuries have been identified, the injury severity score (ISS) can be used to estimate the effect of removing these injuries. The blue lines on Figure 3-10 and Figure 3-11 show the cumulative ISS distribution for the pedestrians who had the "cerebral contusion closed" and "generalised SAH IVH" injuries respectively. For the pedestrians who had the cerebral contusion closed injury, this injury has been removed, and the ISS has been re-calculated using their remaining injuries. The cumulative distribution of this new ISS is shown in pink in figure Figure 3-10. This process was repeated for pedestrians with generalized SAH IVH, the results of which are shown in figure Figure 3-11.

Figure 3-10 shows that removing the “cerebral contusion closed” injury has a greatest effect on the pedestrians with a lower ISS. For example, the proportion of pedestrians with an ISS of 20 or less has increased from about 35% to about 45%, but the proportion of pedestrians with an ISS of 40 or greater has remained constant at approximately 15%.

In contrast to this, Figure 3-11 shows that removing the “generalised SAH IVH” injury makes very little difference to the ISS distribution.



**Figure 3-10. Cumulative distribution of ISS for pedestrians with cerebral contusion closed (n = 158)**



**Figure 3-11. Cumulative distribution of ISS for pedestrians with generalized SAH IVH (n = 133)**

Table 3-6 shows how the average cost of pedestrian casualties is related to their ISS. Higher values of ISS tend to lead to higher costs for the hospital, so the greatest benefit may be gained by targeting injuries which reduce the ISS of pedestrians by the largest amount.

**Table 3-6. Mean cost of surviving pedestrians by ISS**

ISS group	Number of pedestrians	Mean cost per pedestrian
-----------	-----------------------	--------------------------

0-9	196	£4,013
10-16	112	£6,347
17-25	98	£13,958
26-75	89	£25,195

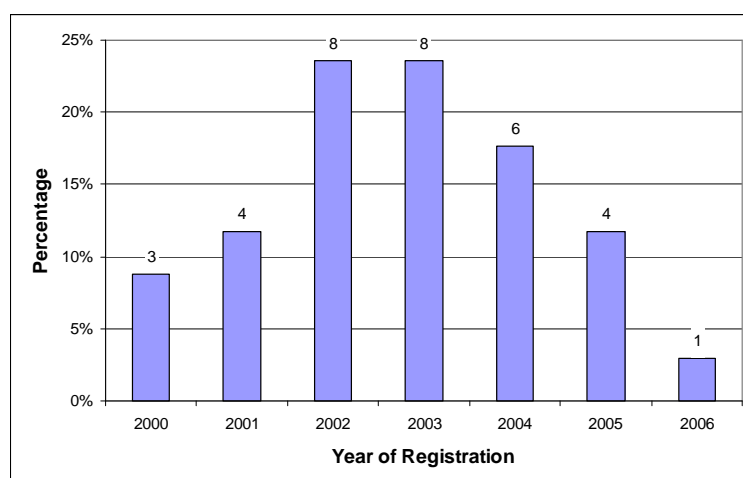
In summary, the analysis of HEMS presented in this section shows one way in which medical information can be used to prioritise injuries. Based on this relatively simple costing model, it is seen that older pedestrians account for the greatest proportion of the cost of pedestrian casualties, because when they are injured they remain in hospital for a long length of time. At the other end of the age scale, pedestrians aged 10-15 years also cost the hospital large amounts of money, because of the large numbers of pedestrian casualties which are in this age group.

In terms of individual injuries, injuries to the brain seem to be associated with the greatest cost, and it is clear that many of these pedestrians have more than one serious brain injury. One possible method to determine the benefit of removing individual injuries is to re-calculate the ISS of the pedestrians with the injury in question, then use the relationship between ISS and cost to estimate the reduction in cost if this injury were removed. This method shows that the benefit of removing the "cerebral contusion closed" injury would be more than removing the "generalized SAH IVH" injury, because the change in ISS distribution is greatest if the "cerebral contusion closed" injury is removed.

These results are valid for the subset of patients recorded by HEMS, which is biased towards more seriously injured pedestrians. If this study could be repeated nationally, it is possible that injuries such as tibia and fibular fractures, which lead to relatively long stays in hospital but are not life threatening, may appear to have a greater cost associated with them than is seen for the HEMS pedestrians.

### 3.4 Fatal file analysis and workshops

This analysis of police fatal accident files held by TRL concentrated on pedestrian collisions with relatively new cars. Figure 3-12 shows the year of registration of the 34 vehicles which struck the 34 fatally injured pedestrians in the files selected for review. All of these vehicles were cars or car-derived vans, and they were all registered in 2000 or later.



**Figure 3-12. Year of registration of the 34 vehicles in impacts with pedestrians**

The rest of this section gives case studies of four cases presented at the injury causation workshop and the key findings from the analysis of the files including injury causation.

### **3.4.1 HEMS-TRL injury causation workshop**

A day long workshop was held at the Royal in which members of the HEMS team and TRL project team looked in depth at four of the fatal files analysed. This section gives a summary of the information in these files, as presented to the HEMS team, and a synopsis of the discussion which followed.

#### **3.4.1.1 Accident 1**

Figure 3-13 shows the scene of this accident. This was a residential street, with a speed limit of 30 mph, and parked cars on either side of the road. The accident occurred when the pedestrian crossed from between parked cars and collided with a car. The speed of the impact was calculated as 20-24 mph. The pedestrian had been crossing from the offside of the vehicle.



**Figure 3-13. The accident scene**

The vehicle involved in the impact was a 2005 Vauxhall Corsa, shown in Figure 3-14. The vehicle did not perform any avoidance manoeuvre before impact with the pedestrian. This vehicle has a rounded bonnet, and is in the "supermini" EuroNCAP category. Figure 3-15 to Figure 3-18 show the damage the vehicle sustained in the impact with the pedestrian. This consisted of scratch marks on the front offside bumper and up the offside of the bonnet, a dent near the base of the offside A-pillar and the adjoining windscreen, and minor damage to the front offside wing.



**Figure 3-14. The Vauxhall Corsa**



**Figure 3-15. Marks to offside bumper**



**Figure 3-16. Scratch marks up bonnet**



**Figure 3-17. Evidence of impact to windscreen and dent in A-pillar**



**Figure 3-18. Damage to front offside wing**

The pedestrian was a 10-year old girl, 138cm tall. She had just exited from a car parked on the road, and was crossing the street to get to her house. It is not known whether she died at the scene, or how long she took to die. After the impact with the vehicle, she was thrown to the side of the vehicle and landed on the carriageway.

The AIS 2+ injuries sustained by the pedestrian were as follows:

- L temporo-parietal region - haemorrhage in deep tissues
- L complex undisplaced # temporal/parietal bone extending into skull base, passing through middle and pituitary fossa
- R temporo-parietal region - extensive area of deep contusion with associated subarachnoid haemorrhage
- R temporo-parietal region - extensive area of deep contusion with associated subdural haemorrhage
- Superficial areas of contusion both frontal lobes bases
- Superficial areas of contusion to bases of both temporal lobes
- Superficial areas of contusion to bases of both occipital lobes
- Gyri flattening - diffuse brain swelling R>L
- Brain stem compression
- Bilateral cerebellar tonsils necrotic
- Midbrain - small Duret-type haemorrhage
- Pons swelling
- Medulla swelling
- Cerebellum swelling

All of these AIS 2+ injuries were head injuries. It is believed that these were caused by the initial impact between the child's head and the base of the A-pillar.

In the workshop, the HEMS and TRL teams were in agreement on the causes of the injuries being due to the impact with the base of the A-pillar. Some questions were raised over the outward looking dent on the wing panel as shown in Figure 3-18. It was decided that this could either be the reflection of light causing the dent to look outward, or the impact of the child with the bonnet caused the bonnet to be pushed down and something inside the bonnet to be pushed outwards into the side panel.

Due to no avoidance manoeuvres being reported before this impact, it was suggested that it may be interesting to look at the frequency of vehicles that took avoidance manoeuvres. This is shown in Table 3-7 in the following section of the report.

#### *3.4.1.2 Accident 2*

This accident occurred on a pedestrian crossing (as shown in Figure 3-19) when the light was green for traffic. The first vehicle that was approaching managed to swerve and avoid colliding with the pedestrian, but the second (following) car struck the pedestrian. The road was in an urban area with a 30 mph speed limit.



**Figure 3-19. The scene**

The car was a Mercedes E220, a large family car with an angular bonnet, registered in 2004. From estimates using witness statements, the car was found to have been travelling at 25 to 30 mph. The driver steered and braked to avoid the collision, although the impact speed remained at 25 to 30 mph. The vehicle sustained damage to the bonnet, A-pillar and windscreen as shown in Figure 3-21 and Figure 3-22.



**Figure 3-20. Mercedes E220**



**Figure 3-21. Windscreen damage**



**Figure 3-22. Bonnet damage**

The pedestrian was a 45 year old female who was crossing the carriageway on a pedestrian crossing facility from the driver's offside. The pedestrian was walking at the time of impact and was thrown to the side of the vehicle landing on the carriageway. The pedestrian was three times over the drink drive limit. The pedestrian died at the scene or on arrival at the hospital.

The pedestrian received the following seven AIS 2+ injuries which have been assigned to various areas of the vehicle:

- Fracture of skull vault, left frontal bone – palpable – A-pillar
- Fracture of left and right orbits with eyes displaced – A-pillar
- Comminuted fracture of facial bone through pituitary fossa – A-pillar
- Fracture of right and left temporal bone and across crown of scalp – A-pillar
- Generalized subarachnoid haemorrhage – A-pillar
- Contusion and laceration left inferior frontal lobe – A-pillar
- Anterior rib fractures with little bruising – Carriageway

In this discussion the teams were surprised that there were no leg injuries of AIS 2+ as the vehicle damage and AIS 2+ injuries would indicate that the pedestrian would probably have been struck on the legs by the bumper area of the vehicle. When the post mortem was re-examined, it was discovered that the pedestrian had bruising to her shins which was probably caused by the bumper.

### 3.4.1.3 Accident 3

As shown in Figure 3-23, this accident occurred at a pelican crossing next to a junction on a residential road with a 40 mph speed limit. The accident occurred when a pedestrian crossed on the crossing without pressing the button. The light was green for cars and an oncoming car collided with the pedestrian on the crossing. The pedestrian was reported to have been looking the opposite way to that from which the car was approaching.



**Figure 3-23. The scene**

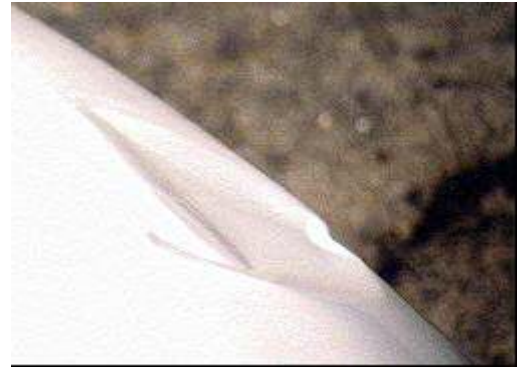
The vehicle involved was a Vauxhall Corsa of 2002 registration year. It was classed as a small family car with a rounded bonnet shape. The reconstruction found the car to have been going straight ahead at a speed between 24 and 34 mph at the time of impact with no avoidance manoeuvres having taken place. During the impact, the vehicle sustained damage to the bonnet (a minor dent, Figure 3-26) and smashed the windscreen, without holing (Figure 3-25).



**Figure 3-24. Front view**



**Figure 3-25. Windscreen damage**



**Figure 3-26. Bonnet damage**

The pedestrian was a 63 year old male who was walking at the time of the collision. He was crossing from the driver's nearside on a pelican crossing. When he was struck by the vehicle he was scooped up onto the bonnet, then came off and was thrown forwards, 14 m from the point of impact, as the vehicle came to a stop. The pedestrian died from his injuries after two days in hospital.

The pedestrian received the following six AIS 2+ injuries which have been assigned to various areas of the vehicle:

- Fracture to right mid tibia – bumper
- Fracture to right fibula – bumper
- Undisplaced fracture to right parietal bone over right orbit and right half of pituitary fossa – windscreen
- Subdural haematoma on right side and partially evacuated haematoma affecting left cerebrum – windscreen
- Swelling to brain – diffuse – windscreen
- Fracture to right ribs 4-6 posteriorly – bonnet

For this case a discussion took place as to whether the causation codes were correct for the injuries, in particular the rib fractures and whether they were due to the impact with the bonnet, or the windscreen. The final decision was that they were caused by the bonnet.

#### 3.4.1.4 Accident 4

As shown in Figure 3-27, this accident occurred near a pelican crossing at a junction on a residential road with a 30 mph speed limit. The accident occurred when a pedestrian was crossing near, but not on, the pedestrian crossing. It is thought that neither the driver nor the pedestrian saw each other.



**Figure 3-27. Scene photograph**

The vehicle involved was a Ford Fiesta registered in 2001. It had a EuroNCAP classification of supermini with a rounded bonnet shape. The reconstruction found the vehicle to have been going straight ahead at a speed between 23 and 28 mph at the time of impact, with an avoidance manoeuvre of braking reported (the car was estimated to have been travelling at 30mph before the braking). During the impact, the vehicle sustained damage to the nearside corner of the bumper, a smashed nearside headlamp, and denting and scratches to the nearside bonnet edge.



**Figure 3-28. Full view of the damage**



**Figure 3-29. Bumper and headlight damage**



**Figure 3-30. Wing denting**

The pedestrian was a 48 year old female who was walking at the time of the collision. She was crossing from the driver's offside. When she was struck by the vehicle she was thrown to the side of the vehicle in a glancing impact and landed 12m from the point of impact. The pedestrian died in hospital on the same day as the collision occurred.

The pedestrian received the following AIS2+ injuries which have been assigned to various areas of the vehicle:

- Minimal subarachnoid haemorrhage – road
- Brain contusion – road
- Fracture to right upper tibia – bonnet, leading edge
- Massive open fracture with irregular edges to right pelvis with prolapsed tissue - bonnet

There was a lengthy discussion on this case due to the injuries being on the opposite side of the pedestrian to that which was struck. Therefore the file was re-read in order to check the side from which the pedestrian was crossing, which confirmed that she was crossing from the offside as stated by multiple witnesses. It was also checked whether the pedestrian was run over as the massive open fracture to the pelvis would suggest that a more severe mechanism had caused this than just an impact with a vehicle. However, the pedestrian was not reported to have been run over, she landed on the pavement. The pelvis injury has therefore been left as due to the impact with the nearside wing as she struck this where the wing meets the bonnet, which is a very stiff part of the wing, but it should be noted that this case was very difficult to put causation codes to. It also had a short post mortem with little information, resulting in only eight injuries for coding in total.

### **3.4.2 Fatal file analysis**

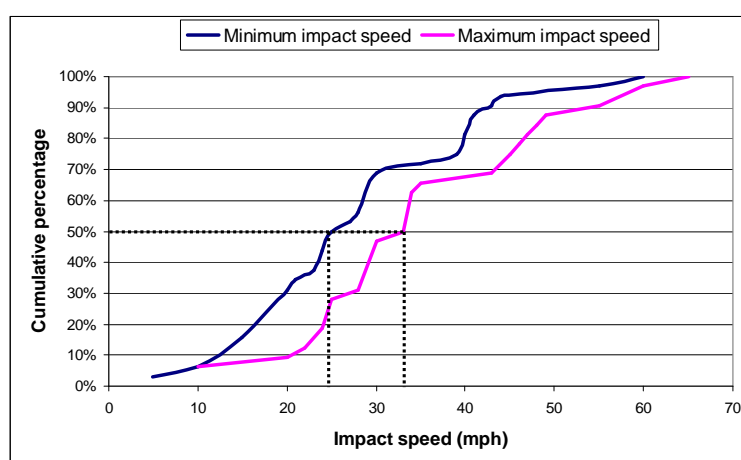
Table 3-7 shows the crash avoidance manoeuvres undertaken by the vehicles before they hit the pedestrians. This shows that 13 (38%) of the vehicles did not perform any avoidance manoeuvre, while 20 (59%) at least braked.

**Table 3-7. Crash avoidance manoeuvres of vehicles striking pedestrians**

Crash avoidance	Number of vehicles
-----------------	--------------------

No avoidance manoeuvre reported	13
Braking (skid marks evident)	9
Braking (no skid marks; driver stated)	6
Braking (other reported evidence)	1
Steering and braking (evidence or stated)	4
Unknown	1

Figure 3-31 shows the cumulative impact speed for the 34 pedestrians in the sample. Each pedestrian had a minimum and a maximum impact speed, which were calculated or estimated based on the information present in the Police fatal files. The 50<sup>th</sup> percentile of the minimum impact speed was approximately 25 mph (40 kph), and the 50<sup>th</sup> percentile of the maximum speed was about 33 mph (53 kph).

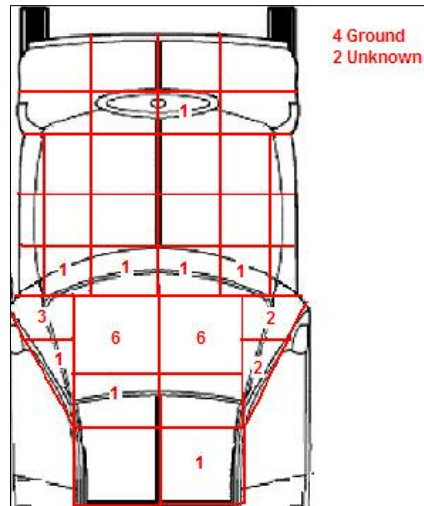


**Figure 3-31. Cumulative impact speed of vehicles striking pedestrians**

The sample of 34 pedestrians was made up of 22 males (65%) and 12 females (35%). There were 6 children under the age of 15, 14 pedestrians aged 15-59, and 14 pedestrians aged 60 years or older.

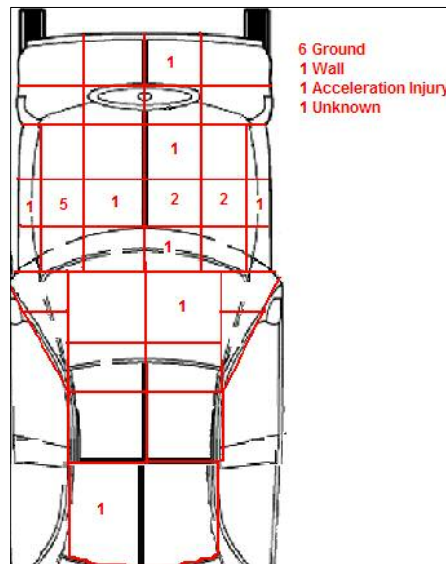
The following sections break down the injuries by body region and show the areas of the vehicle that caused at least one AIS2+ injury. It should be noted again that if two or more injuries to a body region were due to the same zone on the vehicle, the zone was counted only once as having caused an injury in that accident.

Figure 3-32 below shows the number of pedestrians who had an AIS 2+ head injury caused by each zone on the car. For example, if a pedestrian suffered multiple AIS 2+ injuries to their head caused by the A-pillar and the windscreen, a 1 was placed in each of these zones. This was then summed for all the 34 pedestrians. The most frequent impacts were those to the windscreen which account for AIS 2+ head injuries to 12 of the pedestrians. Eight of the pedestrians received AIS 2+ injuries to their heads from the A-pillars.



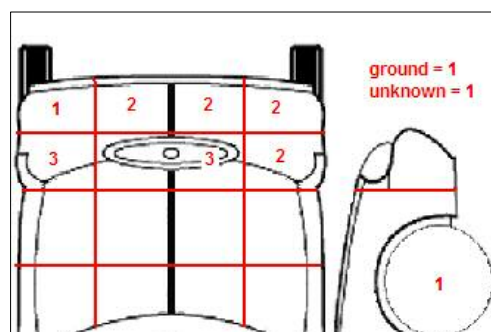
**Figure 3-32. Location of AIS 2+ head injuries**

Figure 3-33 below shows the zones which caused one or more AIS 2+ injuries to a pedestrian's thorax. The most frequent impact zones were those to the rearmost half of the bonnet.



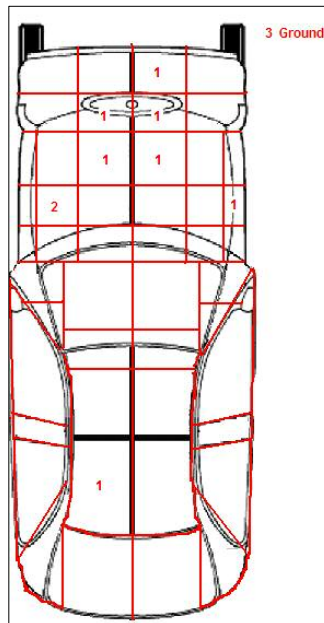
**Figure 3-33. Location of AIS 2+ thorax injuries**

Figure 3-34 below shows the zones which caused one or more AIS 2+ injuries to a pedestrian's left or right leg. In this case, if both legs had AIS 2+ injuries from the same zone of the vehicle, the zone was counted once. The majority of the impacts were to the bumper or the leading edge of the bonnet.



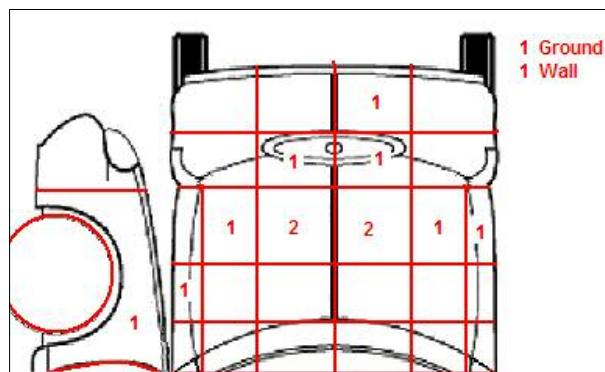
### Figure 3-34. Location of AIS 2+ leg injuries

Figure 3-34 below shows the zones which caused one or more AIS 2+ injuries to a pedestrian's abdomen. The majority of the impacts were to the bonnet.



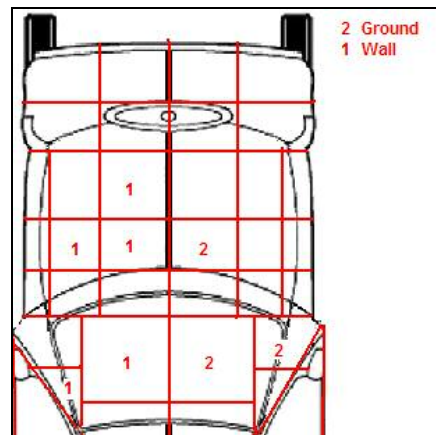
### Figure 3-35. Location of AIS 2+ abdomen injuries

Figure 3-36 below shows the zones which caused one or more AIS 2+ injuries to a pedestrian's pelvis. The majority of the impacts were to the front half of the bonnet.



### Figure 3-36. Location of AIS 2+ pelvis injuries

Figure 3-37 below shows the zones which caused one or more AIS 2+ injuries to a pedestrian's arms. This analysis is carried out in the same way as the legs where, if both arms had AIS 2+ injuries from the same zone of the vehicle, the zone was counted once. The majority of the impacts were to the windscreen, A-pillars or the rearmost zones of the bonnet.



**Figure 3-37. Location of AIS2+ arm injuries**

In summary, these figures show some of the likely causes for the injuries which were seen to be the most costly in section 3.3. Head injuries, which dominate the costs for the pedestrians in the HEMS data, have been caused mainly by impact with the windscreen and A-pillars for these 34 pedestrians. Serious thorax injuries have been caused by the rearmost half of the bonnet, leg injuries were caused by the front bumper, and abdomen and pelvis injuries were caused by the front half of the bonnet. Serious injuries to the arms have been caused by the windscreen, A-pillars, and bonnet.



## 4 Future methodology

### 4.1 Existing systems

A number of successful attempts have been made to link Police data on traffic accidents with the relevant hospital injury records, both in the UK and in other countries around the world.

Stone (1984) was one of the first to identify the need to improve Police records of road traffic accidents by adding hospital treatment data, and developed a method to do this via computer. He used Scottish hospital in-patient records (SHIPS), and created an algorithm for linking individual records to Police STATS19 information. This method of linking has provided a base for much of the similar work done since. For example Simpson (1996) used information collected by survey clerks working in A&E departments and successfully matched this to appropriate STATS19 records. Broughton, Keigan, and James (2001) linked information on injured road users from the Trauma Audit and Research Network (TARN) with individual STATS19 records. Ward, Robertson, Townley, and Pedler (2005) took road traffic casualty data from central London hospitals and created links to Police records by making assumptions on their catchment areas. Keigan, Broughton, and Tunbridge (1999) used an effective method to link SHIPS records to their corresponding STATS19 entries. A smaller report by the Scottish Government (2006) has since updated this and included hospital data up to 2004 as well as tying in data from the 'General Register Office for Scotland' (GROS) and Scottish household surveys on road traffic accidents.

Efforts to link information held on road traffic accident with that held be hospitals can be seen elsewhere around the world, such as the 'Crash Outcome Data Evaluation System' (CODES) in the USA that even includes insurance claim details in its database (NHTSA, 1996). In addition, the Australian equivalent of STATS19, the 'Traffic Accident Data System' (TADS) has successfully been matched to their 'Inpatient Statistic Collection' (ISC) in a way that HES and STATS19 are hoped to be matched (Lujic, Finch, Boufous, Haven, and Dunsmuir, 2008).

There is a system in place in Sweden called STRADA which combines new data from Police and Hospitals on road traffic accidents. STRADA stands for Swedish Traffic Accident Data Acquisition, and it is the national system used in Sweden to record traffic accidents. In this system, the Police and the hospitals produce individual reports on the accident, which are then sent to a central database. Here the reports are combined, creating one report combining all the information provided by the Police and the hospital. In this system it has been observed that only about 50% of the accidents are recorded by the Police compared to those recorded by the hospitals (De Mol and Boets, 2003).

Accidents recorded in some in-depth accident research studies have also been linked to Police data. For example, Table 4-1 shows the severity of linked accidents, as recorded in STATS19 and in TRL's On The Spot (OTS) accident study (Richards, Cookson, and Cuerden, 2008). This shows that the accident severity in STATS19 and OTS is often recorded differently, which mirrors the differences seen in the numbers of accidents recorded in HES and STATS19 (Goldacre et al., 2006). This highlights that a better definition of the problem of road traffic casualties could be developed by combining information in this way, as a solution to the problem of some sources under or over-reporting certain types of accidents.

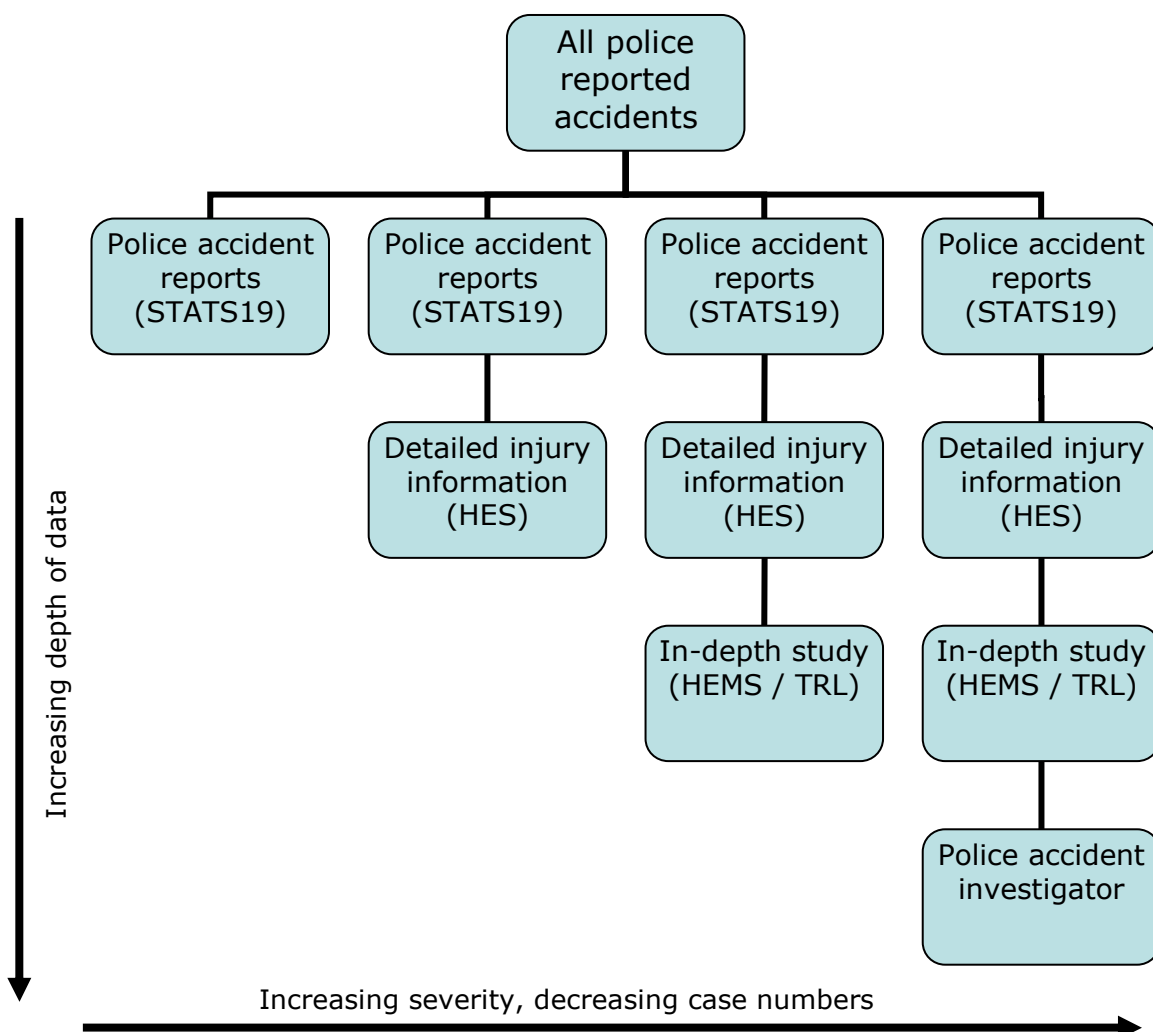
**Table 4-1. Severity in linked STATS19 and OTS accidents**

		Severity in OTS				
		Fatal	Serious	Slight	Non-injury	Total
Severity in STATS19	Fatal	69	1	0	0	70
	Serious	1	230	45	7	283
	Slight	1	95	674	128	898
	Total	71	326	719	135	1251

However, in general the linking of different datasets is not carried out routinely as new data is collected. There are isolated 'pockets' of information, such as that held by the HEMS team, or by the OTS study, which can be linked together to form an information base which can be shared by all the road safety stakeholders. Not every pocket of information would need to be linked, but the most useful and most complete sources could be combined.

## 4.2 Proposed future methodology

Figure 4-1 shows how different sources of data could be linked to form a future study on road traffic accidents. The Police STATS19 records would form the basis of this, because they include accidents of all severities. The detailed injury information from the Hospital Episode Statistics can be introduced for those casualties whose injuries are severe enough that they are admitted to hospital. Some of these studies will also be included in an in-depth study, such as studies run by TRL (e.g. the Co-operative Crash Injury Study, or the On The Spot study) or enhanced data collection by the Helicopter Emergency Medical Service. Finally, for the most severe and fatally injured casualties, Police accident investigator reports will be available. This is a similar proposal to that by Cuerden (1997), which put forward a methodology for a study of pedestrian accidents using different sources of information.



**Figure 4-1. Relationship between sources of data in proposed future study**

In reality, there are a few more combinations than those shown in Figure 4-1; for example, in-depth studies (the On The Spot study and the Co-operative Crash Injury Study) record accidents containing slightly injured casualties, who would not have been admitted to hospital, so could only be linked to the STATS19 accident reports.

#### **4.2.1 Enhanced data collection by HEMS**

A key part of the proposed methodology is enhanced data collection by the HEMS team, so that it can be considered an in-depth study of accidents as well as injuries, and enable the casualties to be linked to their relative STATS19 accident reports. This would involve an accident research team working with the HEMS team, possibly even in some instances attending the same accidents, and recording the accident data required. Working together with the HEMS team would enable the accident and injury information to be brought together in a short timescale. This would allow emerging trends to be identified and remedial measures undertaken on a much shorter timescale than is currently possible.

There are some limitations to this proposal: the HEMS team tend to see the more severe accidents, and cover a relatively small (if densely populated and diverse) geographical

area. The advantage of combining the enhanced HEMS data with all the other sources of data is that they can be used if required to determine exactly how the HEMS sample of accidents and casualties compares to the nationwide accident population.

The accident severity bias in the HEMS and Police accident investigator information means that the accident and injury information will be most detailed for severe and fatal accidents. These are generally the most important accidents to consider in terms of potential countermeasures, as benefits for the most severely injured casualties are likely to benefit those who are less severely injured also.

It should be emphasised that the proposed methodology does not require extra data to be collected; all the required information is already collected, whether it is by the Metropolitan Police as part of their accident investigator reports or STATS19 records, or information that the HEMS team currently collect, enhanced with TRL training. What it would require is an administrator to link the information from the Police and HEMS. Engineering and TRL input would then be required to combine the collected information into a form which could be used for analysis of emerging trends in injury epidemiology.

## 5 Discussion

In this project, TRL have successfully established a link between the accident researchers and vehicle design experts at TRL, and the medical professionals of the Helicopter Emergency Medical Service. This has enabled the benefits of such a link to be explored, such as the sharing of data and expertise, the key findings of which are discussed below.

### 5.1 Key findings

As examples of the sort of research which can be performed using information recorded by different organisations, a number of pieces of analysis have been performed.

This began with the comparison of the “years of life lost” due to traffic accidents and other causes of disease, using mortality statistics collected by the Office for National Statistics. This highlights the importance of the road safety problem: with the exception of ischaemic heart diseases, road traffic accidents cause more days of working life to be lost than any other single disease. Although they cause fewer deaths than some diseases, the average age of people killed in road traffic accidents is much lower than for other diseases, so these deaths have a greater effect on the economy than most other causes.

Comparing the data from HEMS to the national datasets of HES and STATS19 shows that the pedestrian casualties in HEMS tend to have more severe injuries than the national population of pedestrian casualties. This is seen when examining the number of injuries, the duration of stay in hospital, and the type of injuries received by the pedestrians. This relationship is not surprising because HEMS, an emergency helicopter medical service, would be expected to travel to the most serious incidents. This kind of comparison of a subset of data to the national statistics is important if any national conclusions are to be drawn from the subset of data.

The costing model, based on the duration of stay of pedestrians on the ward and in intensive care, is an example of one method which can be used to prioritise injuries using medical information. The costs of individual injuries could be refined if other information was available, such as the operations and procedures performed on the patient while they were in hospital. Costing road traffic injuries in a similar way is already carried out in the USA (Miller, Romano, Zaloshnja, and Spicer, 2001), and is used when considering the cost-benefit of countermeasures designed to increase road safety.

One difficulty of using medical data to prioritize injuries is that it is difficult to account for the effects of other injuries received at the same time. One possible way of doing this has been explored in this report. By calculating the ISS of the pedestrians with and without the specific injury, it can be seen whether removing that injury would have much difference on the injury severity of the patient. A relationship between ISS and the average cost of the casualties to the hospital can be calculated, which can then be used to determine what benefit (in terms of cost to the hospital) would be achieved if individual injuries could be reduced/removed. This method could be used on the HEMS data, or any other suitable injury and treatment information, to calculate the cost and identify injuries which have the greatest potential for cost reduction.

Finally, information from Police fatal files was used to investigate the causes of pedestrian injuries. This work was done in co-operation with the HEMS team, with whom the possible injury mechanisms were discussed at a workshop at the Royal London Hospital, Whitechapel. This was work which could also have been done using the information recorded by the HEMS team, if photographs of the vehicles involved had been available. As an alternative to this, the photographs and post-mortems in Police fatal files were analysed.

The analysis focused on impacts with relatively new cars (registered in 2000 or later), because these are the cars built around the time of the European pedestrian protection legislation and the EuroNCAP testing programme. This legislation includes two tests, based on an impact of a leg with the front bumper, and the impact of a head with the bonnet. Interestingly, although the vast majority of the serious leg injuries in this study are caused by the front bumper, impacts with the windscreen are the most frequent cause of serious head injuries, and no head injuries were caused by the main surface of the bonnet at all. A large number of the serious leg injuries are caused by the area around the bonnet edge, which is also not tested as part of the European pedestrian legislation. This suggests that this sample of impacts does not represent those for which the pedestrian impact legislation was designed.

However, it should be noted that the causes of the injuries determined by the team of experts are estimates. For some injuries there were a number of possibilities, or it was not clear exactly what the cause of the injury was. In these cases, the experts chose the source which seemed most likely to have caused the injury.

Because pedestrians who are fatally injured are likely to be in crashes with different characteristics to those who are less seriously injured, it is difficult to say how representative these results may be of the population of pedestrian casualties, but the finding that the windscreen is the most frequent cause of serious head injuries has also been seen in pedestrian casualties, of all severities, recorded by the On The Spot accident study (Cuerden, Richards, and Hill, 2007).

## **5.2 Future methodology**

A brief methodology has been suggested, showing how the medical engineering link developed in this project could be extended to form an ongoing study of the epidemiology of injuries in road traffic accidents. This is based on linking a number of different data sources together: the Police STATS19 records of accidents; the Hospital Episode Statistics, containing details of the injury and treatment of road traffic casualties admitted to hospital; in-depth accident studies, such as those based at TRL; Police accident investigator reports; and enhanced data collected by the HEMS with a supporting research team.

This study would bring together the Police, accident researchers, and medical professionals, and would disseminate the results to those groups as well as the wider community. The study would only be successful if it provided information for all the people who are involved in road safety. These include: the government, who would have more evidence with respect to the road safety problem; local authorities, who could arguably better direct their resources and improve knowledge of the magnitude of the benefit that interventions could make; NHS trusts, to help allocate resources, as well as potentially improve diagnosis and treatment of injuries; and vehicle engineers, including government or EU legislators, providing robust evidence on how vehicle designs need to be improved.

It will be important to inform doctors and paramedics, especially those who do not attend many traffic accidents, what sort of injuries to expect when they do attend such an accident. This is especially important because changes in the vehicle fleet mean that the epidemiology of injuries in road traffic accidents is continually changing. Organisations that are aware of and experience these changes, such as TRL and HEMS, will be able to share their knowledge with the wider medical community.

Another application would be to help doctors make quicker and more accurate diagnoses. If there is evidence at the scene which shows, for example, that the pedestrian has hit the windscreen of the vehicle, the doctor will know to look for serious head injuries, as the windscreen was found through this study to be the most frequent cause of head injuries. This goes against current thinking, and so more work in this area

is required. Further analysis may reveal, for example, that certain types of head injuries are more likely if the head has hit the windscreen than if the head has hit the A-pillar.

In addition to the benefits for medical professionals, the vehicle designers and legislators will benefit from the closed feedback loop. When they implement changes, they will know what effect they have had on the injuries in real world accidents in the shortest timescale possible. The new distribution of injuries will also enable them to develop solutions to tackle the problems which remain.



## 6 Conclusions

This project has explored the methodology and benefits of a medical engineering link. This has been done by bringing together two institutions: TRL, which has significant experience in accident research and vehicle design safety; and the Helicopter Emergency Medical Service, who have been treating seriously injured road traffic casualties for the last 20 years.

The two organisations have worked together to investigate the causes of pedestrian injuries on new cars, with TRL sharing their expertise of injury causation, and HEMS sharing their expertise on the consequences of the injuries. The HEMS team also provided TRL with the data they have recorded on pedestrian casualties from 2000-2007. This enabled TRL to explore the data and determine the useful information which could be deduced from it, for the benefit of both the vehicle engineering and medical community. It is clear that some relatively simple alterations to the HEMS data, such as photographs of the vehicle damage, would improve the data with respect to engineering content.

Analysis of the years of working life lost due to traffic accidents (as recorded by the Police STATS19 records and the Office for National Statistics mortality statistics) displays the size of the road safety problem: with the exception of ischaemic heart diseases, road traffic injuries are the leading cause of years of working life to be lost in England and Wales. This is principally because of the large number of young people who are killed in traffic accidents compared to other most diseases.

Amongst other analysis, the cost of pedestrian injuries was investigated using the HEMS data and a model based on the number of days spent on the ward and in intensive care. This explored how the medical data collected by HEMS could be used to provide information which is useful to both the medical and vehicle safety design/legislation communities.

Following the creation of the link between TRL and HEMS, and the exploration of its possible benefits, a methodology has been proposed for how the medical engineering link can be developed in the future. This could involve a combination of different data sources: the Police STATS19 records of accidents; the Hospital Episode Statistics, containing details of the injury and treatment of road traffic casualties admitted to hospital; in-depth accident studies, such as those based at TRL; Police accident investigator reports; and enhanced data collected by the HEMS with a supporting research team.

This methodology could be combined with other similar projects which are looking to achieve similar things. For example, the current 'National Fatal Road Crash – Feasibility Study' is exploring the possibility of collecting information on fatal accidents directly from the accident investigators once they have finished their reports. That study is focussing on the behavioural side of road safety.

The continuing development of these links would lead to an on-going study, which could answer the questions and provide continual feedback to all the stakeholders in road safety, including the Police, vehicle engineers, public health professionals, and the government.



## **7 Recommendations**

- Establish a link between the Helicopter Emergency Medical Service, the Metropolitan Police, and TRL, to explore the ways in which the future medical engineering link could be developed.
- Improve the costing model so that it can determine the cost of single injuries from multi-trauma. The results of the costing could also be scaled, using the Hospital Episode Statistics, so that an estimate for the cost of pedestrian injuries nationwide could be determined.



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Alastair Wilson is a Consultant in Emergency Medicine, for Barts and the London NHS Trust. Previous appointments include the Chair of the British Trauma Society and President of the European Society for Trauma & Emergency Surgery. Alastair Wilson has worked at The Royal London Hospital in Whitechapel for the past 20 years. In 1989 he founded the HEMS, which is based at the hospital.

Gareth Davies is the HEMS clinical director. He, along with other members of the team, helps to run London's Air Ambulance. Gareth is also an Accident & Emergency and Pre-hospital Care Consultant working at the Royal London Hospital, Whitechapel and regularly flies in the helicopter to the scenes of accidents.

Elizabeth Foster is Patient Development Sister for HEMS, and has been working on the HEMS team for the last 7 years. Before HEMS Elizabeth worked in accident and emergency for 12 years, and in paediatrics and orthopaedics before that. Elizabeth is responsible for data collection, research and audit, reports, and is Advanced Trauma Life Support course co-ordinator.

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## Glossary of terms and abbreviations

**Cerebral Contusion Closed** - a bruise of the brain which occurs in a number of severe head injuries (20-30%), they are likely to heal on their own without medical intervention but complications can occur.

**Generalized SAH IVH** - Generalized subarachnoid haemorrhage and intraventricular haemorrhage.

**Subarachnoid Haemorrhage** - bleeding into the subarachnoid space surrounding the brain, usually caused by a cerebral aneurysm that has burst (Oxford University Press, 1998). Up to half of all cases of SAH are fatal and 10-15% die before reaching hospital. Those who survive often have neurological or cognitive impairment (Van Gijn J, 2007).

**Subdural haematoma** - is a form of traumatic brain injury in which blood gathers between the dura (the outer protective covering of the brain) and the arachnoid (the middle layer or the meninges). Subdural bleeding usually results from tears in the veins that cross the subdural space. (Oxford University Press, 1998).

**Pneumothorax** - air in the pleural cavity (essentially the space between the chest wall and lung). Any breach of the lung surface or chest wall allows air to enter the pleural cavity, causing the lung to collapse. It can occur without apparent cause or from injuries to the chest. The air must be let out by a surgical incision. (Oxford University Press, 1998).

**Open wound, complicated** - open wounds as coded in ICD9 exclude those that are incidental to fractures, dislocations, internal or intracranial injuries. The description "complicated" includes those with mention of delayed healing, delayed treatment, foreign body or infection (ICD9, 2008).

**Frontal bone** - the bone which forms the frontal part of the cranium

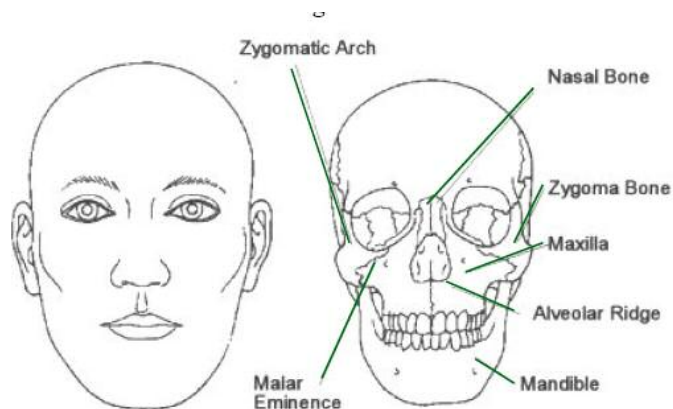
**Malar bone** - (or Zygomatic) these are the bones that form the prominent part of the cheeks (Oxford University Press, 1998). (see Figure 7-1)

**Maxillary bone** - upper jaw (Oxford University Press, 1998). (see Figure 7-1)

**Orbital floor** - The eye socket is a bony cup that surrounds and protects the eye. The floor of the eye socket is the bottom formed from the cheek, upper jaw bone and the palate. The rim of the socket is made from fairly thick bones, while the floor and nasal side of the socket is paper thin in many areas (Gray, 2002). (see Figure 7-1)

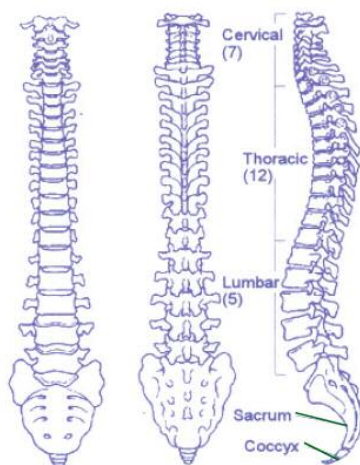
**Parietal bone** - one of two bones which form the sides and top of the cranium

**Temporal bone** - one of two bones on the side of the skull, below the parietal bones



**Figure 7-1. The bones of the face (TARN, 2008)**

**Cervical spine** – consists of the cervical vertebrae which are the seven bones making up the neck region of the backbone. The first vertebra supports the skull, and rotates on the second vertebra, enabling the head to turn. (Oxford University Press, 1998). (see Figure 7-2)



**Figure 7-2. The Spine (TARN, 2008)**

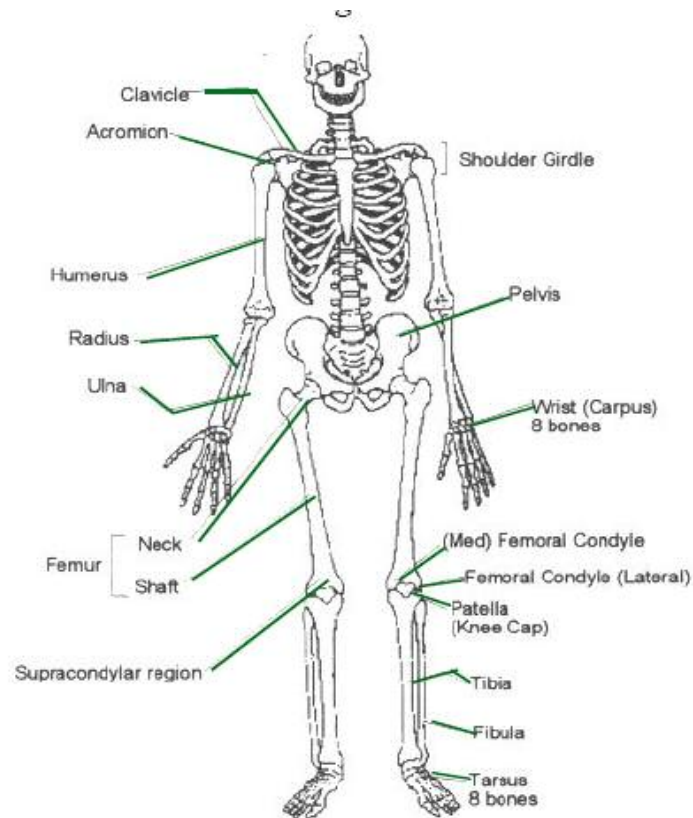
**Pelvis** – the bony structure formed by the hip bones, sacrum and coccyx that protects the organs of the lower abdomen and provides attachment for the bones and muscles of the lower limbs. (Oxford University Press, 1998). (see Figure 7-3)

**Femur** – (or thigh bone) is a long bone between the hip and the knee. (Oxford University Press, 1998). (see Figure 7-3)

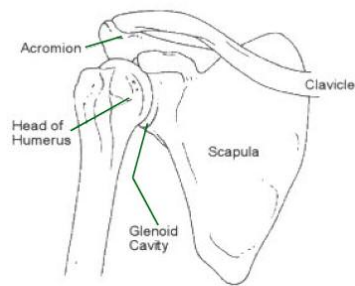
**Tibia** – the shin bone: the inner larger bone of the lower leg. (Oxford University Press, 1998). (see Figure 7-3)

**Fibula** – the long thin outer bone of the lower leg. (Oxford University Press, 1998). (see Figure 7-3)

**Scapula** – the shoulder blade: a triangular bone, a pair of which form the back part of the shoulder girdle. (Oxford University Press, 1998). (see Figure 7-4)



**Figure 7-3. The skeleton (TARN, 2008)**



*Shoulder Girdle*

**Figure 7-4. Shoulder Girdle (TARN, 2008)**