Department for Transport

Road Safety Research Report No. 80

Analysis of the On the Spot (OTS) Road Accident Database

Hannah Mansfield and Alex Bunting,
QinetiQ Ltd
Marieke Martens and Richard van der Horst,
TNO Human Factors

February 2008

Department for Transport: London

Department for Transport
Great Minster House
76 Marsham Street
London SW1P 4DR
Telephone 020 7944 8300
Web site www.dft.gov.uk

To order further copies contact:
DfT Publications
PO Box 236
Wetherby LS23 7NB
Tel: 0870 1226 236
Fax: 0870 1226 237
Textphone: 0870 1207 405
E-mail: dftinf@capita.co.uk

ISBN 978 1 904763 81 9

If you would like to be informed in advance of forthcoming Department for Transport priced publications, or would like to arrange a standing order, call 020 7944 4673.

recycle

Printed in Great Britain on paper containing at least 75% recycled fibre.

CONTENTS

ABBREVIATIONS

AAAM	Association for the Advancement of Automotive Medicine
AIS	Abbreviated Injury Scale
ANOVA	Analysis of Variance
HGV	Heavy goods vehicle
ISI	Injury Severity Index
OTS	On the Spot
PAS	Police Accident Severity
PCA	Principal Components Analysis
RSSD	Road Safety Strategy Division
RTA	Road traffic accident
SME	Subject matter expert
TNO	The Netherlands Organisation for Applied Scientific Research
TRL	Transport Research Laboratory
VRU	Vulnerable road user
VSRC	Vehicle Safety Reseaarch Centre

EXECUTIVE SUMMARY

Overview

The UK Government is seeking to substantially reduce the number of road traffic accidents (RTAs) leading to injury or loss of life. Specifically, relative to the average figures for 1994–98, the Government would like to meet the following road casualty reduction targets by 2010:

- a 40% reduction in the number of people killed or seriously injured in road accidents;
- a 50% reduction in the number of children killed or seriously injured in road accidents;
- a 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 vehicle kilometres.

To develop effective strategies for reducing RTAs, the cause of accidents must be understood. With this in mind, the On the Spot (OTS) project was commissioned to gather in-depth information at the scene of accidents. Since the data collection began in 2000, more than 3,000 accidents have been recorded, and more than 2,000 were available when this study was started in November 2005.

This report details the technical strategy and findings of the analysis undertaken, and provides recommendations on how these findings can be used to inform the formation of road safety policy.

Results

An exploratory analysis of the demographic profile of the OTS database concluded that:

- the vast majority of accidents involve cars (the most frequent road users);
- accidents that involved motorcycles had the highest proportion of Police Accident Severity (PAS) rating of all road user categories;
- fatal and serious injury accidents were most likely to occur on ‘A’ class ‘non-trunk’ roads and 60 mph roads;
- serious accidents were less likely to occur on weekends; and
- the majority of accidents occurred between 3 pm and 8 pm.

A more in-depth analysis was performed by grouping variables using qualitative and quantitative analysis techniques. Linear modelling techniques were used to link together the causal factors to the features of accidents and through to the causes and severities of injuries sustained. This analysis concluded that:

- the injury rate in car accidents was influenced by the speed, impact type and type of vehicle hit in the accident;
- the injury rate in large vehicles was influenced by the impact type and the vehicle hit; and
- the injury rate on motorcycles was influenced by the speed of the impact.

Further analyses were performed to identify the effect of demographic information (e.g. age and gender) on the causal factors of accidents. It was found that:

- male car drivers are more likely to be involved in accidents where the causal factors are speed and aggression or impairment due to alcohol and drugs;
- female car drivers are more likely to be involved in accidents where the causal factor is visual impairment or obscuration;
- drivers under 20 years old are more likely to suffer from inexperience-related accidents;
- inexperience makes drivers less able to cope with the loss of control of their vehicles, for example due to slippery road conditions;
- impairment due to alcohol is more likely to occur between 8 pm and 5 am;
- drivers over 40 years of age are four times more likely to have accidents where fatigue or illness is a causal factor; and
- drivers are more likely to be distracted when there are passengers in the car, but less likely to suffer fatigue-related accidents.

Countermeasures

A range of existing injury-mitigating factors for all occupants of all vehicle types was investigated. Most of the data were not of sufficient quantity to be able to model the impact of mitigating countermeasures adequately. Based on those data that were available it was found that only seat belts provided a significant improvement in injury rate; however, there was evidence to suggest that airbags and sitting in the rear seats of the vehicle reduce injury rates.

Suggestions for changes to the experimental protocol

A range of suggestions for improvements to the experimental protocol were made based on an early analysis of the OTS database and the subsequent findings during the analysis phase of this study. These improvements included:

- suggestions about the layout of questions;
- questions that appeared not to be filled out;

- the coding of missing values; and
- variables that contradict each other.

Further recommendations

Further recommendations of this report are to:

- continue to collect data for the OTS study;
- make alterations to the experimental protocol as listed in Section 6;
- periodically perform a statistical analysis of the OTS database (e.g. at the end of a collection phase); and
- statistically compare the study with similar European studies.

These measures will ensure that road safety policy will remain focused on the areas that can be of most benefit to all road users; in particular the vulnerable road user categories. As the data density in the database is increased, the findings from the analysis of the effects of injury-mitigating strategies will become more robust.

1 INTRODUCTION

1.1 Milestone

This document is offered in fulfilment of the final technical report milestone for the Department for Transport Road Safety Strategy Division (RSSD) project 'Analysis of OTS Road Accident Database' (Contract PPRO 4/001/020). It details the technical strategy and findings of the analysis undertaken and provides recommendations on how these findings can be used to inform the formation of road safety policy.

1.2 Background

The UK Government is seeking to substantially reduce the number of road traffic accidents (RTAs) leading to injury or loss of life. Specifically, relative to the average figures for 1994–98, the Government would like to meet the following road casualty reduction targets by 2010:

- a 40% reduction in the number of people killed or seriously injured in road accidents;
- a 50% reduction in the number of children killed or seriously injured in road accidents; and
- a 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 vehicle kilometres.

To develop effective strategies for reducing RTAs, the cause of accidents must be understood. With this in mind, the On the Spot (OTS) project was commissioned to gather in-depth information at the scene of accidents (Hill and Cuerden, 2005). Data were collected by expert investigators in two geographical locations: the Thames Valley and the Midlands. Investigators typically attended the scene of the accident within 15 minutes of its occurrence and, consequently, were able to collect vital 'perishable' data that might otherwise have been lost. Since the data collection began in 2000, more than 3,000 accidents have been recorded, and more than 2,000 were available when this study was started in November 2005.

The database contains more than 2,000 variables, divided among a number of hierarchical categories, including:

- **accident scene** (climatic conditions, day/night, rural urban, etc.);
- **path** (road geometry, features, markings, signage, surface, sightlines, etc.);
- **vehicle** (type, load, control positions, passive safety equipment);

- **human**, i.e. the person involved in the accident (age, whether they were in control of the vehicle); and
- **injuries** (severity, location, treatment given).

Data were collected for each vehicle and each person involved in the incident and stored in a Microsoft® Access database. A user-friendly front-end browser was developed to provide easy access to the information.

1.3 Objectives

The objectives of this study were to:

- conduct a systematic analysis of the OTS database, highlighting areas that are of importance for policy development;
- gain a better understanding of the causes of accidents and the features of accidents that result in particular injury outcomes;
- provide recommendations for countermeasures by specific accident types; and
- identify possible improvements to the research protocol.

1.4 Analysis team

The analysis of the OTS database was performed by QinetiQ. TNO (the Netherlands Organisation for Applied Scientific Research) Human Factors road safety experts were consulted and provided information to guide the analysis and recommendations for mitigating strategies for accidents and injuries.

1.5 Report structure

A short introduction to the structure and data contained in the OTS database is given in Section 2. The analysis methodology is detailed in Section 3 and the supporting appendix. The results of the analysis of accidents and injuries are given in Section 4. The implication of this analysis for policy change and the identification of countermeasures for specific accident types are discussed in Section 5. Recommendations for the improvement of the research protocol are given in Section 6, and overall conclusions are given in Section 7.

2 ON THE SPOT ACCIDENT DATABASE

2.1 Introduction

The 'On the Spot' (OTS) Accident Database contained data relating to 2,188 road traffic accidents (RTAs) in November 2005 collected over a period of five years in two phases. Data were collected by expert investigators in two geographical locations: the Thames Valley and the Midlands. The two research teams were:

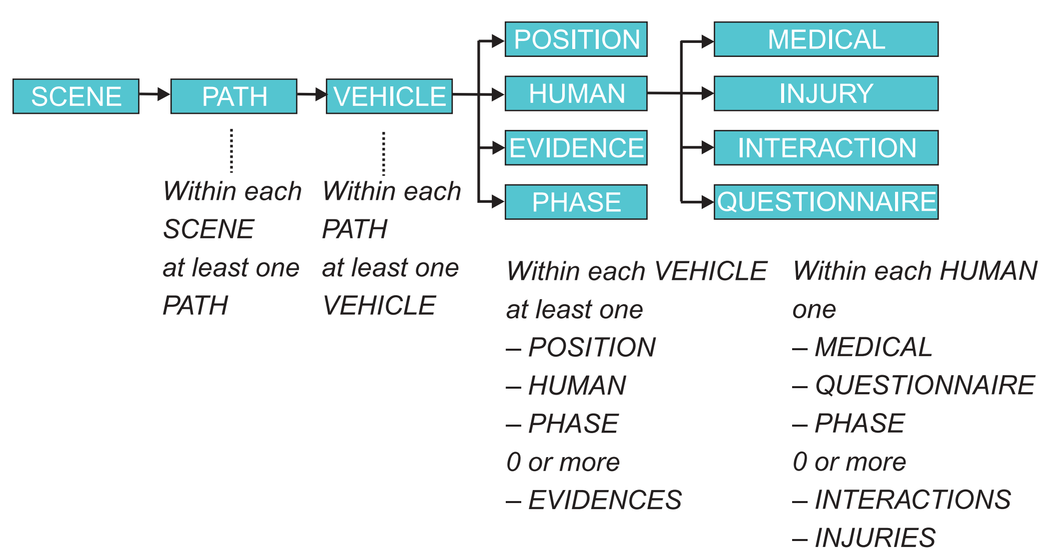
- **Loughborough University, Vehicle Safety Research Centre (VSRC),** collecting data from accidents occurring within the Nottinghamshire region (Midlands); and
- the **Transport Research Laboratory (TRL)** collecting data from accidents occurring within the Thames Valley region (South-East England).

The teams were responsible for collecting the data at the scene of the accidents as and when they occurred, and post-accident by liaison with emergency services, hospitals and local authorities. Data from the two teams were collated into a single Microsoft Access database. The database is viewable via the OTS Browser, which allows the user to view individual accident cases in a user-friendly form.

2.2 Structure of the database

The data are structured into 11 hierarchical sections (see Figure 2.1), with some sections containing more data records than others due to the fact that there are one-to-many relationships within the data. For example, numerous vehicles may be involved in a single RTA.

Figure 2.1: The hierarchical structure of the database



At the ‘scene’ level of the database there are 2,188 records with approximately 200 variables relating to:

- date, time and location of accident;
- environmental conditions (e.g. daylight, weather);
- possible causes and contributory factors of the accident;
- traffic control facilities (traffic signals, crossings, pedestrian/cycle facilities); and
- layout (urban/rural surroundings, junctions, bridges).

For each scene there is at least one ‘path’ record. The ‘path’ of the accident refers to any **one** direction of travel; there can be several paths in a single scene. For example, for two vehicles involved in a head-on collision there will be two path records, since the vehicles were travelling in opposite directions. However, if two vehicles are travelling in the same direction and one vehicle hits the back of the other vehicle, they share the same path record. The path contains variables that relate to:

- layout, class, surface condition and speed limit of the road;
- signs and traffic control;
- pedestrian/cycle facilities;
- weather and visibility;
- traffic density; and
- potential distractions and obstructions.

The ‘vehicle section’ in the database contains a record for each vehicle on each path of the accident; as noted there can be several vehicles for each path. Pedal cycles and pedestrians are also counted as vehicles. The vehicle section contains variables that relate to:

- vehicle type (e.g. car, pedestrians, motorcyclist);
- vehicle make and condition; and
- safety features installed.

For each vehicle there are a number of further subdivisions storing information relating to accident position, any humans involved (further divided into medical, injury reports and questionnaire answers), evidence (e.g. of contact between vehicles) and phase (referring to physical information about the vehicle involved in the RTA – e.g. crushed, rolled).

2.3 Study phases

Phase 1 of the OTS data collection ended in 2003. A review of the data collection techniques and protocol was performed and changes were made before Phase 2 began. The changes made for Phase 2 included:

- inclusion of video clips of the accident paths;
- increased consistency in reporting of missing values for the two research teams;
- a unified sampling plan; and
- database enhancement and improved database management.

The data used in this study comprised the whole of Phase 1 and Phase 2 data up to November 2005.

3 METHODOLOGY

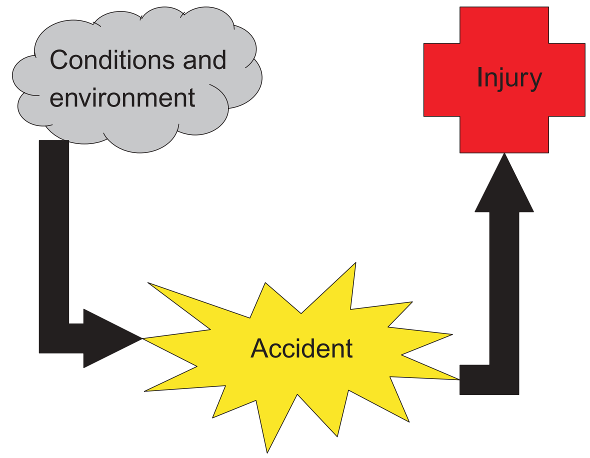
3.1 Approach to meeting the study requirements

A structured analysis of the On the Spot (OTS) database was undertaken with the purpose of first identifying:

- the causal factors of accidents;
- the types of accident; and
- the types of injury.

These are the three components that form the causal chain that characterise road traffic accidents (RTAs) and injuries (see Figure 3.1). By investigating relationships between these components, links in the causal chain and, in turn, the key causes of injury can be determined, along with possible preventative or mitigating factors.

Figure 3.1: The causal chain that characterises RTAs



A three-stage approach to the problem was employed:

- exploration of the underlying dimensions of the data and identification of the factors that characterised accidents;
- examination of associations between factors to investigate the causes of RTAs and injuries; and
- recommendations for countermeasures and suggestions for improvements to the experimental protocol.

3.2 Stage 1: exploration of the underlying dimensions of the data

The OTS database contains a large number of variables (>2,000) pertaining to aspects of the accident scene and participants. Initial exploratory data analysis was undertaken to obtain an understanding of the data content. This was followed by data grouping techniques to simplify the data into suitable categories that were fewer in number than the individual database variables but that retained pertinent information relevant to the study.

Two data-grouping techniques were used:

- a qualitative approach involving input from TNO (The Netherlands Organisation for Applied Scientific Research) subject matter experts in road safety with knowledge of how specific variables relate to certain common underlying themes; and
- a quantitative data reduction technique involving statistical factor analysis.

An example of a qualitative grouping is seen for the contributory factors: impairment through alcohol and impairment through drugs. Although these factors may not correlate statistically, they are strongly related in terms of their effect on an individual's control of a vehicle and their ability to drive safely.

A factor analysis exploits intrinsic associations within the data to identify a smaller number of dimensions that characterise the problem space. For example, the contributory factors of accidents variables – 'inexperience of driving' and 'inexperience of vehicle' – are correlated. After the factor analysis had been performed, these two factors were represented by a single 'inexperience' dimension.

The data were grouped on the three levels outlined in Figure 3.1:

- **causal factors of accidents** – using data from the scene level of the database;
- **types of accident** – using data from the scene and path level of the database; and
- **types of injury** – using data from the injury level of the database.

3.3 Stage 2: associations between factors

After the three causal chain components of RTAs were identified, data analysis was used to determine statistical links in the causal chain. A similar process was used to understand the impact of mitigating factors on the links in the chain (e.g. use of passive safety features).

The Stage 2 analysis comprised two parts:

- investigation of the causes, contributory factors and mitigation measures for RTAs; and
- investigation of the causes, contributory factors and mitigation measures for injuries, **conditional** upon there being an RTA.

The relationship between the factors describing accident type/severity and the injuries was investigated, using the factors describing the vehicle (including passive safety features) as moderating variables. Multiple linear regression techniques were applied to determine the injury type as a function of accident type dimensions and moderating factors. A stepwise selection method was used to identify the most predictive variables.

Outputs of the Stage 2 analysis included:

- the causal factors of accidents, in terms of the characteristics of conditions/environment/scene/vehicle/human that were associated with accidents;
- the relationship between accident type and injuries sustained;
- the effectiveness of passive safety features and other factors associated with vehicle type; and
- quantification and ranking of the above effects.

3.4 Stage 3: recommendations for countermeasures

A set of possible countermeasures was identified by TNO. The ‘causal chain’ models developed in Stage 2 were used to determine the effectiveness of each countermeasure in terms of the reduction of the number and severity of accidents, and the reduction in the number and severity of injuries. Furthermore, an indication is given of their contribution towards the 2010 casualty reduction target.

In addition to the analysis and road safety policy recommendations, the OTS protocol and database were investigated to determine any improvements that could be made in future phases of OTS data collection. Particular emphasis was placed upon improvements that could be made to aid the manipulation and analysis of the data.

4 ANALYSIS OF ACCIDENTS AND INJURIES

4.1 Introduction

This section details the results of the systematic analysis of the 'On the Spot' (OTS) database. The first sub-section describes an initial demographical overview of accidents and injuries outlined in terms of:

- vehicles involved in accident scenes and severity of accidents;
- age of those involved by vehicle type;
- carriageway type, speed limit and severity of accidents; and
- day of the week and time of day.

The second sub-section describes the investigation into the causal factors of accidents. Principal Components Analysis (PCA) was used as a guideline to group the contributory factors into 10 causal factor groups.

The third sub-section categorises accidents into a number of different types, based on the vehicles involved, the direction of impact and the speed of impact.

The fourth sub-section examines the dimensions of injury. The Abbreviated Injury Scale (AIS) injury ratings are used as a basis for an index of accident severity at the individual person level. The summary demographic information (Section 4.2) was gathered at the scene level of the database and therefore uses the Police Accident Severity (PAS) rating rather than the individual level severity rating derived later in the analysis. The PAS rating was used to determine compliance with the Government's accident and injury reduction targets stated in the introduction to this report. Consequently, the rating obtained from the later analysis is mapped back to the PAS rating at the scene level of the database to make meaningful estimates of accident and injury reductions.

An initial analysis into the causes of injury was made. This analysis examines the severity of injury caused for the demographics of accidents.

The final section establishes the associations between the three event groups causal factors of accidents, types of accident and injuries) and employs the associations to explore links between:

- causal factors of accidents and accident type; and
- accident type and resultant injuries.

The final section is organised by vehicle and accident type, and in each section the potential for, and severity of, injury is investigated using statistical modelling techniques.

4.2 Demographic summaries

4.2.1 Vehicles involved in accidents and accident severity

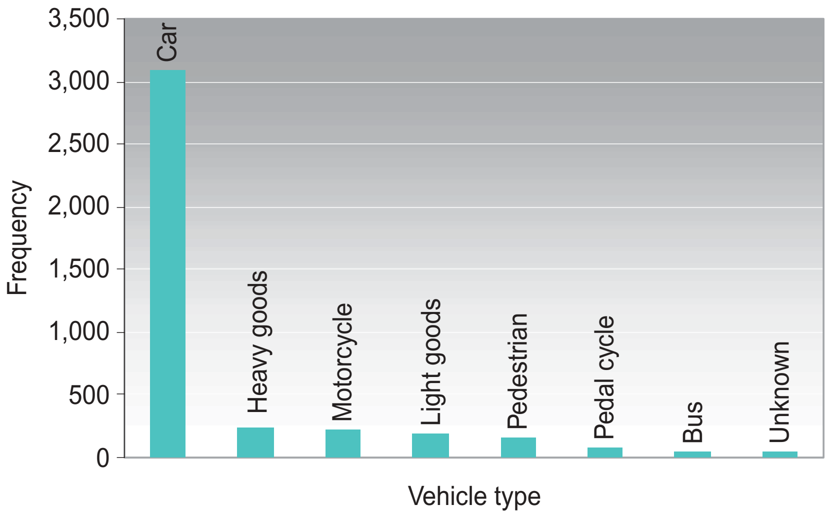
4.2.1.1 Vehicle type

The OTS database contained records and details of 4,082 vehicles (including cyclists and pedestrians) that were involved in a total of 2,188 accident scenes. Table 4.1 and Figure 4.1 show the overall summary of vehicle types that were involved in accidents in terms of frequency/percentage of occurrences in the database.

Table 4.1: Vehicle types in the OTS database (frequencies and percentages)

Vehicle type	Frequency in OTS database	% of all vehicles
Car	3,093	75.7
Heavy goods	235	5.8
Motorcycle	216	5.3
Light goods	195	4.8
Pedestrian	160	3.9
Pedal cycle	82	2.0
Bus	46	1.1
Untraced vehicle/missing data	55	1.4

Figure 4.1: Chart of vehicle types in the OTS database



Cars account for the vast majority (75.7%) of vehicles involved in road accidents. Of the remaining 24%, heavy goods vehicles (HGVs) are the next most frequent type followed by motorcycles, light goods, pedestrians, pedal cycles and then buses.

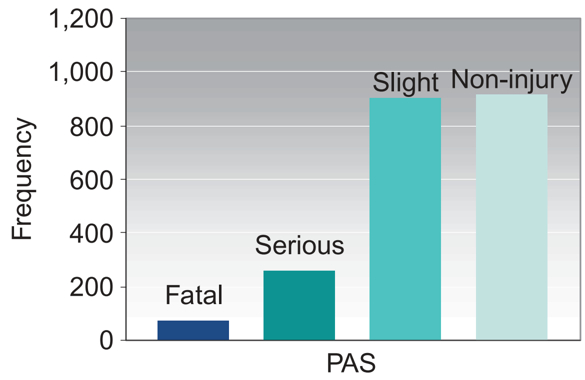
4.2.1.2 Accident severity

The severity of each accident reported by the police was given at the scene level of the database. Four categories of severity are used, which are summarised in Table 4.2 and Figure 4.2. In the remainder of this report these categories will be summarised as fatal, serious and minor/no injury.

Table 4.2: PAS frequencies and percentages

	Frequency	Percentage
Non-injury	917	42.6
Slight	904	42.0
Serious	259	12.0
Fatal	73	3.4

Figure 4.2: PAS rating



The severity rating of the vast majority of accidents was either slight or non-injury (84.6% in total), with 12% being serious and 3.4% being fatalities.

4.2.1.3 Vehicle type and accident severity

Table 4.3 provides a summary of how vehicle types were distributed across accident scenes, i.e. the frequencies of combinations of vehicle types that were involved by accident scene along with relative percentages and the PAS rating of the scenes. In all cases the displayed percentages are for all scenes.

It can be seen from Table 4.3 that the percentage of accidents with a fatal severity rating is low. The most common categories in accidents with fatalities involve:

- single cars;
- two cars;
- one car and one motorcycle;

Table 4.3: Vehicle types by accident scene and PAS							
Number of vehicles involved by vehicle type	**Frequency of scenes**	**% of all scenes**	**% scenes with fatalities**	**% scenes with serious injury**	**% scenes with slight injury**	**% scenes with no injury**	**% scenes with missing values**
1	**719**	**32.9**	**1.2**	**3.2**	**8.7**	**18.6**	**1.1**
Car	613	28.0	0.8	2.1	6.9	17.0	1.1
Motorcycle	53	2.4	0.3	0.8	1.1	0.3	0.0
Heavy goods	29	1.3	0.0	0.2	0.4	0.7	0.0
Light goods	16	0.7	0.05	0.05	0.1	0.5	0.0
Pedal cycle	6	0.3	0.05	0.1	0.1	0.0	0.0
Bus	2	0.1	0.0	0.0	0.1	0.0	0.0
2	**1,170**	**53.5**	**1.7**	**6.9**	**26.0**	**18.6**	**0.3**
2 Cars	603	27.6	0.4	2.2	12.6	12.2	0.1
Car, heavy goods	121	5.5	0.05	0.5	2.3	2.6	0.1
Car, motorcycle	117	5.4	0.4	0.8	3.6	0.5	0.1
Car, pedestrian	115	5.3	0.3	1.5	3.2	0.2	0.0
Car, light goods	60	2.7	0.1	0.2	1.0	1.5	0.0
Car, pedal cycle	58	2.7	0.05	0.5	2.0	0.1	0.0
Car, Bus	20	0.9	0.0	0.05	0.3	0.5	0.0
Car, Unknown	15	0.7	0.0	0.05	0.3	0.3	0.0
Other combinations	61	2.8	0.5	1.0	0.6	0.6	0.0
3	**212**	**9.7**	**0.2**	**1.3**	**4.7**	**3.4**	**0.05**
3 Cars	98	4.5	0.05	0.3	2.4	1.6	0.05
2 Cars, 1 light goods	23	1.1	0.0	0.1	0.4	0.5	0.0
2 Cars, 1 heavy goods	18	0.8	0.05	0.1	0.4	0.2	0.0
2 Cars, 1 unknown	15	0.7	0.05	0.05	0.3	0.4	0.0
Other combinations	58	2.7	0.1	0.7	1.2	0.6	0.0
4 and over	**87**	**4.1**	**0.2**	**0.4**	**1.9**	**1.4**	**0.1**

- one motorcycle; and
- one car and one pedestrian.

However, single motorcycle accidents account for only 2.4% of all accidents, yet one-eighth of the 2.4% result in a fatality.

The most common categories in serious injury accidents are:

- two cars;
- one car;
- one car and one pedestrian;
- one car and one motorcycle; and
- one motorcycle.

Again, single motorcycle accidents account for only 2.4% of accidents, yet one-third of the 2.4% result in a serious incident.

4.2.2 *Age of people by vehicle type*

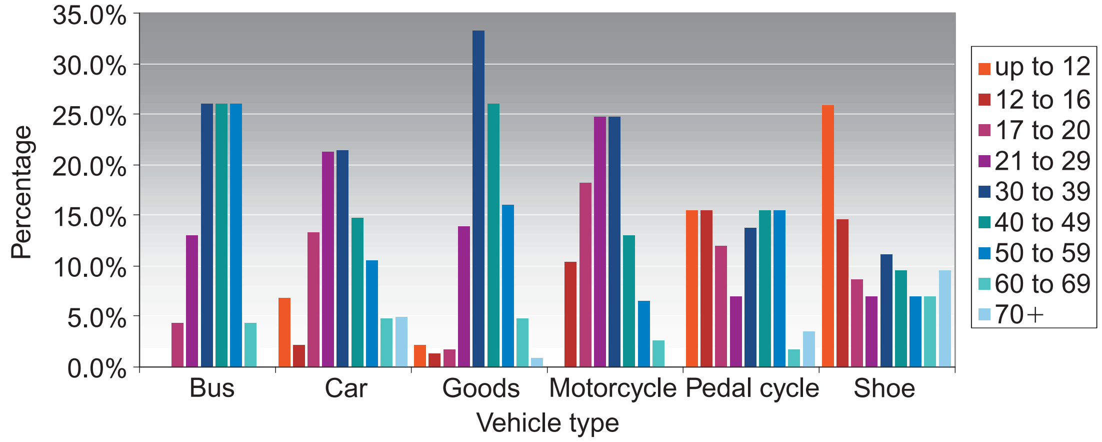
The OTS database contains records of the age of the individuals involved in accidents, where it was possible to obtain. Table 4.4 and Figure 4.3 show the age distributions of people by their mode of transport. Association between age group and vehicle type was tested using a chi-squared test, grouping the ages into 20 and below, 21–29, 30–39, 40–49 and 50+. It was concluded, unsurprisingly, that the age distribution of those involved in accidents differs between transport mode, chi-squared = 155.43, df = 16 ($p < 0.001$). The under 21s are under-represented in accidents in goods vehicles and over-represented on pedal cycles and as pedestrians. The 21–30 group is under-represented as pedestrians and in goods vehicles, while the 31–50 group is also under-represented as pedestrians but constitutes the main source of goods vehicle occupants. The over 50s are under-represented in motorcycle accidents.

Table 4.4: The age distribution of people involved in accidents by mode of transport

	Age group									Total
	<12	**12–16**	**17–20**	**21–29**	**30–39**	**40–49**	**50–59**	**60–69**	**70+**	
Bus	0 0.0%	0 0.0%	1 4.3%	3 13.0%	6 26.1%	6 26.1%	6 26.1%	1 4.3%	0 0.0%	23
Car	158 6.9%	51 2.2%	307 13.3%	489 21.3%	492 21.4%	339 14.7%	243 10.6%	110 4.8%	112 4.9%	2,301
Car driver*	2 0.1%	5 0.3%	190 11.3%	381 22.7%	442 26.4%	288 17.2%	207 12.4%	83 5.0%	78 4.7%	1,676
Car passenger*	154 26.2%	46 7.8%	109 18.5%	98 16.7%	45 7.7%	46 7.8%	31 5.3%	27 4.6%	32 5.4%	588
Goods	5 2.2%	3 1.3%	4 1.7%	32 13.9%	77 33.3%	60 26.0%	37 16.0%	11 4.8%	2 0.9%	231
Motorcycle	0 0.0%	16 10.4%	28 18.2%	38 24.7%	38 24.7%	20 13.0%	10 6.5%	4 2.6%	0 0.0%	154
Pedal cycle	9 15.5%	9 15.5%	7 12.1%	4 6.9%	8 13.8%	9 15.5%	9 15.5%	1 1.7%	2 3.4%	58
Pedestrian	30 25.9%	17 14.7%	10 8.6%	8 6.9%	13 11.2%	11 9.5%	8 6.9%	8 6.9%	11 9.5%	116
Total	202 7.0%	96 3.3%	357 12.4%	574 19.9%	634 22.0%	445 15.4%	313 10.9%	135 4.7%	127 4.4%	2,883

* Car total split into driver and passenger where these can be identified.

Figure 4.3: The age distribution of people involved in accidents by mode of transport



4.2.3 Carriageway class, speed limit and accident severity

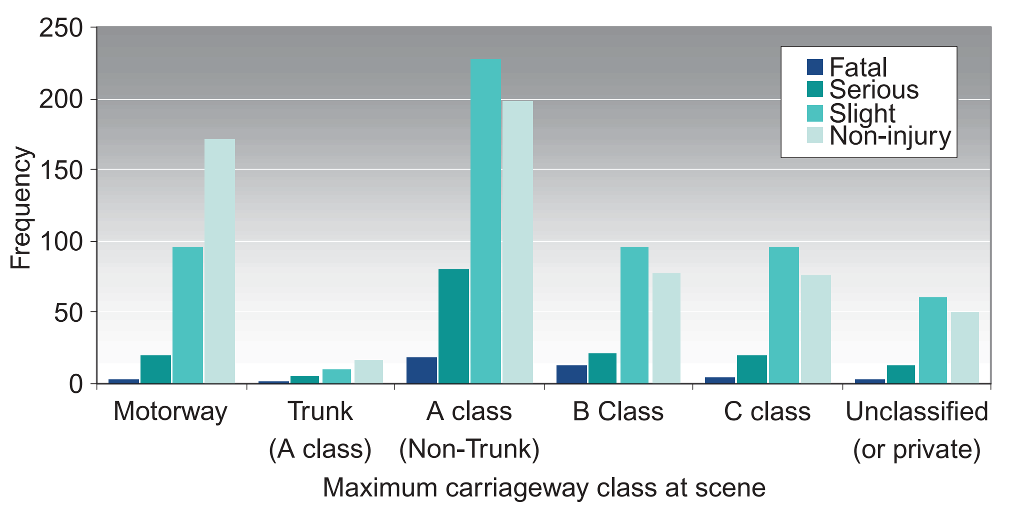
4.2.3.1 Carriageway class

The OTS database contains records of the carriageway on which the accident occurred. There were a large number of missing values in this data field: of the 3,098 accident paths recorded, the carriageway class was not recorded in 1,136 cases. However, a 'maximum' carriageway class could be obtained for most accident scenes, such that the maximum is, in effect, the path with the highest speed/size (i.e. motorway is the maximum class and footpath is at the minimum). For example, an accident scene occurring at the junction of an 'A' class and 'B' class road would have a maximum carriageway class at the scene of 'A' class (note in the case of missing values, the maximum reported carriageway class is obtained). Of the 2,188 accident scenes, the maximum carriageway class was obtained for 1,410 scenes, 1,378 of which had data for PAS. Table 4.5 displays the frequency and percentage of total accidents for the PAS levels and the **maximum** carriageway class of each accident, with rows ordered from maximum to minimum class (see Figure 4.4).

The association between assigned severity and road class was tested using a chi-squared test by grouping the roads into motorway, 'A' class, 'B' class and other. It was concluded that there was an association between road class and severity, chi-squared = 29.14, df = 6 ($p < 0.001$). There is a low incidence of serious and fatal accidents on motorways, a high incidence of serious accidents on 'A' class roads, and a high incidence of fatal accidents on 'B' class roads.

Table 4.5: PAS by carriageway class (frequency and percentage of total accidents)										
Maximum carriageway class for the accident	**Total**		**Fatal**		**Serious**		**Slight injury**		**No injury**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Motorway	290	21.1	3	0.2	19	1.4	96	7.0	172	12.4
Trunk ('A' class)	33	2.4	1	0.1	5	0.4	10	0.7	17	1.2
'A' class (non-trunk)	523	38.0	18	1.3	80	5.8	227	16.5	198	14.4
'B' class	207	15.0	13	0.9	21	1.5	96	7.0	77	5.6
'C' class	194	14.1	4	0.3	19	1.4	95	6.9	76	5.5
Unclassified (or private)	126	9.1	3	0.2	13	0.9	60	4.4	50	3.6
Bus lane (or similar restriction)	4	0.3	0	0.0	2	2	2	0.2	0	0
Footway	1	0.1	0	0.0	0	0	0	0	1	0
Total	1,378	100.0	42	3.0	159	159	586	42.5	591	42.9

Figure 4.4: PAS by carriageway class



4.2.3.2 Speed limit

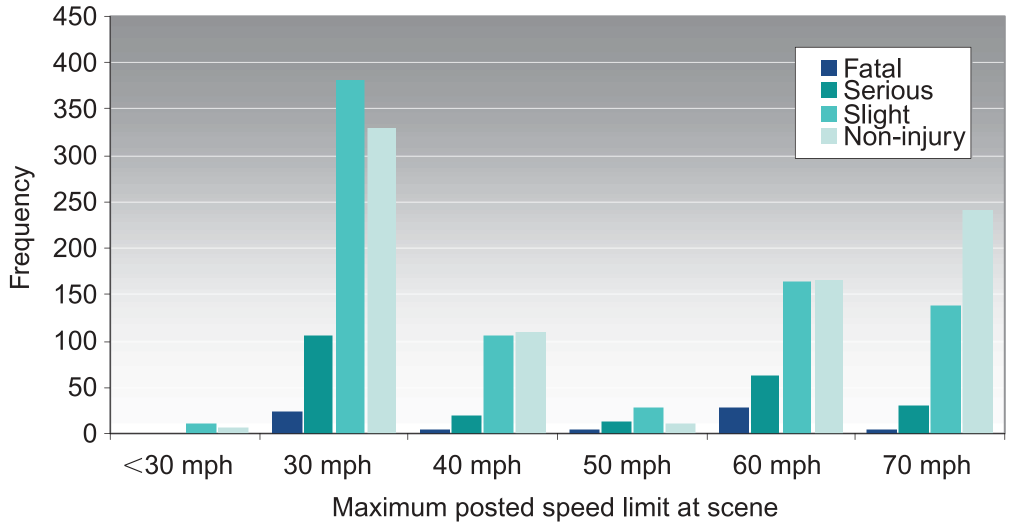
The OTS database contains records of the posted speed limit (including temporary speed restrictions) at the locus of the accident. There were a total of 216 missing data points in the database for this variable. Table 4.6 displays the frequency and percentage of accidents that occurred in a zone of a particular posted speed limit

(Figure 4.5). The speed limit was taken to be the maximum posted speed limit of the scene.

Table 4.6: Accident severity for the maximum posted path speed limit of the scene

Maximum posted speed limit (mph)	Total		Fatal		Serious		Slight		No injury	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
<30	18	0.9	0	0.0	1	0.05	11	0.6	6	0.3
30	841	42.4	24	1.2	106	5.3	381	19.2	330	16.6
40	239	12.0	5	0.3	20	1.0	105	5.3	109	5.5
50	53	2.7	4	0.2	12	0.6	27	1.4	10	0.5
60	420	21.2	29	1.5	62	3.1	164	8.3	165	8.3
70	414	20.9	5	0.3	30	1.5	137	6.9	242	12.2
Total	1,985	100.0	67	3.4	231	11.6	825	41.6	862	43.4

Figure 4.5: Accident frequency and severity by speed limit



It can be seen that the majority of accidents happen on 30 mph roads. The proportion of severe and fatal accidents on 70 mph speed limit roads is much lower than on 60 mph and 30 mph roads. The association between posted speed limit and assigned severity was tested using the chi-squared procedure, grouping the speed limit into 30 mph, 40–50 mph, 60 mph and 70 mph. It was concluded that there was an association between posted speed limit and assigned severity, chi-squared = 37.26, df = 6 ($p < 0.001$). The source of the association was the high number of fatal accidents in 60 mph speed limits and the low number of fatal and serious accidents in 70 mph speed limits. It should be noted that posted speed limit indicates the type of road as well as the potential speed of those involved in an accident and these findings do not necessarily indicate the effect of speed on the seriousness of an accident.

4.2.4 *Accidents by day of the week and time of day*

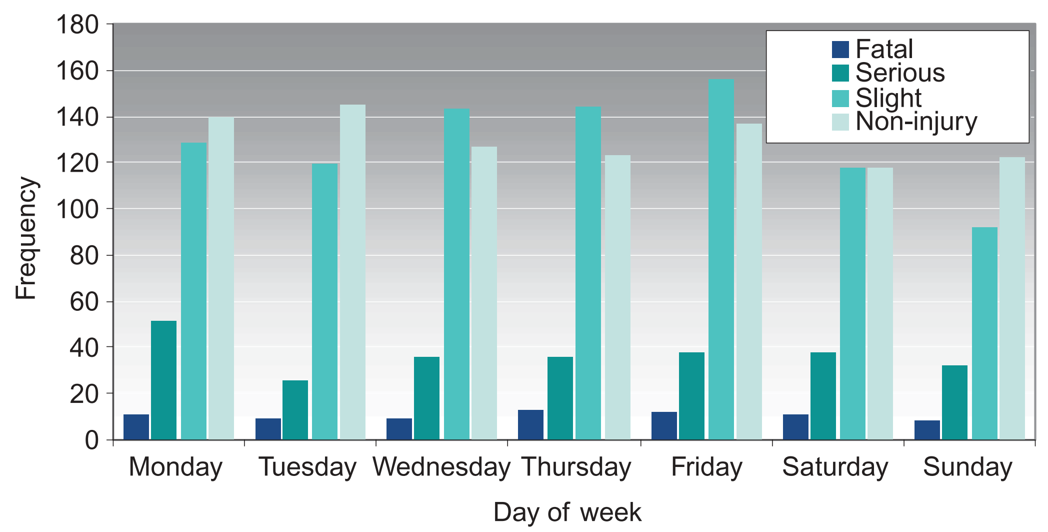
4.2.4.1 Day of the week

The OTS database contains a record of the day of the week on which the accident occurred. There were a total of 10 missing data points in the database for this variable. Table 4.7 displays the frequency and percentage of accidents that occurred on a given day of the week (see Figure 4.6). The 'total' column includes accidents which were not assigned a rating so the percentages do not add up to 100.0%.

Table 4.7: Day of the week that accidents occurred

Day of week	Total		Fatal		Serious		Slight injury		No injury	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Monday	334	15.3	11	0.5	51	2.3	129	5.9	140	6.4
Tuesday	304	13.9	9	0.4	26	1.2	119	5.4	145	6.6
Wednesday	316	14.4	9	0.4	36	1.7	143	6.5	127	5.8
Thursday	322	14.7	13	0.6	36	1.7	144	6.6	123	5.6
Friday	347	15.9	12	0.6	38	1.7	156	7.1	137	6.3
Saturday	290	13.3	11	0.5	38	1.7	118	5.4	118	5.4
Sunday	265	12.1	8	0.4	32	1.5	92	4.2	122	5.6
Total	2,178	100	73	3.3	257	11.8	904	41.3	917	41.9

Figure 4.6: Accident frequency and severity by day of the week



Association between the day of the week and assigned severity was tested using a chi-squared test. It was concluded that there is no evidence to suggest that assigned severity varies with the day of the week, chi-squared = 9.07, df = 12.

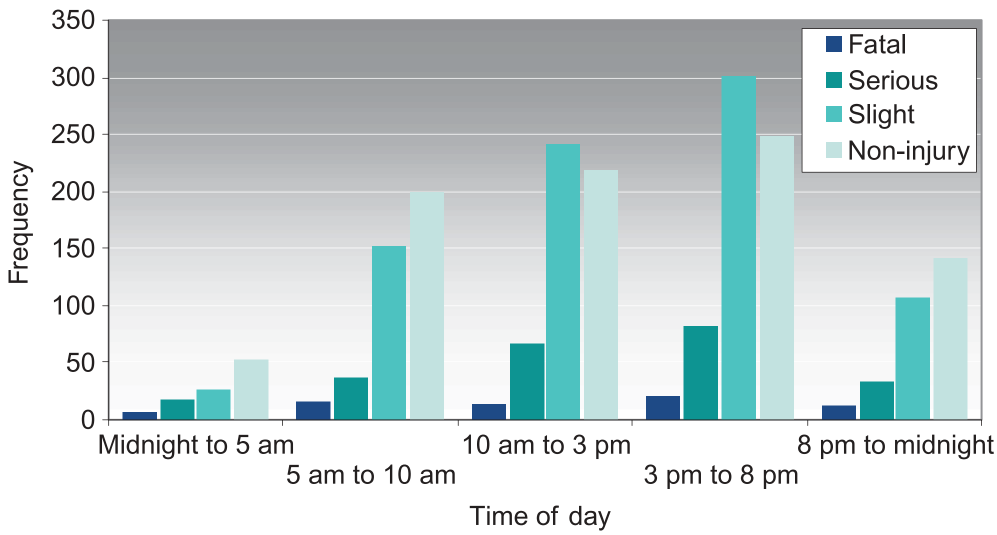
4.2.4.2 Time of day

The OTS database contains a record of the time of day at which the accident occurred. There were a total of 193 missing data points for this variable. Table 4.8 displays the frequency and percentage of accidents that occurred at a given time of day (see also Figure 4.7)

Table 4.8: Time of day that accidents occurred

Time of day	Total		Fatal		Serious		Slight injury		No injury	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Midnight to 5 am	103	5.2	7	0.4	17	0.9	26	1.3	53	2.7
5 am to 10 am	404	20.3	15	0.8	37	1.9	153	7.7	199	10.0
10 am to 3 pm	541	27.1	14	0.7	67	3.4	242	12.1	218	10.9
3 pm to 8 pm	653	32.7	21	1.1	83	4.2	301	15.1	248	12.4
8 pm to midnight	294	14.7	13	0.7	33	1.7	106	5.3	142	7.1
Total	1,995	100.0	70	3.5	237	11.9	828	41.5	860	43.1

Figure 4.7: Time of day at which accidents occurred



Association between the time of day and assigned severity was tested by grouping the time of day into 8 pm to 5 am, 5 am to 10 am, 10 am to 3pm, and 3 pm to 8 pm. It was concluded that the assigned severity and time of day were not associated, chi-squared = 7.92, df = 6.

4.3 Causal factors of accidents

4.3.1 Grouping the factors

When a road accident occurs it is considered to be the result of some failure (human or mechanical) or an incorrect manoeuvre. Such failures and manoeuvres are not actually causes of accidents; they are the result of combinations of underlying factors, for example, the driving conditions. The OTS database contains two structured coding systems for accident causation: the first is based on 54 contributory factors indexed under 'Scene: Causation' and there is a more recent system: 'Contributory factors 2005'. Data for the second system were available for 25% of accidents only in the sample used in this study and it was decided that structured analysis would be confined to the first scheme. The use of text filtering on the interactions forms was also investigated but it was decided that the primary analysis should be based on the relatively complete first coding system as it provided clearly defined factors. The OTS database contains scores for a total of 54 contributory factors. These factors are not likely to be independent, i.e. there are links between factors that mean that they are correlated. In order to perform a meaningful statistical analysis, it is important to group these factors into relatively independent and uncorrelated groups.

As noted in the methodology section, two methods for data grouping were employed:

- a qualitative approach involving subject matter expert (SME) input; and
- a quantitative approach using statistical factor analysis.

Qualitative grouping was used to group factors that were known to relate to common underlying themes. This process was guided by TNO SME input. An example of a qualitative group was the factors impairment through alcohol and impairment through drugs. Although these factors were only weakly correlated, statistically they were strongly related in terms of their effect on an individual's control of a vehicle and their ability to drive safely.

Quantitative factor analysis techniques were also used to guide the grouping process, in particular a technique called Principal Components Analysis (PCA). PCA is a statistical technique for identifying patterns in large datasets based on the underlying structure of the variables. Variables that are particularly correlated are grouped together and the resulting groups are ordered with respect to the amount of data variability they explain. One such group of variables identified by the PCA comprised inexperience of driving and inexperience of vehicle. After the factor analysis was performed these two factors were represented by a single 'inexperience' dimension. The resulting groups obtained after application of both qualitative and quantitative methods are shown in Table 4.9.

Table 4.9: The grouping of OTS contributory factors, based on the qualitative grouping and factor analysis, and the number of scenes where this was a contributory factor

Grouping	OTS contributory factors	Frequency
Inattention/distraction	Distraction through stress or emotional state of mind	21
	Distraction through physical object on or in vehicle	40
	Distraction through physical object outside of vehicle	29
	Panic behaviour	63
	Careless, reckless or thoughtless	352
	Nervous or uncertain	34
	Failure to judge others person's path or speed	367
	Failed to look	191
	Looked but did not see	194
	Inattention	430
	Ignored lights at crossing	23
	Lack of judgement of own path	279
Speed/aggressive driving	In a hurry	143
	Excessive speed	356
	Following too close	145
	Interaction or competition with other road users	26
	Aggressive driving	95
Impairment due to fatigue/illness	Impairment through fatigue	32
	Impairment through illness	42
Impairment due to alcohol/drugs	Impairment through alcohol	128
	Impairment through drugs	12
Visual impairment or obscuration	Cross from behind parked car	21
	View obscured from window	18
	Glare from sun	20
	Glare from headlights	5
	Surroundings obscured by stationary or parked car	43
	Surroundings obscured by moving vehicle	21
	Obscuration due to weather	5
	Failure to see pedestrian in blind spot	1
Inexperience	Inexperience of driving	72
	Inexperience of vehicle	67
Road design and features	Poor or no street lighting at site	11
	Inadequate signing at site	8
	Steep hill at site	4
	Narrow road at site	7
	Bend or winding road at site	52
	Surroundings obscured by bend or winding road	12
	Surroundings obscured by buildings, fences, vegetation	13
Road surface	Poor surface at site	25
	Slippery road at site	87
Vehicle defects	Tyre pressures wrong	8
	Tyre deflated before impact	23
	Tyre worn or insufficient tread	4
	Defective lights or signals	3
	Defective brakes	9
	Other vehicle factor (give details) (63)	25

Table 4.9: (continued)		
Grouping	**OTS contributory factors**	**Frequency**
Other	Disability Person hit wore dark or inconspicuous clothing Other personal factor (give details) (48) Roadworks at site High winds at site Earlier accident Other local factor (give details) (74) Animal out of control	4 12 29 6 2 8 20 8

In the following sections the term 'causal factors' will refer to the causal factor groups in Table 4.9.

It should be noted that fatigue in the OTS database is coded as a number of levels:

- definite cause;
- probable cause;
- possible cause; and
- not a cause.

This study has classified **definite** and **probable** as 'fatigued' and **possible** and **not a cause** as 'not fatigued'. The same technique was used for all factors where similar grading levels had been defined.

4.3.2 *Cause by scene*

Table 4.10 summarises the frequency of accidents by causal factor and the percentage of scenes attributed to the causal factors. There was no information about the cause of the accident for 476 scenes, and 713 scenes had more than one causal factor, hence the total does not equal 100%.

Table 4.10: Frequency and percentage of all scenes attributed to a causal factor

Causal factor	Frequency of scenes	Percentage of all scenes
Inattention/distraction	1,192	54.5
Speed/aggressive driving	604	27.6
Impairment due to alcohol/drugs	138	6.3
Visual impairment/obscuration	123	5.6
Road surface	108	4.9
Inexperience	104	4.8
Road design/features	95	4.3
Other	85	3.9
Impairment due to fatigue/illness	73	3.3
Vehicle defects	70	3.2

Of the total of 2,592 causes assigned to the scenes, it can be seen from Table 4.10 that 1,796 (69.3%) are inattention/distraction or speed/aggressive driving. Further analysis of the scene data indicates that, for 371 scenes, both causes are assigned.

4.4 Features of accidents

4.4.1 Types of accident

There were numerous features of accidents and it was important to reduce these to a smaller set for the statistical analysis to be meaningful. Low-frequency categories were aggregated with other similar categories; where no appropriate match for aggregation was found the data were excluded from the analysis. All missing values were excluded from further analysis.

There were three types of accident feature:

- the type of road user/object that was hit;
- the type of impact; and
- the speed of the impact.

4.4.2 Type of road user/object involved in the incident

The type of road user was aggregated by size and movement (see Table 4.11). Vehicles were aggregated into three categories: car, large vehicle (excluding bus due to lack of data) and vulnerable road user (VRU). The latter observations were grouped in a single category as there were insufficient observations to support detailed analysis by specific type. Stationary objects (including unattended cars and other vehicles) were separated into their own group.

Table 4.11: Type of road user/object involved in the incident

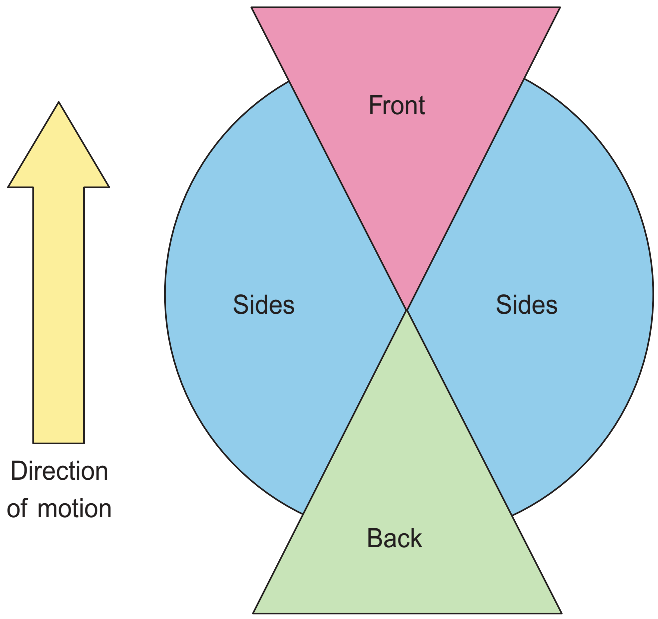
Group	Breakdown
Car	Car
Large vehicles	Light goods vehicle Heavy goods vehicle
VRUs or animals	Motorcycle Pedestrian Pedal cycle Animals
Stationary objects	Pole or narrow object $<$ 41 cm Wide object $>=$ 41 cm Vehicle rolled
Missing	Missing (excluded from further analysis)

4.4.3 *Type of impact*

The type of impact was defined by the direction of force in the accident. The OTS database contains information about the direction of impact for each vehicle involved in the scene using a simple clock face diagram (see Figure 4.8), where:

- 11 o'clock to 1 o'clock on the clock face represents a front impact;
- 5 o'clock to 7 o'clock represents a rear impact; and
- the rest of the clock face directions represent a side impact.

Figure 4.8: Definition of the direction of impact



A number of categories of impact were defined based on the direction of impact of the vehicles involved (see Table 4.12). For example, a head-on crash was defined as the front of one vehicle hitting the front of another vehicle.

Table 4.12: Type of impact

Group	Breakdown
Front impact	Front impact of a vehicle to the side of another vehicle or a stationary object
Shunt	Front of vehicle hits the rear of another vehicle or vice versa
Sideways	Sideways impact to the vehicle from the front of another vehicle or sideways impact to a stationary object
Head on	Front of one vehicle impacts the front of another vehicle
Other	Any other direction of impact
Missing	Missing (excluded from further analysis)

4.4.4 Speed

The estimated speed of the impact was rarely reported in the database, and there were insufficient observations to support statistical analysis. The posted speed was the most complete of the speed data items and provided the most reliable data for the purpose of statistical modelling. Table 4.13 shows the groups for the posted speed limit.

Table 4.13: Posted speed limit of path

Group	Breakdown
< 20 mph	Up to 20 mph (excluded from further analysis)
30 mph	30 mph
40–50 mph	40 mph
	50 mph (this category contained too few cases and was combined with 40 mph)
60 mph	60 mph
70 mph	70 mph
Missing	Missing (excluded from further analysis)

4.5 Injuries

4.5.1 Injury Severity Index

A measure of injury severity at the **individual human** level was determined and termed an Injury Severity Index (ISI). It was important to determine a measure of injury severity at the individual level rather than using the scene-level Police Accident Severity (PAS) rating, since this reflected the worst case at the scene level and was therefore not necessarily representative of all accident-involved persons, where there was more than one involved in a particular scene. Also the severity of injuries depended on the characteristics of the individual (e.g. pedestrian, driver, passenger).

Appendix 1 gives a full outline of how this was derived using information from the injury level of the OTS database as a primary source, while also taking medical summary-level information as a secondary source where injury records were incomplete in some cases. The OTS injury data were arranged to give a record for each accident-involved person and the injuries they sustained, in terms of whether or not they sustained injury to each of the nine Abbreviated Injury Scale (AIS) body regions. The highest AIS severity for each individual was also inserted into the data. A Principal Components Analysis (PCA) on the regions of the body and overall severity of the worst injury sustained was performed to determine an inherent structure to the nature of injuries. A single first principal component resulted from the analysis, which correlated highly with AIS severity and also, to a reasonable extent, with the body regions head, thorax and extremities (shoulders/arms/legs), as these may be the regions prone to the critical injuries that are typical of RTAs. Also the principal component was found to link reasonably well with the overall severity of the accident. This component was named the Injury Severity Index (ISI).

As a crude illustration of the ISI, a rating of zero corresponds to no injury and a rating of 10 corresponds to a definite fatality. The ISI was grouped according to severity. Table 4.14 shows the ISI group, the description of severity and the frequency of injury cases at each level. For comparison, the medical ratings of the casualties where available are appended. There is a strong association between the scores calculated by the two different methods.

Table 4.14: ISI level and description of injuries sustained

ISI group	Description	Frequency	Rating – no injury	Rating – slight injury	Rating – serious injury	Rating – fatal injury	No rating
0	None	3,232	1,584	54	2	3	1,588
1 to 2	Minor	927	139	249	35	0	504
3 to 4	Moderate	443	51	116	45	2	229
5	Serious	92	4	12	21	3	52
6 to 7	Severe	87	1	3	20	8	45
8+	Critical	42	0	2	4	12	24

The ISI is constructed as a linear combination of 10 measures, nine of which are binary. The derived score has properties close to those of an interval measure rather than an ordinal measure, in that the scale has more than 50 distinct possible values between 0 and 10. As such the measure is appropriate for use in both Analysis of Variance (ANOVA) and regression analysis. A more in-depth discussion of the technique and ISI can be seen in Appendix 1.

4.6 Initial analysis

An initial analysis was used to investigate links between the causal factors across all vehicle types. In the second stage of the analysis, accidents were analysed using standard statistical ANOVA techniques by vehicle type.

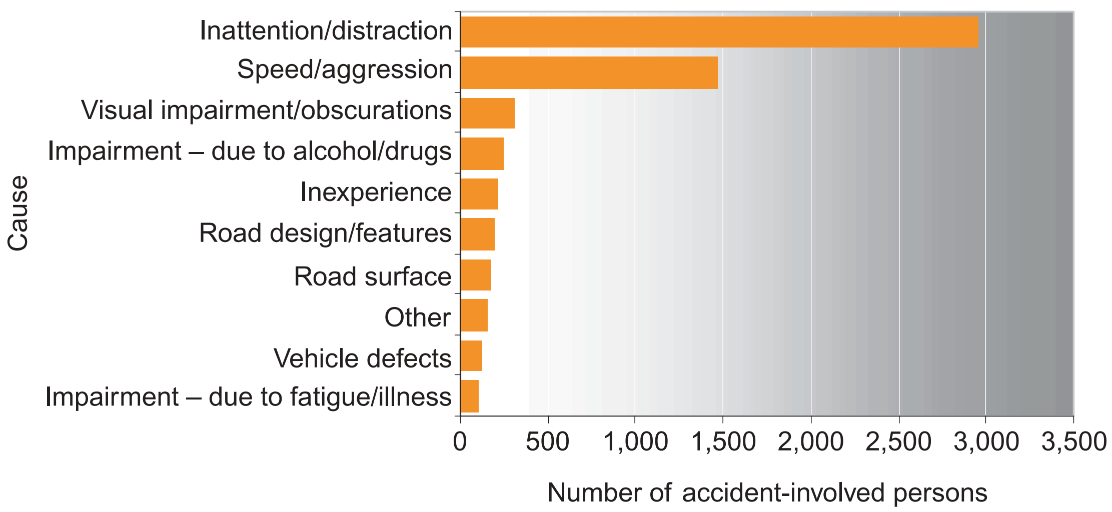
4.6.1 Accident-involved persons and injuries by causal factor

Table 4.15 and Figure 4.9 summarise the number of people involved in accidents of each type and the average ISI of all people involved in an accident of that type. There were a total of 960 accident-involved persons for whom there was no information on the cause of the accident. There were a total of 1,709 accident-involved persons where there was more than one causal factor for the accident; hence, the total percentages below exceed 100%.

Table 4.15: Accident-involved persons by causal factors and the average ISI and percentage of people with ISI of five or higher

Causal factor	Frequency of accident-involved persons	Percentage of all persons	Average ISI	Percentage of people with ISI of five or higher
Inattention/distraction	2,956	60.9	0.83	4.0
Speed/aggressive driving	1,470	30.3	0.92	5.5
Visual impairment/obscuration	308	6.4	0.82	2.9
Impairment due to alcohol/drugs	251	5.2	0.99	7.7
Inexperience	220	4.5	0.78	3.2
Road design/features	190	3.9	1.13	5.3
Road surface	176	3.6	0.98	6.3
Other	158	3.3	0.81	6.3
Vehicle defects	123	2.5	0.65	4.1
Impairment due to fatigue/illness	105	2.2	1.41	8.6

Figure 4.9: Summary of the number of accident-involved persons and the causal factor involved in the accident



It can be seen from this table that the highest average ISI occurred in accidents caused by 'impairment due to fatigue/illness'. Accidents involving 'impairment due to alcohol/drugs' and 'impairment due to fatigue/illness', 'road surface' and 'speed/aggressive driving' have the highest percentages of people with an ISI of five or more. The pattern of expected ISI with assigned accident causes was tested using regression of the logarithm of (ISI + 1) on the presence of the 10 assigned causes and also the presence of the 45 possible pairs of causes. It was concluded that average ISI is increased for those accidents with 'road design/features' ($p < 0.01$) and 'impairment due to fatigue/illness' ($p < 0.001$) as causes, but is reduced for those accidents with 'vehicle defects' as a cause ($p < 0.05$). Based on the analysis of interactions, if both 'speed/aggressive driving' and 'inattention/distraction' are assigned causes, the expected ISI is reduced ($p < 0.05$). If both 'road design/features' and 'road surface' are assigned causes, ISI is also reduced ($p < 0.001$).

There were three interactions with 'impairment due to alcohol/drugs': 'inexperience' ($p < 0.05$), 'impairment due to fatigue/illness' ($p < 0.05$) and 'vehicle defects' ($p < 0.05$), which increased ISI further.

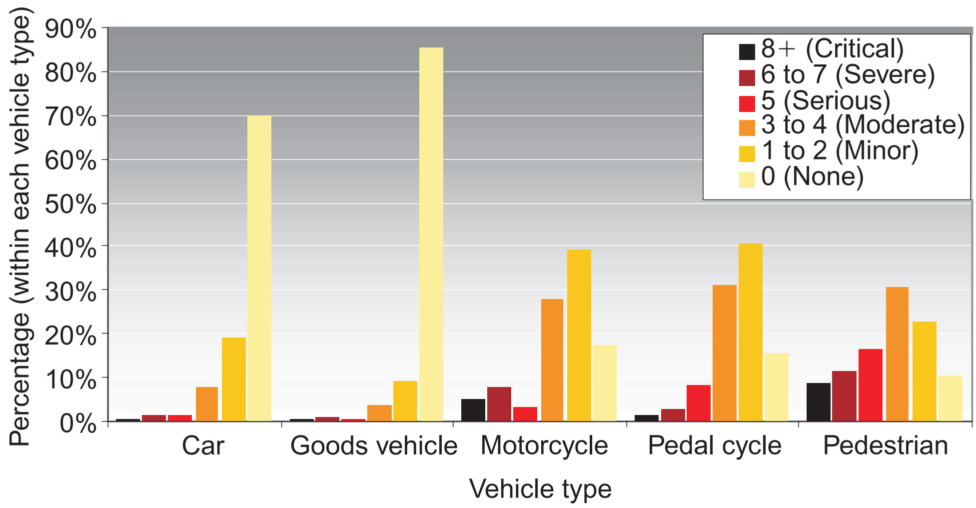
4.6.2 *Injury by vehicle type*

Table 4.16 and Figure 4.10 summarise the number and percentage of accidents for a given mode of transport by the injuries sustained by the occupant.

Table 4.16: ISI by vehicle type

ISI	Car		Goods vehicle		Motorcycle		Pedal cycle		Pedestrian	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0	2,746	69.7	382	85.3	35	17.2	11	15.5	15	10.6
1 to 2	744	18.9	40	8.9	79	38.7	29	40.8	32	22.5
3 to 4	305	7.7	17	3.8	56	27.5	22	31.0	43	30.3
5	55	1.4	2	0.4	6	2.9	6	8.5	23	16.2
6 to 7	49	1.2	4	0.9	16	7.8	2	2.8	16	11.3
8+	17	0.4	2	0.4	10	4.9	1	1.4	12	8.5
Total	3,916	100.0	447	100.0	202	100.0	71	100.0	141	100.0

Figure 4.10: Injuries by vehicle type



It can be seen that the VRU groups have a much lower proportion of 'no injury' or 'minor injury' accidents in comparison to cars and goods vehicles. Pedestrians and motorcycles have the highest rate of accidents, resulting in an ISI of 8+ (fatal accidents). A formal test of these observations was conducted by grouping the ISI data as 0, 1 to 2, 3 to 4 and 5+. It was concluded, using a chi-squared test, that there is an association between the ISI group and transport mode, chi-squared = 880.6, df = 12 ($p < 0.001$). The under-representation of the VRUs in the ISI 'no injury' category and the over-representation in all the other injury categories were all highly significant ($p < 0.001$).

4.6.3 *Accident-involved persons and injuries by causal factor and vehicle type*

Table 4.17 contains the same information as Table 4.15 but is split by the vehicle type that the accident-involved person was in. Figure 4.11 presents the same breakdown of injury rate by cause and vehicle type graphically.

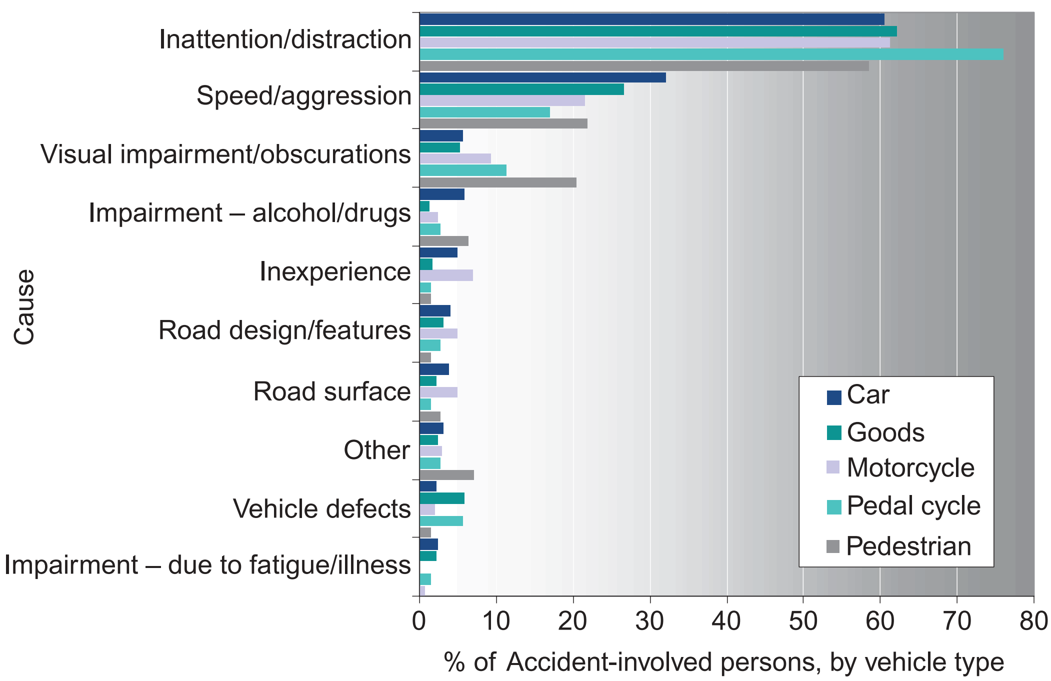
Table 4.17: Accident-involved persons by causal factor and vehicle type

Cause	Vehicle type	Frequency of accident-involved persons	Percentage of all persons for that vehicle type	Average ISI	% persons with severity of ISI five or higher
Inattention/distraction	Bus	35	76.1	0.13	0.0
	Car	2,381	60.4	0.68	2.8
	Goods	278	62.1	0.36	2.2
	Motorcycle	125	61.3	2.46	12.1
	Pedal cycle	54	76.1	2.35	13.0
	Pedestrian	83	58.5	3.44	30.5
Speed/aggressive driving	Bus	3	6.5	0.82	0.0
	Car	1,261	32.0	0.83	4.9
	Goods	119	26.6	0.38	0.8
	Motorcycle	44	21.6	2.80	18.6
	Pedal cycle	12	16.9	1.82	0.0
	Pedestrian	31	21.8	3.81	32.3
Visual impairment/ obscuration	Bus	9	19.6	0.11	0.0
impairment/obscuration	Car	219	5.6	0.42	0.9
	Goods	24	5.4	0.11	0.0
	Motorcycle	19	9.3	2.35	5.3
	Pedal cycle	8	11.3	2.20	12.5
	Pedestrian	29	20.4	3.24	17.2
Impairment due to alcohol/drugs	Bus	2	4.3	0.00	0.0
	Car	227	5.8	0.78	4.5
	Goods	6	1.3	0.87	16.7
	Motorcycle	5	2.5	3.28	40.0
	Pedal cycle	2	2.8	1.97	0.0
	Pedestrian	9	6.3	4.92	66.7
Inexperience	Bus	0	0.0	–	–
	Car	196	5.0	0.70	3.6
	Goods	7	1.6	0.65	0.0
	Motorcycle	14	6.9	1.94	0.0
	Pedal cycle	1	1.4	2.65	0.0
	Pedestrian	2	1.4	0.00	0.0
Road design/features	Bus	3	6.5	0.33	0.0
	Car	159	4.0	0.99	4.4
	Goods	14	3.1	0.67	7.1
	Motorcycle	10	4.9	3.40	20.0
	Pedal cycle	2	2.8	2.56	0.0
	Pedestrian	2	1.4	3.25	0.0

Table 4.17: (continued)

Cause	Vehicle type	Frequency of accident-involved persons	Percentage of all persons for that vehicle type	Average ISI	% persons with severity of ISI five or higher
Road surface	Bus	0	0.0	–	–
	Car	151	3.8	0.79	5.33
	Goods	10	2.2	0.25	0.0
	Motorcycle	10	4.9	3.01	10.0
	Pedal cycle	1	1.4	1.47	0.0
	Pedestrian	4	2.8	4.86	50.0
Other	Bus	5	10.9	0.00	0.0
	Car	124	3.1	0.52	3.2
	Goods	11	2.5	0.09	0.0
	Motorcycle	6	2.9	4.31	50
	Pedal cycle	2	2.8	1.72	0.0
	Pedestrian	10	7.0	3.34	30.0
Vehicle defects	Bus	0	0.0	–	–
	Car	87	2.2	0.58	3.4
	Goods	26	5.8	0.16	0.0
	Motorcycle	4	2.0	2.09	0.0
	Pedal cycle	4	5.6	1.72	0.0
	Pedestrian	2	1.4	5.41	100.0
Impairment due to fatigue/illness	Bus	0	0.0	-	-
	Car	93	2.4	1.49	8.6
	Goods	10	2.2	0.25	0.0
	Motorcycle	0	0.0	–	–
	Pedal cycle	1	1.4	1.47	0.0
	Pedestrian	1	0.7	5.28	100.0

Figure 4.11: Percentage of accident-involved persons within each vehicle type that are attributed to the causal factors



The model used to analyse the relationship between assigned accident causes and expected ISI presented in Table 4.15 was extended to include a main effect of vehicle mode, since the analysis of the data presented in Table 4.16 confirmed an association between mode and ISI. The findings from fitting the extended model confirmed the analysis of Table 4.16 in that VRUs sustain greater injuries ($p < 0.001$), accounting for 20% of the variance in assigned ISI scores. The extended analysis indicated that injuries to those in accidents associated with 'speed/aggressive driving', 'road design/features' and 'impairment due to fatigue/ illness' are increased ($p < 0.01$, $p < 0.01$ and $p < 0.001$, respectively). The findings from the analysis of interactions were unchanged.

There is clearly a much stronger relationship between vehicle mode and injury than between assigned accident cause and injury. This is unremarkable as accidents are caused by an interaction between an individual, the vehicle he or she is controlling and the environment. The consequences of the accident, in terms of injuries sustained, depend on the nature of the impact experienced by all parties to the accident, and the precipitating cause and accident consequences are independent of each other at least to some degree. The descriptive analysis outlined in this section has demonstrated some of the detectable associations between factors that may contribute to the occurrence of an accident and the other factors that may contribute to the incidence of injuries. In the next part of Section 4 a more formal attempt is made to test associations between demographic factors, accident causes, the nature of the impact and the injuries sustained.

4.7 Links between causal factors, accident type and injuries

The analysis outlined in this section is based on the assumption that the causation of injury in road accidents is a two-stage process:

1. The likelihood that an accident will occur is a function of the characteristics of the individual causing the accident (e.g. age, fatigued), the context in which he/ she is using the road (e.g. time of day, weather) and the vehicle that is being driven (e.g. car, motorcycle).
2. The nature of the injuries sustained, given that an accident occurs, does not necessarily depend on the vehicle that caused the accident but depends on the nature of the impact, the other vehicles involved – including pedestrians – and any passive injury prevention devices present.

The analysis of the first part of the process and the establishment of accident causes using objective data require control data to provide evidence of exposure to the associated hazard. In this study there are no exposure data, but there is expert analysis of the accident cause. Some insight into accident causation can be gained by investigating the relationships between the demographic data describing those who are assigned responsibility for an accident, the context in which it occurs and the assigned cause.

The analysis of the pattern of injury, given that an accident has occurred, depends on the vehicles involved in the accident, the nature of the impact, the occupancy of the vehicles and any passive injury prevention devices, such as airbags that were deployed. The OTS database provides considerable detail on these factors. Even if the causes of accidents are not analysed, the causation of injury is still a complex process involving a considerable number of factors, and a full epidemiological analysis requires large data samples. The OTS database contains data for 4,823 individuals who were involved in accidents. Full information on all potentially relevant factors is unavailable for a considerable number of individuals, and this places a severe constraint on the level of analysis that can be undertaken in terms of the combinations of factors that can be considered.

Standard log-linear hierarchical contingency table analysis and linear modelling techniques were used to investigate the links between the causal factors, the accident type and the injuries sustained. The analysis of multi-way contingency tables was limited by the availability of data. The results of the analysis are divided into sections relating to the type of vehicle to which the precipitating factor of the accident was attributable, since vehicle mode is a major determinant of injury sustained, as noted in the previous section.

4.7.1 Cars

4.7.1.1 Causes of accidents

Cars are the most numerous of vehicle groups involved in accidents, and a limited analysis of the relationship between demographic factors and accident context defined by time of day, light conditions, vehicle occupancy and accident cause was undertaken. Of the 2,664 accident-involved persons who were 'in charge" of a car, 841 individuals were identifiable in the data as the car driver to whom the precipitating factor was attributable. The data from these individuals were investigated using a log-linear hierarchical model describing the incidence of accidents using gender, age, time of day, light conditions and number of occupants. These factors were tested separately and in combination with each of the 10 assigned causal factors. Almost all the identified effects were simple interactions with causes, and these were tested as marginal two-way contingency tables and are summarised below in Tables 4.18–4.22.

Gender association with causal factors

The results of the marginal contingency table analysis of the effect of 'gender' on the causal factors of accidents are presented in Table 4.18. It can be seen that males are significantly more likely to have 'speed/aggressive driving' and 'impairment due to alcohol/drugs' as causal factors of accidents. Women are more likely to have a causal factor of 'visual impairment/obscuration'.

Table 4.18: The association between 'gender' and the causal factors of accidents

Causal factor	Gender		Chi-square significance
	Male (%)	Female (%)	
Speed/aggressive driving	38	19	$p < 0.001$
Visual impairment/obscuration	2.7	6.1	$p < 0.05$
Impairment due to alcohol/drugs	12	5.7	$p < 0.05$

Age of driver: associations with causal factors

The results of the marginal contingency table analysis of the effect of 'age' on the causal factors of accidents are presented in Table 4.19. It can be seen that young drivers are more likely to have accidents involving 'speed/aggressive driving', 'inexperience' and 'road design/features' as factors. Drivers over the age of 40 are more likely to have 'impairment due to fatigue/illness' as a causal factor in accidents.

Table 4.19: The association between 'age' and the causal factors of accidents

Causal factor	Age (%)						Chi-square significance
	17–20	21–29	30–39	40–49	50–59	60+	
Speed/aggressive driving	46	42	29	26	15	7.1	$p < 0.001$
Inexperience	16	3.8	5.1	1.3	6.2	0	$p < 0.001$
Road design/features	12	3.8	1.4	2.6	4.2	5.4	$p < 0.01$
Impairment due to fatigue/illness	2.1	3.1	4.3	13	15	14	$p < 0.001$

Time of day associations with causal factors

The results of the marginal contingency table analysis of the effect of 'time of day' on the causal factors of accidents are presented in Table 4.20. It can be seen that 'speed/aggressive driving' and 'impairment — due to alcohol/drugs' were more prevalent as causal factors in night and early morning driving (between 8 pm and 5 am). 'Road surface' was also more of a causal factor in the night and early morning. 'Inexperience' was a causal factor in the early morning and late at night; and there was evidence for an interaction with age ($p < 0.01$). It is interesting to note that the proportion of accidents at different times of day is not affected by 'impairment due to fatigue/illness', although there were more accidents in this category due to illness (42) than fatigue (32).

Table 4.20: The association between 'time of day' and the causal factors of accidents

Causal factor	Time of day (%)					Chi-square significance
	Midnight to 5 am	5 am to 10 am	10 am to 3 pm	3 pm to 8 pm	8 pm to midnight	
Inattention/distraction	38	46	60	56	51	$p < 0.01$
Speed/aggressive driving	45	32	28	27	47	$p < 0.001$
Impairment due to alcohol/drugs	25	3.0	3.8	9.7	16	$p < 0.001$
Inexperience	11	4.1	3.8	6.9	11	$p < 0.05$
Road surface	8.5	14	4.3	2.4	7.5	$p < 0.001$
Other	1.4	4.7	7.0	1.6	4.4	$p < 0.05$

Light condition association with causal factors

The results of the marginal contingency table analysis of the effect of 'light condition' on the causal factors of accidents are presented in Table 4.21. It can be seen that decreasing light levels, twilight and, to a lesser extent, darkness are problems for inexperienced drivers.

Table 4.21: The association between 'light condition' and the causal factors of accidents

Causal factor	Daylight (%)	Twilight (%)	Darkness (%)	Chi-square significance
Speed/aggressive driving	29	52	37	$p < 0.01$
Visual impairment/obscuration	4.7	6.2	1.6	$p < 0.01$
Impairment due to alcohol/drugs	5.4	10	15	$p < 0.001$
Inexperience	4.7	6.2	9.7	$p < 0.05$

Number of vehicle occupants associations with causal factors

The results of the marginal contingency table analysis of the effect of 'car occupants' on the causal factors of accidents are presented in Table 4.22. It can be seen that 'inattention/distraction' is more likely to be a causal factor when there are passengers in the car; however, passengers are associated with a reduction in the likelihood of accidents caused by 'impairment due to fatigue/illness'.

Table 4.22: The association between 'number of occupants' and the causal factors of accidents

Cause	Car occupants (%)		Chi-square significance
	Single occupant	With passenger(s)	
Inattention/distraction	49	60	$p < 0.01$
Speed/aggressive driving	30	41	$p < 0.01$
Inexperience	4.8	11	$p < 0.001$
Impairment due to fatigue/illness	6.9	3.1	$p < 0.05$

Summary of associations of demographic and context variables with causal factors

The limited analysis of associations between assigned accident causes and demographic and context measures suggests that a basic model associating behaviours, such as speeding, with particular demographic groups and the impact of context through road conditions, time of day and the status of lighting conditions is consistent with the data in the OTS database. There are not sufficient accident observations with identifiable individuals as the precipitating agent to permit definition of a full causal model.

Analysis of injuries as a consequence of accidents

- Given that an accident has occurred, the injuries sustained by those involved in the accident are likely to be dependent on:
- the nature of the vehicle/object hit;
- the speed and direction of impact; and
- passive protection measures.

In the following tables the nature of the impacts for cars recorded in the OTS database are summarised. Table 4.23 shows the 'type of vehicle/object hit' by all accidents where the precipitating factor was attributable to a car. The majority of 'car' accidents involved collision with another car.

Table 4.23: Type of vehicle/object hit in 'car' accidents

Vehicle type	Frequency
Car	2,138
Large vehicles	338
VRUs or animal	398
Stationary objects	778
Missing (excluded from model)	287

Table 4.24 shows the frequency of different types of impact in accidents involving cars. The majority of 'car' accidents were front impact or shunt accidents.

Table 4.24: Type of impact in 'car' accidents

Impact type	Frequency
Front impact	1,054
Shunt	949
Sideways	675
Head on	465
Other	402
Missing (excluded from the model)	394

Table 4.25 shows the frequency of different types of impact in accidents involving cars. The majority of 'car' accidents occurred at a posted speed limit of 30 mph.

Table 4.25: Posted speed limit in 'car' accidents

Posted Speed (mph)	Frequency
<30 mph (excluded from the model)	27
30 mph	1,674
40–50 mph	593
60 mph	791
70 mph	797
Missing (excluded from the model)	57

Model of the impact on average ISI

A stepwise linear regression model of injury severity of car occupants was fitted using the following main effects:

- posted speed limit;
- type of road user/object that was hit; and
- type of impact.

All three factors were found to be significant and included in the model.

A baseline model of injury severity was calculated, using the most frequently occurring injury case (i.e. 30 mph speed limit, impact with another car and a front impact) and is shown in Table 4.26.

Table 4.26: Baseline model of ISI for 'car' accidents

Baseline model	Estimated mean ISI
30 mph Impact with another car Front impact	0.64

The estimated mean ISI for the car occupants for all combinations of the three factors in the model are presented in Table 4.27. The shaded regions in the table are those where the type of impact is not applicable to the road user/object hit. The objects in the VRU category were very different, and, while shunts may occur with motorcycles, it was felt that the results reported for this category should be limited to front-impact crashes. The baseline case has been underlined in the table.

It can be seen from this table that the highest injury rates of car occupants occur when the car hits another car or large vehicle head-on at 60 mph. Side-on accidents at 60 mph also have a high injury rate. The lowest injury rates of car participants occur when the car hits a VRU or animal.

Table 4.27: Severity of injury matrix for combinations of the features of accidents						
Speed of road	**Road user/object hit**	**Impact**				
		Front impact	**Shunt**	**Sideways**	**Head on**	**Other**
30 mph	VRU or animal	0.02				
	Stationary object	0.59				
	Car	0.64	0.31	0.80	0.91	0.49
	Large vehicle	0.94	0.61	1.10	1.21	0.79
40–50 mph	VRU or animal	0.22				
	Stationary object	0.49				
	Car	0.84	0.51	1.00	1.11	0.69
	Large vehicle	1.14	0.81	1.30	1.41	0.99
60 mph	VRU or animal	0.75				
	Stationary object	1.22				
	Car	1.37	1.04	1.53	1.64	1.22
	Large vehicle	1.67	1.34	1.83	1.94	1.52
70 mph	VRU or animal	0.17				
	Stationary object	0.64				
	Car	0.79	0.46	0.95	1.06	0.64
	Large vehicle	1.09	0.76	1.25	1.36	0.94

4.7.2 Large vehicles

4.7.2.1 Summary of accidents by features of the accident

Table 4.28 shows the 'type of vehicle or object hit' by all accidents involving a large vehicle. Most large vehicle accidents involved collision with a car.

Table 4.28: Type of vehicle/object hit in 'large vehicle' accidents	
Vehicle type	**Frequency**
Car	251
Large vehicles	58
VRUs or animal	23
Stationary objects	46
Missing (excluded from model)	70

Table 4.29 shows the frequency of different types of impact in accidents involving large vehicles. The majority of 'large vehicle' accidents were shunt impacts.

Table 4.29: Types of impact in 'large vehicle' accidents

Impact type	Frequency
Front impact	91
Shunt	111
Sideways	40
Head on	52
Other	64

4.7.2.2 Model of the impact on average ISI

A stepwise linear regression model of injury severity *of* **large vehicle occupants** was fitted using the following main effects:

- type of road user/object that was hit;
- posted speed limit; and
- type of impact.

The following factors were found to be significant and included in the model:

- type of road user/object that was hit; and
- type of impact.

A baseline model of injury severity was calculated, using the most frequently occurring injury case (i.e. impact with a car and a shunt impact), and is shown in Table 4.30.

Table 4.30: Baseline model of ISI for 'large vehicle' accidents

Baseline model	Estimated mean ISI
Impact with a car Shunt	0.19

The estimated mean ISIs for the large vehicle occupants for all combinations of the three factors in the model are presented in Table 4.31. The shaded regions in the table are regions where the type of impact is not applicable to the road user/object hit. The baseline case has been set in bold in the table.

It can be seen from this table that the highest injury rate for large vehicle occupants occurs with a head-on collision with another large vehicle.

Table 4.31: Severity of injury matrix for combinations of the features of accidents					
Road user/object hit	Impact				
	Front impact	Shunt	Sideways	Head on	Other
VRU or animal	0.03				
Stationary object	0.03				
Car	0.20	**0.19**	0.18	0.90	0.41
Large vehicle	0.79	0.78	0.77	1.49	1.00

4.7.3 Vulnerable road users – motorcycle

4.7.3.1 Summary of accidents by features of the accident

Table 4.32 shows the 'type of vehicle/object hit' by all accidents where the precipitating factor was attributable to a motorcycle. Most 'motorcycle' accidents occurred at a posted speed limit of 30 mph.

Table 4.32: Posted speed in 'motorcycle' accidents	
Posted speed	Frequency
<30 mph (excluded from model)	2
30 mph	109
40–50 mph	37
60 mph	39
70 mph	15
Missing (excluded from model)	4

4.7.3.2 Model of the impact on average ISI

A stepwise linear regression model of injury severity *of* **motor cyclists** was fitted using the following main effects:

- type of road user/object that was hit;
- posted speed limit; and
- type of impact.

The following factor was found to be significant and included in the model: posted speed. A baseline model of injury severity was calculated, using the most frequently occurring injury case (i.e. 30 mph speed limit), and is shown in Table 4.33.

Table 4.33: Baseline model of ISI for 'motorcycle' accidents	
Baseline model	Estimated mean ISI
30 mph	2.34

The estimated mean ISI for motorcyclists for the model is presented in Table 4.34. The baseline case has been underlined in the table. The highest injury rate can be seen to occur at a posted speed limit of 60 mph.

Table 4.34: Severity of injury matrix for combinations of the features of accidents

Speed (mph)	Front impact
30	**2.34**
40–50	2.62
60	3.91
70	2.92

4.7.4 Vulnerable road users – pedal cycle

4.7.4.1 Model of the impact on average ISI

A stepwise linear regression model of injury severity *of* **pedal cyclists** was fitted using the following main effects:

- type of road user/object that was hit;
- posted speed limit; and
- type of impact.

No factors were found to have an effect on injury severity, given that an accident had occurred. A baseline model of injury severity was simply obtained from the average severity and is shown in Table 4.35.

Table 4.35: Baseline model of ISI for 'pedal cycle' accidents

Baseline model	Estimated mean ISI
	2.40

4.7.5 Vulnerable road users – pedestrians

4.7.5.1 Model of the impact on average ISI

A stepwise linear regression model of injury severity *of* **pedestrians** was fitted using the following main effects:

- type of road user/object that was hit;
- posted speed limit; and
- type of impact.

No factors were found to have an effect on injury severity, given that an accident had occurred. A baseline model of injury severity was obtained from the average severity and is shown in Table 4.36.

Table 4.36: Baseline model of ISI for 'pedestrian' accidents

Baseline model	Estimated mean ISI
Posted speed limit 30 mph	3.75

4.8 Injury mitigation strategies

This section examines existing active methods to mitigate against injury in order to determine whether they reduce injury severity. This is done by vehicle, as mitigation strategies differ between vehicle types (e.g. airbags apply to cars and helmets apply to cycles). Where there was a significant reduction in injury rating, the relative difference from the baseline model (see Section 4.7) is reported.

The injury mitigation strategies were tested to determine whether they caused significant differences in ISI. This was done by adding the factor (mitigation present or not) to the linear models calculated in Section 4.7 and using standard statistical ANOVA techniques to test for significance. Each of the factors was investigated in isolation, i.e. without the presence of another mitigating factor in the model.

Three categories of mitigation strategy were identified:

- Road user behaviours: these countermeasures are simple techniques, using technology fitted as standard, which would require a simple change in behaviour of car drivers and passengers to implement (e.g. wearing a seat belt).
- Passive devices: these countermeasures require no behavioural change to implement; they are not necessarily fitted as standard in all cars but the majority of new cars are fitted with them (e.g. airbags).
- Road layout: these countermeasures are changes that could be implemented in new road schemes (e.g. traffic-calming measures).

4.8.1 Cars

Table 4.37 shows a range of countermeasures for car occupants. The only significant effect was the wearing of seat belts. Seat belts were found to significantly reduce the severity of the accident by 0.34 ISI units.

Table 4.37: The effect of countermeasures on ISI				
Countermeasure	**Mitigating factor**	**Relative effect on severity (difference from baseline)**	**Total frequency**	
			Present	**Not present**
Road user behaviour	Wearing a seat belt	−0.34	1,123	160
	Seated in front of car: –by all occupants – passengers only	 No effect No effect*		
Passive devices	Airbags fitted: – by all types – front only – side only	 No effect† No effect No effect	1,071	1,314
	Side beams	Insufficient information	–	–
Road layout	Safety fence presence Traffic calming	No effect No effect	17	3,687

* For the subset of people who were not the driver, there was an indication to suggest that it is safer to sit in the back seats of the car. This factor was only just non-significant at the 5% level ($p = 0.059$).

† The airbag analysis looked at front-seat passengers in front-impact or head-on collisions. Where an airbag was fitted, there was an indication that the airbag reduced the severity of injuries; however it was hard to tell which sorts of accident would trigger an airbag to deploy. It is possible that the inclusion of accidents where an airbag would not have deployed has resulted in the dilution of the positive effect of airbags.

4.8.2 Large vehicles

Table 4.38 shows a range of countermeasures for large vehicle occupants. There were no significant effects of countermeasure on the accident severity rating. It is interesting to note that a high proportion of large vehicle drivers do not wear a seat belt.

Table 4.38: The effect of countermeasures on ISI for large vehicle occupants				
Countermeasure	**Mitigating factor**	**Relative effect on severity (difference from baseline)**	**Total frequency**	
			Present	**Not present**
Road user behaviour	Wearing a seat belt	No effect	43	41
Passive devices	Airbags fitted: - front only	No effect*	50	223

* The size of the positive effect of the presence of airbags was greater than that for cars, although the effect is not significant. The increase in the benefit of airbags could be due to the fact that a larger proportion of large vehicle drivers do not wear seat belts.

4.8.3 Motorcycle

Table 4.39 shows a range of countermeasures for motorcyclists. There were no significant effects of countermeasure on the accident severity rating.

Table 4.39: The effect of countermeasures on ISI

Countermeasure	Mitigating factor	Relative effect on severity (difference from baseline)	Total frequency	
			Present	Not present
Road user behaviour	Helmet worn	No effect	166	14
	Reflective clothing worn	No effect	174	28
	Dedicated motorcycle clothing worn	No effect	83	119

4.8.4 Pedal cycles

Table 4.40 shows a range of countermeasures for pedal cyclists. There were no significant effects of countermeasure on the accident severity rating. It is interesting to note that a large proportion of pedal cyclists do not wear helmets.

Table 4.40: The effect of countermeasures on ISI

Countermeasure	Mitigating factor	Relative effect on severity (difference from baseline)	Total frequency	
			Present	Not present
Road user behaviour	Helmet worn	No effect	5	39
	Cycle lights – applies to twilight/darkness only – Front (Yes/No) – Rear (Yes/No)	 No effect No effect	16	23
	Reflectors – Front – Rear Reflective clothing (Yes/No)	 No effect No effect No effect	 4	 67
Road layout	Cycle lanes	No effect		
	Traffic calming	No effect	7	67

4.8.5 *Pedestrian*

Table 4.41 shows a range of countermeasures for pedal cyclists. There were no significant effects of countermeasure on the accident severity rating.

Table 4.41: The effect of countermeasures on ISI

Countermeasure	Mitigating factor	Relative effect on severity (difference from baseline)	Total frequency	
			Present	Not present
Road layout	Traffic calming – specifically road humps	No effect No effect	3	118
	Poor lighting	No effect		
Road user behaviour	Non-conspicuous clothing	No effect	42	8

5 EFFECT OF COUNTERMEASURES

5.1 Introduction

There are many types of accident countermeasure in place on our roads, in our vehicles and in/on clothing. An analysis was performed to try to determine whether the presence of any of these countermeasures had a positive effect on the injuries sustained given that an accident had occurred. In some cases, however, the data were insufficient to make an accurate assessment.

Based on the analysis of the On the Spot (OTS) database that QinetiQ had performed, TNO Human Factors made a number of suggestions for initiatives that could be employed (including those that had been employed in the past in the Netherlands) to mitigate accident rate and injury rate. They estimated the potential reductions in accident rate and injury rate of such countermeasures and policies. These estimates were used to determine the maximum potential reduction in severe and fatal accidents, and to determine which of these countermeasures would best help to meet the Government targets of:

- a 40% reduction in the number of people killed or seriously injured in road accidents;
- a 50% reduction in the number of children killed or seriously injured in road accidents; and
- a 10% reduction in the slight casualty rate, expressed as the number of people slightly injured per 100 vehicle kilometres.

5.2 Policy change and estimated reduction in accidents and injury

This section is organised by the countermeasures suggested by TNO Human Factors road safety experts. The maximum reduction of accidents and injuries that could be gained from implementing the countermeasure is given. This section concludes with a discussion of the findings and identifies how much these countermeasures could contribute towards the Government targets.

Table 5.1 shows the frequency and percentage of accidents at all levels of the Injury Severity Index (ISI). It can be seen that there are 221 accidents (4.6%) that fall into the serious and above categories. These accidents map directly onto the Police Accident Severity (PAS) ratings of ‘serious’ and ‘fatal’, which were used to determine the Government targets.

The countermeasures were assessed by defining the accident types they were aimed at reducing and by estimating the reduction in injury that could be achieved (e.g. total reduction in the case of separation of road users).

Table 5.1: Frequency and percentage of accidents by ISI level			
ISI	**Description**	**Frequency**	**% of accident-involved persons**
0	None	3,232	67.0
1 to 2	Minor	927	19.2
3 to 4	Moderate	443	9.2
5	Serious	92	1.9
6 to 7	Severe	87	1.8
8+	Critical	42	0.9

5.2.1 *Countermeasure 1: separation of pedestrians and pedal cyclists from other road users*

In the Netherlands, a road design scheme has been developed called the 'Sustainable Road Safety' policy. One of the aims of this scheme is to separate vulnerable road users (VRUs), such as cyclists, from cars and trucks on high-speed roads. This is achieved by discouraging VRUs from using fast roads and diverting VRUs onto cycle paths and pavements that are adequately separated from the main road.

This countermeasure is aimed at reducing accidents involving pedestrians and cyclists, i.e. non-motorist VRUs present on fast roads (>30 mph), by removing the VRUs from these roads. The estimated reduction in injury would be the entire percentage of this type of accident. Table 5.2 shows the frequencies of serious injuries for pedestrians and cyclists for OTS database accidents, split by whether dedicated pedestrian and cycle facilities were present or absent.

Table 5.2: The frequency of serious injury/fatal cases of pedestrians and pedal cyclists by slow/fast roads and the presence of pavement cycle facilities		
Road user	**Speed limit at scene**	**Frequency of individuals seriously injured (as % of all individuals killed/seriously injured)**
Pedestrians	20 to 30 mph	
	– pedestrian facilities	6 (2.7%)
	– no pedestrian facilities	34 (12.7%)
	> 30 mph	
	– pedestrian facilities	1 (0.5%)
	– no pedestrian facilities	10 (4.5%)
Pedal cycles	20 to 30 mph	
	– cycle facilities	
	– no cycle facilities	5 (2.3%)
	> 30 mph	
	– cycle facilities	1 (0.5%)
	– no cycle facilities	3 (1.4%)

For pedestrians who sustained serious injury or were killed on slower speed roads (20 to 30 mph) 34 of the 40 cases occurred where no pedestrian facilities were present. On higher speed roads (>30 mph), 10 of the 11 cases occurred where no pedestrian facilities were present.

For pedal cyclists who sustained serious injury or were killed on slower speed roads (20 to 30 mph), all five cases occurred where no cycle lane facilities were present. On higher speed roads (>30 mph), three of the four cases occurred where no cycle lane facilities were present.

Table 5.2 indicates that the serious injuries of non-motorist VRUs are more frequent on road layouts that do not provide separate dedicated pedestrian/cycle facilities. It is difficult to quantify directly the benefit provided by dedicated facilities, as the lower number of injuries may simply reflect the proportion of roads where facilities are present. We can, however, put an upper bound on the likely benefit: the separation of pedestrians from road traffic in urban environments is likely to prevent, at most, 12.7% of serious injuries/fatalities and the separation of pedal cycles from road traffic in urban environments is likely to prevent no more than 2.3%.

5.2.2 Countermeasure 2: increased spacing between vehicles travelling in opposite directions

Another of the aims of the ‘Sustainable Road Safety’ policy is to increase the separation between vehicles that travel in opposite directions to allow drivers more time to react to the situation; for example, in the case of inattention, the additional spacing will not reduce the inattention but simply give the driver more time to react and take evasive action in the moments leading up to the accident. Figure 5.1 shows an example of a road (in the Netherlands) where this countermeasure has been implemented.

It can be seen that, although there is no central reservation on this road, there is a space between vehicles and oncoming traffic.

This countermeasure is aimed at reducing accidents that involve head-on collisions at all levels of accident speed. The benefits realised in the Netherlands have not been fully examined to date; however, a study in 1997 (Horst *et al.*, 1997) showed that widening the middle space from 0.10 m to 0.30 m helped cars move more than 0.10 m away from the opposing traffic lane so that, on average, there was a minimum of 0.20 m more space between opposing traffic.

It is clear that the benefit of this countermeasure depends on the proportion of head-on collisions that may be prevented. Table 5.3 shows the number and percentage of total injuries that were sustained in this type of accident from the OTS database.

Figure 5.1: Example of additional spacing between opposing carriageways

Table 5.3: The frequency and percentage of total injuries that could be reduced by the presence of central reservation/safety fences, by speed limit

Posted speed limit at scene	Number of individuals killed/seriously injured in a head-on collision		As percentage of individuals killed/ seriously injured
	No safety fence, no central reservation	No safety fence, central reservation <5 m	
30 mph	6	0	2.7
40 mph	4	0	1.8
50 mph	2	0	0.9
60 mph	19	1	8.6
70 mph	0	0	0.0
All speed limits	31	1	14.5

Unfortunately it is not possible to estimate from data contained within the OTS database or the Netherlands example how many of these deaths/serious injuries would have been prevented by this countermeasure. However an upper limit on the benefit can be estimated: it is reasonable to conclude that the total number of people seriously injured or killed could be reduced by up to 14.5% by the introduction of this countermeasure in the UK.

5.2.3 *Countermeasure 3: changes to alcohol policy*

A total of 8.6% of deaths and serious injuries within the OTS database are attributed to alcohol . A summary by vehicle type is given in Table 5.4.

Table 5.4: Serious and fatally injured people in accidents attributed to alcohol per vehicle type	
Vehicle type	**Seriously injured or killed (as percentage of individuals seriously injured)**
Car	10 (4.5)
Large vehicle	1 (0.5)
Motorcycle	2 (0.9)
Pedestrian	6 (2.7)
All vehicle types	19 (8.6)

There are three possible strategies that can be followed to reduce alcohol-related injuries:

- a revision of current regulations relating to alcohol and driving;
- better education and/or enforcement of current regulations; and
- the introduction of systems (e.g. passive safety systems, road design changes) to mitigate the probability and impact of alcohol-related (and other) accidents.

The third of these is not investigated here: impairment due to alcohol includes the slowing of one's response time and, therefore, a well-designed road layout (see Countermeasure 2) would also be of benefit in reducing the frequency of alcohol-related accidents.

To investigate the number of serious and fatal accidents that could have been prevented by better observance of drink-driving laws, the number of failed breathalyser/blood tests was investigated. Table 5.5 shows the summary of the analysis of breath testing. There were only three breath test results recorded in accidents attributed to alcohol at the questionnaire level of the OTS database.

Table 5.5: Summary of breath tests for all accidents attributable to alcohol

Failed test	Passed test	No test	Unknown/not reported on questionnaire
1	2	23	39

As these data are far from complete, the Interaction level of the database was examined for responses in two categories: 'legally fit to drive due to alcohol/recreational drugs?' and 'suffered impairment due to alcohol/recreational drugs?'. The results of this analysis can be seen in Table 5.6.

Table 5.6: Summary of the number of accidents where the driver was unfit to drive		
Suffered impairment?	**Legally unfit to drive due to alcohol or drugs?**	
	Yes	**No/unspecified**
Yes	26	16
No/unspecified	18	5

It is hard to tell from the database whether the 16 persons suffering alcohol-related impairment who were not known to be legally unfit to drive were indeed legally fit to drive (i.e. passed a breath/blood test): individuals may have left the scene before the arrival of emergency services and the OTS team, or the test result may not have been recorded. It is certainly true that, at the very minimum, 62% of alcohol-related accidents recorded within the database involved drivers who were legally unfit to drive.

There are probable benefits in revisiting UK alcohol laws. The Netherlands have recently lowered the legal alcohol limit for young drivers – this is expected to reduce the total number of accidents with alcohol involved by 5% (Mathijssen, 1999). However, evidence from the OTS database perhaps supports a greater potential benefit in better education and/or the enforcement of current regulations.

There are systems available that are designed to prevent people under the influence from driving. An example is a system that stops the car from being started until a breath test is taken; however, such 'alcohol lock' systems are only really appropriate for persistent violators. In Canada, heavy violators who participated in an alcohol lock program showed 65–90% fewer violations for driving than people whose driving licence was taken (Kärki *et al.*, 2001).

As in other areas, data held within the OTS database are not sufficient to estimate the effect of a specific enforcement programme. However, an upper limit on its effectiveness can be estimated: the benefit could be as large as an 8.6% reduction in serious or fatal accidents.

5.2.4 Countermeasure 4: mitigations for impairment due to fatigue or illness

While accidents in the OTS database were infrequently attributed to 'impairment due to fatigue/illness', the proportion of accidents that result in serious or fatal injury was higher than for other categories. A number of Europe-wide initiatives are investigating the use of in-car warning systems to alert the driver of fatigue (Bekiaris, 2004). However, the technology to do this is some years away from the marketplace. The systems being developed could be used to detect when a driver is impaired due to illness (e.g. heart attack) and safely guide the car to the side of the road without incident. If such a system could be developed, then there is the potential to significantly reduce the number of accidents due to fatigue or illness.

There is a range of road safety measures that could be introduced to alert the driver to loss of control of the vehicle. Countermeasure 2 investigated the use of a space between opposing lanes on roads to allow the user extra time and space to take evasive action. Figure 5.2 shows a road (in the Netherlands) that uses the space technique as well as a raised-rib carriageway edge to alert the driver to drifting into the lane of oncoming traffic. A study has showed this to be effective at decreasing the number of road marking crossings from 7.3% to 4.1% for trucks and 0.4% to 0.1% for cars (Horst *et al.*, 1997). Also, more space is available at the outer edge of the road (e.g. a small hard shoulder) to allow room for evasive action for cars drifting off the road.

Figure 5.2: Road with spacing between lanes and a raised-rib carriageway edge on each side of the lane

The European Roadside Infrastructure for Safer Roads (RISER) project (van der Horst, 2005) provides guidelines for the safer design of roadsides. One of the outcomes of this project was that trees along the road do not seem to have much influence on driving behaviour and are not considered to be a serious hazard by road users, which makes them even more dangerous (van den Dobbelsteen *et al.*, 2006).

The OTS database was used to investigate the case for raised-rib carriageway edges. Currently this countermeasure is predominantly used on 70 mph roads (see Table 5.7).

The number of persons seriously or fatally injured on roads was analysed to assess any relationship between the presence/absence of the countermeasure and whether fatigue/illness was a causal factor (Table 5.8). There are no individuals suffering serious or fatal injuries on roads featuring raised-rib carriageway edges where fatigue/illness was a causal factor. There were nine fatigue/illness-related serious

Table 5.7: Accident-involved persons by maximum posted speed where raised-rib carriageway edge is present or not present

Maximum posted speed limit at the scene	Raised-rib carriageway edge line	No raised-rib carriageway edge line
20 mph	0	33
30 mph	5	2,056
40 mph	8	614
50 mph	13	106
60 mph	16	947
70 mph	633	355
All posted speed limits	679	4,142

Table 5.8: Frequency of serious injuries/fatalities where a raised-rib carriageway edge is present or not present

Causal factor	Raised-rib carriageway edge line	No raised-rib carriageway edge line
Fatigue/illness a causal factor	0	9
Fatigue/illness not a causal factor	17	195

injuries/fatalities where this countermeasure was not present. This compares with 17 and 195 serious injuries/fatalities, respectively, where fatigue/illness is not a causal factor. Thus, where there was no raised-rib carriageway, 4.4% of serious injuries/fatalities had fatigue/illness as a causal factor, whereas on raised-rib carriageways there were no serious injuries/fatalities attributed to fatigue/illness. Although it might look superficially convincing, this result cannot be shown to be statistically significant: there is insufficient evidence of a significant reduction in fatigue/illness accidents when a raised-rib carriageway is present. Hence, based on the data in the OTS database, we cannot conclude that a raised-rib carriageway edge will reduce fatigue-related accidents.

5.2.5 Countermeasure 5: enforcement of the restriction of the use of hand-held devices

The use of hand-held devices, such as mobile phones while driving, has been highlighted as a cause of distraction that can result in many accidents, and hence has been made illegal. Within the OTS database, however, only nine cases of individuals at the ‘human behaviour’ level of the database are reported to be using a mobile phone while travelling, one of whom was a pedestrian. It is possible that the use of mobile phones may be under-reported, as accident-involved persons may wish to avoid incriminating themselves.

While the interaction section of the database has the interaction ‘suffered a distraction by an internal event (e.g. phone, radio)’ which appeared in 35 cases, only two of these were related to serious accidents/fatalities and, since mobile phone use cannot be separated from distractions from a radio, no effect of the countermeasure for distractions/lack of attention due to mobile phones can be determined.

Hence the likely effect of a total enforcement/education campaign is likely to be less than (and possibly much less than) 0.9%.

5.2.6 Countermeasure 6: better education of younger drivers

Younger drivers are over-represented in driving accidents. However, age is confounded with a lack of driving experience. By definition, all drivers start their driving careers with limited experience. However, the young are not just over-represented in inexperience-related accidents; they are also over-represented in speed-related accidents.

In Denmark, a national education plan for new drivers was introduced in 1990. This plan was estimated to decrease the accident risk in the first year after getting a licence by 7% (Carstensen, 2002). Since March 2002, newly-qualified drivers in the Netherlands receive a student’s licence that is converted to a full licence after five years, although the effectiveness of this scheme is yet to be assessed.

To estimate the likely impact of similar schemes in the UK, the OTS database was further examined. If it is assumed that the better education of under-21 drivers could reduce the number of ‘speed’ accidents within this age-group to the population mean, the total number of serious injuries/fatalities would fall by 0.8%.

This benefit is comparatively modest as, though at higher accident risk, under-21 drivers make up a relatively small percentage of all motorists.

6 RECOMMENDED CHANGES TO RESEARCH PROTOCOL

6.1 Overview

This section is a summary of the letter report *Proposed Recommendations for Changes to the OTS Data Collection Research Protocol* (Bunting and Mansfield, 2006). This section extends the report based on the analysis since its delivery.

The data held within the On the Spot (OTS) databases were generally of a very high standard. The databases were structured logically, and the data were presented in a manner that lent itself to detailed analysis.

While there appeared to be a small number of problems and/or standardisation issues within Phase 1, these by-and-large appear to have been resolved by Phase 2. Hence, although these presented minor inconveniences to the analysis undertaken under this contract, in most cases no further protocol changes were deemed necessary.

A number of possible improvements to the protocol have been identified, and are listed in the sections below.

6.2 Data integrity issues

Within a large database such as OTS, it is to be expected that inaccuracies/data integrity issues will arise from time to time, perhaps from a mistyping or misreading of information. It is suggested that these could be further minimised by training or additional functionality at the data entry stage to undertake automatic integrity checking. Examples are given below.

6.2.1 Consistencies within data hierarchies

The OTS database is constructed as a relational database. As such, there might be a single entry to describe the scene with multiple corresponding entries on the vehicle database to describe each vehicle involved in the incident. However, it is observed that the data held at the scene level do not always correspond with the lower-level data; for example, Case 1,006 has two cars and two motorcycles in the vehicle-level records whereas three cars and one motorcycle are recorded in the scene-level summary. It is estimated that in the Phase 2 data, approximately 6% of scenes do not have wholly matching vehicle table entries. Other variables and tables are affected in this way.

Another example of this is the injury and medical section of the database. The medical section contains the question M_0001 'Injured'. When the responses to this question are tabulated with the Abbreviated Injury Scale (AIS) injury code (see Table 6.1), it can be seen that the medical level reports an injured case where there are no AIS injury codes at the injury level, and a non-injury case where there are AIS injury codes. It appears that the medical question gives a conservative estimate of the number of injured people in comparison with the AIS injury codes.

Table 6.1: Cross tabulation of the medical 'injured?' question and the AIS injury code (shaded areas show inconsistencies)

I.0003 (AIS code)	M.0001 (injured)	
	No	Yes
No injury specified	3,298	71
Some type of injury (region 1, 2, . . . or 9)	13	1575

Similarly, cross tabulation of the time of day and the light conditions reveals data conflicts (see Table 6.2). The data inconsistencies are shaded.

Table 6.2: Cross tabulation of the time of day and light conditions (shaded areas show inconsistencies)

Hour	Twilight (dawn)	Daylight	Dusk or twilight	Night	Missing
00:00 to 00:59	0	12	1	44	0
01:00 to 01:59	0	0	0	23	0
02:00 to 02:59	0	1	1	25	0
03:00 to 03:59	0	0	0	12	0
04:00 to 04:59	0	1	2	6	0
05:00 to 05:59	4	4	2	10	1
06:00 to 06:59	12	10	12	10	0
07:00 to 07:59	13	104	7	7	0
08:00 to 08:59	2	135	0	1	0
09:00 to 09:59	0	112	0	0	0
10:00 to 10:59	0	124	0	2	1
11:00 to 11:59	0	117	0	0	0
12:00 to 12:59	2	124	0	1	1

Table 6.2: (continued)					
Hour	**Twilight (dawn)**	**Daylight**	**Dusk or twilight**	**Night**	**Missing**
13:00 to 13:59	2	116	0	0	1
14:00 to 14:59	0	84	0	1	0
15:00 to 15:59	2	115	6	2	2
16:00 to 16:59	1	94	10	21	4
17:00 to 17:59	0	99	7	51	1
18:00 to 18:59	2	63	9	70	1
19:00 to 19:59	0	54	11	67	0
20:00 to 20:59	0	19	24	81	2
21:00 to 21:59	0	1	15	63	1
22:00 to 22:59	0	0	1	62	0
23:00 to 23:59	0	1	0	61	0
Missing	0	9	2	3	1

6.2.2 *Consistent coding of data*

There are some inconsistencies remaining in the coding of data, though this has largely been resolved within the Phase 2 databases. For example, with the Variable S_9917: 'Vehicle number of the person to whom the precipitating factor is attributed', it is largely coded numerically, but approximately 10% of the time at the Vehicle Safety Research Centre (VSRC) it is coded with a preceding V, for example 'V1'. In Phase 2, the 'age of driver' field used 999 as the coding for missing data, but it appears likely that this is still sometimes being coded as 99 or 0.

6.2.3 *Missing or not applicable data*

In some accident cases the data are incomplete for a number of reasons, including:

- fatal/serious accidents were inappropriate to follow up in a number of circumstances; and
- accident participants may have left the scene before the emergency services and police arrived (e.g. often in alcohol-related cases).

While the latter of these has been entered in many cases as text comment variables, it would be useful to have a categorical indicator for why a record for injury/interaction/vehicle may be missing or incomplete. A method for making a distinction between missing/not applicable data should be developed and should be used consistently between OTS teams.

Some values are reported as zero when missing data should be recorded. For example, where the speed of the accident is not known, this was recorded as 0 mph. This ambiguity in the data can lead to confusion but could also result in biases in the data analysis.

6.2.4 *Unpopulated or under-populated data fields*

Some fields in the database are rarely filled in and are therefore of no use for analysis purposes. An example of this was H_1121 'Motorcycle Helmet Make Code'. Some fields in the database that would be useful for the analysis of the accident are sparsely populated, for example speed data (see Table 6.3). A considerable proportion of the data is in category 0, 999 or missing.

Table 6.3: Frequency of completion of the speed estimate field

Speed estimate (C.0118)	Frequency
0	3,209
⩽ 10	479
⩽ 20	316
⩽ 30	270
⩽ 40	193
⩽ 50	134
⩽ 60	108
⩽ 70	141
⩽ 80	25
⩽ 90	6
⩽ 100	4
⩽ 120	1
⩽ 999	792
Missing	36

6.3 Data presentation issues

The complex nature of the data suggests that the questions could benefit from re-grouping to assist data entry, reduce potential errors and aid interpretation. For example, the following questions each have check box responses:

H_0044 Vision not obscured
H_0045 Vision obscured by parked vehicle
H_0046 Vision obscured by vehicle in front
H_0047 Vision obscured by slow-moving vehicles
H_0048 Vision obscured by heavy goods vehicle or bus
H_0049 Vision obscured by pedestrians

H_0050 Vision obscured by slope in road
H_0051 Vision obscured by bend in road
H_0052 Vision obscured by tree
H_0053 Vision obscured by vegetation
H_0054 Vision obscured by roadside furniture
H_0055 Vision obscured by wall
H_0056 Vision obscured by building
H_0057 Vision obscured by fence
H_0058 Vision obscured by road works
H_0059 Vision obscured by bright sunlight
H_0060 Vision obscured by dazzle from headlights
H_0061 Vision obscured by misted windows
H_0062 Vision obscured by icy windows
H_0063 Vision obscured by broken or damaged windscreen
H_0064 Vision obscured by other feature
H_0065 Not known whether vision obscured

It is not easy to see that H_0044 and H_0065 are mutually exclusive with all the remaining variables in the list. These questions could be rearranged into a single question with a number of options (see Table 6.4). It is a recommendation of this study that, where possible, categorical data should be made mutually exclusive.

Table 6.4: Suggested layout of the 'Vision obscured?' question

H_XXXX Was vision obscured?			
–No			
–Don't know			
–Yes:	Dazzle	Headlights Sunlight	
	Other vehicles	Parked vehicle Vehicle in front Slow-moving vehicles HGV/bus	
	Own vehicle	Misted windows Icy windows Damaged windows	
	Road	Slope Bend Roadworks	
	Roadside	Pedestrian Trees/vegetation Fence, wall or buildings	

6.4 Linking position in vehicle to human

When considering the link between vehicle features and their possible effects on reducing injuries (e.g. seat belts, airbags), it was necessary to link the 'human' level identification number (SAVHNUM) to that of the 'position' level in the vehicle (SAVPNUM). Since human does not follow position in the hierarchy, this could be done only by cross-referencing the PNUM with the variables H.0101 (seat row number: 1 = front, 2 = rear, etc.) and H.0102 (seat position: offside/nearside). In a number of cases there were inconsistencies in the human data; for example, an H.0101 row 'zero' in some cars means that it is not possible to tell where an individual was sitting. In other cases more than one individual within a particular vehicle were recorded as occupying the same row and position. It is recommended that emphasis be placed on making sure these variables are not left incomplete.

6.5 Incident team schedules

There is currently no record within the database of the duty schedules of OTS incident teams. This would assist in the assessment of condition probabilities relating primarily to time of day, but also to related factors.

6.6 Accident causation (contributory factors system)

The contributory factors system provides a list from which to classify the accident cause(s) at the scene level, and the information collected here was of great use for the analysis of accident causes.

6.6.1 Inclusion of further road design issues

OTS database contributory factors contain many variables regarding accident causation, type and resulting injuries. While these include many human error causes along with some objective characteristics of the scene (e.g. type of junction, type of road surface), there are comparatively few questions concerning perceived design problems with the road layout itself. It is suggested that additional variables be considered to provide an indication of:

- unusual design features;
- conflicting or confusing design features/markings/signage;
- unexpected layout if any road features have recently changed in some way; and
- whether the site has a history of accidents.

6.6.2 Linking contributory factors to vehicles/paths/humans

At present the contributory factors recorded at the scene level are not linked to particular vehicles or drivers. For example, where an accident occurred with inattention as a contributory factor and with one vehicle hitting another, it is a human-related issue. Linking the contributory factor(s) directly to the path level identification number (SANUM), vehicle (SAVNUM) and human (SAVHNUM) to whom the cause is attributed (similar to the method used in the precipitating factor), would assist analysis.

6.7 Suicides

It is a recommendation of this study that suicides should not be recorded in the OTS database. These events are not accidents as such, and have to be removed from the data before analysis.

6.8 Reporting of driving offences

Driving offences, such as driving under the influence of alcohol and driving while using a mobile phone, may be under-reported in the database.

6.8.1 Mobile phones

As was commented in Section 5.2.5, the use of mobile phones while driving has been highlighted as a cause of distraction that can result in many accidents and, as such, has been made illegal. Within the OTS database, however, only nine cases of individuals at the 'human behaviour' level are reported as using a mobile phone while driving. It is possible that the use of mobile phones may be under-reported as:

- it usually cannot be proven; and
- accident-involved persons may wish to avoid incriminating themselves.

It may be useful, where an accident involved more than one vehicle, to include witness information on the other driver's behaviour if this is possible and ethical.

6.8.2 Alcohol/recreational drugs

Of the 2,188 accident scenes in the OTS database, 128 had impairment through alcohol identified as a contributory factor using the 'Scene: Causation' factors. Information on breath and blood tests would be of interest in accident research. This information can be extracted in usable form from the text fields in the database by employing an appropriate filter, although this was not done in this case. It would be useful if alcohol and drugs test pass/fail was an explicit variable at the individual level of the database, provided this information can be obtained legally and ethically.

7 SUMMARY AND WAY AHEAD

7.1 Overview

The UK Government is seeking to reduce substantially the number of road traffic accidents (RTAs) leading to injury or loss of life.

To develop effective strategies for reducing RTAs, the causes of accidents must be understood. With this in mind, the On the Spot (OTS) project was commissioned to gather in-depth information at the scene of accidents. Since the data collection began in 2000, more than 2,000 accidents have been recorded.

This document details the technical strategy and findings of the analysis of OTS data undertaken, and provides recommendations on how these findings can be used to inform the formation of road safety policy.

7.2 Methodology

A combination of qualitative (subject matter expert (SME) opinion) and quantitative (factor analysis) techniques was employed to reduce the 2,000 variables for each accident in the database to variables that classified the:

- causal factors of accidents;
- accident type; and
- injury location and severity.

Statistical modelling techniques were used to analyse the links between these three sets of variables to determine the causal chain of accidents and injuries in RTAs. The identification of the causal factors of accidents was based primarily on the coded factors indexed under ‘Scene: Causation’. Future analysis could exploit the more recent data gathered under ‘Contributory factors 2005’ and could possibly explore the use of the text data collected in the ‘interactions’ forms.

7.3 Results

It was difficult to control for data collection biases in terms of times of day or days of the week, as there was no information about the shifts that were covered. This means that all results presented in this report are open to collection bias.

A simple analysis of the demographic profile of the OTS database concluded that:

- the vast majority of accidents involve cars (the most frequent road users);
- accidents that involved motorcycles had the highest Police Accident Severity (PAS) rating of all road user categories;

- fatal and serious injury accidents were most likely to occur on ‘A’ class ‘non-trunk’ roads and 60 mph roads; and
- the majority of accidents occurred between 3 pm and 8 pm.

A more in depth analysis was performed by grouping variables using qualitative and quantitative analysis techniques. Linear modelling techniques were used to link the causal factors to the features of accidents and through to the causes and severities of injuries sustained. This analysis concluded that:

- the injury rate in car accidents was influenced by the posted speed limit, impact type and type of vehicle hit;
- the injury rate in large vehicles was influenced by the impact type and the type of vehicle hit; and
- the injury rate on motorcycles was influenced by the speed of the impact.

Multi-way contingency table analyses were performed to identify the effect of demographic information (e.g. age and gender) on the causal factors of accidents. It was found that:

- male car drivers are more likely to be involved in accidents where the causal factors are speed/aggressive driving or impairment due to alcohol and drugs;
- female car drivers are more likely to be involved in accidents where the causal factor is visual impairment or obscuration;
- car drivers under 20 years old are, unsurprisingly, more likely to suffer from inexperience;
- inexperience makes car drivers less able to cope with the loss of control of their vehicles, for example due to slippery road conditions;
- impairment due to alcohol is more likely to occur between 8 pm and 5 am;
- car drivers over 40 years of age are four times more likely to have accidents where fatigue or illness is a causal factor; and
- car drivers are more likely to be distracted when there are passengers in the car, but are less likely to suffer from fatigue-related accidents.

7.4 Countermeasures

A range of existing injury mitigating factors for all occupants of all vehicle types was investigated. It was found that only seat belts were associated with a significant improvement in injury rate; however, there was evidence to suggest that airbags and sitting in the rear seats of the vehicle are also of benefit to injury rates. Much of the data was not of sufficient quantity to be able to adequately model the impact of these countermeasures.

7.5 Suggestions for changes to the experimental protocol

A range of suggestions for improvements to the experimental protocol were made based on an early analysis of the OTS database and the subsequent findings during the analysis phase of this study. These improvements included suggestions about the layout of questions, questions that appeared not to be filled out, the coding of missing values and variables that contradict each other. The improvements were linked to particular statistical analysis requirements. On the whole, problems with data integrity in Phase 1 were resolved in Phase 2.

These findings should be implemented for the next phase of OTS data collection.

7.6 Further recommendations

Further recommendations include:

- continue to collect data for the OTS study;
- expand the OTS study to other regions of the UK;
- make alterations to the experimental protocol as listed in Section 6;
- periodically perform a statistical analysis of the OTS database (e.g. at the end of a collection phase); and
- statistically compare the study with similar European studies.

These measures will ensure that road safety policy will remain focused on the areas that can be of most benefit to all road users; in particular the vulnerable road user categories. As the data density in the database is increased, the findings from the analysis of the effects of injury-mitigating strategies will become more robust.

8 REFERENCES

Bekiaris, E. (2004) Conclusions and gained knowledge during the three-years of AWAKE research. *Proceedings of Road Safety Workshop,* Balocco, Italy.

Bunting, A. and Mansfield H. (2006) *Proposed Recommendations for Changes to the OTS Data Collection Research Protocol.* QinetiQ letter report for contract CHS/512680/0001/03.

Carstensen, G. (2002) The effect on accident risk of a change in driver education in Denmark. *Accident Analysis and Prevention*, 34, 111–121.

Hill J. and Cuerden, R. (2005) *Development and Implementation of the UK On the Spot Accident Data Collection Study – Phase 1*. Road Safety Research Report No. 59. London: Department for Transport.

Horst, A. R. A. van der, Vos, A. P. de and Folles, E. (1997) Lane-keeping behaviour at profiled road markings on motorways: a before and after study. *Proceedings of the ICTCT 97 Conference, 5 Safety Statistics and Evaluation Studies*. Lund: Lund University of Technology. p. 1–8.

Kärki, O., Evers, C., Bernhoft, I. M. and Mathijssen, R. (2001) Alcohol interlock implementation in the European Union: feasibility study. In C. Bax (ed.), *Final Report of the European Research Project. D2001-20.* SWOV, Leidschendam.

Mathijssen, M. P. M. (1999) *Schatting van de effecten van verlaging van de wettelijke limiet voor alcoholgebruik in het verkeer*. (Estimation of the effects of lowering the legal blood alcohol content limit on alcohol use in traffic) R-99-11. SWOV, Leidschendam.

van den Dobbelsteen, G. J. H., Griffioen-Young, H. J. and Janssen, H. J. W. (2006) *Why Do People Speed? A Behavioural Model to Support Policy and Enforcement* (in Dutch). TNO-DV3 2006 M047. Soesterberg: TNO Human Factors.

van der Horst, R. (2005) Roadside infrastructure and driver behaviour. *Proceedings of RISER Project Final Seminar*, 30 November–1 December 2005, Budapest, Hungary.

APPENDIX 1
DATA HANDLING

A1.1 Injuries

A1.1.1 Data tables used

Based on exploration of the database, the injury level of the database hierarchy was believed to provide the highest fidelity information, so this was used as a primary source for the description of injuries with the medical level of the database, which should provide one medical summary per accident-involved person (as in Figure 2.1, which shows the data hierarchy).

Each injury recorded has variables to describe where it was sustained by body region (see Table A1.1). An accident-involved person can therefore have 0, 1 or more injuries and associated records. The data contained 7,565 injury records (including non-injuries) for 3,364 accident-involved persons.

Table A1.1: AIS body region codes

Code	Body region
1	Head
2	Face
3	Neck
4	Thorax
5	Abdomen and pelvic contents
6	Spine
7	Upper extremities
8	Lower extremities
9	External, burns and other trauma

The Abbreviated Injury Scale (AIS) is used by the OTS data collectors as a record of the severity of injuries. This scale was developed by the Association for the Advancement of Automotive Medicine (AAAM) in Illinois, USA. Initially created in 1971 to aid vehicle crash investigations, it has since been further extended to increase its relevance to medical audit and research. It is anatomically-based, consensus-derived and utilised globally. The code has a number of components, the key ones being the injury **severity** and the **body region**, and a further code relating to detail on the nature of the injury. Each OTS injury record gives the AIS for the injury.

The injury record variables by AIS body region and AIS severity code (Table A1.2) for that region were used to determine the overall injury of each accident-involved person.

Table A1.2: AIS severity codes	
Code	**Severity**
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum, unsurvivable

A dataset containing one record for each accident-involved person was created such that a column was inserted for each AIS body region to represent the presence (or lack) of injury in that AIS region for that accident-involved person by use of a binary variable (1 = injured and 0 = uninjured) for that region. Similarly, a column for each body segment AIS severity scale was added (0 = no injury through to 6 = unsurvivable). From this the maximum AIS severity of injury sustained to the body overall was derived (again overall AIS severity of 0 for anyone who sustained no injuries).

Note that, where the injury record indicated a region as injured and the severity as unknown/missing at the injury level of the database, it was none the less possible to use the medical summary level, which contained maximum AISs for each region. These are retrieved where possible.

A1.1.2 Dealing with a lack of injury records

One finding from the data was that there seemed to be different approaches used in recording data where a person involved in the accident was uninjured. Either an injury record was added and left blank to indicate there were no injuries to record, or there was no injury record at all. The latter of these approaches seems more common during Phase 1 of the data collection; however, in these cases no distinction can be made between uninjured and missing data at the injury level (I00) of the database. Since 2,181 accident-involved persons in the database had no record at the I00 level to indicate whether they were injured or uninjured, effort was made to recover data by cross-referencing information at the medical summary level (M00).

The OTS severity variable (M.0033) was chosen as the variable with best fidelity to cross-reference variables to retrieve accident-involved persons who had no injury record but an M.0033 recorded as a severity of ‘Uninjured’. This meant that 1,545 uninjured accident-involved persons could be recovered; the remaining 636 persons had some indication of injury from M.0033 but with no details of injury or severity, hence these were discarded.

4,909 records of accident-involved persons remained available for analysis at this stage.

A1.1.3 Principal Components Analysis

A Principal Components Analysis (PCA) was performed on the resulting data set of 10 variables: a binary variable was created for each of the nine body regions to indicate injury/lack of injury along with maximum injury severity sustained anywhere in the body, on a scale of (0, 1, . . . 6). Component 1 of the PCA was highly correlated with maximum AIS severity and, to a lesser extent, the body regions head, thorax and extremities (shoulders, arms and legs). These may be regions more prone to the critical injuries that are typical of RTAs and other body regions may usually sustain less severe injuries. Within the OTS data, the types of injury sustained to the skin and neck (i.e. not including spine) regions all had low severity; hence these did not correlate well with Component 1. A new severity index variable was generated from this component and this was standardised to a 0–10 scale (0 = uninjured up to 10 = maximum severity of injury). This standardised component was named the Injury Severity Index (ISI).

A1.1.4 Mapping the ISI to PAS rating

These new variables constitute the dependent variables that form a description of injuries. To link them to causes of injuries, they were matched to the vehicle type at the ‘vehicle’ level of the database. The removal of accident-involved persons who could either not be matched to a vehicle or whose vehicle type was ‘Unknown’ left 4,850 accident-involved persons in 3,566 separate vehicles within 2,034 accident scenes. A cross-tabulation of the two variables was made and it was seen that accidents with an ISI of five or above corresponded to accidents with PAS rating of serious or fatal (the levels that were used to determine the Government statistics on RTA reduction). Where missing data about the type of vehicle occurred, it was not possible to link individuals in the data to a type of road user (car occupant, pedestrian, etc.) and so for most of the analyses a further reduction in the data left 4,823 accident-involved persons for whom reliable medical **and** road user type information existed.

APPENDIX 2
DATA ENHANCEMENTS

This appendix has been produced by TRL Limited. TRL have been involved in the collection of data for the On the Spot (OTS) Road Accident Database project since its inception in 2000.

A2.1 The dataset used in this report

The OTS project is now in its third phase, with Phase 3 starting in October 2006.

The OTS datasets used to produce this report were:

- Phase 1 release d (November 2005); and
- Phase 2 release c (December 2005).

The two datasets contained information relating to 1,513 and 675 accidents, respectively; a combined dataset of 2,188. The final Phase 1 and 2 dataset contained data relating to 3,025 accidents.

During Phase 2, both TRL and the Vehicle Safety Research Centre (VSRC) made a sustained effort to enhance and improve the data collected by the OTS project. Vehicle speed and direction information, reconstruction data and the STATS19 2005 accident causation system were also added to the OTS dataset, and, where possible, these enhancements were retrospectively applied to the Phase 1 investigations. Unfortunately, these enhancements and improvements occurred after December 2005 and were therefore not included in the dataset used to produce this report.

Where possible TRL have implemented QinetiQ's suggested improvements to the structure of the OTS database and its associated front-end prior to the start of Phase 3.

The following describes some of the key enhancements which were made to the OTS database during Phase 2.

A2.2 Enhanced velocity and reconstructions – phase data

In Phase 2, a new system for recording reconstruction information was introduced. It enabled both investigating teams to record estimates of the speed of a vehicle at different stages in the accident.

The system provided investigators with a method of recording:

- the distance the vehicles travelled, pre-, during and post-crash;
- the velocity changes they experienced; and
- the accident reconstruction techniques used to calculate the speed of the vehicles at different stages of the accident.

For instance, the system enables an investigator to record, as in this example from the OTS database, that:

> a vehicle was travelling at a constant speed of 40 mph, before the driver applied his brakes and steered to the left; this resulted in the car skidding for 10 metres before it collided with a tree at 30 mph (the vehicle experienced a 15 mph change in velocity during the impact); the car then spun for a further 4 m before coming to rest.

At each stage the investigator can record, in the OTS database, the speed at the start of the phase, for example the car speed at the start of the skid and at the end of the skid, the distance the vehicle skidded and the direction the vehicle was travelling in at the start and at the end of the skid.

A2.3 Contributory factors

In Phase 2 the project continued to use the contributory factors codes defined in the Phase 2 protocols (Broughton *et al.*). In addition, the new STATS19 2005 contributory factors forms were also completed for every OTS Phase 2 case, and Phase 1 cases were retrospectively coded.

A2.4 Enhanced highway information – road environment prior to and beyond the locus of the accident

A system of recording information relating to the road environment prior to and beyond the locus of the accident was created. The system allowed investigators to record information relating to changes in the speed limit of the road, the road friction, the road layout and changes in road alignment, as well as other physical infrastructure parameters. This unique information will enable analysis to be undertaken in order to investigate the effect that changes of road parameters have on the causes and consequences of road traffic accidents.

A.5 References

Broughton, J., Markey, K.A., and Rowe, D. (1998) *A New System for Recording Contributory Factors in Road Accidents*. TRL Report 323. Transport Research Laboratory: Crowthorne.