Research to improve safety and mobility

Pedal Cyclist Fatalities in London: Analysis of Police Collision Files (2007-2011)

Report Authors:

Rachel Talbot, Steve Reed, Jo Barnes, Pete Thomas,
Transport Safety Research Centre, Loughborough University

Nicola Christie,
Centre for Transport Studies, University College London

UCL

Loughborough University

Transport Safety Research Centre

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Undertaken on Behalf of:
Transport for London

Prepared by:
Transport Safety Research Centre, Loughborough University
Centre for Transport Studies, University College London

The views expressed in this report are those of the authors and not necessarily those of TfL.

Amendment record

12 Sep 2013	Original Issue
23 Dec 2013	Second Draft
2 April 2014	Third Draft
10 September 2014	Final copy

Distribution

Copy 1	Kerri Cheek – Transport for London
Copy 2	Loughborough University - Research Office (Copy)
Copy 3	Loughborough University - TSRC (Copy)

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Transport Safety Research Centre

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EXECUTIVE SUMMARY

The objective of this research report is to support the development of the forthcoming Cycle Safety Action Plan being prepared by Transport for London to be published in 2014. TfL wished to improve the understanding of the factors which lead to collisions involving fatally injured cyclists and those with life-changing injuries. The research focussed on an in-depth analysis of collisions that occurred between 2007 – 2011 when there were 79 fatal and life threatening collisions involving cyclists of which 53 were available for analysis.

This report presents an analysis of the key risk factors that contributed to the collisions and it identifies a set of countermeasures to improve cyclist safety. These were then evaluated according to the number of applicable crashes and evidence found in effectiveness studies. The availability of robust effectiveness studies was found to be limited, partly due to the lack of exposure data and partly due to the difficulties in evaluating some kinds of measures. The main recommendations are below. These are mainly based on the evidence available from the analysis of the sample of fatal and life threatening crashes and additional evidence from effectiveness studies was taken into account where available. The recommendations included are for various parties to take forward. These organisations include central Government, Transport for London, local authorities, the police, vehicle manufacturers and cycle training organisations.

Recommendations for cycling infrastructure

- Identify and implement best international practice in cycle infrastructure and work towards emulating it within the UK legal, regulatory and behavioural context
- Design road infrastructure with an emphasis on cyclists' needs and aim for a world leading provision
- In addition to providing for safer, more comfortable cycling on main roads, expand and connect the network of dedicated cycle routes away from heavily trafficked roads and ensure they connect to key destinations
- Establish criteria for when to separate cycle and motorised traffic. This guidance should include reference to traffic flows and speed and indicate where complete segregation in space or time is appropriate
- Establish guidance on carriageway and lane widths that avoid creating pinch points for cyclists
- Introduce advanced signal phasing or infrastructure for cyclists to give segregation in time or space at junctions

- Support proposals for changes to regulations that allow cyclists to cross the first stop line at Advance Stop Lines (ASLs) at any point

Messages for cyclists

- Allow a safe gap when passing parked cars i.e. a doors width
- Large vehicles need a larger space to the left of them when making left turns than cars/vans – they may straddle the lanes or use lane 2 to turn left
- Awareness of large vehicles' blind spots – especially to the front and nearside front corner – avoid positioning the bicycle within these
- Do not undertake large vehicles on the approach to a junction irrespective of ASL provision
- Assume a positive 'primary position' on the approach to a junction rather than ride to the nearside
- Do not undertake vehicles by riding on the pavement as this makes cyclists much less visible and is dangerous to pedestrians
- Do not wait or join a road to the nearside of a large vehicle, even if they are in the next lane along – hold back or join in a gap
- Where possible choose a road position and use hand signals that communicate your intention to other road users
- Take a consistent/predictable path when cycling – especially through junctions e.g. use lane markings as a position guide especially on curving or staggered junctions

Recommendations to help prevent fatal collisions with large vehicles

- Public Sector organisations to use and promote the use of Delivery Servicing Plans and Construction Logistic Plans to reduce/minimise lorry movements during commuting hours
- National Government to extend the scope of Health and Safety responsibilities to incorporate work-rated road safety
- Vehicle manufacturers to design lorry cabs that minimise front and side blind spots and facilitate maximum driver direct vision - EU and national Government to amend relevant regulations to facilitate this

- Vehicle manufacturers to improve the visibility of left turn indicators - EU and national Government to amend relevant regulations to facilitate this
- Vehicle manufacturers and lorry operators to fit and retrofit all lorries (unless proved impossible or impractical) with front and redesigned full (horizontal and vertical) side guards without exception - national Government to amend relevant regulations to facilitate this
- Strongly deter cyclists from passing to the left of HGVs using campaign, training and educational methods
- Evaluate the casualty reduction effectiveness of, and where appropriate lobby for:
    - the benefits of driver direct vision and the contribution of eye contact to sharing the road safely
    - improved mirrors showing the presence of cyclists at the front and nearside-front cab area, while the truck is both stationary and moving
    - vehicle safety technology, such as camera monitoring systems and sensing devices, in detecting cyclists alongside the cab and on the nearside of lorries
    - the application of automatic/emergency braking on lorries and other large vehicles, its effects on drivers and the behaviours of other road users

Recommendations to help prevent fatal collisions with cars

- EU and national Government to extend pedestrian protection in European regulation and EuroNCAP to include cyclists (eg. pedestrian impact protection and Automatic Emergency Braking Systems)

Recommendations regarding road user behaviour

- Continue to enforce drink-driving and speeding laws
- Increase the legal compliance of bicycle lights
- Increase the lighting effectiveness of bicycle lights
- Promote the voluntary use of cycle helmets
- Instigate research to increase the protective effect of cycle helmets
- Use experience-based initiatives to demonstrate large vehicle blind spots

- Offer driver training that places greater emphasis on the awareness of cyclists, especially targeting common scenarios such as HGVs making left-turns
- Lobby national Government to:
    - include the use of simulators in driver or HGV-licensing tests to increase trainee drivers' exposure to sharing the road with cyclists
    - include a mandatory road safety module in the Driver Certificate of Professional Competence

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1. INTRODUCTION

This report describes research, which was conducted on behalf of Transport for London (TfL), that examined pedal cyclist fatal and serious injury crashes with a view to identifying the factors contributing to them. In addition, possible changes and measures that may have prevented or mitigated these crashes were considered. The focus was on police collision files which detailed pedal cyclist fatal and serious injury crashes which occurred in London between 2007 and 2011. This is the second time such a study has been conducted - the first being a study of police collision files for pedal cyclist fatal and serious injury crashes occurring in London between 2001 and 2006 which is reported in Keigan et al (2009).

1.1. Background

Road safety in the UK has improved considerably with UK fatal casualties falling to a record low of 1,637 in 2012, a reduction of 49% since 2000. There was a similar reduction in the total numbers killed and seriously injured (KSI) with a reduction of 40% since 2000. Cyclist casualties have not followed the national trend however, and an analysis of the UK STATS19 data shows that over the same period the numbers of killed or seriously injured cyclist casualties increased by 21%.

In comparison, KSI casualties in Greater London reduced by 51% between 2000 and 2012 while cyclist KSI casualties increased by 59% in a context of a threefold increase in cycling levels on main roads.

The increasing emphasis on cycling safety that this data indicates is needed is reinforced by other factors including pressures towards healthy lifestyles, reduced environmental impact of transport and reducing congestion. The Mayor of London has set a target of a 400% increase in cycling by 2026 against a 2001 baseline. All of these factors are expected to increase the amount of cyclist traffic in the coming years and are commonly the focus of national and local government policies. This increase in exposure is expected to result in an increase of cyclist casualties unless levels of risk decline at a faster rate.

Perceived risk of becoming involved in a crash is often greater than the actual risk and is more likely to reduce individual’s willingness to cycle, therefore demonstrable safety gains are likely to be necessary to achieve the 400% increase in cycling target.

1.1.1. General policy approaches: characteristics of the best performing countries for cycling safety

Since the mid-1970s, the Netherlands and Germany have implemented many improvements to cycling infrastructure; as an example of the benefits of these improvements cycling in the Netherlands is three times safer than the UK (OECD, 2007) (Figure 1) and much safer for children (Figure 2) (Christie et al 2007). The Netherlands experienced an 81% fall in the cyclist fatality rate between 1978-2006 (Figure 3) and an increase of 36% in the distance cycled per inhabitant. This casualty reduction has taken nearly 30 years to achieve. During this time all European countries including the UK have seen a rapid growth in motorised travel.

Pucher and Buehler (2008) argued that the safety and popularity of cycling has been achieved through policies that have restricted car use and more than doubled the bikeway network including a significant network of separate paths (Berlin 860km, Amsterdam 400km and Copenhagen 400km). The provision of separate facilities for cyclists has been described as the 'cornerstone of policies to make cycling safe, comfortable and attractive for all'.

In countries with extensive cycling infrastructure, a higher proportion of the population cycle and this may confer safety benefits (Jacobsen, 2003). The BIKE PAL cycling safety ranking (ETSC, 2012b) showed that, for the countries where the data are available, cycling is safer per distance travelled in the countries where more people cycle.

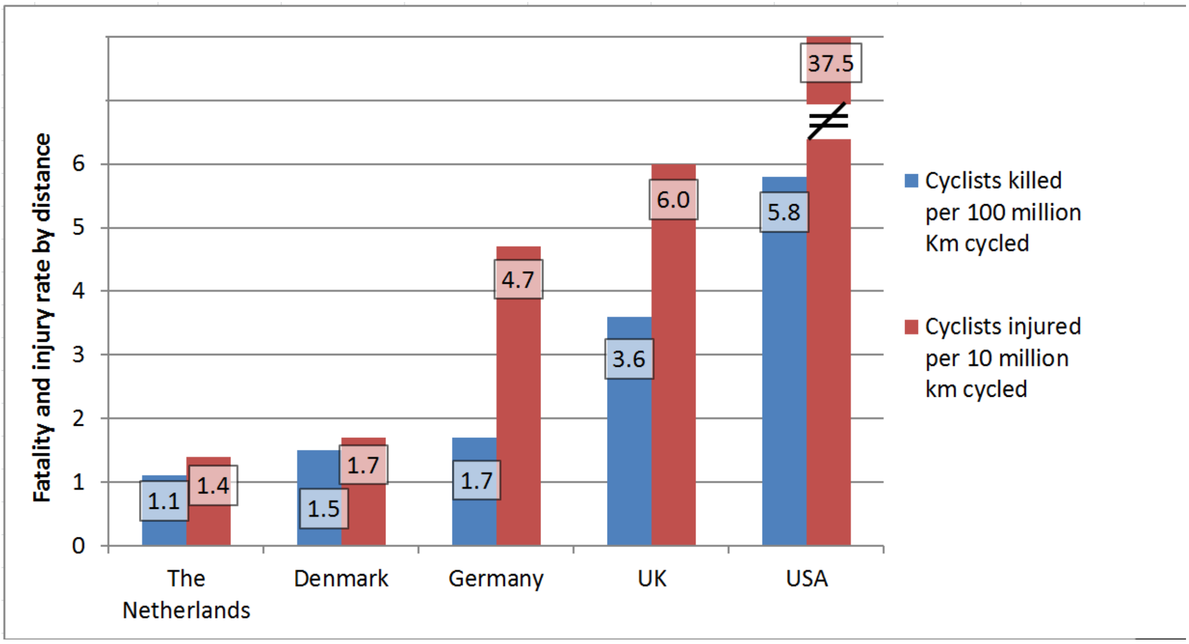

Figure 1: Cyclists killed and injured exposure based rates (extracted from: Pucher and Buehler, 2008)

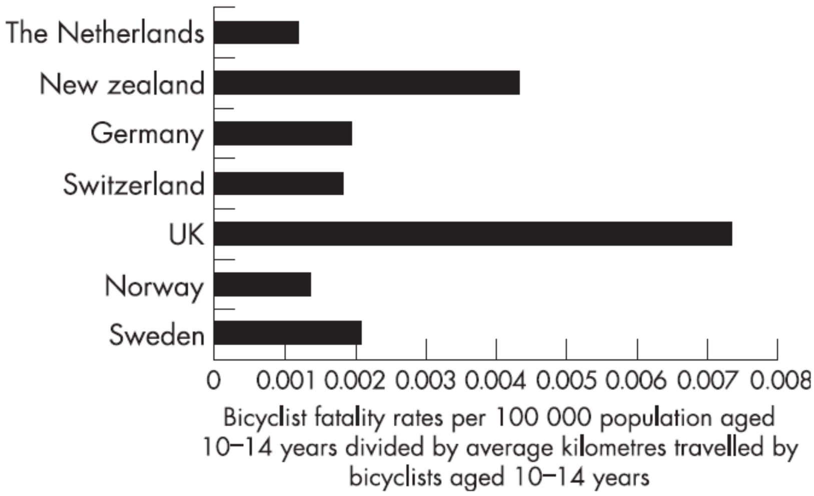

Figure 2: Exposure based fatality rates for child cyclists (extracted from: Christie et al 2007)

Source: Netherlands Ministry of Transport (2007)

Figure 3: Cycling levels and Cyclist fatality rates for the Netherlands 1950-2005 (extracted from: Pucher and Buehler, 2008)

1.2. Aims and Objective

The main objective of this research was to better understand in London how fatal and a small number of the most serious injury crashes involving pedal cyclists occur and how these crashes and the resulting injuries can be prevented. To achieve this, the study aimed:

- to extract and analyse data from police files of crashes involving fatal and seriously injured cyclists occurring in London between 2007 and 2011,
- to identify the main factors that caused or contributed to these crashes,
- to consider and evaluate countermeasures that could have prevented or mitigated these crashes,
- to recommend action that could be taken to assist in preventing such crashes occurring in the future.

1.3. Approach

The search for effective countermeasures to reduce the societal costs, e.g. cost of treatment, loss of a worker, of traffic crashes has prompted many crash investigation studies globally which analyse the characteristics and circumstances of individual crashes in order to identify common factors. An early model of accident causation was developed in the context of industrial accidents by Heinrich (1931). The model explained an accident as a step in a sequential chain of events or circumstances, each of which was dependent on the previous event. By removing one of the events the consequent circumstance would be avoided and the accident prevented. The model is typical of what are now called simple linear sequential models.

Since the 1930’s the multi-factorial nature of crash causation has been recognised and modified versions of the simple linear model have been developed to apply to road traffic crashes. Haddon (1968) applied epidemiological concepts to propose what is now termed the Haddon matrix as a method to capture the influence of several components of safety including the road user, vehicle and infrastructure. He also introduced the sequential nature of crash events by identifying separately the pre-crash, crash and post-crash phases. The model has had widespread application to clarifying road safety problems and has led to many successful safety interventions. Nevertheless the model has limitations as it does not explicitly incorporate the concept of exposure, nor does it facilitate an assessment of the interactions between components. If an aspect of human behaviour is identified as a risk factor the tendency is to look for a countermeasure that directly addresses that behaviour whereas there may be more efficient but indirect solutions.

More recent models of accident causation developed for industrial processes have come to consider the development of risks within a closely coupled, integrated system of which humans are a part. All components of all systems have a variation in performance whether they are human, mechanical or algorithmic. Systems that are increasingly tightly coupled are less resilient to the effects of adverse circumstances. Humans in the control loop have the opportunity to adapt behaviour to enable the system to accommodate adverse conditions but in a tightly coupled system a minor human error can result in a major outcome.

In considering the behaviour of systems Reason (2000) identified two types of error that may occur. Active failures are unsafe acts that are committed by people who are components in the system. He states that they may take a variety of forms including slips, lapses, fumbles, mistakes, and procedural violations. Secondly he identifies latent conditions, which represent attributes of the system – design, functionality, operation. Normally these deficiencies have no consequence and there are no adverse outcomes. However, when the trigger of an active failure aligns with the latent conditions of the system it may result in an adverse outcome. Reason (2000) illustrates this with the so-called Swiss cheese model (Figure 4).

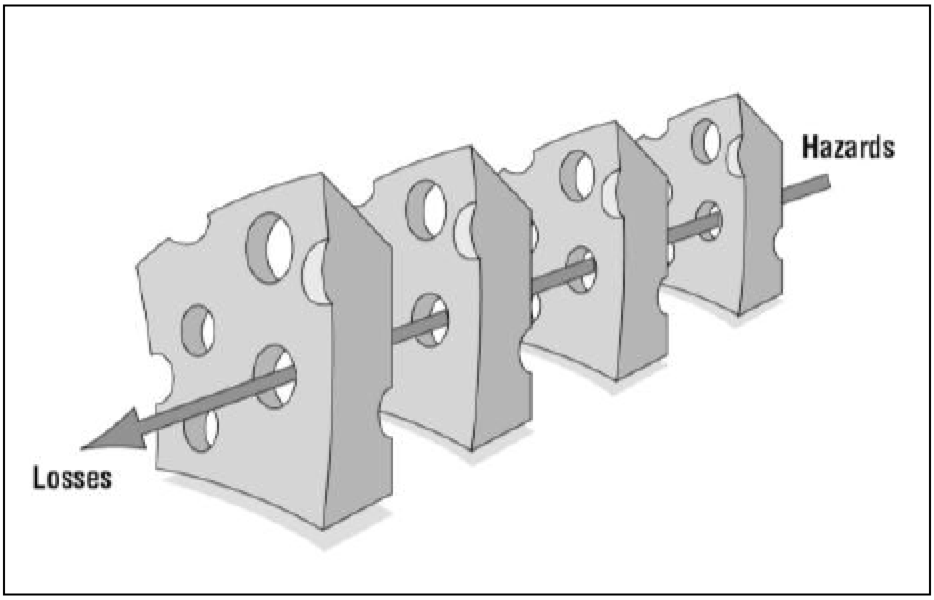

Figure 4: Swiss cheese model of accident causation (Reason 2000)

Reason provides the analogy that the slices of the cheese represent defensive layers based on engineering or behaviour constraints while the holes represent the active and latent failures in the system. Normally the holes are moving around, opening and closing and there are a number of defensive layers in operation that prevent adverse events. A hazardous scenario is only able to result in damage when the holes are aligned and each defensive layer is breached.

For further explanation of the above models, see Thomas et al. (2013).

The principles of the accident causation models discussed above have guided the approach used in the collection of data from police fatal and serious injury crash files, the analysis of that data, as well as the identification of potential countermeasures. To this end, it can be said the crashes are failures in a road traffic system made up of four components:

- Environment: This includes aspects such as infrastructure and weather conditions.
- Vehicle: All vehicles (including bicycles), their design and safety systems.
- Road user: The human behaviour element in the system - drivers, pedestrians, pedal cyclists, motorcycle riders etc.
- Management: These are the indirect influences of the system including legislation, policy and procedures e.g. licensing, congestion charging, fleet management, which in turn influences factors such as who is on the road and when.

These components are not in isolation as they are all interlinked and each component can affect another in the system. For example a driver may drive differently (road user) in different weather conditions (environment) or misinterpret unfamiliar infrastructure. The number of HGVs driving on London roads with Class VI mirrors fitted is dictated by the relevant legislation and company policy (management/vehicle) but the absence of a Class VI mirror could result in the driver failing to see a pedal cyclist (road user).

1.4. Structure of the report

The report is divided into four main chapters. Chapter 2 gives an overview of the methodology, the data collection and analysis methods and the process involved in developing countermeasures.

Chapter 3 includes the main findings of the analysis of the fatal and serious cyclist crashes. It describes the main characteristics of the sample and a number of crash groups identified within it as well as giving an overview of the injuries sustained.

Chapter 4 discusses possible measures that could have prevented or mitigated the crashes in the sample. It suggests specific countermeasures and gives examples of potential ways of implementing them. These countermeasures and the number of crashes they apply to are summarised at the end of the chapter.

Chapter 5 gives a brief overview of the evidence of the potential for crash and/or injury reduction found in systematic reviews for the countermeasures as well as summarising them. Chapter 5 should not be considered in isolation to the rest of the report.

Chapter 6 is a summary of the main findings and sets out a series of recommendations for action that could assist in preventing or mitigating future pedal cycle crashes.

2. METHODOLOGY

2.1. Protocol development

In order to develop effective countermeasures, there was a need to collect detailed information about the fatal and serious crashes from the police files that could answer the questions: ‘what happened in the crash?’ and ‘why did the crash occur?’. The first task was therefore to establish a protocol that set out what data to collect and how it should be collected to ensure accuracy.

A number of exercises were undertaken to investigate what data should be collected. A meeting was held with the TfL Cycle Safety Working Group to gather information about key issues relating to cyclists in London and the types of questions that they would like the data from fatal and serious crash reports to answer. Reviews were also conducted of the type of data that had previously been collected in crash investigation databases such as the SafetyNet Fatal Accident and Accident Causation Databases[1], DREAM manual[2] and the DaCoTA project’s Pan-European In-Depth Accident Investigation Online Manual[3]. This allowed a variable list to be established that would allow the detail of each crash to be recorded. Haddon’s matrix for pedal cyclist fatalities was used as a final cross check to establish that no key data had been missed.

A preliminary visit was made to the police station in Hampton where the files were accessed to establish what was available. All files were in paper form and no electronic records were accessible. There was a variation in the quantity of information in each file, according to the complexity of the case and whether a prosecution had occurred. The key documents were identified as:

- the police collision investigation report;
- scene and vehicle photographs;
- scene plan;
- CCTV images;
- driver interview transcripts;
- witness statements;
- post-mortem reports.

A simple database was created using the programme SPSS, to allow quantitative data to be recorded such as time and date of crash, vehicle type, age, gender, impairment, as well as more detailed qualitative descriptions such as crash description, vehicle defects, information about road narrowing and route information. Other supplementary information was to be recorded on paper such as mirror positions, vehicle damage, copies of scene plans and crash scenario diagrams

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[1] http://erso.swov.nl/safetynet/fixed/WP5/D5.5%20Glossary%20of%20Data%20variables%20for%20Fatal%20and%20accident%20causation%20databases.pdf
[2] http://www.dreamwiki.eu/
[3] http://dacota-investigation-manual.eu/

designed to show pictorially the crash narrative. Key details from witness statements, police investigation conclusions and the TSRC data collectors' initial conclusion about each crash were all systematically recorded. Injury data collected from post-mortems and hospital consultant witness statements were recorded separately on an excel spread sheet. Injury data included Abbreviated Injury Scale (AIS, 2005) codes, injury descriptions, toxicology and date of death.

2.2. Case collection and quality control

A small scale pilot was conducted to test the data collection protocols. Data on the crashes and resulting injuries were collected from ten crashes that were chosen to ensure that a variety of vehicles were included. This resulted in a small number of alterations to the database. It also highlighted the importance of the photographs in understanding the crashes so permission from the Metropolitan Police was sought and granted to take copies of a few key photos for each case. Identifying features such as faces, registration numbers and company names were removed from the stored copies ensuring that all information recorded by the team remained strictly anonymous.

To limit variations in data coding a glossary was developed following the pilot to explain how to code certain variables and to record the data coding conventions that were developed during the early phases of data collection.

It was initially planned for just two members of TSRC staff to collect the data relating to crashes, but due to the time consuming nature of the data collection activity, a third person was necessary. All three data collectors had previous experience in recording crash data. Injury data was recorded by a medical expert who is a Certified Abbreviated Injury Scaling Specialist.

Throughout the data collection period, the data collections regularly discussed the recording of the cases to ensure that a consensus was reached and to limit variation between data collectors.

Once all crashes had been entered in the database the cases were checked to ensure the quality of both the data entry and the coding.

As a supplement to the information gathered from the police files, TfL provided context data such as STATS19 records of previous crashes at the particular location, infrastructure alterations that had been carried out following the fatal/serious crash and GIS location maps.

2.3. Case reviews and countermeasure development

As there was so much detailed information available about the fatal and serious crashes, it was decided that a case review approach was the most appropriate way of identifying the contributory factors that were associated with each crash and ways in which these could have been avoided or mitigated.

Contributory factors were not assigned according to a pre-defined list. Instead, the case review approach involved reviewing all the information available for each crash including the database variables, photos, scene plans, injury data and context data. Factors that contributed to the crash were recorded under the headings, environment, vehicle, road user (both cyclist and driver/other rider) and management. Countermeasures were then assigned, where possible, to each contributory factor.

All researchers, including the data collectors, took part in the case reviews. Initially these were conducted by groups of 4-5 researchers until the method had been fully established and then each crash was reviewed by two researchers, either individually or in discussion with each other. A number of cases where the nature of the injuries was of special interest were reviewed with the medical expert.

The major advantages of this holistic approach were that by reviewing each crash individually, all the factors that contributed to the crashes were identified, not just those that occurred most frequently. Also the expertise of the individual researchers in a wide range of different areas e.g. causation analysis, human factors, vehicle design, risk factors could be utilised to generate a broad range of countermeasures.

Once all the case reviews had been conducted, the countermeasures were categorised under the headings of infrastructure, vehicle, road user and management. Similar countermeasures within each heading were then grouped together and formed the basis of the countermeasures chapter (Chapter 4).

3. CRASH DATA ANALYSIS AND CONTRIBUTORY FACTORS

3.1. Sample selection

The objective of the study was to examine the causes of crashes where cyclists were killed or sustained serious life-changing injuries as these were the only type of Police Investigation files available. A total of 79 such crashes were investigated by the Metropolitan Police Road Death Investigation Unit. A number of files were not available because either it was not possible to trace the file (11 crashes) or the cases were still active (7 crashes). The files for 6 crashes were available but were not included in the analysis as key documents such as the police collision investigation reports, scene plans and photos were not available, making it impossible to get an accurate picture of the crash. The 55 crashes in the sample included two involving a pedestrian where the pedestrian was the fatality and the cyclist sustained either serious injuries in one case or slight injuries in the other. These cases were excluded from the analysis.

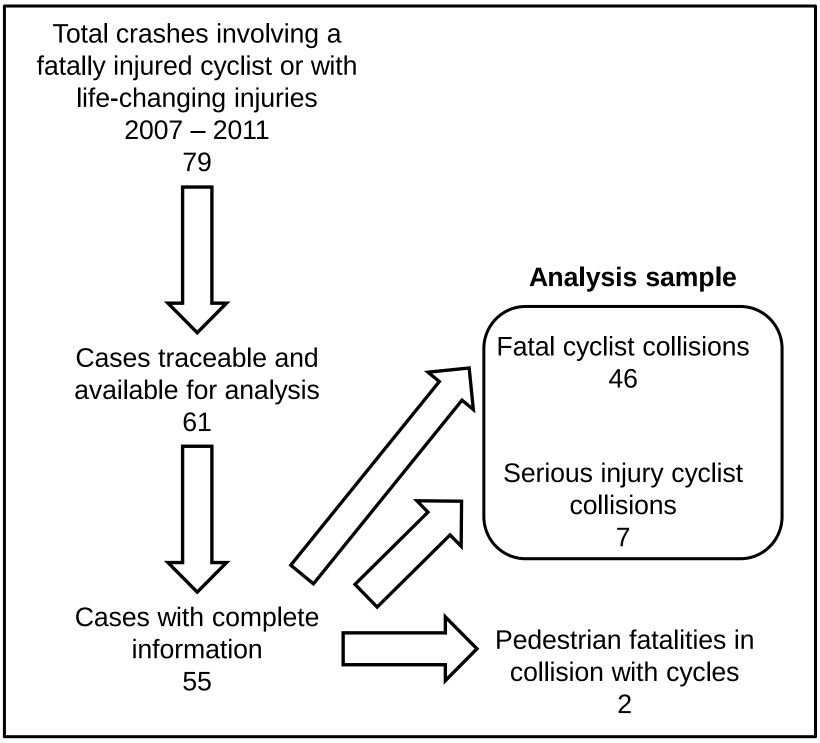


Figure 5: Derivation of analysis sample

The final sample therefore comprised 53 cases and is summarised in Figure 5. Forty-six were fatal pedal cyclist crashes, using the internationally accepted definition of death within 30 days. A further 7 involved a seriously injured pedal cyclist whose injuries were considered to be life threatening at the time of the crash. The ‘serious’ group includes one cyclist who died 2 months following the crash due to complications. For the purposes of this report, the fatal and serious crashes have been grouped together as the characteristics of these crashes, in terms of crash causation, are similar to those of the fatal crashes.

Table 1 shows the distribution of crashes included in the sample and those investigated by the Road Deaths Investigation Units by year.

Table 1: Number of crashes and year

Year	Number of crashes included in Sample	Number of crashes investigated by Road Deaths Investigation Units
2007	10	14
2008	12	14
2009	10	12
2010	14	17
2011	9	22
Total	55	79

Figure 6 gives an overview of the locations of the crashes included in the sample and the type of crash in terms of primary collision partner i.e. the vehicle that was involved in the interaction with the pedal cyclist that initiated the crash[4]. This figure appears to show a difference in the spread of crashes depending on the collision partner. For example the crashes where HGVs were the primary collision partner are clustered in the central region whereas crashes involving cars are more widely distributed. Fifty-seven percent (30/53) of the crashes occurred on roads which are the responsibility of the local London Boroughs and 43% (23/53) occurred on roads which Transport for London are responsible for (TLRN roads).

[4] If the initial interaction was between the pedal cyclist and another cyclist or a stationary object (including a parked unattended car) the crash is counted as a 'pedal cycle' crash – even if the cyclist was subsequently in collision with another type of vehicle.

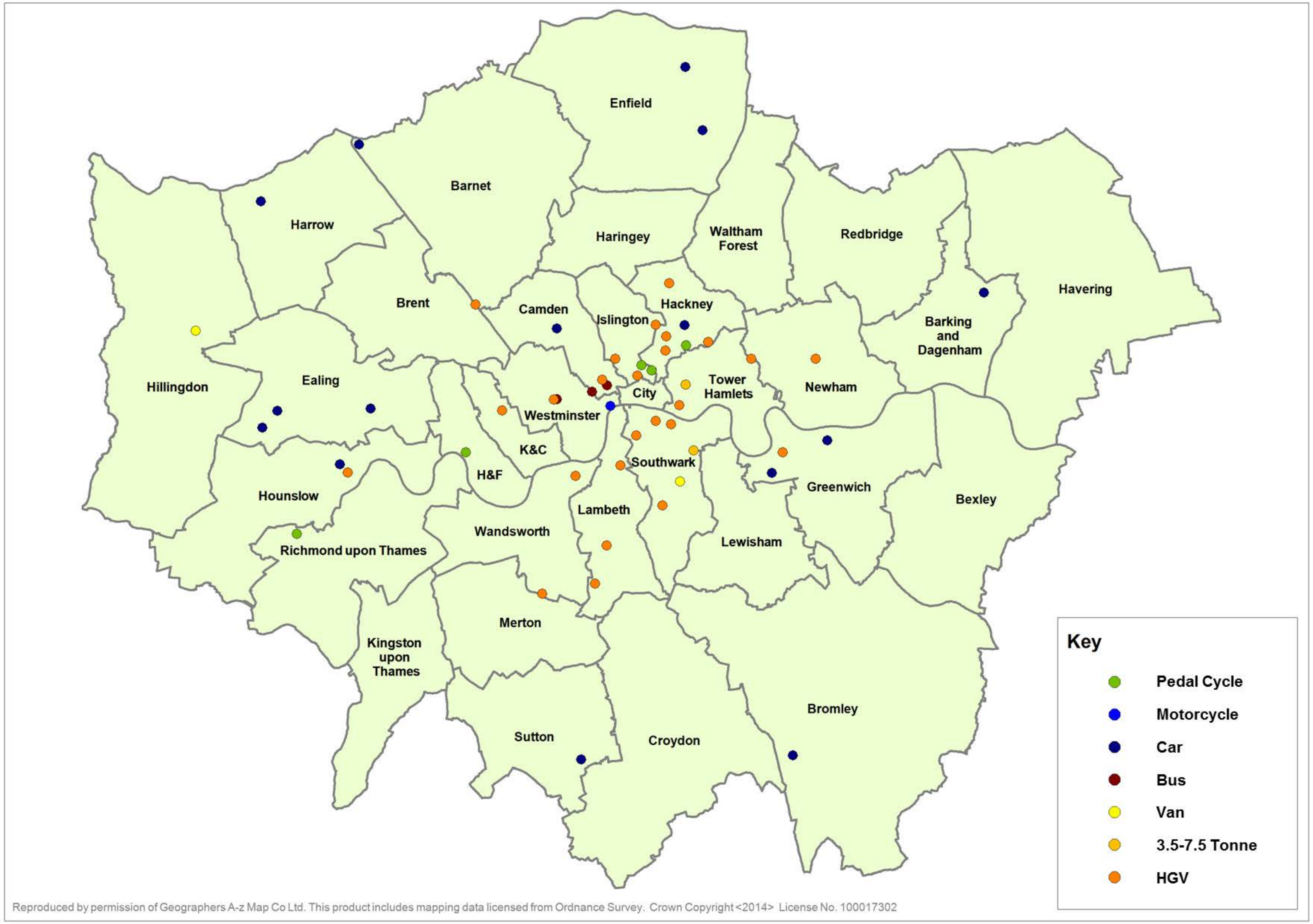


Figure 6: Crash locations by primary collision partner

The crash histories were available for the locations of 48 of the sample crashes. STATS19 data, provided by TfL, was analysed for the 36 months prior to the sample crash date. Locations are classified in the STATS19 data via a collision assignment network which defines Nodes, Links and Cells:

- A Node is the junction of two or more classified roads (M, A, B and former C class roads)
- A Link is the classified road between nodes
- A Cell is a 500m x 500m OS grid square, defined by the co-ordinates of the bottom left corner, to which collisions on unclassified roads are assigned

If the crash was at a Node, the Node was used to extract the crash history data and if it was on a link or in a cell a 50m circle around it was created to extract the data. Therefore the crashes included in the crash history data did not necessarily occur on the exact location of the sample crash – they could have occurred in a wider area including other arms of the same junction.

Two of the crashes occurred at approximately the same location and a further 3 locations had 1 other fatal crash within the 36 month time period. This was a single motorcycle crash in 1 case and a pedal cycle verses a HGV in the other 2.

Twenty-six locations had a history of injury crashes involving pedal cycles within the 36 months leading up to the crash included in the sample. Figure 7 shows how many locations previously had 1 or more slight, serious or fatal crashes that involved a cyclist, excluding the crash included in the sample. Injury pedal cycle crashes had occurred once or twice at 14 locations and at 3 locations the number of previous injury crashes involving pedal cyclists was high – 14, 15 and 40 crashes respectively.

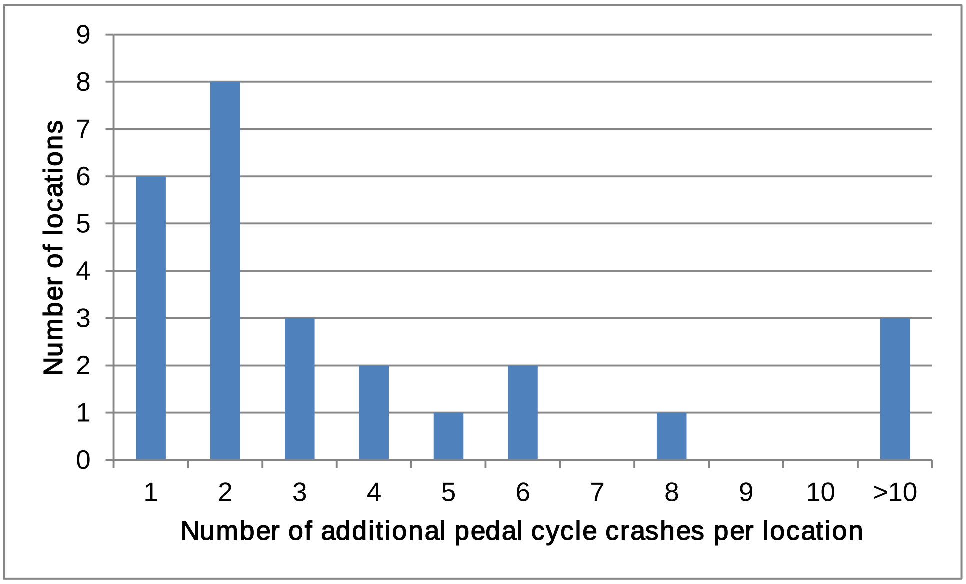


Figure 7: Pedal cycle collision history for sample crashes (36 months)

As the primary focus of this report is crashes involving pedal cyclists who sustained fatal or serious injuries, the 2 crashes involving pedestrians will be briefly described and then excluded from the remaining sections of this report. This leaves a total of 53 crashes included in the sample.

In both the crashes where pedal cyclists collided with pedestrians whose injuries proved fatal, the pedestrian was crossing the road from the nearside (left) of the cyclist. One crash occurred on a pedestrian crossing, where the pedestrian had stepped onto the road in response to a green man. In this case the pedal cyclist was waiting at a red light and set off as the lights changed to get ahead of following traffic. In the other crash there were no pedestrian facilities and the pedestrian stepped onto the road into the path of a pedal cyclist who had just overtaken a stationary bus.

3.2. Crash analysis - overview

This section presents an overview of the basic characteristics of the crashes incorporated in the sample and compares them with the equivalent data for fatalities occurring across Great Britain with data derived from STATS 19 covering the same period 2007 – 2011.

3.2.1. Crash characteristics

The distribution of fatal and serious pedal cycle crashes that occurred between 2007 and 2011 across the year is shown in Figure 8. Of the 53 fatalities and seriously injured in the sample, 40 (73%) took place in the 6 months November to April compared to 42% nationally. Inspection of the data for the complete group of cyclist fatalities indicates this difference is a characteristic of cyclist collisions in London and not an artefact of the cases included in the sample. There seems to be insufficient exposure data to fully clarify the underlying trends.

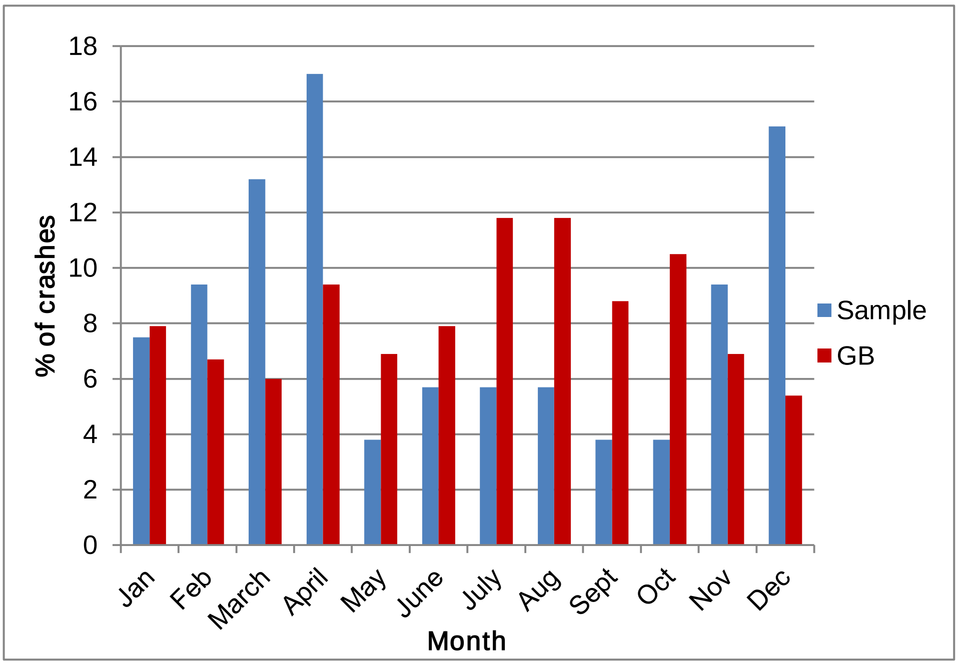


Figure 8: Crashes by month

Higher numbers of crashes occurred per week day than per weekend day (Figure 9). 93% of cyclist fatalities in London were as a result of collisions during weekdays compared with 69% nationally. The number of crashes was largest during the morning peak travel times – in particular during the two hour period between 08:00 and 09:59 when 13/53 (25%) crashes occurred compared with 12% nationally, with a further 10 crashes occuring between 10:00am and 11:59. A smaller number were associated with the evening peak travel times between 16:00 and 17:59 . Seven of the 53 (13%) fatal crashes occurred in this two hour period compared with 14% nationally (Figure 10).

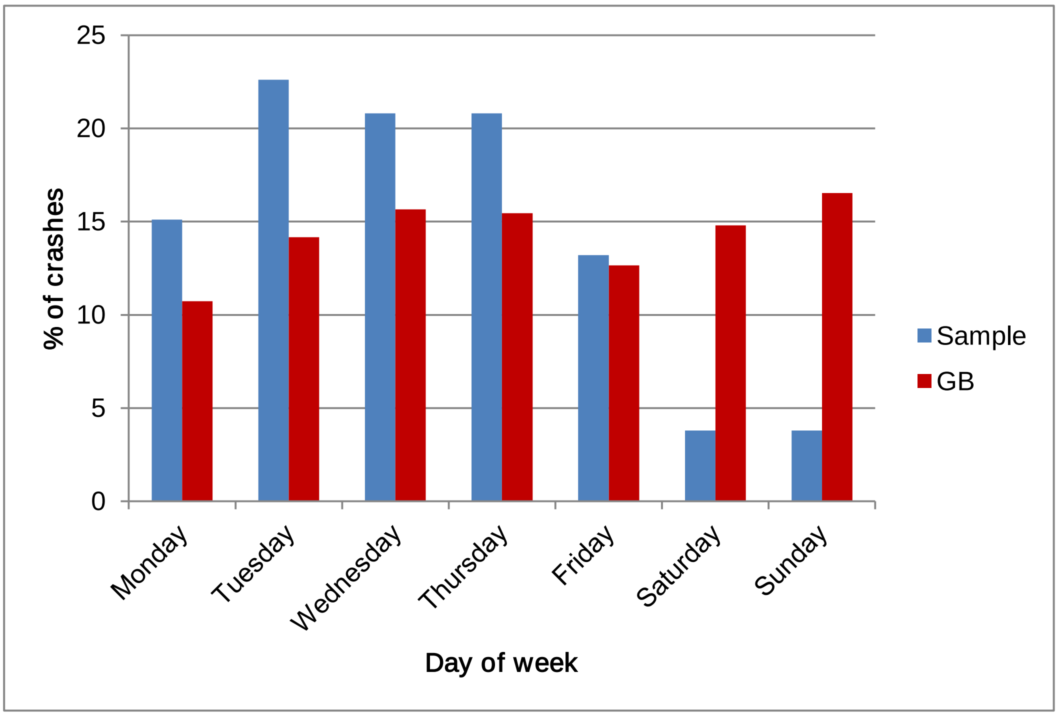


Figure 9: Crashes by day of the week

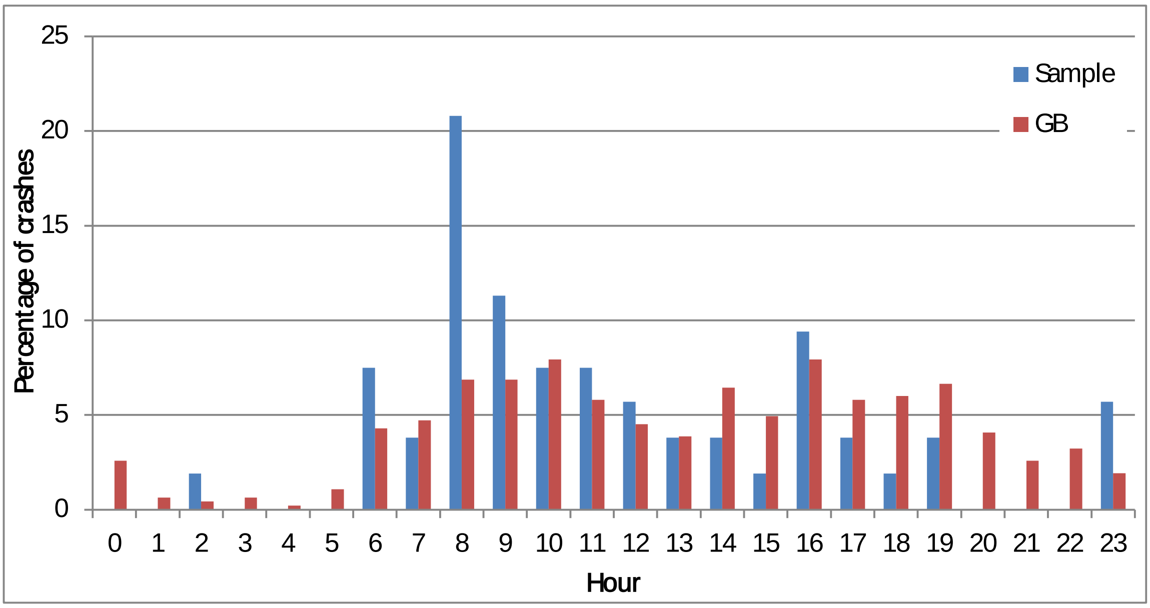


Figure 10: Percentages of Crashes by hour

The majority (39/53, 74%) of crashes in the sample occurred in daylight compared with 74% nationally and all crashes in darkness conditions occurred where artificial street lighting was present compared with only 59% nationally (Table 2). The majority of crashes occurred when the weather was fine or cloudy (48/53, 91%) with only a small number (3/53, 6%) occurring while it was raining (Table 3). Correspondingly, the road was dry in the majority (43/53, 81%) of crashes with wet or icy conditions occurring in a small number of crashes (9/53 17%) (Table 4). This suggests that inclement weather and poor road conditions were not a major factor in contributing to the crashes occurring between November and April. This may be influenced by pedal cyclists choosing not to ride in such weather conditions but pedal cycle travel rates by weather condition were not available to analyse this further.

Table 2: Crashes by light condition

Light Conditions	Number of crashes	% of crashes	% of crashes GB
Daylight	39	74	74
Partial light	1	2	0
Darkness with artificial light	13	25	14
Darkness (no artificial lights)	0	0	13
Total	53	100	100

Table 3: Crashes by weather condition

Weather Condition	Number of crashes	% of crashes	% of crashes GB
Fine	48	91	91
Rain	3	6	7
Not known	2	4	2
Total	53	100	100

Table 4: Crashes by road condition

Road Condition	Number of crashes	% of crashes	% of crashes GB
Dry	43	81	77
Wet	8	15	22
Ice	1	2	1
Not known	1	2	0
Total	53	100	100

The following tables show the class of road (Table 5), carriageway type (Table 6) and speed limit of the roads (Table 7) at the locations of the sample crashes. Forty crashes occurred on A-roads and the majority of the sample crashes occurred on roads with a speed limit of 30mph (47/53, 89%). Almost two-thirds of the crashes (34/53, 64%) took place on single carriageway roads. Thirty-nine crashes occurred at a junction, 25 of which were signalised. The most common junction type (18/53, 34%) was crossroads (Table 8).

Table 5: Crashes by road class

Road Class	Number of crashes in sample	% of crashes	% of crashes GB
A	40	76	53
B	1	4	12
C	3	2	12
Unclassified	10	19	23
Total	53	100	100%

Table 6: Crashes by road type

Road type	Number of crashes in sample	% of crashes	% of crashes GB
One way street	11	21	1
Dual carriageway	8	15	21
Single carriageway	34	64	71
Unknown	0		7
Total	53	1	100

Table 7: Crashes by speed limit

Speed limit	Number of crashes in sample	% of crashes	% of crashes GB
20	1	2	1
30	47	89	48
40	3	6	11
50	0	0	5
60	0	0	25
70	2	4	11
Total	53	100	100

Table 8: Number of crashes per junction type

Junction Type	Number of Crashes in sample	% of crashes	% of crashes GB
Not at or within 20 metres of junction	14	26	52
Roundabout	4	8	7
T or staggered junction	11	21	23
Slip road	1	2	2
Crossroads	18	34	10
Multiple junction	1	2	1
Other junction type	4	8	5
Total	53	100	100

Table 9 shows the primary collision partner for the 53 fatal and serious crashes examined. Primary collision partner is defined as the vehicle that was involved in the interaction with the pedal cyclist. If the initial interaction was between the pedal cyclist and another cyclist or a stationary object (including a parked unattended car) the crash is counted as a 'pedal cycle' crash – even if the cyclist was subsequently in collision with another type of vehicle.

A HGV was the collision partner for nearly half of the crashes with cars making up the next largest collision partner group. The pedal cycle group includes 2 crashes where the initial collision occurred with another cyclist and the remaining 3 were caused by the cyclists losing control or hitting a stationary object.

Table 9: Number of crashes by primary collision partner

Crash Participant	Number of Crashes	% of Crashes
Car	15	28
Van	2	4
Bus/Coach	3	6
3.5 - 7.5t	2	4
HGV	25	47
Motorcycle	1	2
Pedal Cycle	5	9
Total	53	100

The majority of the crashes (48/53) involved 2 vehicles – the pedal cycle and a collision partner. Three crashes involved 3 vehicles and a further 2 were single vehicle crashes although another road user (a coach) may have contributed to the collision in one of these cases.

3.2.2. Crash Manoeuvre

Table 10 shows the crash manoeuvres recorded for the 53 fatal and serious pedal cycle crashes in the sample and Table 11 shows the crash manoeuvres recorded per collision partner type. The crash manoeuvres were coded according to a pre-existing list and as such are standard terms, routinely used by Transport for London. The most common manoeuvres were another vehicle turning left across the path of the pedal cycle (17/53) and another vehicle running into the back of the pedal cycle (9/53). Other common manoeuvres included the pedal cycle and the other vehicle travelling alongside each other (5/53), the pedal cycle failing to give way and colliding with another vehicle (4/53), and the pedal cycle and other vehicle colliding when both turning left (4/53). HGVs make up the largest share of vehicles turning left across the path of the pedal cycle (14/17) and the most common crash type for crashes involving cars was pedal cycle fails to give way and collides with other vehicle (4/15).

Table 10: Crash manoeuvres for sample crashes

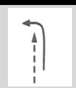
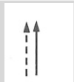
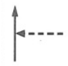
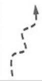
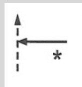
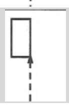
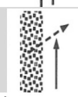
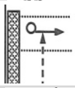
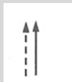
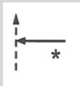
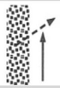
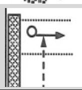
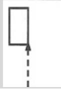
Manoeuvre (P/C = Pedal Cycle)	Diagram	Number of crashes	% of crashes
Other vehicle turns left across the path of P/C		17	32
Other vehicle runs into rear of P/C		9	17
P/C and other vehicle travelling alongside each other		5	9
P/C fails to give way or disobeys junction control & collides with other vehicle		4	8
P/C and other vehicle collide when both turning left		4	8
No other vehicle hit by P/C. Various manoeuvres or loss of control only		2	4
Other vehicle fails to give way or disobeys junction control & collides with P/C		2	4
Head on collision between P/C and other vehicle		2	4
P/C hits parked vehicle		1	2
P/C hits open door / swerves to avoid open door of other vehicle		1	2
P/C loses control & hits other vehicle - various manoeuvres		1	2
P/C changes lane to left, across the path of other vehicle		1	2
P/C rides off footway into path of other vehicle		1	2
P/C in collision with pedestrian on crossing		1	2
Other vehicle turns right across the path of P/C		1	2
P/C and other vehicle collide when both turning right		1	2
Total		53	100

Table 11: Crash manoeuvre by collision partner

Manoeuvre (P/C = Pedal Cycle)	Diagram	Car	Van	Bus/Coach	3.5 - 7.5 tonne	HGV	Motorcycle	Pedal Cycle only
Other vehicle turns left across the path of P/C		1			1	14		1
Other vehicle runs into rear of P/C		2	1	1		5		
P/C and other vehicle travelling alongside each other		1				3	1	
P/C fails to give way or disobeys junction control & collides with other vehicle		4						
P/C and other vehicle collide when both turning left				1	1	2		
Head on collision between P/C and other vehicle		2						
Other vehicle fails to give way or disobeys junction control & collides with P/C		1				1		
No other vehicle hit by P/C. Various manoeuvres or loss of control only								2
P/C hits open door / swerves to avoid open door of other vehicle		1						
P/C rides off footway into path of other vehicle		1						
P/C rides across road at pedestrian crossing into path of other vehicle		1						

Manoeuvre (P/C = Pedal Cycle)	Diagram	Car	Van	Bus/Coach	3.5 - 7.5 tonne	HGV	Motorcycle	Pedal Cycle only
Other vehicle turns right across the path of P/C		1						
P/C hits parked vehicle						1		
P/C loses control & hits other vehicle - various manoeuvres			1					
P/C changes lane to left across the path of other vehicle				1				
P/C and other vehicle collide when both turning right						1		
Total		15	2	3	2	27	1	3

3.2.3. Vehicle characteristics

One hundred and twelve vehicles were directly involved in the sample including the 53 pedal cycles being ridden by the cyclists who sustained fatal and serious injuries in the sample. All of the vehicles except for a coach and a 3.5-7.5 tonne truck, collided with the cyclist and resulted in the fatal or serious injuries either by direct impact or by a resulting contact with, for example, the road surface.

The types of vehicles that were involved in the crashes are shown in Table 12.

Table 12: Number of vehicles by vehicle type

Vehicle Type	Number of vehicles	Percentage of vehicles
Car	16	14
Van	2	2
Bus/Coach	4	4
3.5-7.5 tonne truck	3	3
HGV	27	24
Motorcycle	1	1
Pedal Cycle – case vehicles	53	47
Pedal cycle – collision partner	2	2
Total	112	100

This section presents the main characteristics of the vehicles involved in each crash. Given the relatively small numbers of some vehicle types the vehicles are considered in three groups – bicycles, small vehicles and large vehicles. Table 13 below shows how these categories map onto standard definitions of vehicle types as specified by EC and UK STATS19 (DfT 2013) definitions. The car-derived van (CDV) in the sample has been classified together with cars since it was the front end of the CDV that struck the cyclist. The one taxi in the sample has also been grouped with cars as the driver was not working at the time of the crash.

Table 13: Classification of vehicle types

Size category	Vehicle type	Crash Sample	UN ECE	STATS 19
Small vehicles	Bicycles	Bicycles	No category	Bicycles (vehicle code 1)
	Car	Car	M1	Car or taxi (vehicle code 9 or 10)
	Car derived van	Car	N1	Goods vehicle <3.5T (vehicle code 19)
	Light Commercial Vehicles (LCV)	Van	N1	Goods vehicle <3.5T (vehicle code 19)
	Motorcycle	Motorcycle	L1, L3	Motorcycle, all engine sizes (vehicle codes -02, 03, 04, 05, 97)
Large vehicles	Bus or coach (one or two decks)	Bus or coach	M2, M3	Bus, coach (vehicle code 11)
	All goods vehicles > 3.5T including tipper, concrete mixer, drop-side, refuse and skip lorries	3.5 – 7.5 tonne truck Heavy Goods Vehicle (HGV)	N2, N3	Goods vehicle over 3.5 T and under 7.5 T (vehicle code 20) Goods vehicle 7.5 tonnes and over (vehicle code 21) Goods vehicle – unknown weight (Vehicle code 98)

3.2.3.1. Pedal cycles – fatally or seriously injured riders

The most common type of pedal cycle ridden by cyclists who were killed or seriously injured was a mountain bike (23/53, 43%) followed by a commuter/hybrid style bike (11/53, 21%) and a road bike (10/53, 19%) (Table 14). There were no electrically propelled bicycles in the sample and none of the cycles ridden were rented from the TfL/Barclay's cycle hire scheme.

Table 14: Types of pedal cycle included in the sample

Pedal Cycle type	Pedal Cycle type image	Number of Pedal Cycles	Percentage of Pedal Cycles
Mountain bike		23	43
Commuter/ hybrid bike		11	21
Road bike		10	19
Shopper		6	11
Folding		1	2
Other		2	4
Total		53	100

Seven of the 53 pedal cycles were considered by police vehicle examiners to have defects, 4 of these involved had limited functionality of the brakes, 1 was missing a rear reflector, 1 pedal cycle had very low tyre pressure and no further information was provided about the defects in the last case. The police classed defects in 2 cases as ‘not contributory’ and made no comment in the other cases so it is not considered that cycle maintenance has been a contributory factor in any of the fatal and serious crashes in the sample.

18 pedal cyclists in the sample were fitted with lights. The following table (Table 15) shows how many pedal cycles were fitted with front and/or rear lights.

Table 15: Lights fitted on pedal cycles

Lights fitted	Number of Pedal cycles	Percentage of Pedal cycles
Yes - no further details	1	2
Front only	3	6
Rear only	3	6
Front and rear	11	21
No evidence of lights fitted	35	66
Total	53	100

Not all of the lights that were fitted to pedal cycles were in use at the time of the crash. Out of the 14 crashes occurring in darkness or partial light, lights were in use on 7 pedal cycles. Out of these 7, front and rear lights were used on 5 pedal cycles with rear only on the other 2. Front and rear lights were in use on 1 pedal cycle involved in a crash occurring in daylight and it is not known whether lights were used in the remaining crashes.

3.2.3.2. Small Vehicles

The group of 19 small vehicles comprised cars, vans below 3.5 tonne and motorcycles. The numbers in each group are shown in Table 12. Both vans in the sample were panel vans and the motorcycle was a Touring style, as illustrated in Figure 11.

Figure 11: Illustration of panel van and touring motorcycle

A variety of car body styles were included in the sample (Table 16). This included only one taxi ('black cab' design) which was not working at the time of the collision, so no distinction has been made between this vehicle and the other cars included in the sample in this report.

Table 16: Car body styles included in the sample

Car type	Number of Cars	Percentage of Cars
Hatch	6	38
Saloon	4	25
Car Derived Van	1	6
Off-road/SUV	4	25
Taxi	1	6
Total	16	100

Minor defects which would lead to MOT failure were recorded for 1 van but they were not classed as contributory. Three cars had defects but these were only considered contributory in 1 case where illegally tinted front windows were present.

Table 17 describes the different interactions that occurred between the pedal cycles and the small vehicles in the sample. Being thrown clear of the vehicle (to nearside, offside and glancing impact) was the most common type of interaction followed by being thrown onto or over the vehicle.

Table 17: Interaction between pedal cycle and small vehicle

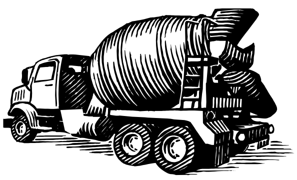
Interaction	Cars	Vans	Motorcycle
None (swerve round door)	1		
Glancing Impact	2		1
Scooped up and came off vehicle	4		
Thrown to nearside	2	1	
Thrown to offside	1		
Thrown over vehicle	3		
Dragged by vehicle	3		
Went under vehicle		1	
Total	16	2	1

3.2.3.3. Large vehicles

This group of large vehicles comprised 34 buses and coaches and Heavy Goods Vehicles over 3.5 tonne, (Table 12), including construction, refuse and other vehicle types.

The bus/coaches vehicle group was made up of 3 buses that were double decker public service buses and 1 coach that was a single decker. The majority of HGV/3.5-7.5 tonne vehicles had rigid bodies with only 3 being articulated and 1 being a tractor unit without a trailer. All 3 articulated HGVs were curtain style. The most common HGV type was tipper with 11 HGVs being of this type (Table 18) followed by flat / drop side (5) and box (4).

Table 18: HGV and 3.5-7.5 tonne truck types included in sample

HGV/3.5-7.5 tonne type	HGV/3.5-7.5 tonne type image	Number of HGV/3.5-7.5 tonne	Percentage of HGV/3.5-7.5 tonne
Tipper		11	37
Flat or drop side		5*	17
Box		4*	13
Skip carrier		3*	10
Curtain sided articulated vehicle		3	10
Refuse Lorry		2	7
Tractor Unit only		1	3
Cement mixer		1	3
Total		30	100

*Includes 1 3.5-7.5 tonne truck

Defects were found on 4 HGVs however these were not considered to be contributory causes of the crashes.

In 25 of the 34 (74%) crashes involving large vehicles, the pedal cyclist was run over and in a further 6 (18%) crashes the pedal cyclist was run over and dragged along the road by the wheels of the vehicle (Table 19). This contrasts with the small vehicles where most of the crashes involved pedal cyclist being thrown clear of or over the vehicle (Table 17).

Table 19: Interaction between pedal cycles and large vehicles

	Bus/coaches	3.5-7.5 tonne	HGV
None (no contact with coach)	1		
Run over and dragged by vehicle			6
Run over by vehicle	2	2	21
Other	1	1	
Total	4	3	27

3.2.4. Road user characteristics

The following sections detail aspects about the road users including age, gender, impairment, journey purpose and previous convictions. It also covers aspects relating to the use of technology, distraction and in the case of pedal cyclists, the use of high visibility clothing and helmets. Section 3.2.4.1 addresses pedal cyclists, section 3.2.4.2 drivers/riders of small vehicles and section 3.2.4.3 drivers of large vehicles.

3.2.4.1. Pedal cyclists

The characteristics of the pedal cyclists presented in this section include all fatally or seriously injured pedal cyclists, the two pedal cyclists who were collision partners have been excluded. The following table (Table 20) shows the distribution of gender and age for the pedal cyclists in the sample as well as information of impairment and previous convictions. Just over half of the pedal cyclists were male with just under a third in the 20-30 year old age group and just over a third in the 30-40 year old age group. A relatively small number of pedal cyclists were impaired by alcohol or drugs and only 2 had previous convictions which were for non-driving offences however it was not possible to confirm whether any cyclists had driving convictions.

Table 20: Pedal Cyclists gender, age, impairment and previous convictions

		Cyclists (n=53)
Gender	Male	29 (55%)
	Female	24 (45%)
	Not known	0
Age	<20	2 (4%)
	20-30	16 (30%)
	30-40	19 (36%)
	40-50	6 (11%)
	50-60	3 (6%)
	60+	7 (13%)
	Not Known	0
Impairment	Alcohol	1 (2%)
	Illegal substances	1 (2%)
	Medication	1 (2%)
Previous Convictions	Driving	N/A
	other convictions	2 (2%)

Commute was the most common journey purpose for pedal cyclists in the sample however it was not possible to establish the journey purpose for 40% (21/53) of the pedal cyclists included in the sample (Table 21).

Table 21: Pedal cyclists' journey purpose

Journey Purpose	Pedal cyclists (N=53)
Casual or social	8 (15%)
Commuting	19 (36%)
To/from school	2 (4%)
Work	3 (6%)
Not Known	21 (40%)

Seven (13%) pedal cyclists were wearing headphones when the crash occurred and headphones were considered to be a possible distraction for 2 of these cyclists. Two pedal cyclists were distracted by other traffic and companions (one on the same pedal cycle, one on another) were a possible distraction for another 2 pedal cyclists.

Use of high visibility clothing and protective equipment

Table 22 shows that 11 (21%) of pedal cyclists wore high visibility clothing and 22 (42%) wore a helmet. It is known that one pedal cyclist was not wearing their helmet correctly enabling it to slip off the head during the crash.

Table 22: Use of high visibility clothing and protective equipment

		Number of cyclists	Percentage of cyclists
High visibility	Worn	11	21
	Not worn	42	79
Helmet	Worn (fitted correctly)	21	40
	Worn (fitted incorrectly)	1	2
	Not worn	28	53
	Not Known	3	6

Out of the 11 cyclists who wore high visibility clothing, four wore full jackets, one cyclist wore a yellow waterproof with a reflective strip on the back, three cyclists wore tabard/gilet style tops, one of which also wore ankle bands, and one cyclist only wore ankle bands. A further two cyclists had luggage that was described as high visibility – in one case this was a rucksack cover and a second was carrying two high visibility newspaper delivery bags; one over the shoulder and another strapped to the rear luggage rack.

In the 14 crashes that occurred in darkness or partial light, three cyclists wore high visibility clothing. This was a jacket in 1 case, a gilet in another and a yellow waterproof with reflective strips on the back in a third case.

3.2.4.2. Drivers/riders of small vehicles

The following table (Table 23) shows the distribution of gender and age for the 19 drivers of small vehicles included in the sample as well as information about impairment and previous convictions. The majority (15/19, 79%) of drivers were male with the most common age group being the 40-50 year range. A greater proportion of drivers of small vehicles were impaired by alcohol (3/19, 16%). than pedal cyclists (1/53, 2%).

Table 23: Gender, age, impairment and previous convictions of small vehicle drivers

		Car drivers (n=16)	Van drivers (n=2)	Motorcycle riders (n=1)
Gender	Male	12 (75%)	2	1
	Female	3 (19%)	0	0
	Not known	1 (6%)	0	0
Age	<20	2 (13%)	0	0
	20-30	1 (6%)	0	0
	30-40	2 (13%)	1	0
	40-50	5 (31%)	0	1
	50-60	2 (13%)	1	0
	60+	3 (19%)	0	0
	Not Known	1 (6%)	0	0
Impairment	Alcohol	2 (13%)	1	0
	Illegal substances	0	1	0
	Medication	2 (13%)	0	0
Previous Convictions	Driving convictions	3 (19%)	1	0
	Other convictions	0	0	0

The car drivers had a range of journey purposes although commuting or driving in a work related capacity were the most common (Table 24). The van drivers were both undertaking journeys for work and the motorcycle rider was commuting.

Table 24: Journey purpose of drivers of small vehicles

Journey Purpose	Car drivers (n=16)	Van drivers (n=2)	Motorcycle riders (n=1)
Casual or social	3	0	0
Commuting	5	0	1
To/from school	1	0	0
Work	5	2	0
Not Known	2	0	0

One car driver had a satellite navigation system running in their vehicle at the time of collision however they were familiar with the route so it is unknown whether it was being actively attended to. None of the drivers of small vehicles were known to be using a hand held or hands free phone at the time of collision. Possible distraction was suggested as a contributory factor for three car drivers. Loud music and other traffic were possible distractors for two drivers and the third driver was observed by a witness to be facing towards the rear of the car at the time of the crash.

3.2.4.3. Drivers of large vehicles

This group includes all drivers of the 27 HGVs, the 3 3.5-7.5 tonne vehicles, the 3 buses and the coach.

Table 25 shows the gender and age distribution of drivers of large vehicles as well as their impairment and previous convictions. The majority of drivers were male (33/34) with only 1 female bus/coach driver. These drivers tended to be in the older age categories (40+) with 1 bus/coach driver and 2 HGV drivers in the 20-30 years old age category and 6 HGV drivers in the 30-40 years old age category.

Table 25: Gender, age, impairment and previous convictions for drivers of large vehicles

		Bus/Coach drivers (n=4)	3.5-7.5 tonne vehicle drivers (n=3)	HGV drivers (27)
Gender	Male	3	3	27(100%)
	Female	1	0	0
	Not known	0	0	0
Age	<20	0	0	0
	20-30	1	0	2 (7%)
	30-40	0	0	6 (22%)
	40-50	0	1	8 (30%)
	50-60	1	0	7 (26%)
	60+	2	1	4 (15%)
	Not Known	0	1	0
Impairment	Alcohol	0	0	1(4%)
	Illegal substances	0	0	0
	Medication	0	0	0
Previous Convictions	Driving	1	1	6 (22%)
	Other convictions			1(4%)

Six (22%) of the HGV drivers had previous driving convictions (Table 25). For the majority of these drivers, it is not known whether the convictions related to driving a private vehicle or a HGV, however 1 driver's offence was exceeding goods vehicle speed limits.

The journey purpose was not known for one HGV driver but all the other large vehicle drivers were driving for work. None of the Bus/Coach or 3.5-7.5 tonne vehicle drivers were recorded as using telephones or navigation systems at the time of the crash. Three HGV drivers were using a phone (3/27, 11%), two hands free and one hand held, and a satellite navigation system was running in three of the HGVs. The use of the hand held phone was considered to be a distraction and the use of hands free phones was considered to be a possible distraction. Other traffic was considered to be a possible distraction for one bus/coach driver and one HGV driver. Other things that were recorded as possible distractions were pedestrians (one HGV driver) and offside mirror checks (one bus/coach driver).

3.2.5. Crash Characteristics

This section describes the characteristics of the crashes and presents the main contributory factors derived from the inspection of each case. These characteristics include the key details of the interactions between cyclists and the collision partners. The crashes are grouped into categories defined by crash characteristics including the basic manoeuvre and collision partner shown in Table 26 below.

The crash groups allow the nature of the crashes to be described and commonalities between crashes to be identified. For each group a description of the key characteristics has been made and the primary contributory factors, as identified during the case review exercise (see section 2.3), have been listed along with the number of crashes. Other more general factors may have been identified as a risk factor in the crash however only those that relate to the specific crash are listed here. For example factors relating to exposure or the operational management of the network affect crash risk at a system level and may not be discernible at an individual crash level. System level measures are addressed separately in the later countermeasures section.

The use of the term 'priority' in Table 26 refers to legal right of way so if the cyclist had priority, then the other vehicle should have given way to them and vice versa.

Table 26: Categories of cyclist collisions

Crash group	Number of crashes	
1. Cycle only – single vehicle crashes		**5**
• *Loss of control/collision with stationary object*	*3*	
• *Collision with another cyclist*	*2*	
2. Collisions with cars		**15**
• *Junction collision – car had priority*	*6*	
• *Same direction*	*3*	
• *Junction collision – cyclist had priority*	*3*	
• *Head-on*	*2*	
• *Opening door*	*1*	
3. Collisions with goods vehicle > 3.5T		**27**
• *Truck turning left*	*16*	
• *Truck and bicycle alongside in same direction*	*9*	
• *Junction collision – cyclist had priority*	*2*	
4. Collisions with buses		**3**
5. Collisions with vans		**2**
6. Collisions with motorcycles		**1**
Total		**53**

The figures do not map exactly onto manoeuvre figures in Table 10 and Table 11 as more detailed analysis has taken further account of additional crash factors as well as the basic manoeuvres. For example a left turning truck may hit a pedal cyclist to the rear and be classified as an impact to the rear of pedal cyclist but grouped with the left turning trucks as its road positioning and behaviour more accurately reflect that category for this analysis.

The sections below present information on each of the crash groups, in general the numbers of cases in each group are relatively low so the key features of each case are presented; each crash has been assigned to one group only. Each crash may have more than one applicable contributory factor so the total factors in each group will not always be the same as the total crashes.

3.2.6. Crash group 1 - Pedal cycle crashes

This group includes five crashes where a motorised vehicle was not involved in the initiation of the crash. These have been categorised into the following groups:

- Loss of control (3 crashes)
- Collision with another cyclist (2 crashes)

3.2.6.1. Crash group 1: Loss of control (n=3)

Three crashes were characterised by the cyclist losing control. In the first the cyclist manoeuvred around a parked car, slid due to the snow/icy conditions and sustained fatal injuries due to contact with the ground. In the second the cyclist lost balance whilst overtaking parked cars and at the same time, being overtaken by a coach. The cyclist had a passenger on their handle bars and sustained serious injuries. A third case involved a cyclist colliding with a parked car, falling off then being run over by an oncoming tipper lorry, this case is classified as a single vehicle collision since the tipper contributed to the injury causation not the crash causation.

Contributory factors

- Other vehicle not allowing cyclist enough space when overtaking (1 crash)
- Heavy load on handle bars - child (1 crash)
- Snow/Ice (1 crash)
- Road narrowing due to parked cars (1 crash)
- Pedal cyclists not allowing themselves enough space when overtaking (1 crashes)

3.2.6.2. Crash group 1: Collision with another cyclist (n=2)

Two crashes involved 2 cyclists colliding with each other. The first is thought to have been as a result of a misinterpreted left turn manoeuvre where the fatally injured cyclist moved to the right before turning left and was in collision with a cyclist following behind. The second case involved a collision between two cyclists that resulted in a cyclist being run over by a tipper lorry. While the lorry accounted for the fatal injuries sustained it was the cyclist collision that was the primary contributory factor.

Contributory factors

- Inappropriate positioning for left turn manoeuvre - cyclist (1 crashes)
- Pedal cyclists not allowing themselves enough space when overtaking (1 crash)
- Other vehicle not allowing pedal cyclist enough space - travelling in close proximity to pedal cyclist in same lane (1 case)
- Complex busy junction (1 crash)
- Road narrowing due to parked cars (1 crash)
- Load on handle bar – cycle lock (1 crash)

3.2.7. Crash group 2 – collisions with cars

There were 15 cyclists who were killed or seriously injured following a collision with a car. In every case, except one involving an opening car door, there was a direct impact between the car and the cyclist. The collisions were categorised into five groups.

- Junction collision, car has priority (6 crashes)
- Same direction collisions (3 crashes)
- Junction collision, cyclist has priority (3 crashes)
- Head on collisions (2 crashes)
- Opening door (1 crash)

3.2.7.1. Crash group 2: Junction collision, car has priority (n=6)

Six crashes occurred when the cyclist crossed the road on which the motorised vehicle (car in all cases) was travelling. In all six crashes, it is thought that the cyclist needed to cross as the road intersected their intended route. All collisions took place on roads with a 30 mph speed limit except one which had a 40 mph limit.

One crash occurred when a car, which was exiting a car park, collided with a cyclist travelling on a segregated pavement style cycle path and approaching from the left. Three crashes occurred when the cyclist was attempting to ride across a dual carriageway from the nearside (left) of car and in each the cyclist was hit in lane 2.

Another crash involved a child cyclist crossing the road at the exit of an off-road cycle path which was surrounded by trees/foliage reducing visibility of the cyclists. The remaining crash occurred when a cyclist attempted to cross a road that intersected a contraflow cycle lane, however in this case, the cyclist was not in the cycle lane when commencing the manoeuvre.

The three dual carriageway crashes occurred in the dark where none of the cyclists had lights and the remaining three had sight obstructions as contributory factors.

Contributory factors

- Confusing road markings on intersection between cycle infrastructure and exits/entrances (1 crash)
- Cycle paths intersecting with entrances/side roads (2 crashes)
- Reduced driver vision: permanent sight obstruction of cyclists approaching on segregated cycle paths (2 crashes) and an on-road contraflow cycle path (1 crash)
- Reduced cyclist vision – permanent sight obstruction of vehicles approaching (3 crashes)
- Illegal speeds - driver (2 crashes)
- Cyclist riding without lights in the dark (3 crashes)
- Cyclists possibly distracted by companion – on same bike (1 crash); on separate bike (1 crash)

3.2.7.2. Crash group 2: Same direction collisions (n=3)

Three crashes were characterised by the cyclist and the car travelling in the same direction, with the cyclist initially ahead, and the driver did not see the cyclist in time to avoid the collision.

In one of these crashes, the car clipped the cyclist with its wing mirror on a 40 mph road. The other two involved cars travelling over the 30mph speed limit (by more than 10mph), one of which involved the cyclist exiting a cycle lane with the intention of turning right when the speeding driver hit them.

Two crashes occurred in the dark and one in daylight. One cyclist, out of the two crashes occurring in darkness, used bicycle lights and was wearing high visibility clothing (yellow jacket with reflective panels).

Contributory Factors

- Large speed differential between cyclist and other vehicle (3 crashes)
- Car travelling at illegal speed (2 crashes)
- Cyclist riding without lights in the dark (1 crash)
- Driving too close to the cyclist (1 crash)

3.2.7.3. Crash group 2: Junction collision, cyclist has priority (n=3)

Three crashes involved cars failing to give way to a cyclist by either pulling out onto (n=1) or turning off (n=2) the road the cyclist was travelling on.

One involved a car pulling out to turn left and colliding with a cyclist travelling on the main carriageway and approaching from the car's right-hand-side.

The second crash involved a car turning into a slip road, which led to a motorway, from lane 2 of a dual carriageway and colliding with a cyclist travelling across the slip road on the main carriageway. The remaining crash occurred when a car turned right into a side road and collided with a cyclist travelling across the mouth of the side road in the opposite direction. The police report indicated the possibility the cyclist may have been pushing the bicycle although this was not confirmed.

Contributory factors

- Inappropriate crossing facilities from cycle path at junction with exit slip road from high speed road (1 crash)
- Reduced driver vision – tinted side windows (illegal - 35% visibility) (1 crash)
- Inappropriate driver manoeuvre – exiting dual carriageway from lane 2 (1 crash)
- Car travelling at illegal speed (1 crash)

3.2.7.4. Crash group 2: Head on collisions (n=2)

Two crashes involved head on collisions where it was not clear why the vehicle/cyclist came into conflict. Both involved cars. One occurred on a blind bend on a relatively narrow country road where a cyclist travelling in the centre of the road collided with an oncoming car. The second occurred when, for reasons unknown, a car travelled onto the opposing carriageway and partially onto the pavement and collided with an oncoming cyclist. There were no sight obstructions in the latter collision.

Contributory factors

- Car speed too fast for stopping sight distance (1 crash)
- Inappropriate manoeuvre – driver crossing to opposing lane into path of cyclist (1 crash)
- Inappropriate cyclist positioning (1 crash)

3.2.7.5. Crash group 2: Opening door (n=1)

In this crash, a car door was opened into the path of the cyclist as the driver had retracted the car wing mirrors before exiting the vehicle and therefore did not see the cyclist. This car also had tinted side windows that would have reduced visibility from the vehicle. In this latter case, a speed cushion is thought to have been a contributory factor as the cyclist took a path very near the parked cars in order to avoid riding over it. In this way the speed cushion can be said to have reduced the width of road available to the cyclist (road narrowing).

Contributory factors:

- Road narrowing caused by traffic calming (1 crash)
- Retraction of wing mirrors before existing vehicle (1 crash)
- Reduced driver vision – tinted side windows (within legal limits) (1 crash)

3.2.8. Crash group 3 – collisions with large goods vehicles

For the purposes of this analysis, the 25 crashes that involved an initial contact between the cyclist and HGVs have been grouped with the 2 crashes that involved initial contact with 3.5-7.5 tonne trucks as their characteristics and crash types are very similar. These are referred to in this section as 'trucks' - other trucks that are included in the sample but were not involved in an initial contact with the pedal cyclists have been excluded from this table. The collision groups have been subdivided into 3 categories and the numbers of cases are shown in Table 27 together with the body type of the truck.

Table 27: Truck body type and collision group

Truck body type	Truck Turning left	Truck and bicycle in same direction	Junction collision – cyclist has priority	Number of crashes
Box	3	1		4
Curtain sided	1	2		3
Flat or drop side	1	2	1	4
Skip carrier	2	1		3
Cement mixer	1			1
Tipper	8	2		10
Tractor unit only		1		1
Refuse lorry			1	1
Total	**16**	**9**	**2**	**27**

3.2.8.1. Crash group 3: Truck turning left (n=16)

The majority of the crashes involving trucks occurred when the cyclist is intending to travel straight ahead and the truck turns left either into a side road or to change lanes. To describe the full range of this type of crash and to highlight 'special cases', the turning left truck crashes have been split into 4 subgroups as follows:

- Setting off – cyclist in Advanced Stop Line (ASL) area (4 crashes)
- Moving/Alongside (7 crashes)
- Unpredictable cyclist behaviour (3 crashes)
- Left turn only traffic, cyclist facility straight ahead (2 crashes)

Truck turning left: Setting off - cyclist in Advanced Stop Line (ASL) area (n=4)

Four crashes occurred when both the cyclist and the truck set off in response to a green light, having previously been stationary, with the cyclist in an ASL area. ASLs are used at some signalised junctions to demark an area where cyclists can wait at a red light ahead of the motorised traffic (Figure 12).

Figure 12: Example of an Advanced Stop line (Metropolitan police image[5])

In three cases, the cyclist had entered an ASL before the lights turned green and are thought to have undertaken the truck while it was stationary. In the fourth case, the truck had entered the ASL resulting in several cyclists becoming positioned on its nearside – it is not known in this case whether the cyclists undertook the truck or were already in the ASL. It was thought that the cyclists were intending to travel straight ahead and one or more were in collision with the truck as it commenced its left turn.

Contributory factors

- Reduced driver vision – cyclist in directly in front of truck (3 crashes), cyclist to nearside (1 crash)
- No Class VI mirror fitted (2 crashes)
- ASL positioned cyclist in area with limited direct vision from the truck (4 crashes)
- Inappropriate positioning – truck entered ASL (1 crash)
- Possible distraction - driver using hands free phone (1 crash)
- Distraction - driver using hand held phone (1 crash)

Truck turning left: Moving/Alongside (n=7)

Seven crashes occurred whilst negotiating a junction, when the truck and cyclist were travelling alongside each other or the cyclist was slightly ahead. In 5 crashes this was due to the cyclist undertaking the truck on the approach to the junction and in one the truck overtook the cyclist on approach to the junction. The remaining crash, occurred on a large busy junction and the cyclist was caught up by the truck after entering the junction ahead of the truck.

It was thought that the cyclists were intending to travel straight ahead and were in collision with the truck as it commenced its left turn.

It is difficult to judge the exact relative positions of the truck and cyclist in these cases as the cyclist was always moving and the truck may have also been moving or just started moving as a result of a change in the traffic light signal to green.

[5] http://content.met.police.uk/Article/Advanced-Stop-Lines/1400018009433/1400018009433

Collisions occurred at the front or nearside front cab area with the cyclists being run over by the front and/or rear wheels.

Contributory factors

- Complex busy junction (1 crash)
- Shared lane for straight on and left turning traffic – pedal cyclist and HGV in same lane (6 crashes)
- Reduced driver vision – cyclist to nearside of truck (6 crashes), cyclist directly in front of truck (1 crash)
- No Class VI mirror fitted (1 crash)
- Inappropriate positioning – cyclist undertaking truck (5 crashes)
- Truck not allowing pedal cyclist enough space - driving in close proximity to the rear of pedal cyclist (2 crashes)
- Late operation of left turn indicator - truck indicated when at front of queue as the traffic light changed to green (2 identified crashes – possibly more but limited evidence available)

Truck turning left: Unpredictable cyclist behaviour (n=3)

Three crashes occurred where cyclists had undertaken vehicles on the approach to junctions by using the pavement. In two cases cyclists rode on the pavement to undertake buses and entered lane 1 to the nearside of the truck. In both of these cases the truck was in lane 2 of 2 and the gap that the cyclists entered in lane 1 was there because other motorists were allowing space for the trucks left turn. In the third case, a cyclist undertook stationary traffic by walking on the pavement and re-entered the road at the front of the queue for the traffic lights and adjacent to the truck.

Contributory factors

- Complex busy junction (1 crash)
- Reduced driver vision – cyclist to nearside of truck (3 crashes)
- HGV turning left from a straight on only lane (2 crashes)
- Inappropriate positioning – cyclist positioning themselves in truck blind spot (2 crashes), cyclist undertaking truck (1 crash)
- Possible distraction: Driver using hands free phone (1 crash)
- Truck not indicating (1 crash)

Left turn only traffic, cyclist facility straight ahead (n=2)

Two crashes occurred on one way sections of junctions where 2 lanes of traffic turn left but a bus and cycle only lane is straight ahead. The road layout/infrastructure encouraged cyclists to cross the 2 lanes of left turning traffic to access the bus and cycle lane and did not provide appropriate infrastructure to access that lane. Both crashes occurred between a cyclist starting in lane 1 and a truck travelling in lane 2. For one crash it was unclear whether the cyclist's intention was to travel straight on or they were trying to join lane 2 and follow the road to the left. The road infrastructure at the site of the second crash has been subsequently altered to create a path to the bus and cycle only lane ahead by redesigning lane 2 as bus and cyclists only.

Contributory factors

- Cycling infrastructure requiring cyclists to cross free flowing traffic to enter (2 crashes)
- Reduced driver vision – cyclist to nearside of truck (2 crashes)
- Inappropriate positioning - cyclist in nearside of lane 1 when needed to be in lane 2 (2 crashes)

3.2.8.2. Crash group 3: Truck and cyclist moving in same direction (n=9)

Nine crashes occurred when cyclists and trucks were travelling in the same direction and in the same lane and collided while travelling alongside each other. Seven of these crashes are characterised by the cyclist ‘running out of space’ meaning that the available lane width narrowed forcing the cyclist and truck into closer proximity.

Of these, five crashes occurred at junctions – both the truck and the cyclist were turning left in two cases, turning right in one and travelling straight on in two. The sixth occurred as the road narrowed on the approach to a junction and the seventh crash occurred in close proximity to a pelican crossing on a build-out.

In three of the same direction crashes, the truck was just starting to move in response to a green light and the cyclist was probably moving. In one crash both the truck and the cyclist were setting off from stationary and for three both the cyclist and the truck were moving when the crash occurred.

There were ASLs present at two junctions, it was not known whether one cyclist had entered it before both vehicles moved off in response to a green light and began to turn left. In the second crash the cyclist had entered an ASL and in the third the cyclist pulled into a gap in front of a truck that was several vehicles away from the lights. The cyclist’s intended manoeuvre at the junction was not known.

Initial contact (5 crashes)/loss of control (2 crashes) occurred at the nearside front area (cab). In one of the loss of control cases, a damaged road surface resulting in the cyclist clipping the kerb, which contributed to the crash. The cyclist was run over or dragged by the rear wheels in five crashes, the front wheel in one crash and both the front and rear wheels in the remaining crash.

Contributory factors

- Reduced driver vision – cyclist on nearside of truck (6 crashes)
- Reduced driver vision – cyclist directly in front of truck (2 crashes)
- Inappropriate positioning – cyclist undertaking truck (4 crashes)
- ASL positioned cyclist in area with limited direct vision from the truck (1 crash)
- No Class VI mirror fitted (1 crash)
- Road narrowing – pedestrian facilities (3 crashes), parking bays/parked cars (1 crash)
- Pedestrian guard rails and kerb stones – maintaining cyclist in proximity to truck (2 crashes)
- Road damage (destabilising cyclist) – pot hole (1 crash); rutted surface (1 crash)
- Truck not allowing enough space for cyclist - overtaking on approach to red light (1 crash)

3.2.8.3. Crash group 3: Junction collisions – cyclist priority (n=2)

Two crashes involved trucks that failed to give way to a cyclist. One involved a truck turning left out of a minor road and colliding with a cyclist approaching from the right. The cyclist was travelling in a shared bus and cycle lane that ended at the junction and recommenced immediately after it.

The other crash involved a truck turning into a car park across the path of a cyclist on an on-road cycle lane (same direction – which ended at the car park entrance). In this case, however, the cyclist was effectively legitimately undertaking the truck as the truck was travelling in a slower moving lane.

Contributory factors

- Cycle lanes intersecting entrances/side roads (2 crashes)
- Cyclist undertaking slower moving truck (1 crash)

3.2.9. Crash group 4 – collisions with buses (n=3)

Three crashes involved double decker public service buses. Although these crashes could have been grouped with the HGV/3.5-7.5 tonne vehicles, they have been treated separately here as the PSV body style and route types are different. The lower driving position and large wing mirrors provide the PSV driver with much better vision than most HGVs. PSVs sometimes travel in areas where other motorised vehicles are prohibited and many bus lanes in London are shared by cyclists.

One crash was 'left turn/moving alongside' and another was a conflict within a junction where the cyclist moved lanes to the offside as the PSV moved to the nearside. A contributory factor in this latter crash was an illusion of road narrowing created by adjacent road works and the junction bending to the left. The third involved a cyclist being crushed between two buses at a road works site. The first two crashes occurred at night and the third during the day.

Contributory factors:

- Complex busy junctions (1 crash)
- Road narrowing due to road works (2 crashes)
- No road markings on junction (1 crash)
- Inappropriate positioning – cyclist undertaking bus (1 crash)
- Driver not allowing cyclist enough space to perform a manoeuvre (1 crash)
- Inappropriate lane positioning – both driver and cyclist (1 crash)

3.2.10. Crash group 5 – collisions with vans (n=2)

Both of the vans in this section were panel vans with a maximum weight of 3.5 tonnes. One crash involved a van travelling on a 70mph dual carriageway road which had changed lanes into the lane the cyclist was travelling in shortly before the collision. This occurred within an hour of sunset when it is thought that the sun was low and potentially causing glare.

In the second crash, the cyclist was run over by a van in stop-start traffic, when the cyclist lost control while trying to overtake the van to its offside. In this latter case it is thought that the cyclist was destabilised when their handle bars clipped the side of a lorry travelling in the opposite direction.

Contributory Factors

- Large speed differential between cyclist and other vehicle (1 crash)
- Possible impaired driver vision – sun glare (1 crash)
- Inadequate space for overtaking selected by cyclist (1 crash)
- Load on handle bars (1 crash)

3.2.11. Crash group 6 – collisions with motorcycles (n=1)

Only one crash involved a motorcycle. This occurred when a motorcycle clipped the cyclist with its wing mirror whilst attempting to overtake, having just undertaken a taxi which was travelling immediately behind the cyclist. It is likely that the taxi blocked the motorcyclists view of the cyclist prior to the motorcyclist's undertake manoeuvre.

Contributory Factors

- Reduced driver vision – temporary sight obstruction (1 crash)
- Motorcyclist did not allow enough space for the cyclist when overtaking (1 crash)
- Undertake manoeuvre by motorcyclist immediately prior to crash (1 crash)

3.3. Relative movement of cyclists to large vehicles

One aspect of cyclist and driver behaviour that was a focus of the analysis of crashes involving large vehicles (HGVs, 3.5-7.5 tonne trucks, buses and coaches) was undertake and overtake manoeuvres. These manoeuvres have been examined in this section in the context of relative movement to determine how the cyclist and large vehicle moved relative to the other on the lead up to the crash. Relative movement can be described broadly as a movement made by one of the collision partners that brought them into the collision; for example a cyclist may overtake a stationary truck on the approach to a red light (the cycle moved relative to the truck) or a truck may overtake a moving cyclist (the truck moves relative to the cyclist). The information is intended to guide future recommendations relating to driver and cyclist education.

Determining relative movement of cyclists and other vehicles on the approach and around a collision is fraught with difficulties. For example, in cases with information such as CCTV footage (‘from’ the vehicle or ‘of’ the vehicles), the combination of low frame rate, poor image resolution and compromised camera location often provide poor detail; CCTV is not normally designed or positioned to capture information on cycle crashes. Cases with corroborative witness information can be used to an extent but witnesses can rarely give precise measurements or accurate speeds with which to precisely place relative positions throughout the event.

The two broad categories of interest within this analysis were whether the cyclist passed the large vehicle or whether the large vehicle passed the cyclist; hence determining the vehicle which moved relative to the other. Within this it is also possible to identify the status of the other vehicle; whether it was stationary or also moving. For added depth it was also possible to determine whether the large vehicle was turning left or right (it was not always possible to determine where the cyclist was heading hence this information is excluded from the cyclist categories). 30 large vehicle crashes were appropriate to be included in the analysis and the number of crashes in each of the above categories is recorded in Table 28.

Table 28: Relative movement of cyclists and large vehicles at point of collision

Relative movement	Number of crashes
Cyclist overtaking stationary large vehicle	2
Cyclist overtaking moving large vehicle	0
Cyclist undertaking stationary large vehicle	11
Cyclist undertaking moving large vehicle (not turning)	1
Cyclist undertaking moving large vehicle which was turning right	0
Cyclist undertaking moving large vehicle which was turning left	8
Both moving together (similar speed)	2
Large vehicle overtaking stationary cyclist	0
Large vehicle overtaking moving cyclist	3
Other crash configuration	3

In total 22 of the 30 vehicles that manoeuvred relative to the other vehicle by travelling at the higher speed were cyclists. Within this group the most common scenario involved undertaking a stationary large vehicle to the nearside (eleven cases). A further eight cases involved a cyclist making a manoeuvre relative to the large vehicle as it was attempting or in the process of turning left. It should be noted at this point that these eight undertake manoeuvres may have been due to the large vehicle slowing down and not necessarily because of any conscious choice on behalf of the cyclist.

With large vehicles the relative movement in respect to the cyclist was overtaking a moving cyclist (3 crashes).

3.4. Analysis of injuries

This section describes the injuries that were sustained by the pedal cyclists in the sample who were fatally injured. Injury information was extracted from the post-mortem reports of the fatalities. A standard system, the Abbreviated Injury System (AAAM 2008) was used to record the details using a form that was readily analysed. Each injury is allocated a seven digit code that describes the injury and rates the severity according to a 6-point scale where a severity of 1 indicates minor injuries such as cuts and bruises while 6 indicates injuries that are currently untreatable. A code of 9 indicates insufficient information to code the injuries. The Maximum AIS (MAIS) is then derived for each body region. The injury information of the seriously injured casualties was extracted from the police files however these rarely contained sufficient levels of detail to enable an accurate coding and therefore pedal cyclists with serious injuries were excluded from this analysis.

3.4.1. Injury patterns

Recordable injuries were available for 41 of the 46 of the fatally injured cyclists. Injuries were coded using AIS 2005 (2008 update) and where incomplete details of injuries were noted a conservative severity code was assigned. The Maximum AIS was assigned to each casualty and ranged between MAIS 3 and MAIS 6 (Figure 13).

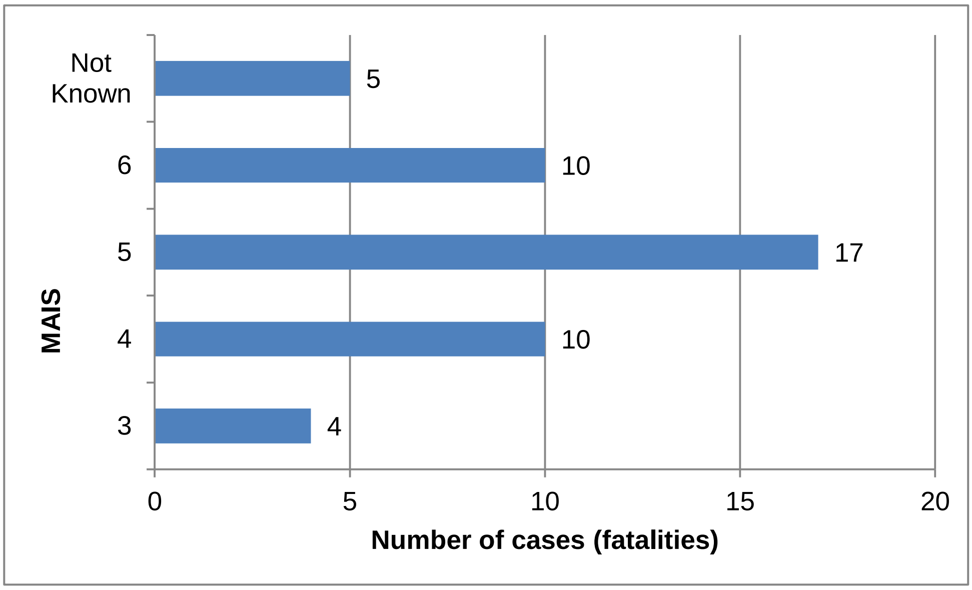


Figure 13: MAIS distribution of fatalities

This variation in severities was further reflected in the Injury Severity Score (ISS), which is a measure of the multiplicity of injury and is a better predictor of risk of death than AIS. ISS is calculated as the sum of the squares of the AIS values of the three most severely injured body regions and is specified as having a maximum value of 75 (Figure 14)

$$Injury\ Severity\ Score = MAIS_{head}{}^2 + MAIS_{chest}{}^2 + MAIS_{legs}{}^2$$

Figure 14: ISS score formula with example body regions

Overall the mean ISS was 39 (range 9-75, standard deviation 22). Figure 15 shows the median ISS value of the cyclists in collision with large vehicles – trucks and buses – was approximately 34 compared with 46 for those in collision with cars however the two distributions were not significantly different.

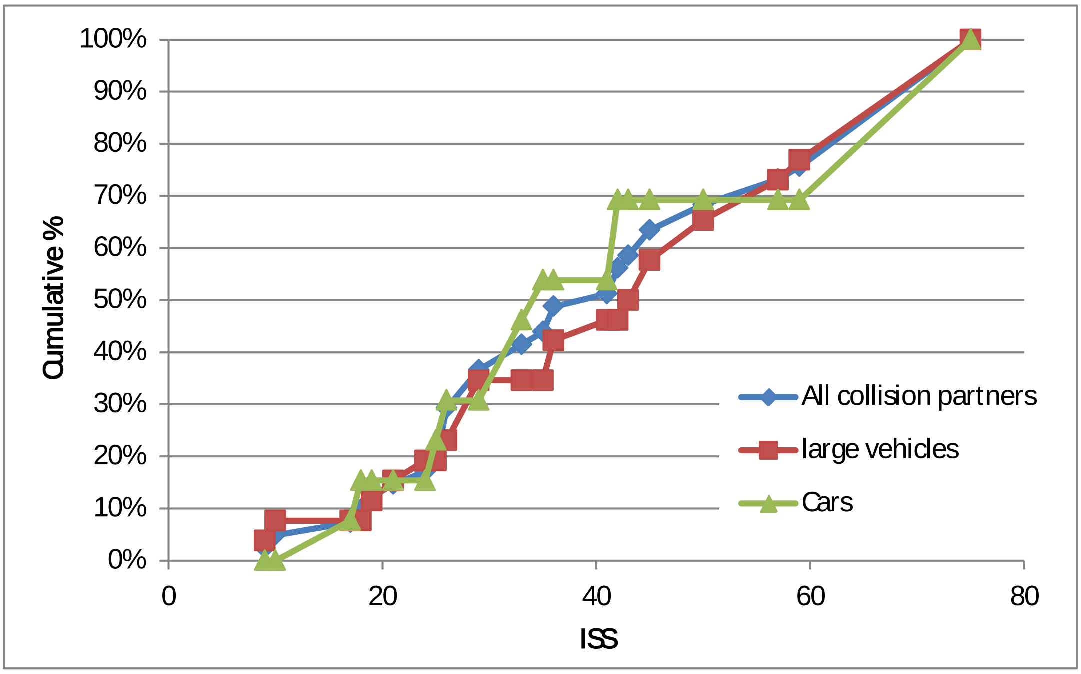


Figure 15: Cumulative percentage of ISS score

The MAIS for each body region all of the fatally injured casualties is presented below in Table 29 which shows the distribution of the highest severity injuries. There were 5 fatalities for whom detailed injury information was not available, and the table shows that the body regions most commonly injured was the external body surface which were sustained by 37 of the 41 cyclists with known injuries. These injuries were typically cuts and bruises which did not involve a high threat to life. Figure 16 below shows the pattern of injuries rated AIS 3 or above and at AIS 4 or above.

Table 29: MAIS for each body reason for fatally injured pedal cyclists

Body region	Head & neck	Face	Thorax	Abdomen	Extremities	External
MAIS1	0	0	0	0	0	25
MAIS2	3	6	1	5	12	12
MAIS3	5	1	4	1	7	0
MAIS4	5	1	13	9	5	0
MAIS5	8	0	5	4	2	0
MAIS6	7	0	5	0	0	0
No injury	13	33	13	22	15	4
Not known	5	5	5	5	5	5
Total	46	46	46	46	46	46

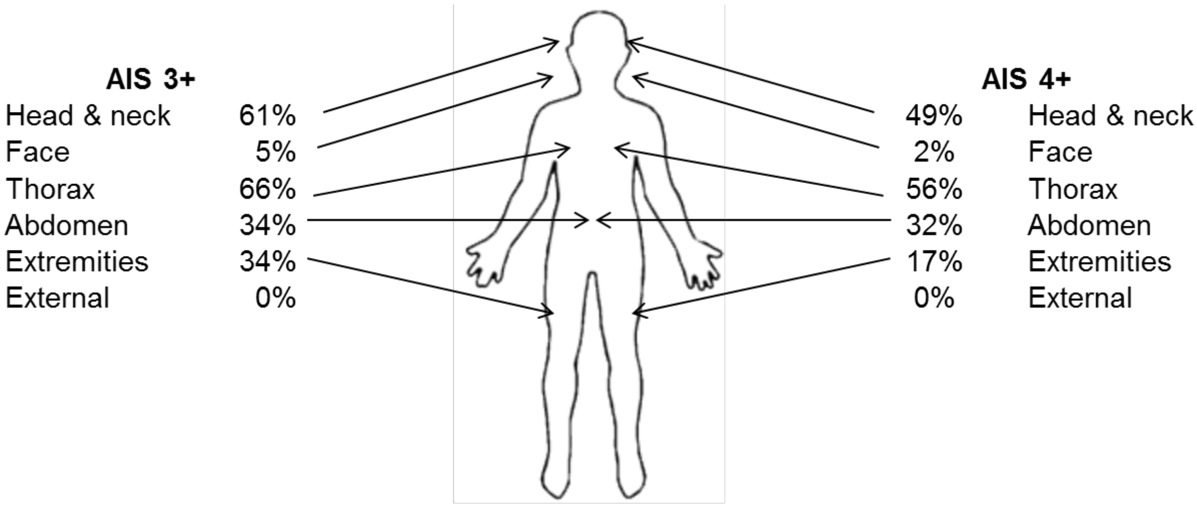


Figure 16: Distribution of body region AIS for cyclist casualties

Figure 16 shows that the body regions most commonly injured at each of the severity levels were the thorax and the head/neck. 66% of the casualties with known injury details sustained AIS 3+ injuries to the thorax and 56% at AIS 4+.

Overall the injuries sustained to the face and external body regions were minor AIS1 injuries incorporating bruises, lacerations and abrasions to all body regions. The MAIS2 external injuries constituted serious degloving or avulsion type skin injuries often from the tyres of the vehicles involved.

Head and neck injuries ranged between skull fractures and moderate brain injury (MAIS2), to the more serious brain injuries/neck injury (MAIS3-5) and to the catastrophic crush type injuries (MAIS6).

The face sustained relatively fewer injuries but those serious MAIS3&4 injuries were typically a result of crush type injuries destroying the facial bones.

The thorax was defined to include the thoracic spine but on the whole the MAIS3-MAIS5 injuries were combinations of organ injury and severe fractures to the ribs. The MAIS6 injuries were again crush type injuries destroying the integrity of the chest.

The abdomen contains various organs of which the damage ranged between minor contusion or laceration organ injury to the ‘burst’ type injuries at MAIS4 and MAIS5.

In the extremities the MAIS2 injuries were fractures to the arms and legs and those MAIS 3+ injuries were femur or pelvic fractures.

This analysis has focussed on the injuries of fatally injured cyclists in London. To add a further dimension and to put these injuries in context, a newly available national database was examined. The data comprises STATS19 which was linked to the Hospital Episode Statistics data (HES) for the years 1999 to 2010[6]. HES data is collected when a person is treated at an NHS hospital and injury and illness information is recorded using the International Classification of Diseases (ICD-10). The linked dataset incorporates details of the injuries of 16,011 seriously or slightly injured cyclists who sustained 31,211 injuries which have been categorised by body region in Figure 17. The head was the most frequently injured body region followed by lower extremities and upper extremities. This suggests that the prevention of head injuries is a priority for mitigating slight and serious injury crashes involving pedal cyclists.

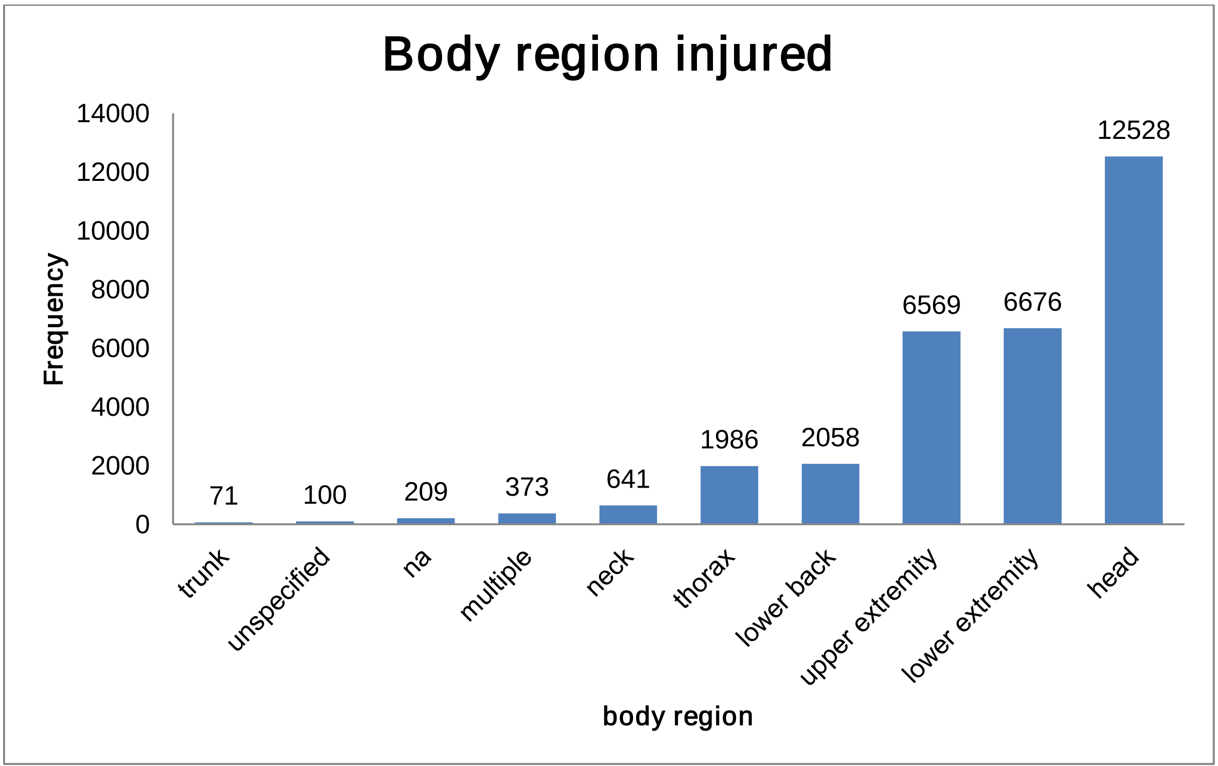


Figure 17: STATS19 and HES Linked data – body region injured

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3.5. Summary of main factors contributing to cyclist fatal and serious crashes

The contributory factors identified amongst each group of collisions in this section are those that are specific to each crash. This section summarises the factors into three groups relating to the environment and infrastructure (Table 30), vehicles (Table 31) and road user behaviour (Table 32). It should be noted that more than one factor may apply to each crash.

3.5.1. Infrastructure contributory factors

Table 30: Environment/Infrastructure contributory factors

Contributory Factor	Collision Partner						Total
	Pedal Cycle	Car	Van	Motor-cycle	Bus	HGV / 3.5-7.5 tonne	
Complex busy junctions	1				1	2	4
Cycle infrastructure integration		4			1	15	20
Vision obstructions		6	1	1			8
Road narrowing	2	1			2	6	11
Blind bend		1					1
Road surface condition	1					2	3
Total	4	12	1	1	4	25	47

The most common group of infrastructure-related contributory factors were those describing the manner in which cycle infrastructure integrated with the wider road system. There were 20 cases where this was found to relate to the crash causation, typically these described junctions where cyclists within an ASL were not in the line of direct vision of a truck driver (5 crashes) and a lane that was shared by cyclists going straight-on with an adjacent truck turning left (6 crashes). There were a further 6 crashes where a cycle lane or path ended at a junction with no further support for cyclists (6 crashes).

A further 11 factors identified road narrowing as contributing to the causes of the collisions. Narrowing most commonly occurred where pedestrian facilities such as build-outs or guard rails were present (5 crashes) and where parked cars or traffic calming facilities reduced the available road width (4 crashes).

A further category of factors observed was identified as the presence of a complex, busy junction (4 crashes). Such a junction would have very high motorised vehicle flows together with high cyclist flows and the fatalities were often indicative of a location where many non-fatal cyclist collisions also occurred.

A common feature of these first three groups of factors is that they all involve increased conflicts between cyclists and motorised road users as a result of high traffic flows, a reduced road space or other infrastructure designs.

3.5.2. Vehicle contributory factors

Table 31: Vehicle contributory factors

Contributory Factor	Collision Partner						Total
	Pedal Cycle	Car	Van	Motor-cycle	Bus	HGV / 3.5-7.5 tonne	
Driver vision of cyclist		2				30	32
Pedal cyclist run over/dragged by vehicle		2	1		2	29	34
Load on handle bars	2		1			1	3
Total	2	4	2		2	59	69

There were two main groups of vehicle factors that related either to the injury or crash causation. 34 fatal cyclists sustained their injuries by being run over or dragged along by the collision partner, 29 of these involved trucks. While many of the trucks were equipped with side guards these were not generally sufficient to prevent the cyclist injuries since in most cases the cyclist was already on the ground before the second axle approached – see section 4.3.1.3 for an analysis of side guards in the sample.

The second most common factor, also most commonly relating to trucks, involved the driver not having direct vision of the cyclists i.e. sight of the cyclists without reliance on mirrors. In 19 crashes direct vision to the left side of the vehicle was inadequate with a lack of direct vision to the front of the truck a factor in a further seven crashes. While class V or Class VI mirrors may have been fitted to the truck, the combination of field of view, driver workload and the relative movements of the cyclist and truck resulted in the truck driver not seeing the cyclist before the collision.

3.5.3. Road user contributory factors

Table 32: Road User contributory factors

Contributory Factor	Collision Partner						Total
	Pedal Cycle	Car	Van	Motor-cycle	Bus	HGV / 3.5-7.5 tonne	
Positioning – cyclist[7]	1				2	15	18
Positioning - other vehicle[8]				1	1	1	3
Not allowing self enough space when overtaking – cyclist	2		1				3
Not allowing cyclist enough space - other vehicle[9]	2			1	1	2	6
Inappropriate manoeuvring[10]		2				5	7
Distraction: other vehicle driver						3	3
Distraction – cyclist		2					2
Alcohol impairment (over legal drink drive limit)	2	2	1			1	6
Retraction of wing mirrors before existing vehicle		1					1
Other vehicle travelling at illegal speed		5					5
Pedal cyclists riding without lights in the dark		4					4
Total	5	16	2	2	4	27	58

There were 58 road user related factors recorded, these related to the decisions made while in control of the vehicles in the time preceding the crash. There were 18 crashes where the cyclist took an inappropriate position in relation to the collision partner, 15 of these involved trucks and a further two buses. In these crashes the cyclist typically moved forward to the left side of the truck or bus either while it was stationary or whilst it was moving into position at a junction. This placed the cyclist in a zone of potential conflict with the vehicle where it was inherently more difficult for the truck driver to see the cyclist. This factor is closely related to vehicle factor "Driver vision of cyclist".

Inadequate space was also identified as a factor relating to the crash causation in a total of 9 crashes. Six of these occurred when the driver of a vehicle passed too

[7] E.g. undertaking, positioning self in blind spot, poor lane position for intended manoeuvre
[8] E.g. overtaking immediately prior to crash, entering ASL
[9] E.g. when overtaking or not allowing cyclist enough space to perform their manoeuvre
[10] E.g. exiting a junction from the wrong lane, late operation of indicators, crossing to opposite carriageway

close to the cyclist and the two involved a cyclist passing through a gap that was too small in order to overtake or undertake and the remaining case involved a cyclist travelling too close to parked cars when overtaking.

There were six crashes that involved road users being above the legal limit for alcohol, in four of these it was the driver and in two it was the cyclist who was above the legal alcohol limit. There were also five crashes that involved a driver travelling above the speed limit, a car driver in all cases, and a further four where cyclists were riding in the dark without lights. In all of these crashes it was concluded that the factors did increase the risk of the collision occurring.

Distraction was less common, involving only three of the drivers who were definitely or probably distracted by using a phone and two cyclists who may have been distracted by other cyclists. The case review did identify seven cyclists who were using headphones at the time of the collision and these were judged to have increased the risk of the crash in two crashes.

4. COUNTERMEASURES

4.1. Introduction

The countermeasures detailed in this chapter set out measures that could have prevented or mitigated the crashes and injuries detailed in this sample. The sample is small because fatalities and serious injuries occur relatively infrequently and because the overall number of casualties for London is relatively small at around 4,000 per year.

The countermeasures and related discussion have been split into four elements of the road system: Infrastructure, Vehicle, Road User and Management. These cannot be viewed in isolation from each other as they are interlinked within the road system. The most effective approach will be to take measures from all four sections for implementation. Some countermeasures will have a bigger impact than others, some may be more achievable in the short term and some in the long term and the cost will differ substantially between them. No attempt has been made in this document to rank countermeasures in terms of these variables - however a general evaluation according to evidence from systematic reviews has been undertaken and discussed in Chapter 5.

Two types of countermeasures have been addressed in this chapter – specific and general. Most of the countermeasures fall into the specific category and aim to address specific contributory factors as identified in chapter 3. For these countermeasures, the contributory factors and relevant number of crashes have been stated within the text. The second type, general countermeasures, are measures that apply to the majority of crashes and/or the road system as a whole. All countermeasures and the number of crashes that relate to them are summarised at the end of this chapter in section 4.6.

Countermeasures are indicated by bold italic text and enclosed in a box along with a discussion of the specific countermeasure(s) and relevant examples of how the countermeasure could be implemented. Indented countermeasures are a more detailed variation of the main countermeasure. These sections do not discuss every option available and the choice of which countermeasures to implement requires expert knowledge of infrastructure and location which is beyond the scope of this report.

4.2. Infrastructure related countermeasures

Changing the infrastructure is complex and may affect many different road users whose views need to be taken into account alongside impacts on capacity. There are a number of stakeholders that also need to be involved. For example, whilst Transport for London (TfL) has produced London Cycling Design Standards (LCDS, TfL 2005) implementing change may also require regulatory actions from the DfT.

Many countries adopt broad principles about how cyclists should be accommodated within the infrastructure and in particular whether or not cyclists should be segregated from other vehicles. The German Guidelines for Cycling Facilities (ERA 2010, cited in ETSC 2012a), 2010 use a function based on traffic speed and traffic volume when recommending whether bicycle-specific infrastructure must be built for the protection of cyclists. They recommend that cyclist and motorised traffic is mixed only in cases of relatively low speed and low traffic volume e.g. less than 800 vehicles per hour at 30 Kph (18mph) or less than 400 at 50 Kph (31mph) (zone I, Figure 18). Some form of physical separation should be used for all other situations – cycle lanes within zone II and greater forms of physical segregation in zones III and IV (Figure 18).

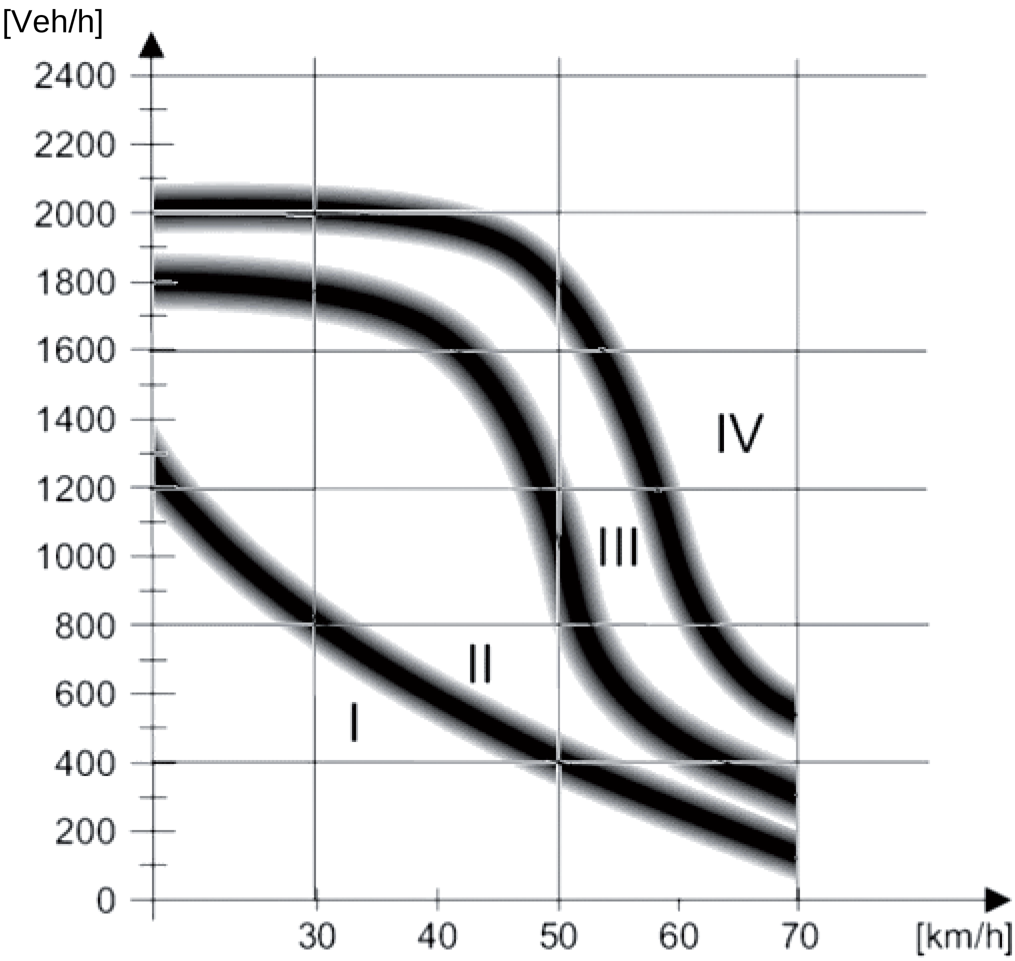

Figure 18: ERA speed verses flow diagram for determining level of segregation (2010, cited in ETSC 2012a)

Similarly the DfT (2008) recommend that separate cycle tracks should be used where flows are more than 300 vehicles per hour and speeds are greater than 40 mph though below this speed, even when flows are high, they recommend that either lanes or tracks can be used. The London Cycling Design Standards (TfL, 2005) have similar recommendations stating that cycle lanes or off-carriageway cycle tracks or shared paths should be used where motor vehicle speeds and/or flows are medium or high (greater than 30 mph and 3000 vehicles per day). The Manual for Streets 2 (CIHT, 2010), suggests that such analysis based on place and movement may be preferable.

The Manual for Streets 2 provides guidance for the design, construction, adoption and maintenance of urban streets. These principles include:

- Applying a user hierarchy to the design process with pedestrians and cyclists at the top
- Promoting an inclusive environment that recognises the needs of people of all ages and abilities
- Reflecting and supporting pedestrian and cyclist desire lines in networks and detailed designs
- Moving away from hierarchies of standard road types based on traffic flows and/or the number of buildings and adopt an alternative approach of defining street hierarchies, based on their significance in terms of both place and movement.

This is reflected in the Road Task Force's (RTF) framework for managing and developing London's roads (RTF, 2013). It is described as a local and network approach where the 'Place' (local) needs are balanced with the 'Movement' (network) needs, taking into account whether these needs of local or strategic significance. This has led to the development of the London street family which is comprised of 9 road typologies as set out in Figure 19.

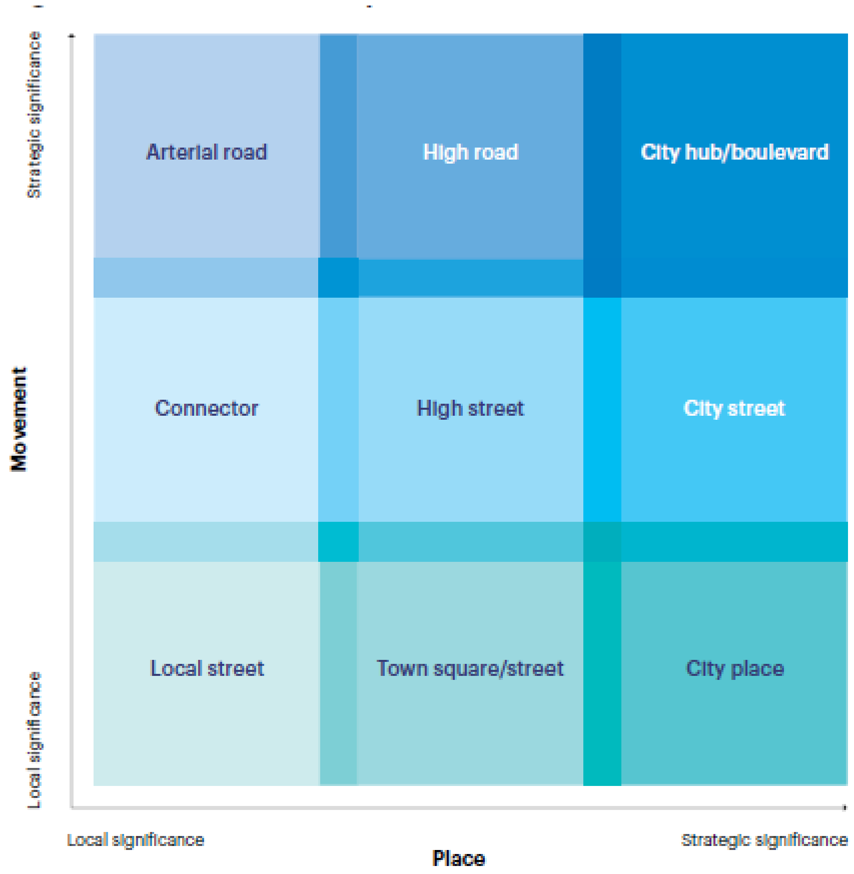

Figure 19: The London Street family (RTF, 2013)

The need/appropriateness of different types of infrastructure to benefit cyclists is therefore informed by the designation of the road/route as set out in Figure 19.

Two additional factors that relate to this and also influence what kind of infrastructure is appropriate are traffic mix and the speed differential between road users at a particular location. Traffic mix refers to the share of different types of vehicles that use a particular stretch of road and this relates to the likelihood of vehicles with different mass interacting as this creates an increased risk of harm as a result of a crash for the vehicle with the small mass. For example, cyclists may need more protection to be provided by the infrastructure if there is a high volume of both cyclists and HGVs negotiating the same junction. Alternatively, the classification above would be used to identify roads and places where cyclist-vehicle conflicts should be minimised.

Speed differential is an issue for cyclists when other road users can travel the same stretch of road at a much greater speed. For example, on roads with speed limits of 40mph or more, the majority of cyclists would be travelling much slower than the rest of the traffic giving motorists less time to react to the presence of a cyclist than on slower speed roads. The consequences of a crash are also likely to be greater in this situation as the cyclist would be hit at a much faster speed.

If bicycles and motorised vehicles are to share the same space, then the risk to the cyclist has to be managed by minimising the number of conflict points the cyclist has to encounter. The majority of conflict points, where road users potentially can share the same space at the same time, occur at junctions as illustrated in Figure 20.

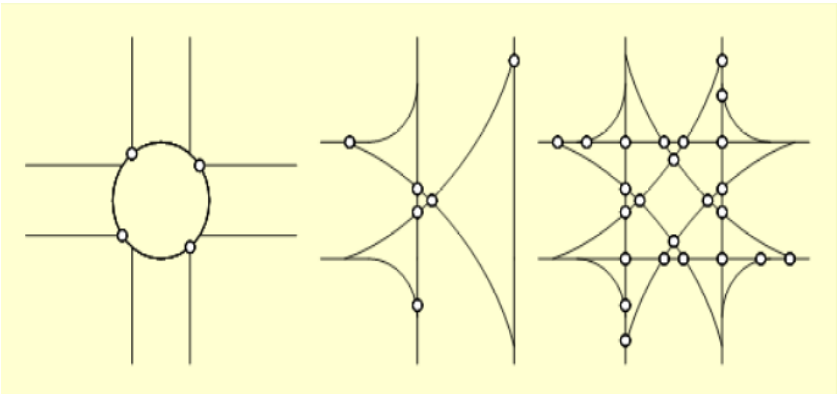

Figure 20 Junction conflict points, cited in ETSC (2012a)

When negotiating busy complex junctions, cyclists encounter many more conflict points than shown in Figure 20. Multilane stretches of roundabouts that make it necessary to travel a distance between entry and exit create both linear sections and zones of conflict points where traffic has to change lanes. It is particularly important to create safe infrastructure at such locations as they are likely to be important routes for cyclists as well as other road users. Such junctions also increase the likelihood of cyclists coming into contact with large vehicles – the type of vehicle that has the potential to do them most harm. Examples of such junctions are Marble Arch and Old Street roundabout.

Redesigning or replacing one junction type for another can reduce the number of conflicts. However for cyclists, potential conflict points can also occur on roads where infrastructure such as lane narrowing, parked cars or traffic calming are present as they force cyclists and other road users to change their road positioning.

A judgement has to be made about whether it is possible to adequately reduce/minimise conflict points through infrastructure design on a route or at a particular location. If conflicts points cannot be reduced then, the only other option is to reduce exposure to conflict points is to segregate cyclists from other traffic. This segregation could be in time and/or space e.g. allowing cyclists a head start at traffic lights or be partial or full physical segregation e.g. a junction bypass or off road cycle track. The most appropriate application of segregation is very dependent upon location therefore this report can only discuss potential solutions. The authors do not advocate a one size fits all approach. There is a policy to increase cycling by providing a more attractive environment and it is considered that segregation should be preferred unless on road risks (speed, flow and number of conflict points) are sufficiently low. The locations of the fatal cyclist collisions tend to occur along main routes and towards the central areas of London where there are higher flows of cyclists and motorised traffic, these tend to be areas of higher conflicts where large degrees of segregation between cyclists and motorised traffic could provide substantial safety benefits.

4.2.1. Complexity of designing infrastructure for cyclists

It is envisaged that for some road types on-road cycle provision may provide sufficient levels of safety given the level of conflicts whereas for others with movements as strategic significance, segregated cycling infrastructure is likely to be the only option. It is recommended that a manual is created that sets out guidelines for the most appropriate infrastructure for each of the road types depicted in Figure 19. This can then be used to guide the design process.

Create a manual with guidelines for appropriate cycling infrastructure for each of the road typologies in the London street family

Conduct an area review when designing new or altering existing road infrastructure to take into account cyclists needs

It is important that cyclists are taken into account when new infrastructure is introduced, not just when cycle infrastructure is proposed or existing infrastructure is modified. The Manual for Streets 2 defines minimum design levels for cyclist provision however to encourage increased cycling it is necessary to decrease real levels of risk and to increase perceived cyclist safety. To achieve this it is necessary to go beyond the minimum design standards and provide the very best cycling environment possible. Many examples from other countries with high cycling levels are available to illustrate particular features and practices (Urban Movement, 2014).

Independently introducing a single piece of infrastructure may introduce unintended conflict points into the road system if the road infrastructure of the specific location and the surrounding area is not taken into account.

In addition the likelihood of cyclists using cycle infrastructure has to be taken into account during the design process as there will be little safety benefit if the infrastructure is not used or not used in the way in which it was intended. A way of ensuring that cycling infrastructure is fit for purpose is to engage cyclists by employing methodologies such as co-design. Co-design is where users, in this case cyclists, play an active role in the design process by discussing issues and potential design solutions in settings such as focus groups.

In addition to applying a road safety audit it is recommended that a review is conducted of the specific location and surrounding area affected by the proposed new or alterations to existing road infrastructure. This review should include traffic flow and the routes taken by road users using the existing infrastructure. It should also take into account how the proposed infrastructure links into what exists already and the implications for cyclists. This process should be used to identify measures that could be included to minimise the risk of cycling. Road safety auditors would have a valuable advisory role in the review however the review should not replace the road safety audit.

Additional guidelines for designing cycle infrastructure can be found in TfL's LCDS (TfL, 2005) and the Department for Transport report *Cycle Infrastructure Design* (DfT 2008).

4.2.2. On-road or segregated cycling facilities

The following sections addressing segregated cycling facilities (section 4.2.3) and on-road cycling facilities (section 4.2.5) aim to set out countermeasures to the factors identified as contributing to the fatal and serious crashes included in the sample.

4.2.3. Segregated cycling facilities

If the purpose of the road, e.g. promoting movement of strategic importance, or the physical restraints of the location make it too difficult to introduce on-road cycling infrastructure, then the cyclists' exposure to conflict points has to be reduced by using segregated cycle infrastructure:

Segregation can be used to reduce the likelihood of crashes between pedal cyclists and motorised vehicles occurring as it reduces the number of conflict points. However, most segregated infrastructure intersects roads without segregation and at these points the risk of crash can be high.

Two crashes in the sample occurred whilst the pedal cyclists was travelling on a segregated cycle track/path – at the point at which the track/path intersected a road/entrance without segregation. In a third crash the cyclist was travelling on the main carriageway alongside a segregated cycle path. During the case review process, suggestions for improvements in segregation were suggested for all three of these crashes.

For the remaining 50 sample crashes, the judgement about whether segregation would have reduced the likelihood of the crash is a complex one. If the segregation was to be complete then the majority of crashes could be avoided however practical constraints such as available space and the cost-benefit of implementation of this makes this option unrealistic. Segregation is most likely to be of value for 10 of the sample crashes where the traffic speed and/or flow was relatively high. The case review process identified the value of segregation at the particular location for a further 4 crashes.

Therefore, for 14 cases, segregation has been identified as an intervention that could mitigate future crashes and in a further three cases making improvements to existing segregation could have a similar effect. That is not to say that segregation would be of no value in the remaining cases, rather that there was insufficient information available to the researchers in order to make that judgement.

Use segregated cycle infrastructure unless the risks and conflicts associated with on-road cycling are sufficiently low.

Segregated cycling infrastructure can be used in a variety of different ways from a small section to route cyclists through a junction to a whole route where cyclists are separated from motorised vehicles. Where there are wide pavements infrastructure could allow left turning cyclists or those heading straight on to negotiate the junction alongside pedestrians. This could be done by cutting a path across the pavement to safely route cyclists through the junction (see Figure 21).

An important consideration to be made when designing segregated infrastructure is the likelihood of cyclists using it. According to DfT (2008) off road routes in urban areas may not be preferred if the cyclist has to give way at many entrances and side roads and the path repeatedly ends on one side of the road and continues on the other. In these circumstances cyclists should have priority over vehicles emerging from the entrances.

For busy complex junctions, one effective option may be to build specific cycling infrastructure that separates cyclists from other traffic without increasing their journey time. An example of the type of infrastructure that has been used in other countries is the Hovenring constructed in the Netherlands (Figure 21). Care has been taken to reduce the impact on cyclists by lowering the level of the road passing beneath it therefore allowing shallower grade entrance and exits ramps.

Figure 21: Example of grade separated cycle infrastructure in the Netherlands – the Hovenring

The Hovenring example is a highly complex solution, however many other options are available for full or partial segregation. For example, if adjacent land is available then cycle only tracks or shared cycle and pedestrian footpaths could be considered. Routes through adjacent park land might provide an alternative – especially if this speeds up the cyclist's journey. Opportunities for routing cyclists along lower flow routes or lanes could also be considered, such as use of a contraflow bus lane to bypass the gyratory system. This could increase the relative safety of cyclists by reducing exposure to other vehicles (see Figure 24).

4.2.4. Managing the interaction between cycling facilities and other roads

An issue highlighted by the fatal and serious crashes is that cyclists are vulnerable when the cycling infrastructure they are using intersects another road. The following contributory factors were recorded for 4 crashes:

- Cycle lanes/paths ending at intersections with entrances/side roads' was contributory in 4 crashes (2 cars, 2 HGVs)
- Confusing road markings on intersection between cycle infrastructure and exits/entrances (1 car)

In addition, sight obstructions were identified as contributory factors in three cases involving cars where the cyclist was attempting to cross other roads that intersected the segregated cycle path (2 cases) and on-road lane (1 case) that they were travelling on.

Consider how to facilitate safe entrance and exit to cycling facilities

Many of the conflict points that a cyclist will encounter occur when they are entering and exiting a cycle facility whether it is 'on-road' or 'segregated'. This has previously been discussed in relation to ASLs (see section 4.2.5.3 'The role of Advanced Stop Lines (ASLs)') but is equally important for other types of infrastructure.

Establish and maintain clear sight lines both for cyclists and other road users when cycle path/tracks cross other roads

Physically being able to see each other is a necessity for both the visibility of cyclists and the vision of motorised road users:

Vegetation, boundary fences and buildings can reduce road users' vision of each other. The cyclist needs to be able to get into a position that allows them to see and be seen. Vegetation may need removing or cycle tracks moving/extending to allow this to happen. Regular checks will be necessary to ensure that vegetation has not regrown and the existence of a cycle lane/track needs to be taken into account when inserting new roads/entrances/exits.

Design road infrastructure that prioritises cyclists

Another way of managing the intersections between cycling facilities and other roads is to use infrastructure that prioritises cyclists and if necessary, provides them with a right of way.

Providing or altering road infrastructure that prioritises cyclists was identified as a countermeasure in eleven crashes. In some crashes such changes would not require changes in legislation e.g. replacing give way markings with stop lines (2 cases). However in six crashes, the suggested changes may require some kind of regulatory change e.g. changes to existing road markings or potentially legislation to require motorised vehicles to give way to cyclists.

For example, replacing ‘give way’ markings with ‘stop’ lines when a minor road intersects with a major road that has cycling facilities (e.g. a cycle lane) may give motorists more time to look for and see approaching cyclists.

Another possible solution would be to segregate cycle paths and provide segregated routes across intersections. For example, introducing a segregated ‘fly over’ for cyclists would also allow cyclists to safely negotiate intersecting roads, for example when the road is high speed e.g. cycle tracks/paths alongside grade separated roads with slip roads.

An example of another way of prioritising the cyclist would be to give them the right of way when a segregated cycle track/path intersects another road. A regulatory and/or legislative change (at national level) would be needed to establish this officially however there may be circumstances where motorised vehicles would be encouraged to give way to cyclists. For example, where the road intersecting the cycle track is an entrance/exit to a car park, give way lines and painted cycle lane in the entrance could require motorised vehicles to give way when entering and exiting. An advantage of legislation would be that cycle tracks or shared paths may become more attractive to cyclists. However there is likely to be a short term increase in conflicts at such intersections while motorised road users get used to the new legislation.

4.2.5. On-road cycling infrastructure

It is important to provide on-road cycling infrastructure that is effective for cyclists. The Local Transport Note 2/08, Cycle Infrastructure Design (DfT 2008, p35), sets out a number of benefits of cycle lanes:

- create a comfort zone, especially for less experienced cyclists nervous about mixing with motor traffic
- assist cyclists in difficult or congested situations
- allow cyclists to bypass features intended to slow or exclude motorised traffic
- help guide cyclists through complex junctions and provide route continuity to help with navigation
- help control the speed of motor traffic by narrowing the all-purpose traffic lane, and
- help to raise driver awareness of cyclists.

The analysis of the fatal and serious injury crashes highlights a number of issues cyclists encounter while riding on the road and the following sections and countermeasures seek to address these issues.

Where segregated infrastructure is not necessary for high levels of safety, provide infrastructure to facilitate cyclists sharing the same space and or route with other road users.

4.2.5.1. Conflicts where left turning traffic share the same space as pedal cyclists travelling straight on

One issue highlighted by the sample was that conflicts occur when HGVs/3.5-7.5 tonne vehicles are turning left and the pedal cyclist is travelling straight on. Three contributory factors were identified in Section 3:

- Cycling infrastructure requiring cyclists to cross free flowing traffic to enter (2 crashes)
- Shared lane for straight on and left turning traffic – pedal cyclist and HGV in same lane (6 crashes)
- HGV turning left from a straight on only lane (2 crashes)

Provide infrastructure to separate cyclists travelling straight on from left turning vehicles at junctions
Facilitate large vehicle left turns from lane 1/Nearside lane

Evidence from the fatal and serious crashes also suggests a frequent conflict between cyclists riding down the nearside of a traffic lane and large vehicles turning left. The relative movement analysis described in Section 3 showed that in eight cases, the cyclist was undertaking a large vehicle that was turning left. The issue appears to be exacerbated with multiple lanes and dual priority lane markings, e.g. left turn and straight on traffic in the same lane, as illustrated by Figure 22:

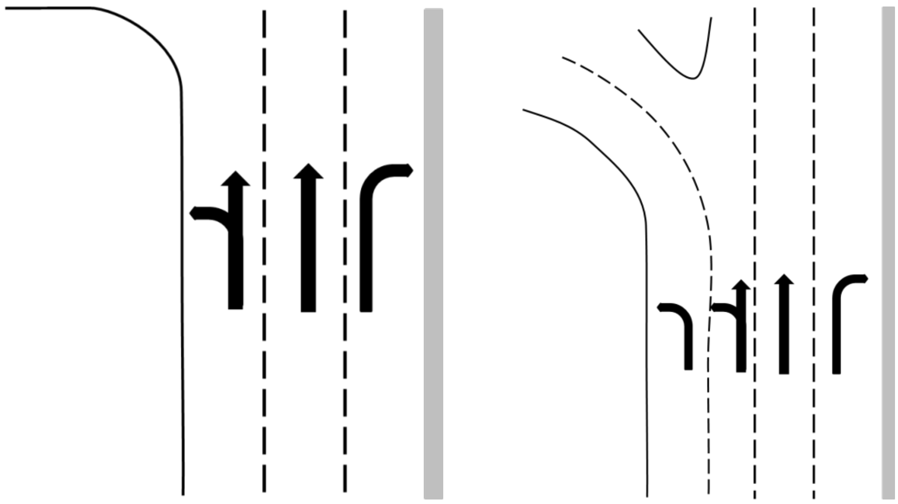

Figure 22: Road junctions with multiple lanes and dual priority markings

When an HGV turns left from a lane that is designated ‘straight on and turn left’ the cyclist and driver are more likely to misinterpret each other’s intentions. This can be associated with road positioning where HGVs, in order to turn left, may need to use the extreme offside of the lane or lane 2. Equally a cyclist's position and intention (to continue ahead) may be correct for the road markings present.

At junctions where lane priorities allow; for example, a 'left and ahead' in addition to 'ahead only', then consideration should be given to making the nearside lane 'left turn only'. With this in place it is possible to move the cycle lane to a central road position reducing turning conflicts and emphasising cyclist priority across the junction. Creating a central cycle lane on the offside may carry its own risks as the potential for conflict is not removed entirely and as with all measures need careful monitoring and evaluation. At junctions which do not allow this intervention; for example where lanes are designated ahead and left in addition to a right turn, or space dictates that there is only one lane, it may be necessary to investigate more innovative solutions.

Where more complex junctions are concerned (see continuous conflict points) involving multiple lanes with multiple priorities then consideration should be given to re-routing cycles who are travelling across these e.g. by use of segregation or encouraging a more central road positioning.

In order to reduce the need for HGVs to move to the offside or lane 2 in order to turn left, the angle needed to make the turn may need to be altered and obstacles such as parked cars and bus stops may need to be moved further away from the junction.

In circumstances where it is not possible to separate left turn and straight on traffic or there is still a need for HGVs to move to the offside or lane 2 to make the turn, and an ASL is present, consideration should be given to routing cyclists into ASLs. For example entry points could be created between lanes for cyclists intending to travel straight on and/or right. Any nearside entry point should be designated as left turn only. (See section 3 for more discussion on ASLs).

One possible course of action would be to combine infrastructure design ideas from the continent and the UK to create a junction design which allows safe priority travel for cyclists by reducing the turning conflict while still allowing large vehicles to turn in their desired direction. For example, a combination of the bus stop bypass (Figure 23) and the Dutch junction design (Figure 24) could allow a junction design such as that shown in Figure 25. However infrastructure imported from other countries cannot be directly implemented without consideration of the UK regulatory framework and legislation changes at a national level which may be necessary to incorporate them in to the UK road system.

Figure 23: Bus stop bypass cycle lane (TfL image)

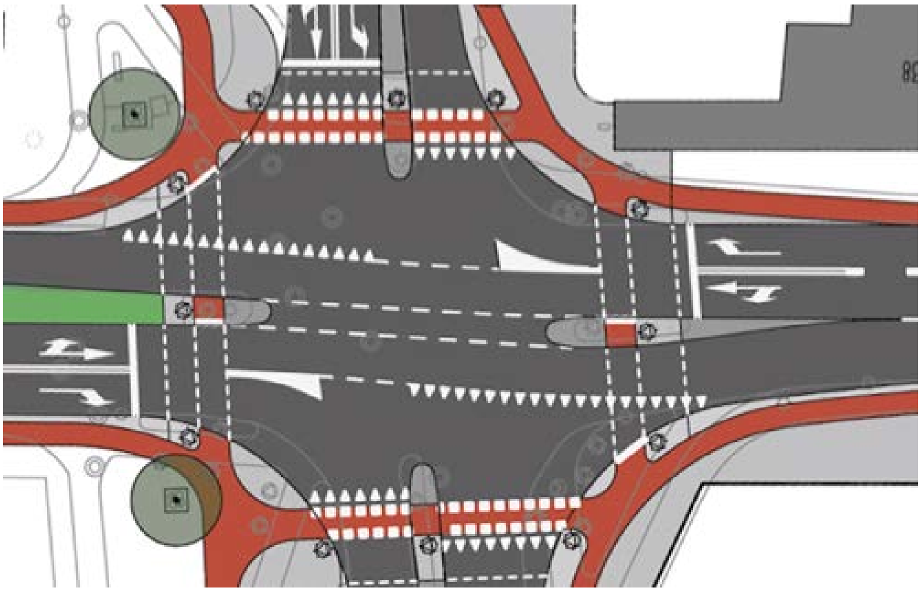

Figure 24: Dutch style junction (Image from Bicycle Dutch[11])

[11] http://bicycledutch.wordpress.com/2013/04/12/what-qualifies-as-dutch-design/

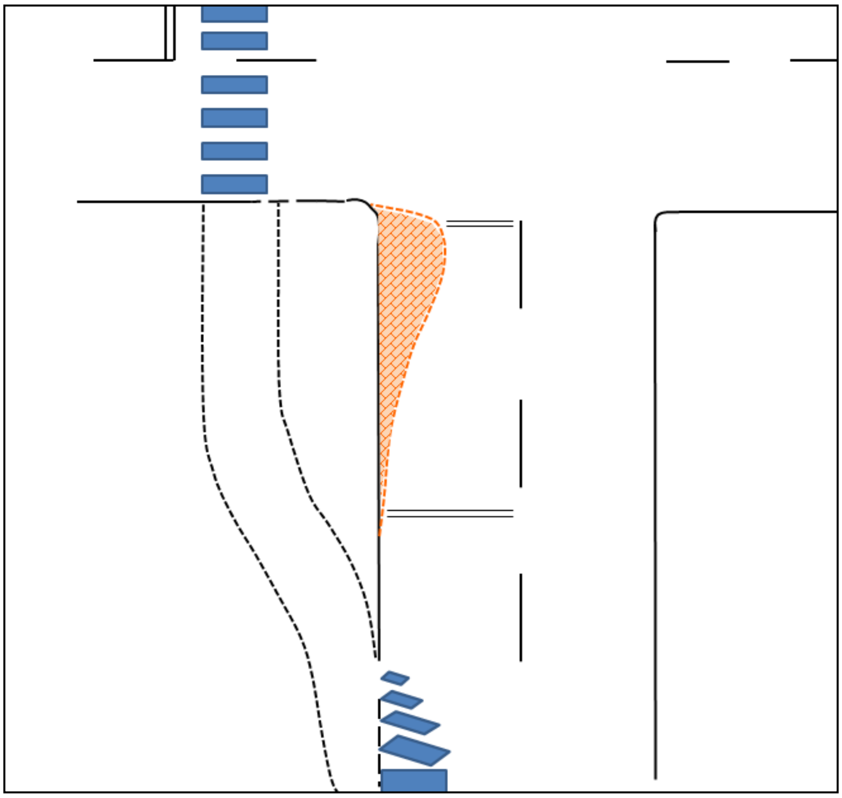

Figure 25: combination junction

Enhancements to this junction which may be useful include a textured and coloured surface treatment which, although safe to cycle over if remaining on the carriageway, may provide information to cyclists to either choose the bypass or change to an assertive road position to cross the junction. This surface treatment could usefully form the arc described by a rigid or articulated lorry as it makes a left turn. This could provide learning for cyclists transferable to other untreated junctions.

Priority across the joining road could also be maintained by raised crossings with markings indicating priority for cyclists (requiring legislation change at a national level). Raising the crossing point would increase visibility for drivers of trucks turning left by providing direct sight of the cyclist through the windscreen rather than relying on close proximity or rear view mirrors.

4.2.5.2. Assisting cyclists to maintain a consistent predictable path

When a cyclist is required to change their position due to changes in infrastructure, there is an increased likelihood of conflicts occurring. Specific aspects of infrastructure were found to be contributory in the fatal and serious crash sample:

- Road narrowing due to Traffic calming – 1 crash (1 car)
- Road narrowing due to parked cars/parking bays – 2 crashes (2 HGV/3.5-7.5 tonne)
- Road narrowing due to pedestrian facilities – 3 crashes (3 HGV/3.5-7.5 tonne)
- Road narrowing due to road works – 2 crashes (2 bus)

In addition, lane/road narrowing/widening can occur continually over short distances; these restrictions are often subtle but ultimately reduce available space for cyclists. These restrictions can occur with or without junctions when lanes are added or removed or can occur when external factors such as buildings or bridges force the road narrower. Junctions can often change width between the entrance and exit, particularly if the exit of a junction is at a different angle to the entrance or it enters a narrower road. Certain junctions may also give an illusion of narrowing – for example when the junction itself forms a bend in the road. This illusion can be exacerbated when lane markings do not continue through the whole of the junction.

Where cyclists and larger vehicles are required to travel in close proximity, e.g. sharp left turns, road narrowing, then provision needs to be made to allow collisions to be avoided if mistakes are made. In some circumstances, high kerbs and pedestrian guards can contribute to a fatality if they prevent the cyclist from moving away from the large vehicle.

The following factor was found to contribute to crashes involving HGVs:

- Pedestrian guard rails and kerb stones – trapping/preventing escape (2 crashes)

This issue can be exacerbated when lane and or road/widths reduce e.g. road narrowing at the entrance to a junction.

Establish predictable road or lane widths to prevent pinch points that result in unexpected crowding of cyclists and motorists into short stretches of limited space

Establishing predictable road/lane widths was identified as a countermeasure in 4 crashes involving large vehicles:

It is easier for a cyclist to negotiate a junction if the road and lane widths are predictable. Where possible road and lane widths should remain constant – especially at junctions and care should be taken to maintain the width of cycle lanes where present. Consideration should be given as to whether junctions on a bend could be ‘smoothed’ to reduce or eliminate the impacts of the bend.

Consider the impact of roadside parking on cyclists

Special consideration of cyclists should be made when making decisions on where parking is allowed and the introduction of parking bays and traffic calming measures:

A need for cycling facilities as well as parking was identified in 2 crashes and it was suggested that removing or discouraging parking would be a countermeasure in a further 2 cases.

On-road parking can increase the likelihood of conflicts between cyclists and other road users by forcing cyclists to change their road positioning and narrowing the area of road available that has the effect of moving cyclists and motorised vehicles in much closer proximity. Cyclists therefore need to be taken into account when considering how to facilitate on-road parking e.g. through the provision of parking bays and deciding where parking should be prohibited e.g. in close proximity to junctions.

Use 'cycle friendly' traffic calming when there is a need to reduced traffic speed

Introducing traffic calming was identified as a countermeasure for 8 crashes – cars were involved in 7 of these crashes and the remaining case involved a HGV:

Reducing the speed of traffic is necessary both for cyclist and pedestrian safety. Where cyclists and pedestrians are required to cross roads as part of a journey at locations where these road users are prioritised (local significance, place of importance) it is important to keep motorised traffic speeds low.

Where traffic calming is introduced on a route which cyclists use, considerations of the impact to cyclists should be made. For example speed cushions can require the cyclist to change position. In addition speed cushions placed alongside parking bays may force the cyclist to travel in close proximity to parked cars and therefore be vulnerable to opening doors. Figure 26 shows how placing a speed cushion adjacent to on-street parking effectively encourages cyclists to cycle either side of the calming measure and could lead to conflicts with the 'door zone' of parked vehicles.

Figure 26: Speed cushion traffic calming adjacent to on street parking

There are many design solutions that could benefit cyclists. For example, build outs which allow cyclists a path through them and raising ASLs and pedestrian crossings, could reduce the speed of motorised traffic whilst minimising the risk to the cyclist. By repositioning or redesigning the road layout around the speed cushion more space and a more direct route for cyclists could be achieved, repositioning the cushions to straddle the lane marking can provide a safe path through the calming measures. In these cases it is also possible to involve wider-tracked vehicles (such as HGVs) with the calming measures whereas before they could pass over a centrally positioned cushion without any reduction in speed. Emergency service vehicles can also still straddle the middle cushion if required.

Preserve space for cyclists - Especially at points where kerb stones and guard rails contribute to road narrowing

Removing pedestrian guardrails and or lowering or smoothing the edges of kerb stones to allow them to be mounted by a cyclist, would assist cyclists to move away from large vehicles in an emergency. However pedestrian safety would have to be taken into account.

If this is not possible and there are large numbers of HGVs and cyclists using the route then some kind of separation/segregation may be necessary such as cycle only left turn lanes separated by kerb stones.

Provide clear routes for all road users through junctions e.g. by using clear road markings

Providing additional guidance to vehicle drivers and cyclists through the use of road markings was identified as a measure that could assist the vehicles and cyclists in maintaining a predictable position and therefore reduce the likelihood of the collision occurring in 4 crashes involving large vehicles:

Misleading junction markings, no lane demarcations through junctions and promoting nearside entry to ASLs can all increase the likelihood of conflicts between cyclists and other road users at junctions.

Cyclists need a predictable path that routes them into and out of a junction safely. This may be achieved through the continuation of lane markings so that both cyclists and other road users do not unintentionally leave their lane. Road marking/colour could be used to encourage cyclists to use a central position if travelling straight on or a more offside position to turn right and other motorists may become more aware of the need for cyclist to occupy more road space.

4.2.5.3. The role of Advanced Stop Lines (ASLs)

ASLs have been added to junctions throughout London with the aim of allowing cyclists to get ahead of other vehicles and to use this space to safely negotiate junctions. ASLs were present in 12 crashes that involved a HGV or 3.5-7.5 tonne vehicle truck but they did not necessarily contribute to the crash.

This study of fatal and serious crashes has highlighted a number of issues relating to ASLs – particularly with regards to interactions with larger vehicles. The following factors were found to contribute to the crashes included in the sample:

- ASL positioned cyclist in area with limited direct vision from the truck - 5 crashes
- Reduced driver vision – cyclist directly in front of truck - 7 crashes
- Poor positioning – cyclist undertaking other vehicle – 12 crashes (11 HGV/3.5-7.5 tonne, 1 bus)
- Reduced driver vision – cyclist to nearside of truck - 19 crashes

When a HGV is directly behind an ASL the driver has limited direct sight of cyclists within the ASL (see section 4.3.1 for further discussion of the vision afforded by HGVs). Class VI mirrors have not been required to be retrofitted to HGVs and even when they are, cyclists are not always noticed by the driver. The presence of, and entry markings to ASLs also encourage cyclists to undertake vehicles in order to enter them, which increases the likelihood of conflict with left turning vehicles. The point at which signal lights change is a particularly vulnerable time for the cyclist.

In nine crashes, it was identified that introducing advanced phasing in addition to an ASL may have avoided the crash but this is dependent on cyclists having a safe entry path to the ASL:

Introduce advanced phasing for cyclists alongside ASLs
Introduce a 'no vehicle' zone in between the stop line and ASL

Introducing advanced phasing where cyclists have their own green signal for a period of time before the rest of the traffic is allowed to move would combat the forward vision issues associated with large vehicles. These may offer advantages when the junctions are relatively short, though may be less effective when the junctions are long and any advantage may be lost to overtaking traffic   Using a countdown signal that warns approaching cyclists of the length of time before other traffic is released could reduce conflicts with cyclists trying to get past stationary traffic to the ASL.

Another approach that could be used alongside advanced phasing is the introduction of double stop line creating a no vehicle zone between the motorised vehicle stop line and line demarking the start of the ASL (see Figure 27). This would increase the likelihood of cyclists being seen, allow for eye contact to be made between driver and cyclist, and increase the time available for cyclists to perform their manoeuvres before other traffic catches up.

Figure 27: ASL with double stop line. Example from the Netherlands[12]

Establish safe entry paths for ASLs

As previously discussed, establishing a safe path through junctions for cyclists is important and the entry point to an ASL therefore is also important. Where left turning and straight on traffic is separated, entry points should be between the 2 lanes. The same applies if there is a separate right hand lane. For some junctions it may be more appropriate to encourage cyclists to enter the ASL at any point.

In addition, ASLs may be inappropriate at some locations – especially those where the junction design creates a pinch point between the cyclist and other vehicles. In this case alternative solutions such as segregated infrastructure should be considered to avoid the conflict caused by undertaking. See section 4.2.3.

12 http://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Bike_marks_Bergen_Vanderbilt_jeh.jpg/330px-Bike_marks_Bergen_Vanderbilt_jeh.jpg

4.3. Vehicle related countermeasures

Vehicle related countermeasures either aim to prevent crashes (primary safety) or mitigate the consequences in terms of injury when a crash has occurred (secondary safety). Technological interventions can be passive, e.g. warn the driver, or active, e.g. apply the brakes. They aim to mitigate driver errors and prevent these from having serious consequences.

4.3.1. Crashes involving large vehicles – incl. HGVs, 3.5-7.5 tonne vehicles and buses

There are a number of issues associated with crashes involving large vehicles. The first is the ability of the driver to see cyclists around the vehicle – this is a particular issue for HGVs and some 3.5-7.5 tonne category vehicles. The second is that often drivers are unaware that they have hit something and this leads to the third issue, where the rider is run over by the large vehicle.

4.3.1.1. Trucks – field of vision

The current design of HGV cabs restricts the amount of road that can be viewed directly by the driver when seated in the driving seat. The following figures (Figure 28 and Figure 29) illustrate the area of road that is typically not directly visible from the cab to the front and nearside.

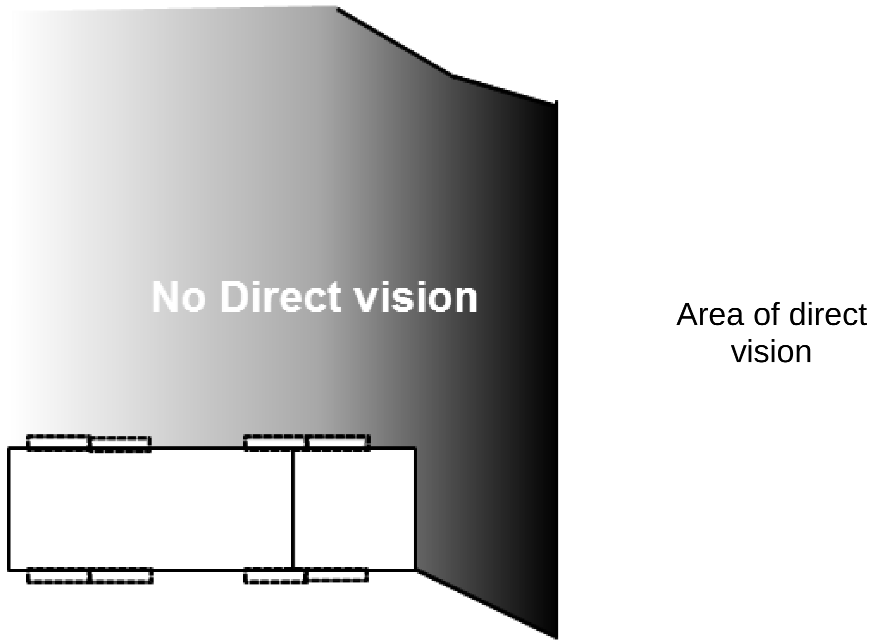

Figure 28: Area visible by driver from cab to front and nearside

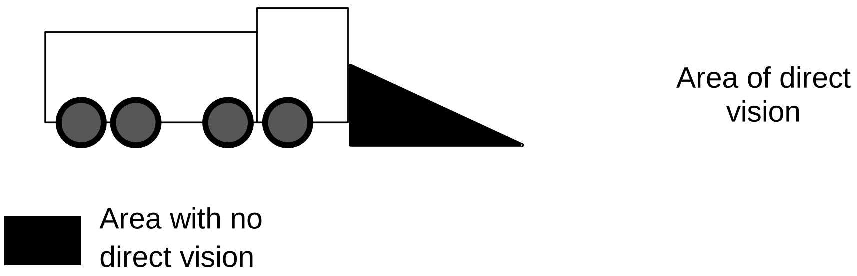

Figure 29: Area of road not visible to driver seated in cab to the front

The HGV or 3.5-7.5 tonne vehicle driver is therefore reliant on mirrors to check the presence of cyclists around the cab area. Figure 30 and Figure 31 show the mirrors typically fitted to HGVs and 3.5-7.5 tonne vehicles. It was possible to establish the majority of the mirrors that were fitted to 29 out of the 30 HGVs and 3.5-7.5 tonne vehicles included in the sample. All 29 were fitted with nearside Class II (main) mirrors and 27 of these were also fitted with nearside Class IV (wide-angle) mirrors. Twenty-six were fitted with offside Class II mirrors – it was not known whether the remaining 3 had these mirrors. Out of the 26 HGVs/3.5-7.5 tonne vehicles with Class II mirrors, 15 were also fitted with offside Class IV mirrors. The Class II and offside Class IV mirrors afford the driver vision to the rear of the cab area.

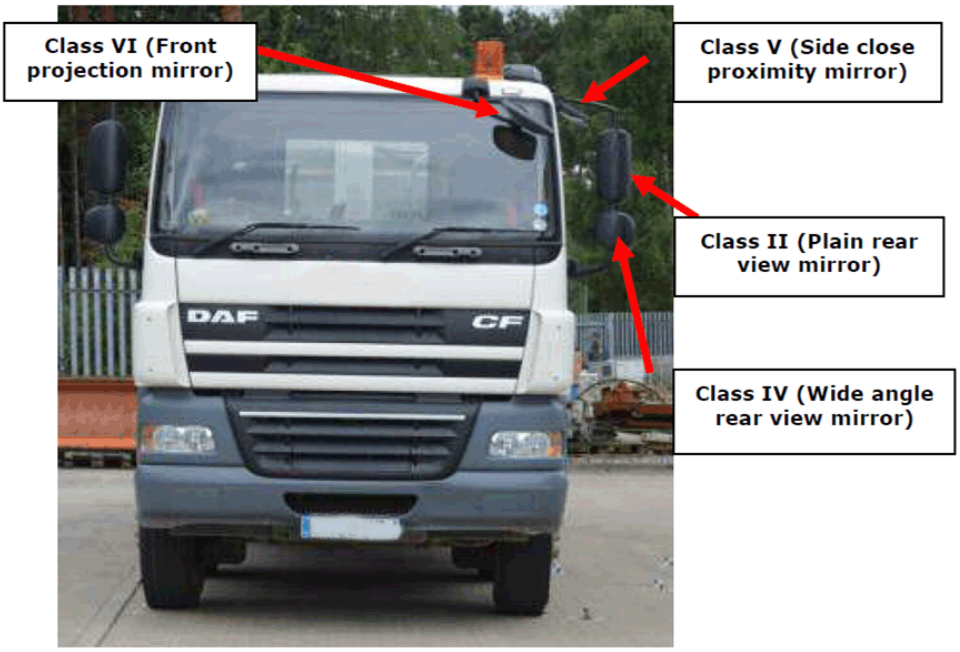

Figure 30: Mirrors typically fitted to HGVs/3.7-7.5 tonne vehicles (Delmonte et al 2013)

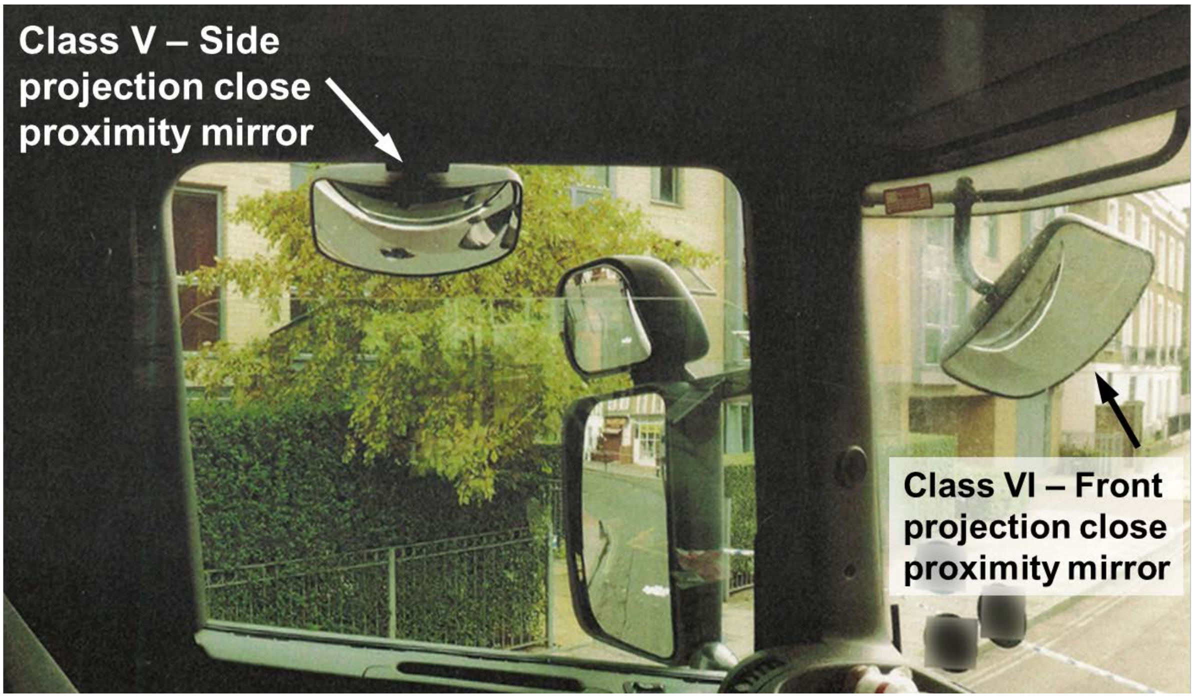

Figure 31: HGV mirrors – view from cab (Delmonte et al 2013)

Vision of the front and nearside cab area is provided by front (Class VI) and close proximity (Class V) mirrors respectively. Figure 32 and Figure 33 show the area of road typically visible to the driver in the front and nearside close proximity mirrors, respectively, as defined by the regulations.

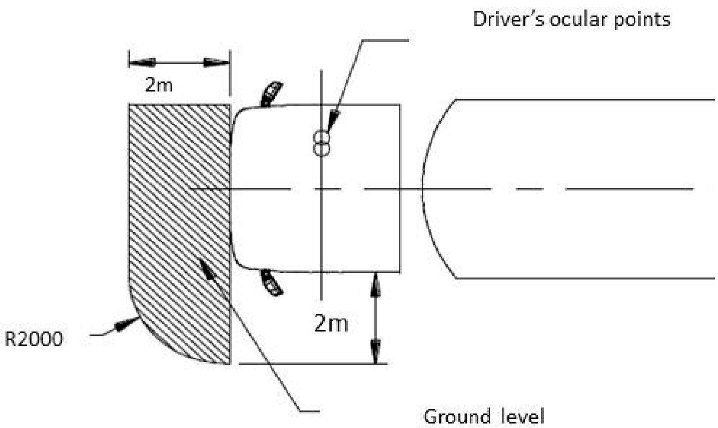

Figure 32: Definition of Class VI mirrors - European Commission regulation 2003/97/EC (Robinson and Cuerden, in press)

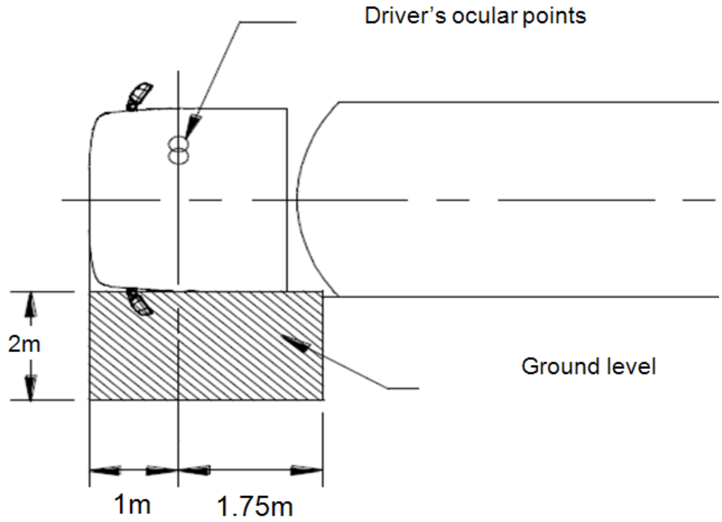

Figure 33: Definition of Class V mirrors - European Commission regulation 2003/97/EC (Robinson and Cuerden, in press)

As shown in Table 33, the majority of HGV/3.5-7.5 tonne vehicles in the sample were fitted with nearside Class V, close proximity mirrors. The Class VI front mirrors were less commonly fitted with 14 of the sample having these mirrors.

Table 33: Number of HGVs and 3.5-7.5 tonne vehicles fitted with Class V and/or Class VI mirrors

Mirror Class	Class V – Close proximity (nearside)	Class VI - front
Fitted	27	14
Not fitted	1	12
Not known	1	4

4.3.1.2. Crash sample – truck driver vision

The following contributory factors relating to the vision from HGV/3.5-7.5 tonne trucks included in the sample were identified:

- No Class VI mirror fitted (12 cases); and contributing to crash (4 cases)
- Reduced driver vision – pedal cyclist in directly in front of truck (7 crashes)
- Reduced driver vision – pedal cyclist to nearside of truck (19 crashes)

In 25 cases, the cyclist's initial contact with the HGV/3.5-7.5 tonne trucks was around the front and nearside front cab area (see Figure 38). This also suggests that drivers in the sample struggled to see cyclists that are positioned around this area.

Fit/Retro-fit Class VI mirrors to all large vehicles with forward blind spots
Redesign HGV cabs to facilitate increased direct forward vision
Review the effectiveness of existing mirrors in showing the present of cyclists around the front and nearside front cab area – particularly while moving

Cook et al (2011) examined the vision afforded by HGV and 3.5-7.5 tonne vehicle mirrors in a variety of scenarios including lane change manoeuvres on the motorway. They identified concerns about the mirrors currently fitted that have potential implications for pedal cycle and HGV/3.5-7.5 tonne vehicle interactions. They established that it may take over 5 seconds for a truck driver to properly check a full set of mirrors and in this time a moving cyclist could be missed because the driver was not checking the relevant mirror at the time when the cyclist was visible.

The second issue raised by Cook et al (2011), as illustrated in Figure 34, was a blind spot that they identified between the vision currently provided by the close proximity (Class V) mirror (lower, red visual cone shown in the figure) and the area visible directly by the driver (upper, blue cone) that could lead to the driver missing road users such as cyclists who are located in this position.

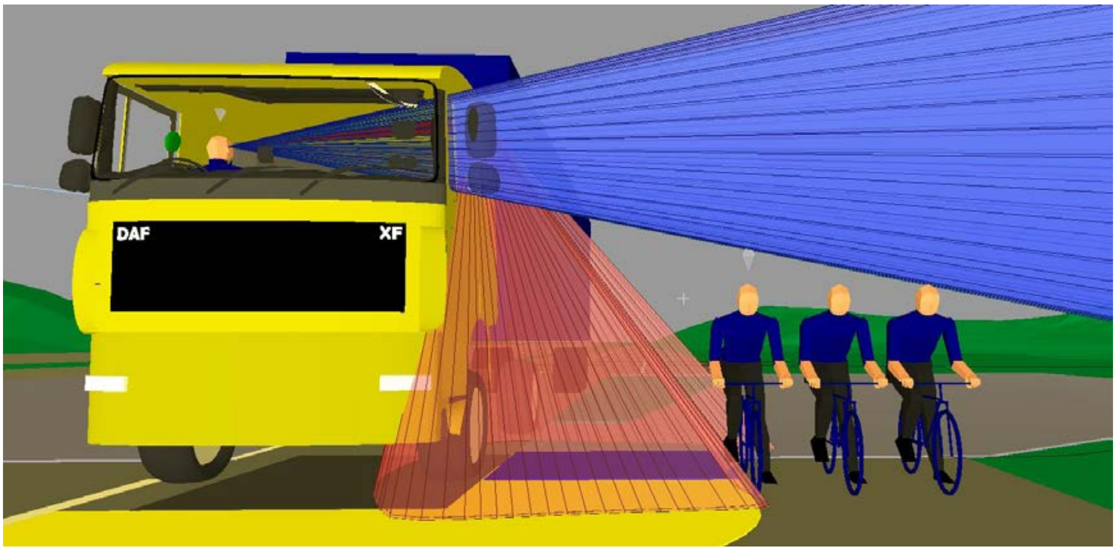

Figure 34: Blind spot between the standard close proximity (Class V) mirror and the volume of space observable through the passenger window. Image by S. Summerskill, from the work of Cook et al. (2011), reproduced with permission.

The need for a larger field of view in the Class V mirror has been recognised and EC legislation has been amended to increase the area of road that should be visible using a Class V mirror on vehicles registered post 2014 (UNECE R46 Rev 5) – Figure 35.

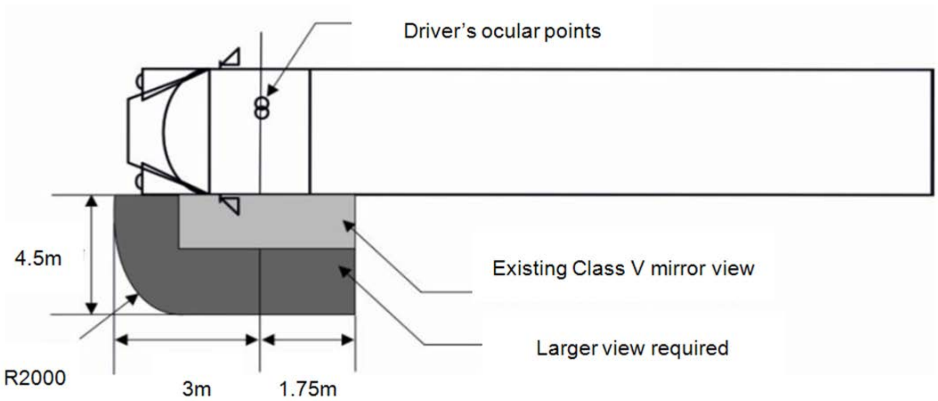

Figure 35: Definition of Class V mirrors in UNECE R46 Rev 5 (for vehicles registered post 2014 (Robinson and Cuerden, in press)

It is not possible to judge whether either of the issues raised by Cook et al (2011) contributed to the crashes in the sample however a characteristic associated with the majority of the fatal and serious crashes was that the driver stated that they did not see the cyclist prior to the collision. There are a number of possible reasons why in these cases the driver failed to see the cyclist including:

- The driver did not look – either because of a lack of awareness of the purpose of the close proximity mirror (Class V) and front (Class VI mirrors) or because their attention was focused on other aspects of the environment (other traffic, pedestrians, changing traffic signals).
- The driver checked the mirrors, but the cyclist was only visible for a very short period of time as the cyclist or both the cyclist and the large vehicle were moving so the driver's opportunity to spot the cyclist was reduced.
- The driver checked the mirrors, but did not identify what they saw as a cyclist, e.g. they thought they were a pedestrian, or the image was not clear enough, e.g. the vehicle was moving.

It is worth noting here that it was not possible to identify exactly if the mirrors were correctly positioned for each driver. As the collisions were historic only police photographs of the mirror positions and interview evidence from the driver was available. Detailed reconstruction of mirror views is a complex task and was beyond the scope of this project.

The field of view using mirrors is defined by EC Directive 2003/97/EC which specifies the area at ground level that must be visible when the mirrors are correctly adjusted. These measurements are based on research conducted using stationary trucks and in relation to other road users that are stationary. These conditions most closely relate to traffic scenarios where vehicles are stationary at a junction before moving off. In many cases however the truck and cyclist move relative to each other before the collision and this may mean the cyclist is only within the field of view of a close-proximity mirror for a matter of seconds.

Ways to increase the likelihood of the driver seeing the cyclist include, retrofitting mirrors known to increase vision (Class VI), decrease the reliance on mirrors, i.e. increase the area visible by direct vision to the front of the vehicle (Figure 36), and to explore ways of improving the vision provided by the existing mirrors.

Figure 36: Redesigned lorry cab for improved direct vision of cyclists (London Cycling Campaign image)

There is also anecdotal evidence from police interview records of the fatal and serious cycle collisions that drivers can be very focussed at signalised junctions. Most commonly attention appears to be directed towards the traffic signals themselves and as such there may be an advantage in installing convex mirrors on junctions. This has an additional benefit as there is also good anecdotal evidence from the same interview material that truck mirrors are used incorrectly (for example only for parking), not used, not fitted (i.e. retrofitted to older trucks) or are insufficient for providing adequate views around the vehicle. A mirror situated near the signal could resolve both of these issues; helping preoccupied drivers spot cyclists and enhancing the view around their vehicle (Figure 37).

Figure 37: convex mirror situated adjacent to traffic signals (TfL image)

Evaluate the casualty reduction effectiveness of proximity sensors in detecting the presence of cyclists and other road users alongside the cab

Improving the vision provided by the cab windows and mirrors is unlikely to prevent all crashes involving large vehicles. There may be value with additional assistance when the driver makes a mistake or a cyclist is in a blind spot at a critical moment. One way to do this would be to fit proximity sensors to the cab area (front, nearside front and possibly offside front).

This could be a relatively simple system where sensors provide an audible warning to the driver when a cyclist or pedestrian is in close proximity or about to be hit (cf. parking sensors). Such passive systems would require through testing and careful calibration to minimise false positives which would reduce the likelihood of the driver attending to the warning.

Proximity sensing systems are available as retrofit equipment, however there is no scientifically based research known to the authors that fully evaluates the effectiveness of the systems in reducing casualties. Furthermore many of the collisions with cyclists take place at junctions where the driver workload is relatively high and may be related to the truck driver paying attention to some road users and missing the cyclists. The introduction of an additional warning system may simply add an additional distraction to the driver and the apparent benefits may not be materialised. It is therefore essential that the proximity systems are fully evaluated to properly understand any impact on casualties.

Evaluate the casualty benefits resulting from the application of automatic/emergency braking to large vehicles

Another more complex system could link in with other crash prevention systems such as autonomous braking, whereby it detects when a cyclist or pedestrian is about to be hit and triggers an automatic response.

Once the driver (or vehicle) becomes aware that they are about to hit a cyclist there is a need to quickly apply the brakes and bring the vehicle to a standstill before the cyclist is run over. There is unlikely to be enough time to achieve this with conventional braking due to the mass of large vehicles so some kind of technological intervention is required.

The passive option would be a system which is triggered when the driver engages in emergency braking that forcefully stops the vehicle quickly. This may be effective when a driver responds to an audible warning from a proximity sensor. If the driver only applies braking after they have hit or ran over the cyclist then all it would do is reduce the distance a cyclist is dragged and this is probably not enough to prevent fatal or serious injuries.

A more effective system could be one which in response to a proximity sensor trigger, applies the brakes automatically and therefore is not reliant on the driver understanding that a crash is about to occur and responding quickly enough to prevent it.

The European commission has recently mandated the fitting of advanced emergency braking systems (AEBS) to all new large vehicles to be implemented between 2013 and 2018 (EC Regulation No. 661/2009). The AEBS should detect the possibility of a collision with a preceding vehicle, warn the driver by a combination of optical, acoustic or haptic signals and, if the driver takes no action, automatically apply the vehicle's brakes. As yet there is no requirement that this type of system would be effectively triggered by pedal cyclists and an advance would be to develop and evaluate prototypes for truck applications.

4.3.1.3. Side Guards

Side guards are fitted to vehicles with a maximum gross weight of more than 3.5t to prevent motorised vehicles from going under them. They are also intended to prevent vulnerable road users such as cyclists and pedestrians from falling under these vehicles. Twenty-nine cyclists in the sample were seriously or fatally injured by vehicles in the 3.5-7.5 tonne and HGV truck category and all 29 received their injuries by being run over by one or more wheel(s).

As all the cyclists in the sample were fatally or seriously injured it is not possible to identify cases where side guards successfully prevented injuries, however it is possible to identify further details of the interaction between the cyclist and the truck.

Legislation governs the fitting of side guards and there are a number of vehicle types that are exempt from this. Out of the 29 HGV/3.5-7.5 tonne vehicles in the sample, it was not possible to identify whether or not side guards were fitted for 3 vehicles (2 tippers and 1 box truck). Out of the remaining 26, 11 vehicles were fitted with side guards and 15 were not. Table 34 shows the vehicle types included in the sample that were fitted with side guards and those which were not.

Table 34: Vehicle types in sample with and without side guards

With side guards	
Box	3
Curtain sided	3
Flat or drop side	4
Cement mixer	1
Without side guards	
Tractor unit only	1
Refuse lorry	2
Skip carrier	3
Tipper	9
Not Known	
Box	1
Tipper	2

The collision scenarios observed for the crashes involving HGV/3.5-7.5 tonne trucks in the sample show that in the majority of cases there was no physical interaction between the side guard, where fitted, and the cyclist. The majority of interactions between cyclist and HGV/3.5-7.5 tonne truck occurred at the front and nearside front (cab area) where no guards are fitted. The areas where initial contact was made between the cyclists and trucks are illustrated in Figure 38.

Two scenarios were common – in the first the cyclist was hit by the front or nearside front area of the cab and immediately run over by the front wheels (n=13). In the second, the cyclist was knocked to the ground, went under the lorry and then was run over by the rear wheels (rigid) or trailer wheels (articulated) – often because the lorry was turning left. (n=9). In the remaining four crashes, the cyclists fell to the ground between the front and rear wheels and were run over by the rear wheels. Side guards were only fitted to one lorry in these latter crashes.

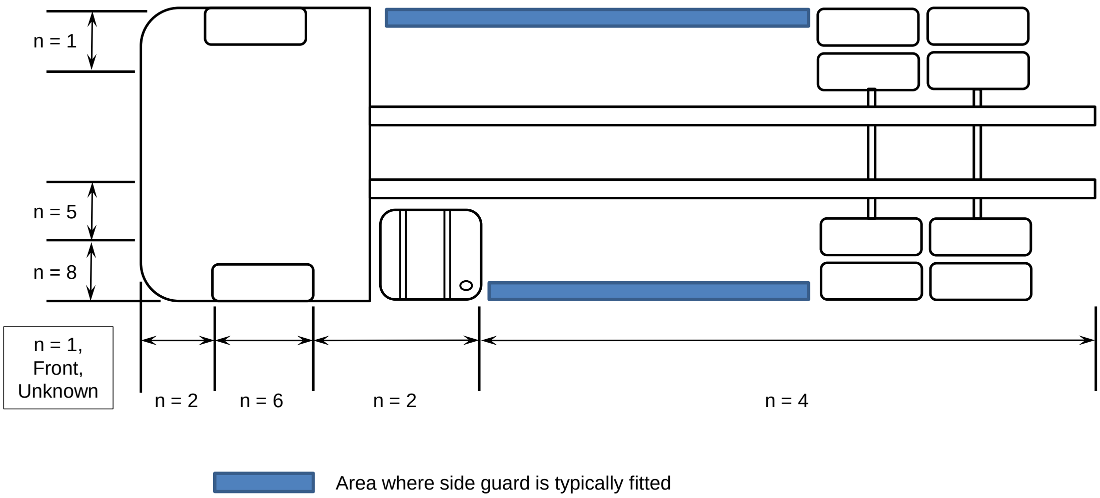

Figure 38: First contact point between HGV/3.5-7.5 tonne vehicle and pedal cycle

Out of the 11 crashes that involved vehicles with side guards fitted, 7 cyclists were run over by the front wheels and 4 were run over by the rear wheels. In these latter 4 cases it can be said that the side guards fitted to the vehicles were not effective in preventing the cyclist from going under the truck. In 2 crashes the cyclist went under an articulated lorry by going under the fuel tank area of the tractor unit where no side guard was fitted. In another crash, marks on the side guard suggested that it initially prevented the cyclist from going under the truck, but there was a gap between the end of the side guard and the fuel tank which allowed the cyclist to fall under the rear wheels. In the remaining 2 cases, the cyclist was on the ground and went underneath the side guard.

In the 15 crashes involving vehicles without side guards fitted, 7 cyclists were run over by the front wheel(s) and 8 were run over by the rear wheel(s). Out of the 8 that were run over by the rear wheels, side guards may possibly have prevented the cyclist from going under the lorry in 3 cases on the assumption that had a side guard been fitted, the cyclist would have fallen against it and not directly to the ground. Based on the analysis of the crashes involving vehicles with side guards, it is thought that side guards, as they are currently designed, would have been unlikely to have prevented the riders going under the lorry if they were already on the ground.

An important aspect that examining fatal and serious crashes reveals is that all the crashes studied involving HGVs and the majority of those involving other large vehicles result in the rider being run over by one or more of the vehicles' wheels. 29 pedal cyclists were run over or dragged by HGVs or 3.5-7.5 tonne trucks and 2 were run over by buses. Preventing cyclists from going under large vehicles is imperative in preventing this type of crash.

Fit all large vehicles with front and redesigned full (horizontal and vertical) side guards
Extend existing side guards to include areas previously exempt e.g. fuel tanks
Remove exemptions to side guard legislation

The analysis detailed above suggests that side guards in their current form and design may not provide the required level of protection to cyclists. Presently side guards have many roles to play only one of which is to deflect vulnerable road users away from the vehicle - unfortunately they cannot be effective if they allow the road user to fall beneath or between them under the vehicle. The limitations of existing side guards can be seen when comparing Figure 39 below with a current truck (Figure 40) which shows how different current side guard fitment is to an ideal safer system illustrated by the MAN truck concept.

The height of the side guard (i.e. the distance of its lower edge to the ground) is critical in maintaining contact with a vulnerable road user as they fall to the ground; the current design allows a gap between the ground and the sideguard of up to 550mm which is large enough for a for a cyclist (or pedestrian) to fall beneath the vehicles' wheels. Likewise, continuous coverage down the side of a vehicle is advantageous as any hole in the protection (e.g. ending a side guard at a fuel tank) allows opportunity for a cyclist to fall to the ground under the vehicle.

Figure 39: Concept truck design with extended side guards (MAN)

Figure 40: Basic side guard fitment compliant with current regulations

The second part of the countermeasure is to protect cyclists who are already on the road surface as this is a common scenario amongst cyclists who are run over by the rear wheels.

There is a need for a new design of guard that provides protection towards the front and nearside of large vehicles. This guard must prevent a road user who is on the ground from going under the vehicle; in addition they could also push the road user clear.

Providing exemptions to certain kinds of vehicles e.g. tractor units, tipper lorries, produce large gaps in the safety of the road system. Therefore it is important to carefully assess the necessity of exemption – particularly in the case of tractor units – and seek design solutions that meet the needs of types of large vehicle that are required to travel on uneven terrain while maintaining the safety of vulnerable road users. For example, some kind of retractable side/front guards might be most appropriate or guards that operate within a technology system that deploys them on detecting a crash is about to occur with a vulnerable road user.

In all of these countermeasure areas there are opportunities to prevent the cyclist from going under large vehicles and are also highly likely to be effective for other vulnerable road users, i.e. pedestrians and motorcyclists.

One example that might be suitable for adaption and modification, and one that has been around for many years in other transport modes is a ‘cow catcher’ style guard.

These devices have been used on city trams (Nottingham, Helsinki) to prevent people from being run over and deploy when they detect someone on the ground near the front of the vehicle. It is possible to envisage a number of different interventions based on technology which is available today. For example using an autonomous braking system as described in the previous section as an initial intervention before a physical guard such as those used on trams is deployed.

4.3.2. Crashes involving small vehicles (car, van, motorcycles)

Of the 53 fatal and seriously injured cyclists there were 15 that were in collisions with cars and recent developments in car safety technologies have the potential to prevent the collisions or mitigate the injuries.

Promote the extension of pedestrian impact protection to include cyclists under European regulation and EuroNCAP

In Europe, car safety levels are determined by either regulation or the EuroNCAP consumer test protocols. Both include a series of tests intended to ensure that the front sections of cars do not cause serious injuries to pedestrians. The impact tests are based on a stereotype crash configuration where a car strikes a child or adult pedestrian, a minimum level of protection is required before the car can be sold under the Whole Vehicle Type Approval. Higher levels of protection are rewarded by EuroNCAP with higher ratings in its scores. Up to 11 cyclist impacts with cars were in conditions similar to the test conditions although a closer scrutiny might reduce this number.

The current regulatory and EuroNCAP tests do not specifically address cyclist safety, nevertheless it is likely that many of the pedestrian impact zones tested on the car will also be relevant to cyclist impacts. The test conditions – velocity, location of impact etc. - may differ however and it is recommended that the test conditions be evaluated to assess the benefits and feasibility of extending the requirements to cover the specific collision conditions of cyclists.

Promote the development of Automatic Emergency Braking Systems to include cyclists with a view to extend the scope of European regulation and EuroNCAP tests.

Recent advanced braking systems provide cars with the capability to detect obstacles and automatically apply the brakes; this enables the car to either stop before a collision occurs or to reduce the velocity thereby mitigating the injuries. Developments of these systems enable the car to detect a hazard at speeds up to 50 kph (~31 mph) and also to extend the objects detected to include vulnerable road users. Potentially up to 14 of the cyclists struck by cars may have been detected by these advanced braking systems and therefore the injuries either prevented or mitigated although a closer scrutiny is necessary to be definitive.

Fit retractable mirrors that only retract when the driver has left the vehicle

One crash type associated with cars and vans involves cyclists being knocked off their pedal cycles or forced to swerve and losing control as a result of car/van doors being opened into their path. Cyclists are particularly vulnerable as they are likely to be travelling much closer to parked cars and are much quieter than motorised vehicles. This risk factor may be addressed by driver training and as such will also be discussed in the Road User section (section 4.4), however the fatal case in this sample that involved a car door opening highlighted a potential issue with retractable wing mirrors.

As the wing mirror is a key tool in assessing whether it is safe to open a car door, retracting the mirrors before exiting the car/van reduces the ability of the driver or passenger to do this. It is also common for older drivers to have a reduced neck mobility and therefore rely more on wing mirrors for rearward vision. Only allowing mirrors to retract when the driver has got out e.g. when locking the vehicle would mitigate this issue.

4.3.3. Countermeasures for Bicycles

Although difficult to objectively quantify, the majority of drivers in the sample either stated in their police interview or demonstrated by their actions that they did not see the cyclist before the collision. Only 11 out of the 53 fatally or seriously injured pedal cyclists wore high visibility clothing (see section 3.2.4.1). In the 14 crashes occurring in the dark, 7 pedal cyclists were not using any lights (see section 3.2.3.1).

An approach to increasing the likelihood of a cyclist of being seen is to increase the visibility of the bike:

Promote increased visibility on pedal cycles
Create/promote a bike 'signature' to increase cycle recognition

This can be achieved through light and reflection.

There are potential limitations with bicycle lights which may lead to the rider forgetting or choosing to not use them including limited battery life and concern about theft. Battery technology is improving and providing an indicator of low battery life and fast chargers could improve this issue.

Manufacturing lights that cannot be easily removed from the bike frame by a potential thief or are integral to it so are never removed - with a detachable battery or solar charging – could address the issue of theft.

Encouraging the use of lightweight lights that can be mounted or integral to helmets would make it more likely that those who wear helmets always have their lights with them or provide an additional light source that might help the cyclist to be identified as a cyclist.

A way of addressing the issue of drivers 'looking' but not 'seeing' cyclists, might be to create a bicycle signature. Bright colours and retro-reflective material or small lights could be added to a combination of the bike frame, wheel rims and spokes, handle bars, seat mounts and pedals etc. in a way that assists the driver in identifying the cyclist. Retroreflection on pedals may be particularly effective at night and in twilight conditions as they would highlight the movement of the pedals which can then be associated with a pedal cyclist. Recently published research however indicates that high-visibility clothing may only have a non-significant impact on casualty reduction (Miller 2012).

However, increasing the cyclists visibility is not in itself likely to solve the problem of cyclists not being seen as 'look but did not see' instances are as associated with the road users expectations as the actual visibility of the vehicle.

4.3.4. Communication

Good communication between road users is essential to avoid crashes, however in slow or stop start traffic where undertake and overtake manoeuvres between cyclists and other motorists are common, it is easy for signals about intentions to be missed. Also cyclists are limited to a small set of hand signals which may destabilise the bicycle and many cyclists (and drivers) will have received no or little training about their correct use.

The crash analysis identified a gap in communication that resulted in cyclists passing on the inside of a truck that was turning left and in some cases the cyclists were unaware of this. In the sample of fatal and serious injury crashes, 8 crashes were identified where the cyclist undertook a left turning truck.

There are a number of reasons for this behaviour including a misunderstanding of large vehicles' road positioning and space requirements for left turning, the cyclist not seeing the vehicles' indicators and the vehicle not indicating early enough for the cyclist to take action – this latter constraint was identified as being contributory in 2 crashes involving HGVs that were included in the sample

Explore/research improved vehicle to vulnerable road user communication using advanced telematics solutions

Direct communication from one road user to another is likely to be the most effective, and technology may have a part to play in facilitating communication with cyclists and other vulnerable road users. A small number (7) of cyclists in the fatal and serious crash group were wearing head phones and an area to explore would be could vehicles actively communicate with vulnerable road users by harnessing existing technology e.g. blue tooth via music players and smart phones or use advances in vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication technologies.

Improve visibility of left turn indication on large vehicles

Vehicle related countermeasures can address the potential issue of cyclists misinterpreting road positioning and not seeing indicators. It was observed in many cases that once the cyclist had passed the rear of the truck the turn indicators were often difficult or impossible to observe. This presented a particular difficulty when truck drivers indicated late in their manoeuvre.

Indicators could be made more visible by using bigger repeaters and not obscuring repeaters by other vehicle elements such as mud guards and load. A more physical indicator such as a flexible, mechanically operated arm similar to trafficators (see Figure 41) could also achieve this.

Figure 41: Trafficator

4.4. Road user related countermeasures

Road user behaviour governs many aspects of the operation of the road system. It can be influenced by infrastructure, vehicle design and system management and in many ways these can be the most effective methods of behavioural change. However there is also a need to try and influence behaviour by providing road users with information about how they can behave in a way that keeps themselves and other road users safe. A road user's understanding and beliefs about themselves and others in the road system will directly influence how they will behave when using it. The culture of a particular country has a large influence on this.

The main methods of providing road users with information is through training and various awareness raising measures such as campaigns and specific interventions. It is difficult to quantify the effect of this kind of measure – especially as formal training can be influenced by social norms – e.g. the use of flashing headlights in the UK to signal that you are giving way to another vehicle is neither taught nor in the highway code, yet is adopted by the majority of drivers.

The study of fatal and serious crashes allows the identification of behaviour and knowledge that had the involved road users been able to use them, the crashes could have been avoided. This sets out what cyclists and drivers need to know, not how they could be taught that information.

The key failures in the system that relate to road user behaviour have been identified as follows:

- Drivers not understanding cyclists' needs
- Cyclists not understanding drivers' needs
- Drivers not observing cyclists
- Cyclists not being visible
- Communication breakdown

The following sections will discuss this in more detail and set out the key things that drivers and cyclists need to know.

4.4.1. Understanding Drivers/Cyclists needs

This relates specifically to space and positioning. The following contributory factors in relation to space and positioning were identified for the sample crashes:

- Poor positioning – cyclist undertaking other vehicle (12 crashes: 11 HGV, 1 bus)
- Poor positioning – cyclist positioning themselves in truck blind spot (2 HGV crashes)
- Pedal cyclist not allowing themselves enough space when overtaking (2 crashes – 1 pedal cycle, 1 van)
- Other vehicle not allowing cyclist enough space when overtaking (3 crashes, 1 pedal cycle, 1 motorcycle, 1 HGV)
- Other vehicle driving in close proximity to the rear of cyclist (2 HGV crashes)
- Poor manoeuvre – other vehicle crossing path of cyclist without allowing space (2 car crashes)

Cyclists' need for space on the road appears to be poorly understood by other road users and in some cases cyclists themselves. Cyclists appear narrow and therefore judged as not needing much space but the inherent instability means that it is more difficult to maintain the same path. There is a need to move round uneven areas of road surface and both wind and the close proximity of other road users can add to the cyclist's instability. Cyclists may not be aware of threats to themselves such as opening car doors and the closing of gaps on the nearside of HGVs as they turn left.

Cycle and driver positioning is also poorly understood. Cyclists, especially those who do not drive, may be unaware of the wide swing necessary for large vehicles to turn left. Drivers tend to expect cyclists to always be on the nearside of a lane and to be easy to overtake. Cyclists also can believe that the safest place for them is on the nearside and may not be aware of the dangers of undertaking. Cyclists may also encounter aggression if they attempt to take a more assertive road position. There is a requirement for understanding and tolerance on the part of both cyclists and motorised road users of the need for a cyclist at times take a more positive road position to safety perform a manoeuvre or negotiate a junction.

Messages for drivers

- Give a wide berth when overtaking cyclists – large vehicles in particular can affect the stability of the cyclist when they pass
- If there is not sufficient space, give way to the cyclist – even if they do not have the official right of way
- Give space to cyclists – hold back if necessary, they may be taking a ‘primary position’ in the road to perform a manoeuvre
- Do not drive right up to or into an ASL as this reduces visibility of the cyclist
- Avoid overtaking a cyclist just before a junction (especially when the intention is to turn left) or when there is stopped or slow moving traffic ahead

Messages for cyclists

- Allow a safe gap when passing parked cars i.e. a doors width
- Large vehicles need a larger space to the left of them when making left turns than cars/vans – they may straddle the lanes or use lane 2 to turn left
- Awareness of large vehicles’ blind spots – especially to the front and nearside front corner – avoid positioning the bicycle within these
- Do not undertake large vehicles on the approach to a junction irrespective of ASL provision
- Assume a positive ‘primary position’ on the approach to a junction rather than ride to the nearside
- Do not undertake vehicles by riding on the pavement as this makes cyclists much less visible and is dangerous to pedestrians
- Do not wait or join a road to the nearside of a large vehicle, even if they are in the next lane along – hold back or join in a gap
- Where possible choose a road position and use hand signals that communicate your intention to other road users
- Take a consistent/predictable path when cycling – especially through junctions e.g. use lane markings as a position guide especially on curving or staggered junctions

4.4.2. Observing cyclists – mirror use

A greater expectation that they will encounter cyclists is likely to increase a driver’s ability to observe cyclists. However a more tangible behaviour change would be where drivers check their mirrors for cyclists and have an increased awareness of the need for this.

When examining the fatal and serious crashes involving HGVs, it was not possible to establish whether in reality the driver had checked their mirrors or not as the only evidence was driver self-report. In most cases the driver showed an awareness of the need to check mirrors for cyclists however in a few cases answers in the police interview suggested that some drivers use the close proximity mirrors primarily as parking mirrors. There also might be a need for a greater number of checks than drivers are routinely taught.

Good training on mirror use to spot cyclists is essential for all road users but this may need reviewing in the case of HGVs. There is also the issue that most drivers only do 1 test at the beginning of their driving career and unless they established good mirror habits then, they are unlikely to increase the number of mirror checks as a result of publicity campaigns.

Training need for all drivers

- Need to actively look for cyclists using direct vision and mirrors

Training needs for large vehicle drivers:

- Need to check mirrors and repeat check close proximity mirrors while stationary, as they start to move and as they commence a turn.
- Need to check mirrors and close proximity when moving to a nearside position during normal driving

4.4.3. Cyclist Visibility

Cyclists appear to have very little control over whether or not another road user observes them in daylight as a cyclist who positions themselves visibly and is wearing bright clothing, and reflectors may still not be seen. The relationship between wearing high visibility clothing and reduced crash risk is unproven. Miller (2012) examined the relationship between the use of high visibility equipment and reported crash rates and found a non-significant association. More recently Walker et al (2013) examined the effects of a variety of tabards on the passing proximity of cars and found no difference for a range of styles including high-visibility and markings “Police” (sic). The only version that showed a significant effect was marked “Police – video recording”.

Wearing bright high contrast clothing might make the cyclist more visible but this should not be relied upon. Clothing technology – both reflective and light emitting – is improving and this may allow simple clothing items that can be worn that increase the cyclist’s visibility.

Wearing clothes with retro-reflective properties are likely to improve visibility at night and help in their identification as a cyclist.

In the UK, the use of front and rear lights at night is mandatory for cyclists although not all cyclists in the sample complied with this. Out of the 14 crashes that occurred in darkness or partial light, 7 pedal cyclists used lights however only 5 of these used both front and rear with the remainder using rear only. This could be due to wide variety of reasons from lack of compliance with the law to lack of awareness that artificial lighting does not provide adequate vision of cyclists. Additional flashing lights worn on cloths, backpacks or the helmet may increase the likelihood of a cyclists being recognised as a cyclist and could help create the cyclist ‘signature’ as discussed in section 4.3, however this requires more detailed research. It is also possible that the use of lights in the day time would make cyclists more identifiable but again this is an area that needs greater research.

Messages to cyclists

- High contrast clothing may increase visibility but not necessarily the likelihood of being seen
- Artificial street lighting does not remove the need for cycle lights
- Using cycle lights when it is dark is mandatory

4.4.4. Use of information and entertainment systems

It is difficult to assess whether the use of information systems such as navigation or telephones or entertainment systems led to distraction for the road users in the fatal and serious injury cases.

Seven cyclists wore headphones but despite the manifold distraction issues presented it is thought that only two cases headphone wearing could have contributed to the crash. It is unlikely that measures to encourage cyclists not to wear headphones while cycling would reduce the number of fatal crashes. A more effective strategy may be to explore ways of utilising headphone in direct communication between motorised vehicles and cyclists as discussed in section 4.3.4.

Three HGV drivers were on the telephone at the time of their crashes – in 2 cases using a hands free device and in the other it was not clear whether the call was taken hands free or not. All three drivers were turning left at a junction (2 light controlled cross roads and 1 light controlled roundabout). In 2 of these cases using the phone was thought to have led to missed mirror checks and was therefore a distraction. In the remaining case the phone use was not considered contributory by the police but the driver was not indicating so it is possible that the phone call was also a distraction in this case.

Using a phone while driving, albeit hands free, will add to a drivers workload, which may be considerable in the case of a HGV negotiating a left turn at a junction. It is therefore advisable for HGV drivers not to use their mobile telephones at all while driving. This could be achieved through legislation or through appropriate integration of the telephone into the vehicle systems.

Message for HGV drivers

- Refrain from talking on a phone while driving, even if a hands free device is available

4.4.5. Communication between road users

As discussed in the Vehicle section (section 4.3), misunderstanding the other road users' is likely to increase the risk of a crash occurring. This is exacerbated in the case of cyclists as drivers are often not regular cyclists and cyclists may not be drivers so the rules they cycle/drive to may not be understood by the other party.

It is important that cyclists actively communicate with drivers and establish eye contact so that they know that the other driver has seen them. This could be achieved by positioning or more active techniques such as waving. Using audible sound such as bells or whistles could also be beneficial but these would have to be directional and only likely to be effective if the driver has direct sight of the cyclist.

It may be beneficial to cyclists if drivers, especially of HGVs, signal their intention to turn well in advance. If a driver only signals their intention to turn left when they start moving, for example in response to a green light, then this may be too late for the cyclist who has already commenced an undertake manoeuvre. Late signalling was identified as a contributory factor for 2 of the sample crashes involving HGVs.

Message to cyclists

- Use strategies such as eye contact, waving or using a bell/whistle to attract the attention of drivers and ensure that they can see you

Message to drivers

- Activate indicators well in advance of the point of turning before stopping at traffic lights and ensure that indicators are left on whilst stationary

4.4.6. Helmet use

Twenty-nine cyclists in the fatal and serious injury crash sample are known to have sustained a head injury. Out of these, 14 (48%) were wearing a helmet at the time of collision although this was fitted incorrectly in one case. Seven crashes were identified where wearing a helmet or a correctly fitted helmet, would have probably mitigated the head injuries sustained. It is unlikely however that wearing a helmet would have prevented the head injuries entirely. In contrast there were also 4 crashes where the only impact to the cyclist was from the road, in all four of these cases the cyclist was not wearing a helmet and in all four the cyclist died as a result of head injuries.

In addition, analysis of the dataset[13] that links STATS19 with Hospital Episode Statistics reveals that head was the most frequently injured body region for cyclists sustaining slight or serious injuries (see Figure 16).

The prevention and mitigation of head injuries to cyclists therefore is a major objective of casualty reduction strategies nationally.

Promote the voluntary wearing of cycle helmets

The protective benefits of cycle helmet use have been examined by many researchers with the most recent work being conducted by Elvik (2011). Elvik combined the results of 23 separate studies using a statistical technique called meta-analysis to derive an estimate of the changes in injuries when helmets are used. The

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most recent analysis included a control of several confounding factors including publication bias, time trends and zero score cells. The results were lower than previous estimates and Elvik concluded that the risk of sustaining head injury is 58% lower for cyclists who wear a bicycle helmet than for the cyclists who do not, with a 95% confidence interval of 45% – 75%. For brain injury, the best estimate of risk seems to be 47% lower (with a confidence interval of 29% –75%). If all investigated head, face and neck injuries are considered together, the risk decrease appears to be smaller but still present (factor of 85%, 95% confidence interval: 74% –98%).

Helmets are likely to be the most effective in crashes without contact with a motorised vehicle or where the speeds are low and the cyclist is not run over. Standard helmets compliant with the European standard (EN-1078) are thought to offer too little protection in crashes cyclists are in collision with cars travelling at higher speeds (DaCoTA, 2012). It should also be noted that the injury risk figures quoted in this section relate to the risk of injury, given the cyclist is involved in a crash – they are not related to the risk of becoming involved in a collision.

42% (22/53) of the cyclists in the fatal and serious sample were wearing a helmet when they were involved in a crash which suggests that helmet wearing rates in London may be relatively high – although the sample cannot be said to be representative of the general cycling population.

There is scientific evidence that helmet wearing reduces the risk of head injury. Despite this, mandating the wearing of bicycle helmets may not be an effective countermeasure. DaCoTA (2012) describes a number of reasons for this including potentially negative behavioural changes in motorists in response to seeing a cyclist with a helmet e.g. passing closer and cyclists when wearing a helmet e.g. riding faster and reductions in the numbers choosing to cycle following the introduction of mandatory helmet wearing legislation. However for the latter case the long term effects on the numbers of cyclists are not known.

4.4.7. Road user countermeasures – approaches targeting behavioural change

It is not enough to just set out the training and knowledge needs of cyclists and drivers. Attempts must be made to communicate the required knowledge and provide opportunity for training additional to the formal training of drivers.

Changing road user behaviour is challenging and can take a long time if cultural influences are involved. Actively engaging road users e.g. in a training or experience exercise is likely to be more effective than providing passive information, e.g. in the form of leaflets or TV campaigns. Certain groups may be more difficult to reach than others. It is recommended that a mixture of approaches should be taken including multi-media campaigns, changes to formal driver training, cyclist training schemes and community interventions.

- ***Include real world cycle scenarios in hazard perception tests***
- ***Training: Greater emphasis on awareness of cyclists – especially for HGV drivers - and common scenarios e.g. turning left where cyclists are very vulnerable***
- ***Use simulators to increase trainee HGV drivers' exposure to incidents involving cyclists.***

- ***Provide free short cycle skills training and refresher courses***
- ***Trained cycle instructors offering free or low cost cycle awareness sessions with companies; drivers experience riding pedal cycles.***
- ***Initiatives based in the community – focus on lower income, e.g. giving away pedal cycle lights***
- ***Experience based initiatives (e.g. TfL awareness events that put cyclists in HGV cabs to demonstrate blind spots – 'Exchanging Places')***
- ***Conduct a wide reaching awareness campaigns to try and start moving culture to be more tolerant and aware of cyclists.***

4.5. Traffic and infrastructure – system management related countermeasures

This section addresses countermeasures that affect the road system as a whole.

Half of the fatal and serious crashes involving HGVs (14/27) occur between 07:00 and 09:59 with a further 10 occurring between 10:00 and 11:59. There is a particular peak between 08:00 and 08:59 when 10 crashes occurred. There is no equivalent peak of crashes for the afternoon rush hour (16:00-18:59pm) but it is unknown whether this is due to a lower number of HGVs on the road at this time. It may also be that journeys from work to home are more spread out over time.

Restrict HGV movement during commuting times

A way of reducing cyclist's exposure to HGV conflicts would be to restrict HGV movement during times when the most commuting activity occurs. This could be done through regulation or incentive, for example increasing the congestion charging for HGVs between 08:00 and 09:00am. The effect this would have on the distribution of traffic for the rest of the day would need examining, as would the economic impact of delaying when deliveries to building sites can be made.

4.5.1. Enforcement

Violation of traffic laws was found to be a contributor to the fatal and serious crashes in a few cases.

The notable instances were cars travelling at speeds exceeding the speed limit (5 cases) and cycling at night without lights (4 crashes) or with only 1 light (2 rear only, 1 front only). This includes 4 crashes where both the driver was travelling over the speed limit and the cyclist had no (3 crashes) or rear only (1 crashes) bicycle lights in use.

One speeding driver was not traced and two were young drivers (<22 years of age). Another of the speeding drivers had previous convictions of driving without a licence or insurance.

The cases where the cyclist was not using lights or was only using 1 light represents 64% (9/14) of all the crashes that occurred in the dark. This suggests that there may be a compliance issue and the need for greater enforcement. One method of encouraging cycle light use through enforcement would be to waive a Fixed Penalty Notification if cycle lights are purchased from the police.

There was no evidence in the police files that cyclists or other motorists were passing through traffic signals while they were set to red.

4.5.2. Cyclist visibility

A way to encourage the visibility of cyclists is to influence the nature of products available for purchase.

Encourage manufacturers to build in retro-reflective material into retail bikes

Encouraging manufactures to add retro-reflective material/paint to bikes in a standardised way e.g. frame, pedals and handle bars, would assist in creating a bike signature as discussed in section 4.3.

Incentivise the purchase of high contrast and retro-reflective containing products through subsidy/price reduction

Consumers can be influenced to purchase cycle equipment with greater conspicuity properties through price reduction on certain styles. For example the white or yellow version of a range of cycle helmets could be reduced in price in relation to other colour options to encourage their purchase.

4.5.3. Site/Fleet management

A number of HGV and 3.5-7.5 tonne trucks included in the sample can be said to be related to the construction industry, e.g. Tipper (n=11), Flat/drop side (n=5), Skip carrier (n=3), Cement mixer (n= 1). Construction sites should take responsibility for the safety of these vehicles in addition to those responsible for managing the specific fleets of vehicles.

Construction site managers should be responsible for the safety of the journeys made by contractors to and from site

Restrict trucks to specific main road routes

There is a necessity for trucks and other vehicles to access construction sites however this increases the risk to cyclists using the roads in the area. To encourage construction related business to adopt high safety standards, the journeys made to and from construction sites – especially those made by trucks – should be included in the health and safety remit of construction site managers.

Site managers should apply a strategy that sets out the routes that should be used to and from sites in a way that limits the exposure of cyclists to HGVs. The strategy should also set out the safety equipment that should be fitted to vehicles and the procedures that should be adopted by drivers. These requirements should be enforced by vehicle checks that have to be passed before a vehicle is allowed to enter the site.

The standards and procedures adopted by the Crossrail project could be used as an exemplar for this.

4.6. Summary of Countermeasures

The following tables summarise the countermeasures discussed in Chapter 4 and the number of fatal and very serious injury pedal cycle crashes in the sample that they apply to. This summary should not be taken out of the context of the explanatory text in Chapter 4. Sub countermeasures are aligned to the right hand side of the column.

There have been limited evaluation studies conducted of road safety measures and the evidence of the systematic evaluations that relate to these countermeasures is presented in Chapter 5.

Table 35: Infrastructure countermeasures – evidence from the sample of fatal and very serious injury crashes

Infrastructure Countermeasures	Number of relevant cases (n = 53)
Create a manual with guidelines for appropriate cycling infrastructure for each of the road typologies in the London street family	General guidance
Conduct an area review when designing new or altering existing road infrastructure to take into account cyclists needs	General guidance
Use segregated cycle infrastructure unless the risks and conflicts associated with on-road cycling are sufficiently low	General guidance
Consider how to facilitate safe entrance and exit to cycling facilities	5
Establish and maintain clear sight lines both for cyclists and other road users when cycle path/tracks cross other roads	3
Design road infrastructure that prioritises cyclists	11
Where segregated infrastructure is not necessary for high levels of safety, provide infrastructure to facilitate cyclists sharing the same space and or route with other road users	General guidance
Provide infrastructure to separate cyclists travelling straight on from left turning vehicles at junctions	8
Facilitate large vehicle left turns from lane 1/Nearside lane	2
Establish predictable road or lane widths to prevent pinch points that result in unexpected crowding of cyclists and motorists into short stretches of limited space	4 (8 cases with narrowing as causation factor)
Consider the impact of roadside parking on cyclists	2
Use 'cycle friendly' traffic calming when there is a need to reduced traffic speed	1
Preserve space for cyclists - Especially at points where kerb stones and guard rails contribute to road narrowing	2
Provide clear routes for all road users through junctions e.g. by using clear road markings	4
Introduce advanced phasing for cyclists alongside ASLs	9
Introduce a 'no vehicle' zone in between the stop line and ASL	5
Establish safer entry paths for ASLs away from nearside entry	12

Table 36: Vehicle countermeasures – evidence from the sample of fatal and very serious injury crashes

Vehicle Countermeasures	Number of relevant cases (n = 53)
Fit/Retro-fit Class VI mirrors to all large vehicles with forward blind spots	4
Redesign HGV cabs to facilitate increased direct forward vision	7
Review the effectiveness of existing mirrors in showing the present of cyclists around the front and nearside front cab area – particularly while moving	26
Evaluate the casualty reduction effectiveness of proximity sensors in detecting the presence of cyclists and other road users alongside the cab	26
Evaluate the casualty benefits resulting from the application of automatic/emergency braking to large vehicles	26
Fit all large vehicles with front and redesigned full (horizontal and vertical) side guards	31
Extend existing side guards to include areas previously exempt e.g. fuel tanks	3
Remove exemptions to side guard legislation	3
Promote the extension of pedestrian impact protection to include cyclists under European regulation and EuroNCAP	11
Promote the development of Automatic Emergency Braking Systems to include cyclists with a view to extend the scope of European regulation and EuroNCAP tests.	14
Fit retractable mirrors that only retract when the driver has left the vehicle	1
Promote increased visibility on bikes	General guidance
Create/promote a bike 'signature' to increase cycle recognition	General guidance
Explore/research vehicle to vulnerable road user communication using advanced telematics solutions	7
Improve visibility of left turn indication on large vehicles	8

Table 37: Road user countermeasures – evidence from the sample of fatal and very serious injury crashes

Road User Countermeasures	Number of relevant cases (n = 53)
Promote the voluntary wearing of cycle helmets	7
Include real world cycle scenarios in hazard perception tests	General guidance
Training: Greater emphasis on awareness of cyclists – especially for HGVs & common scenarios e.g. left turning where cyclists are very vulnerable	General guidance (27 HGV/3.5-7.5 tonne)
Use simulators to increase trainee drivers exposure to incidents involving cyclists.	General guidance (27 HGV/3.5-7.5 tonne)
Provide free short cycle training and refresher courses	General guidance
Cycle training/awareness courses/instructors go into companies – free/low cost (teach drivers to ride bike and how to position self to increase awareness of needs).	General guidance
Initiatives based in the community – focus on lower income. E.g. include giving away lights	General guidance
Experience initiatives (e.g. TfL awareness events that put cyclists in HGV cabs) – demonstrate blind spots.	General guidance (27 HGV/3.5-7.5 tonne)
Conduct a wide reaching awareness campaigns to try and start moving culture to be more tolerant and aware of cyclists.	General guidance

Table 38: Management countermeasures – evidence from the sample of fatal and very serious injury crashes

Management related Countermeasures	Number of relevant cases (n = 53)
Restrict HGV movement during commuting times	14
Encourage manufacturers to build in retro-reflective material into retail bikes	General guidance
Incentivise the purchase of high contrast and retro-reflective containing products through subsidy/price reduction	General guidance
Construction site managers should be responsible for the safety of the journeys made by contractors to and from site	20 (construction type vehicles)
Restrict trucks to specific main road routes	General guidance

5. EVIDENCE BASED AND NATIONAL POLICY APPROACHES

This section looks at the evidence concerning the effectiveness of measures to reduce collisions and injuries among cyclists in relation to a systems approach focusing on the environment, the road user, vehicle and operations. Approaches to cyclist safety are shown in two ways. Firstly, local specific measures that were amenable to evaluation have been identified and secondly, broader policy approaches implemented by the best performing countries are referred to in section 5.2. Evaluation in terms of changes in injury collisions are largely only available for local infrastructure schemes. In this summary we have identified evidence for cycle safety interventions based on a systematic review of high quality studies and have looked at the best performing countries to explore what measures they implement. The best performing countries are those which achieve a low level of risk i.e. a low rate of casualties per 'unit' of cycling whether that is number of trips, time taken or kilometre cycled. Only three European countries, GB, Denmark and the Netherlands, routinely measure the numbers of cyclists and distance travelled through national travel surveys although other countries such as Norway and Sweden carry out ad hoc surveys to estimate risk, but this data is not updated yearly. These data show that the UK does not perform well compared to other European countries such as Norway, Denmark, the Netherlands and Sweden (see Figure 42).

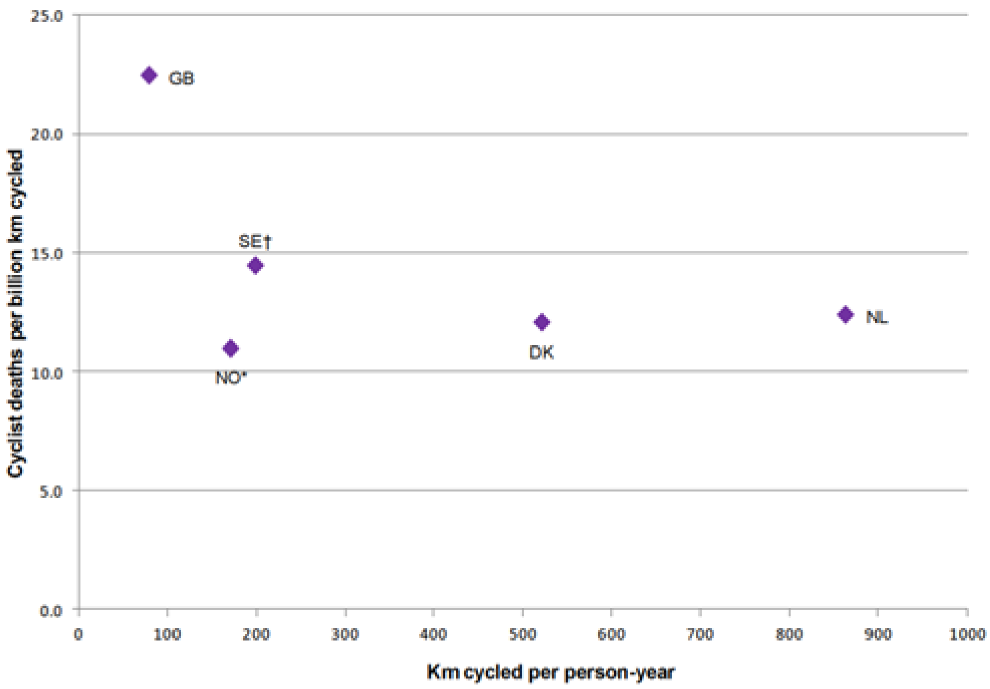

Figure 42: Cyclist fatalities and Km travelled in the best performing countries (from ETSCb)

5.1. Local schemes

Table 39 shows the type of measure, the evidence of safety benefit in terms of statistically significant findings and whether there are benefits for other road users. However, there are a number of caveats regarding interpreting evidence. A key issue in interpreting the results of the evaluation of interventions to improve cyclist safety is that changes in exposure, i.e. the amount of cycling pre and post implementation is often not collected and therefore this limits what can be concluded about reduction in risk expressed as the number of casualties (numerator) divided by the number of cyclists (denominator).

This is extremely important because any changes in the number of cyclists may affect casualty levels and lead to wrong conclusions about the effectiveness of different measures in reducing casualties. For example, a road with new cycling measures such as a cycle superhighway may attract more cyclists and therefore may be associated with more casualties than before but the risk (e.g. casualties per km) may have decreased or stayed the same.

The table below shows local measures that are amenable to statistical evaluation. This is largely based on the most recent systematic reviews of road safety measures including cycling infrastructure carried out by Elvik et al (2009) who identified ‘best estimates’ of changes in cyclist casualties using meta-analysis. Most of the studies included in the meta-analysis came from Scandinavian countries, the Netherlands and a few from the UK. However, most of the studies have not controlled for the number of cyclists before and after installation and it is unclear what role changes in exposure i.e. amount of cycling, may have had.

A notable finding is that many of the measures aimed at improving safety for cyclists may also confer benefits to other road users, these are identified below. Creating a safer environment for cyclists may also encourage more cycling which has potential benefits for health also discussed in this chapter.

In terms of understanding the cost and benefits of these measures Elvik et al (2009) quote evidence that finds the benefits of an integrated network of routes for pedestrians and cyclists in terms of improved health, reduced collisions, travel times and feeling unsafe are at least four to five times the costs in terms of investment and maintenance.

Table 39: Local measures evaluation evidence

Local measure[14]	Evidence of effectiveness for cyclist injury collision	Evidence of for other effectiveness for other road users (where available)
Cycle lanes in traffic	Significant decrease along road BUT significant increase at junctions	Significant decrease observed for pedestrians and car occupants
Coloured cycle lanes	Significant decrease along the road in cyclist casualties (simple junctions) BUT significant increase at complex junctions	Non-significant increase for pedestrians and car occupants
Cycle paths	Significant decrease along road BUT significant increase at junctions	Significant decrease for car occupants
Interrupted cycle paths (end before junction)	Significant decrease	Not available
Continuing cycle paths at give way junctions	Non-significant decrease	Significant reduction for pedestrians and non-significant increase for car occupants
Shared pedestrian and cycle tracks	No significant decrease	Non-significant reduction for pedestrians
Advance Stop Lines (ASLs) (without reservoirs)	Non-significant decrease	Non-significant reduction
20 mph zones supported by engineering measures	Significant decrease (children)	Pedestrians (children)
Side entry treatments for junctions, together with raised cycle crossings and improved signalisation of roundabouts	Significant decrease	Not available

[14] In the Elvik study cycle lanes are a separate designated space on the carriageway, cycle paths are spaces that is physically separated from the carriageway, e.g. by kerbstones and tracks for walking and cycling are roads for pedestrians and cycles travelling in both traffic directions, which are physically separated from the carriageway usually on one side of the road only.

Cycle lanes

Elvik et al (2009) showed that for cycle lanes in traffic:

- There were significantly fewer collisions amongst cyclist compared to roads without lanes.
- There are casualty reduction benefits to all road users
- At junctions there are more collisions on roads with cycle lanes
- There are fewer reductions for cyclists than other road users and one possible explanation is that there are an increased number of cyclists and increased speed of cyclists.

Elvik et al looked at other features of cycle lanes in relation to junctions and concluded that:

- Interrupted cycle paths (where the path ends immediately before the junction) were associated with a significant reduction in collisions. The potential explanation of this was that it makes cyclists feel unsafe and therefore more cautious and that it forces communication between road users;
- Continuing cycle paths at give way junctions were associated with a non-significant reduction in cyclist casualties;
- Advance Stop Lines (ASLs) (without reservoirs) were associated with a non-significant reduction with the evidence indicating that there is some misuse of ASLs by motorists who stop on the line rather than behind it; a finding corroborated by Allen et al (2005) for ASLs with reservoirs which showed that these were often encroached by drivers;
- Coloured cycle lanes showed a significant reduction in cyclist casualties but were more effective in simple vs. complex junctions where they could increase risk. In fact, the evidence shows that there is an exponential increase in casualty risk between casualty rates at one, two to four arm junctions.

Separate cycle paths

Elvik et al (2009) found that there were only small changes in total collisions on separate cycle paths but again the number of cyclists had not been controlled for. Paths alongside roads saw a significant decrease in cyclist collisions along the road but an increase at junctions, with a net increase in casualties for cyclists associated with cycle paths. This was explained by a potential lack of communication between cyclists and drivers because of the separation along the road.

Combined walking and cycling paths

Elvik et al (2009) found that the total number of collisions was not reduced on combined walking and cycling paths but there was a non-significant reduction in pedestrian collisions along the road, and again there was no control for exposure.

Traffic calming

Traffic calming of residential neighbourhoods keeping speeds at 30 km/hr or 20 mph supported by engineering measures to deter speeding by cars has shown statistically significant casualty reductions among child cyclists and pedestrians in

London (Grundy et al 2009). The best performing countries also allow cycling in both directions on all such traffic-calmed streets, even when they are one-way travel for cars and promote ‘bicycle streets’ - narrow streets where cyclists are given priority over the whole width of the street (Pucher and Buehler, 2008).

Complex junctions

Managing conflict points especially at complex junctions is also a key strand of approaches by the best performing countries such as the Netherlands e.g. Dutch style roundabouts (SWOV, 2010). Side entry treatments for junctions, together with raised cycle crossings and improved signalisation of roundabouts, have been shown to reduce cyclist casualties in the UK (Reid and Adams, 2011). In Sweden, a study by Gårder et.al (cited in ETSC 2012a) found a 33% reduction in collisions involving cyclists when junction crossings were raised. In this case, the raised junction was used as a measure to reduce traffic speed.

5.1.1. Vehicle

No systematic evaluation studies of introducing technology to vehicles or changes in vehicle design in relation to reducing cyclist collisions/casualties were found.

5.2. Broader policy approaches associated with the best performing countries

5.2.1. Road user

Education and training

There is little research evidence on the effectiveness of training and education programmes however, partly but not solely because it is difficult to associate the specific events of a crash to previous learning experiences of road users. Furthermore there are some circumstances where it can be demonstrated that training can result in more high risk behaviours (Kinnear, 2013) and it cannot be considered that education and training are the most effective means of casualty reduction. However, the best performing countries have comprehensive cycling training courses for virtually all school children and special cycling training test tracks for children combined with rigorous training for drivers to encourage them to respect pedestrians and cyclists, and avoid collisions (Pucher and Buehler, 2008).

5.2.2. Injury Mitigation

The role of the pedal cycle helmet in mitigating head injuries has been widely researched and evaluated. Elvik (2011) reviewed previous meta-analyses resulting in 23 different studies and concluded that, while the effectiveness was lower than previous meta-analyses, the risk of sustaining head injuries is 1.72 times higher (i.e. nearly twice the risk) for cyclists not wearing a helmet than it is for cyclists who do wear a helmet.

5.2.3. Management

Legislation

The best performing countries have special legal protection for children and elderly cyclists whereby motorists are assumed by law to be responsible for almost all crashes with cyclists which is strictly enforced by the judiciary. The law of ‘proportionate liability’, assuming that the larger vehicle should be responsible for a crash and this would offer cyclists greater protection. The ‘liability’ refers to responsibility for reparations in terms of civil law, rather than criminal blame. This law only regulates the party’s insurance company that pays for damage after an unintentional crash. There has been no identified review of the direct impact of these measures on casualty reduction and an estimate of casualty reduction effectiveness in the UK context cannot therefore be made.

5.3. Summary of evidence and countermeasures

The evidence for the countermeasures from the sample of fatal and serious pedal cycle crashes in terms of number of cases, as described in Chapter 4 is summarised with the evidence from systematic evaluations in the following tables. Table 40 contains the countermeasures with some evidence from evaluation studies and Table 41 contains those which do not have such evidence. As previously stated there is limited evidence from evaluation studies therefore the number of crashes relating to each countermeasure may give a more reliable picture of their value.

Although there has been little systematic evaluation of these countermeasures, the analysis of the fatal and serious crashes indicated (Chapter 3) that if a range of countermeasures from each of the system components are successfully implemented, then there is likely to be a reduction in fatal cyclist casualties.

Table 40: Countermeasures with evidence from evaluation studies

Countermeasures addressed by systematic evaluation	Number of relevant cases (n=53)	Relevant evidence	Evidence of effectiveness for cyclists	Evidence of benefit for other road users
Infrastructure				
Use segregated cycle infrastructure unless the risks and conflicts associated with on-road cycling are sufficiently low	General guidance	Cycle paths	Significant decrease along road **BUT** significant increase at junctions	Significant decrease for car occupants
		Shared pedestrian and cycle tracks	No significant decrease	Non-significant decrease for pedestrians
Consider how to facilitate safe entrance and exit to cycling facilities	5	Interrupted cycle paths (end before junction)	Significant decrease	Not available
		Continuing cycle paths at give way junctions	Non-significant decrease	Significant decrease for pedestrians and non-significant increase for car occupants
Where segregated infrastructure is not necessary for high levels of safety, provide infrastructure to facilitate cyclists sharing the same space and or	General guidance	Cycle lanes in traffic	Significant decrease along the road in cyclist casualties (simple	Non-significant increase for pedestrians and car occupants

route with other road users			junctions) **BUT** significant increase at complex junctions	
		Coloured cycle lanes	Significant decrease along road **BUT** significant increase at junctions	Significant decrease for car occupants
Use 'cycle friendly' traffic calming when there is a need to reduced traffic speed	1	20 mph zones supported by engineering measures	Significant decrease (children)	Significant decrease for child pedestrians
Introduce a 'no vehicle' zone in between the stop line and ASL	5	Advance Stop Lines (ASLs) (without reservoirs)	Non-significant decrease	Non-significant decrease for all
Establish safe entry paths for ASLs	12	Not specifically evaluated		
Road User/Injury Mitigation				
Promote the voluntary wearing of cycle helmets	7 (where a helmet might have mitigated injuries)	Effect of wearing a helmet on injury mitigation	Significant decrease	Not Known

Table 41: Countermeasures without evidence from evaluation studies

Other Countermeasures which have not been addressed by systematic evaluations[15]	
Infrastructure	**Number of relevant cases (n = 53)**
Create a manual with guidelines for appropriate cycling infrastructure for each of the road typologies in the London street family	General guidance
Conduct an area review when designing new or altering existing road infrastructure to take into account cyclists needs	General guidance
Establish and maintain clear sight lines both for cyclists and other road users when cycle path/tracks cross other roads	3
Design road infrastructure that prioritises cyclists	11
Provide infrastructure to separate cyclists travelling straight on from left turning vehicles at junctions	8
Facilitate large vehicle left turns from lane 1/Nearside lane	2
Establish predictable road or lane widths to prevent pinch points that result in unexpected crowding of cyclists and motorists into short stretches of limited space	4 (8 cases with narrowing as causation factor)
Consider the impact of roadside parking on cyclists	2
Preserve space for cyclists - Especially at points where kerb stones and guard rails contribute to road narrowing	2
Provide clear routes for all road users through junctions e.g. by using clear road markings	4
Introduce advanced phasing for cyclists alongside ASLs	9

[15] Sub countermeasures are right justified

Establish safe entry paths for ASLs	12
Vehicle	**Number of relevant cases (n = 53)**
Fit/Retro-fit Class VI mirrors to all large vehicles with forward blind spots	4
Redesign HGV cabs to facilitate increased direct forward vision	7
Review the effectiveness of existing mirrors in showing the present of cyclists around the front and nearside front cab area – particularly while moving	26
Evaluate the casualty reduction effectiveness of proximity sensors in detecting the presence of cyclists and other road users alongside the cab	26
Evaluate the casualty benefits resulting from the application of automatic/emergency braking to large vehicles	26
Fit all large vehicles with front and redesigned full (horizontal and vertical) side guards	31
Extend existing side guards to include areas previously exempt e.g. fuel tanks	3
Remove exemptions to side guard legislation	3
Promote the extension of pedestrian impact protection to include cyclists under European regulation and EuroNCAP	11
Promote the development of Automatic Emergency Braking Systems to include cyclists with a view to extend the scope of European regulation and EuroNCAP tests.	14
Fit retractable mirrors that only retract when the driver has left the vehicle	1
Promote increased visibility on bikes	General guidance
Create/promote a bike 'signature' to increase cycle recognition	General guidance
Explore/research vehicle to vulnerable road user communication using advanced telematics solutions	7

Improve visibility of left turn indication on large vehicles	8
Road User	**Number of relevant cases (n = 53)**
Include real world cycle scenarios in hazard perception tests	General guidance
Training: Greater emphasis on awareness of cyclists – especially for HGVs & common scenarios e.g. left turning where cyclists are very vulnerable	General guidance (27 HGV/3.5-7.5 tonne)
Use simulators to increase trainee drivers exposure to incidents involving cyclists.	General guidance (27 HGV/3.5-7.5 tonne)
Provide free short cycle training and refresher courses	General guidance
Cycle training/awareness courses/instructors go into companies – free/low cost (teach drivers to ride bike and how to position self to increase awareness of needs).	General guidance
Initiatives based in the community – focus on lower income. E.g. include giving away lights	General guidance
Experience initiatives (e.g. TfL awareness events that put cyclists in HGV cabs) – demonstrate blind spots.	General guidance (27 HGV/3.5-7.5 tonne)
Conduct a wide reaching awareness campaigns to try and start moving culture to be more tolerant and aware of cyclists.	General guidance

Management	**Number of relevant cases (n = 53)**
Restrict HGV movement during commuting times	14
Encourage manufacturers to build in retro-reflective material into retail bikes	General guidance
Incentivise the purchase of high contrast and retro-reflective containing products through subsidy/price reduction	General guidance
Construction site managers should be responsible for the safety of the journeys made by contractors to and from site	20 (construction type vehicles)
Restrict trucks to specific main road routes	General guidance

6. DISCUSSION AND RECOMMENDATIONS

This research has been undertaken against the backdrop of a TfL policy target to increase cycling by a factor of four by the year 2026 against a baseline of 2001 levels. Alongside this is a further target to reduce the numbers of those killed and seriously injured on London's roads by 40% by the year 2020 against a baseline of 2005-09, with cyclists accounting for approximately one-fifth of all KSIs in 2013. To achieve this target alongside increasing cyclist exposure, the levels of cycling risk must reduce rapidly. There is a cyclic dependency since the amount of cycling is partially determined by the perceived levels of safety which may not always have a strong evidence base. Levels of cycling are likely to be undermined by a high media focus on safety levels.

The objectives of this research were to analyse fatal and life-changing serious injury crashes, to identify the key contributory factors and to recommend countermeasures and future safety policies to reduce cyclist crashes. Of the 79 fatal collisions that occurred in the area covered by the Metropolitan Police in the years 2007 – 2011 there were 53 that were relevant and which had full details available for analysis. These have formed the sample of crashes that has been studied in this analysis. The cases are representative of fatal cyclist collisions that take place in London however they have some characteristics that differ from the crashes that take place nationally. Key areas of difference include:

- Fatal collisions with trucks which describes 51% of fatalities in London compared with 20% nationally
- The speed limit of the roads where 89% of fatalities in London took place on roads with a 30 mph speed limit compared to 48% nationally
- The period of the year when the collisions occurred-73% of the collisions occurred in the six month period from November to April compared to 42% nationally

Given these differences some of the priorities for action identified in this report for implementation may be different at a national level however many of the detailed implications for cyclist safety will still apply.

The analysis of the crashes has identified a large number of risk factors that have contributed to the fatally and seriously injured casualties. When examining the crash at this very detailed level it is apparent that each one has a unique set of factors that led up to the crash. Nevertheless it has been possible to group the contributing factors at a more general level and to identify a number of key areas where co-ordinated action can potentially result in significant improvements in cyclist safety. These areas and the recommendations that result from them are based on the crash data analysis and relate to cycling infrastructure, vehicle design and road user behaviour and management

The conclusions we can make about effective interventions are limited by the lack of well controlled evaluation studies. There has been inadequate research focus into the casualty reduction effectiveness of a range of road safety measures and while it is possible in many cases to identify the numbers of cases that a countermeasure will relate to it is not always possible to make any estimate of the numbers of casualties that may be prevented. For example a measure that could be introduced to reduce cyclist casualties from truck collisions concerns the use of automatic systems to detect the presence of cyclists to one side of the truck. Such systems are available to truck operators and anecdotally they are appreciated by some truck drivers. Nevertheless the authors have not been able to identify any systematic evaluations that demonstrate the systems do in fact reduce casualties so while it is possible to state that the systems are directionally sound and address a real-world problem it is not possible to estimate the impact on casualties.

The following sections set out the countermeasures that are most likely to be effective in the form of recommendations for action. These are either based on the number of crashes in the sample which are applicable – a minimum of 7/53 (~15%) – or for the general countermeasures, those which are thought to be most aligned with best practice.

6.1. Infrastructure developments

The design and operation of the road network is fundamental to the reduction of cyclist risks, by managing the interactions between road users the network has great potential to decrease or increase conflicts involving cyclists. Continental European countries and cities where cycling is common generally have well-developed infrastructure and higher safety levels, therefore a comparison with similar EU Member States indicates that much higher levels of cyclist safety could be possible for London and the UK. This report focuses on cyclist safety and seeks to identify suitable measures to improve the levels of risk. The experience from countries with high levels of cycling is that many of the measures introduced to improve cyclist safety will also increase the attractiveness of cycling, Pucher and Buehler (2008). There are likely to be additional benefits that increase the safety of other road users including pedestrians.

A common characteristic of high cycling countries is that the provision of cycling infrastructure is a basic part of the transport network. Many cities have a network of cycle routes bringing cyclists from residential areas through to common destinations. These particular cycle routes may often follow a separate route that attracts cyclists and separates them from motorised traffic. Separate cycle paths and provision of physically segregated cycle lanes on the road minimise opportunities for conflicts between cyclists and motorised road users and this is particularly important in areas with higher flows of cyclists and motorised road users. Cycle lanes are integrated within the road or pavement depending on traffic flows and where possible lane widths for motorised traffic are maintained. Segregation in terms of time and space can be achieved within on-road cycling infrastructure, for example by introducing measures that allow cyclists to get ahead of other traffic at junctions (Advanced phasing, double stop lines). Some guidance about the level of risk in terms of flow and speed that could form a threshold for the introduction of cycling facilities and segregation is available from comparisons with other countries (ETSC 2012a), the DfT (2008) and the London Cycling Design Standards (TfL, 2014) (see section 4.2). The classification of roads being undertaken by the Roads Task Force (RTF, 2013) provides a framework that can be used to establish the appropriate level of infrastructure needed to improve cycling safety.

Research has not found substantial reductions in risk where there are segregated facilities however the studies do not control for changes in exposure. The introduction of new cycling facilities is intended to promote cycling and increase exposure so any safety evaluation that does not account for these changes will not provide an accurate estimate of safety benefits. Theoretical considerations indicate that reductions in conflicts between cyclists and other road users are most likely at junctions and this analysis has shown that 74% of fatal collisions occur while negotiating junctions. Even in high cycling countries junctions remain a challenge however there are many good examples of junction management (See chapter 4 for some examples and ETSC 2012a) with elements that may be beneficial for cycle safety in London.

This analysis has also identified a particular road environment that has been termed “complex, busy junctions”. These are locations where several roads may intersect, flows of cyclists and motorised traffic are high, particularly in peak hours, and multiple lanes and exits result in very many opportunities for conflicts. Fatalities may be accompanied by high numbers of non-fatal cyclist collisions. These are areas where it is very difficult to reduce the safety of cyclists without a complete segregation from other traffic.

Recommendations for cycling infrastructure

- Identify and implement best international practice in cycle infrastructure and work towards emulating it within the UK legal, regulatory and behavioural context
- Design road infrastructure with an emphasis on cyclists’ needs and aim for a world leading provision
- In addition to providing for safer, more comfortable cycling on main roads, expand and connect the network of dedicated cycle routes away from heavily trafficked roads and ensure they connect to key destinations
- Establish criteria for when to separate cycle and motorised traffic. This guidance should include reference to traffic flows and speed and indicate where complete segregation in space or time is appropriate
- Establish guidance on carriageway and lane widths that avoid creating pinch points for cyclists
- Introduce advanced signal phasing or infrastructure for cyclists to give segregation in time or space at junctions
- Support proposals for changes to regulations that allow cyclists to cross the first stop line at Advance Stop Lines (ASLs) at any point

6.2. Collisions with vehicles

6.2.1. Collisions with trucks

Over 50% of fatally injured cyclist casualties were involved in collisions with trucks, most commonly at junctions where the truck turned left. Common characteristics of these crashes included:

- The cyclist had moved alongside the truck on its nearside usually as a result of undertaking but sometimes having been overtaken by the truck
- The truck driver was not aware of the presence of the cyclist despite the availability of Class V and sometimes Class VI mirrors
- The impact with the cyclist took place either at the left side of the front of the truck or at the front cab area part of the truck left side

- Once knocked to the ground the cyclist was run over by a wheel on either the first or second axle of the vehicle

There are two fundamental aspects to this group of cyclist fatalities – that the cyclist moved into close proximity to the truck and that the truck driver was unaware of their presence. Truck cabs typically place the driver eye-height at around 2.5 m above the ground, coupled with the high lower edge of the windscreen it is not possible for the driver to have a direct line of sight to shorter objects that are close by. While these problems are readily described the countermeasures are not so straightforward. Mirrors are used to extend the field of view of the driver and covering the area to the left (Class V) and in front (Class VI) of the cab however these still did not prevent a number of the fatalities occurring. The interviews included in the police reports analysed revealed that some drivers were not aware of the purpose of the mirrors and others did not look when they needed to. This has implications for the Safe Urban Driving course. A truck cab can be a busy work environment, particularly when traffic is congested or at junctions, and there are many competing demands on the driver's attention. Furthermore if either the cyclist or the truck is moving the cyclist may pass through the field of view of a Class V mirror in less than two seconds, in contrast experimental studies have indicated it may take over five seconds to properly check all mirrors (Cook et al, 2011).

The primary long-term solution for the deficiencies in vision is to promote a redesign of truck cabs. Current discussions taking place at European level do concern the design of trucks and the direct vision requirements of the drivers could potentially be included. The issue of truck vision has also been identified as an objective within the new European research funding programme called "Horizon 2020". A considerable period of time is needed for any redesign of truck cabs to be made and have any effect. As well as the time needed for development to take place there may also be a need to change regulations, finally the typical life of a truck can be over 10 years so it may be that 15 or 20 years are needed to develop new designs and for them to completely penetrate the vehicle fleet.

In the shorter term there may be some improvements to safety by requiring Class VI mirrors to be retrofitted and by further truck driver training and education. The use of cyclist detection systems to give a warning to the truck driver or cyclist or to automatically operate the brakes may also provide benefit. Unfortunately the authors have not been able to identify any scientifically based evaluations of sensing systems so any casualty reduction benefit is unproven.

In many cases the cyclist placed themselves in the position alongside the truck by their own choice, presumably unaware of the dangers involved. In some cases the cyclist may have felt encouraged to undertake the truck by the presence of an access cycle lane leading to an Advanced Stop Line. This study has shown that being alongside or immediately in front of a truck can be a location of very high risk. Despite public campaigns this continues to occur and while these campaigns should be maintained alternative methods to reduce these conflicts should be explored. A previous section of this report has identified the need for a closely integrated cycling network. One aspect of this involves the need to develop and implement new traffic management methods to prevent these conflicts occurring. Possibilities include, but are not limited to:

- Advance phasing traffic lights to enable cyclists to move off before other vehicles
- A clear zone between the rear of an ASL and the stopping line for vehicles to permit cyclists to be in a zone of direct vision
- Rerouting cyclists towards junctions with fewer trucks travelling in the same direction as part of a wider cycling network
- Preventing or limiting trucks from being in areas with high cyclist flows at peak times

The crash data analysis indicated that tipper trucks were the most common type, accounting for 11 of the 30 trucks (see Table 18) involved in collisions. Analysis of collision type for the tipper trucks shows that they do not differ in comparison to collision type for other truck types. It is therefore considered that the larger numbers are a result of the large amount of construction work taking place in London over the period studied. Twenty of the 30 trucks in the sample can be said to be construction related (tipper, flat/drop side, skip carrier, cement mixer) and safety gains could be made if the safety of journeys to and from site became the responsibility of the construction site management as well as the individual fleet operators.

Tipper trucks, together with skip carriers and refuse lorries are not required to be fitted with side under-run guards, these are structures fitted to the side of many trucks by regulation and are intended to prevent cars from passing underneath the truck side. They are also intended to prevent pedestrians and cyclists from being knocked under the truck. The crash analysis has shown that in most cases the initial contact with the cyclist took place ahead of any of the areas that would be covered by side-guards as they are currently designed and fitted, also the cyclists were probably on the ground before there would have been the chance of an interaction with a side guard. An inspection of the crashes indicated the presence of side-guards (current design) could have prevented the injuries in at most three cases. It would be necessary to extend the current design of side guards both horizontally and vertically and to fit guards on the front of trucks to prevent or mitigate injuries in the majority of the crashes included in the sample. It should be noted however that this research has only examined fatal or very serious collisions and it is not possible to estimate the numbers of crashes where a cyclist interacted with a truck with injuries that were prevented by a side-guard. A full evaluation of the potential benefits of improved side-guard standards should include a review of non-fatal cyclist crashes.

Recommendations to prevent fatal collisions with large vehicles

- Public Sector organisations to use and promote the use of Delivery Servicing Plans and Construction Logistic Plans to reduce/minimise lorry movements during commuting hours
- National Government to extend to scope of Health and Safety responsibilities to incorporate work-rated road safety
- Vehicle manufacturers to design lorry cabs that minimise front and side blind spots and facilitate maximum driver direct vision - EU and national Government to amend relevant regulations to facilitate this
- Vehicle manufacturers to improve the visibility of left turn indicators - EU and national Government to amend relevant regulations to facilitate this

- Vehicle manufacturers and lorry operators to fit and retrofit all lorries (unless proved impossible or impractical) with front and redesigned full (horizontal and vertical) side guards without exception - national Government to amend relevant regulations to facilitate this
- Strongly deter cyclists from passing to the left of HGVs using campaign, training and educational methods
- Evaluate the casualty reduction effectiveness of, and where appropriate lobby for:
    - the benefits of driver direct vision and the contribution of eye contact to sharing the road safely
    - improved mirrors showing the presence of cyclists at the front and nearside-front cab area, while the truck is both stationary and moving
    - vehicle safety technology, such as camera monitoring systems and sensing devices, in detecting cyclists alongside the cab and on the nearside of lorries
    - the application of automatic/emergency braking on lorries and other large vehicles, its effects on drivers and the behaviours of other road users

6.2.2. Collisions with cars

There were 15 of the 53 cyclists who were killed in collision with cars and 11 sustained their injuries from contact with the car. Potential actions fall into two main areas – collision avoidance and collision mitigation and there is an association with other areas of recommendation.

Nine of the 15 collisions occurred at junctions as a result of either the driver or cyclist not conforming to junction control requirements. In the majority of cases the cyclist was crossing a junction inappropriately however there were a minority of occasions where the driver was the active crash participant. All of the 9/15 crashes occurred at non-signal controlled junctions and there were no fatalities as a result of a cyclist or a car crossing a junction on a red light. While infrastructure can help, it is important that road users use safe driving or cycling practices. In the cases where the cyclist chose to cross the junction there is no information regarding why the cyclist believed it was safe to cross as no interviews were available. The three drivers who were the active participant all stated they did not see the cyclist.

The current vehicle safety regulations, determined under the Whole Vehicle Type Approval and also as applied by EuroNCAP, do include requirements for the protection of pedestrians sustaining impact to the front of the vehicle. These requirements have not been specifically developed to provide protection for cyclists however there are many similarities of contact locations and injury types. These regulations and EuroNCAP tests provide a sound framework that can, in principle, be extended to incorporate the needs of cyclists however further development and evaluation will be needed to achieve this. Nevertheless it is considered that improving the safety levels of cars for cyclist impact does have the potential to reduce fatalities.

Additional developments in vehicle technology have led to the introduction of Automatic Emergency Braking Systems, these detect hazards and apply the brakes accordingly. Existing systems can avoid crashes up to speeds of around 50 kph (31 mph) and reduce the severity of impact at higher speeds. Systems now entering the market do have some capability to detect pedestrians and cyclists under certain conditions even though the primary detection concerns other moving motorised vehicles. Technologies are developing very rapidly and these systems have the potential to have a significant impact in avoiding or mitigating collisions, this can be encouraged through EuroNCAP and by regulation.

Recommendations to help prevent fatal collisions with cars

- EU and national Government to extend pedestrian protection in European regulation and EuroNCAP to include cyclists (eg. pedestrian impact protection and Automatic Emergency Braking Systems)

6.3. Road user behaviour

This analysis of fatal cyclist collisions has the objective to identify the main risk factors that influenced the collisions and led to the event. By definition the crashes were initiated by a human action however this analysis does not seek to attribute blame, this being unhelpful for future crash prevention. In general the human behaviours leading to a crash can be considered to be either high risk behaviours such as drink driving or speeding, or they are the result of errors. Previous research has indicated that errors of detection, prognosis or decision are generally the most common.

This analysis has found that five of the 53 collisions involved a road user who was travelling above the speed limit, in all of these cases the excess speed was judged to be a factor in the crash causation. There were also two cyclists and four other road users who were above the legal blood alcohol limit for driving and in all of these cases alcohol was considered to be a key factor. As with all types of traffic collisions the prevention of drink driving by all road users and speeding behaviour continues to be an important priority in casualty reduction.

The large majority of fatal cyclist collisions are more properly characterised as resulting from driver or cyclist errors. Previous discussion has addressed the perception and decision errors relating to cyclist fatalities in collision with trucks. Training and education of all road users continues to be important to help cyclists and vehicle users to adopt safer practices and to improve the understanding each has of the other. There is little research evidence on the effectiveness of training and education programmes however, partly but not solely because it is difficult to associate the specific events of a crash to previous learning experiences of road users. Furthermore there are some circumstances where it can be demonstrated that training can result in more high risk behaviours (Kinnear, 2013), due to the paucity of research in this field this study examined novice drivers but it could be equally transferrable to novice cyclists. It therefore cannot be considered that education and training are the most effective means of casualty reduction.

There was little evidence in the crash analysis that high risk cycling behaviours contributed to crashes, although the behaviour in three crashes was described as unpredictable. In these crashes the behaviours involved the pedal cyclist entering the road at unsuitable points placing them on the left of a truck, out of direct vision, having previously used the pavement to undertake other vehicles. There was one case where the cyclist’s behaviour was judged by the police as ‘ reckless’ as they rode out of a park entrance into the road apparently without slowing or looking.

Eleven (21%) of the 53 cyclists wore high visibility clothing. Although seemingly a practical and positive provision there is little clear evidence of a safety benefit from such clothing. Miller (2012) examined the relationship between the use of high visibility equipment and reported crash rates and found a non-significant association. More recently Walker et al (2013) examined the effects of a variety of tabards on the passing proximity of cars and found no difference for a range of styles including high-visibility and markings "POLITE" (sic). The only version that showed a significant effect was marked "Police – video recording".

Fourteen of the crashes occurred at night and only 7 of these 14 cyclists used rear lights including five that used front and rear lighting. Like the use of high-visibility clothing the use of front and rear lights at night initially appears beneficial however there is again little research evidence to support a reduction in casualties. Unlike the use of high-visibility clothing however, the use of cycle lights and reflectors at night is mandated although additional benefits from lights could be derived from new research into identifying a minimum standard or, similar to hire scheme bicycles, having cycle lighting or reflective surfaces built into cycle components.

Twenty-two of the fatal or seriously injured cyclists wore cycle helmets yet despite this many still sustained head injuries. Most of these however were involved in extremely serious interactions with trucks and an examination of the post-mortem reports showed that they had sustained direct contact with the wheel of the truck. The impact forces were typically very high, considerably greater than the protective capabilities of any helmets worn. It is of note that head injuries in four of the five collisions where the cyclist lost control and involved no vehicle impact were caused by the cyclists head striking the roadway, in all of these cases the cyclists died as a result of these head injuries and all of them were not wearing a helmet. The protective effect of cycle helmets is well researched and the injury reduction benefits are probably the most justified of all cycle safety measures. In the most recently published research Elvik (2011) reviewed previous meta-analyses and concluded that the risk of sustaining head injuries is 1.72 times higher (i.e. nearly twice the risk) for cyclists not wearing a helmet than it is for cyclists who do wear a helmet.

Some studies have indicated that the introduction of mandatory helmet use tends to decrease the amount of cycling undertaken by deterring some cyclists. These studies have typically been conducted over a small number of years and there is no long term data available to determine whether cycling rates recover. Nevertheless the conclusions regarding the use of cycle helmets are clear. The voluntary use of cycle helmets provides statistically significant reductions in head and brain injury approximately halving the rate of injury. The effectiveness is not complete and some commentators point to the impact speeds used in the cycle helmet approval tests and the European CEN standard has been found to be less demanding than the corresponding US Snell requirements.

Recommendations regarding road user behaviour

- Continue to enforce drink-driving and speeding laws
- Increase the legal compliance of bicycle lights
- Increase the lighting effectiveness of bicycle lights
- Promote the voluntary use of cycle helmets
- Instigate research to increase the protective effect of cycle helmets
- Use experience-based initiatives to demonstrate large vehicle blind spots

- Offer driver training that places greater emphasis on the awareness of cyclists, especially targeting common scenarios such as HGVs making left-turns
- Lobby national Government to:
    - include the use of simulators in driver or HGV-licensing tests to increase trainee drivers' exposure to sharing the road with cyclists
    - include a mandatory road safety module in the Driver Certificate of Professional Competence

6.3.1. Best practice guidance

As previously discussed the effects of behaviour change measures are difficult to evaluate and therefore it is difficult to quantify the effect of subsequent behavioural changes on safety. However there are certain measures that could be taken that signify best practice and could have an influence on both cyclists and other road users' behaviour over time. The following recommendations are therefore suggestions for action but are not based on a specific number of crashes included in the sample or systematic evaluation studies.

- **For cyclists, consider:**
    - providing free short cycle training and refresher courses
    - implementing community-based initiatives which focus on lower income groups (for example, giving away bicycle lights and helmets)
    - incentivising the purchase of high contrast and retro-reflective products
- **To improve how road users share the road, consider:**
    - conducting wide-reaching awareness campaigns to encourage cultural change to achieve more tolerance and awareness towards cyclists
    - running cycle training and awareness courses to businesses which also provide low cost cycle training for both cyclists and drivers highlighting key safety messages (e.g. road positioning)
- **Work with cycle stakeholders and partners to consider:**
    - lobbying for real-world cycle scenarios to be included in the hazard perception test to make novice driver more aware of the hazards associated with cyclists
    - encouraging manufacturers to build in retro-reflective material into new bicycles

6.4. Monitoring progress in cycle safety, understanding the causes of cycle crashes

All safety policy-making relies on the availability of suitable data to monitor progress and to explain the causes of collisions. No one type of data can provide all of the analysis required and the most important data includes:

- Crash totals disaggregated by severity, road user type and other factors to enable monitoring of trends
- Exposure data to enable measurements of risk and crash rates to be calculated
- Performance indicators – estimates of the outcomes of road safety measures that relate both to the measure and to the crash/injury risk
- In-depth data to identify the key risk factors involved in collisions in order to develop future countermeasures

Transport for London appears to have a relatively good set of data available to support cycle safety policy-making with two exceptions. There is little data available on the amount of cycling undertaken – numbers of trips, distances travelled by disaggregated sections of the population – this is a serious deficiency when trying to estimate the impact of cycling safety measures in the face of changing cyclist travel. Secondly while the availability of the fatal crash data from the Metropolitan Police is a highly valuable resource there is no corresponding data regarding non-fatal collisions which may comprise more than half of the road safety burden related to cyclists. While the support of the MPS was invaluable in retrieving the case material a substantial workload was involved and this may not be available for future studies in times of austerity.

The review of research has identified a significant lack of evaluation studies that provide estimates of effectiveness of many of the common measures for cyclist safety. There is little evidence upon which to prepare new road safety policies and the value, a gap experienced by many cities and countries wishing to increase cycling and to improve cycle safety. Many of the measures that may be applied in London are likely to be scrutinised elsewhere to identify the transferability of schemes, the availability of well-managed evaluation studies will therefore not only support future cycle safety policies in London but may have an impact across the world. In particular a further knowledge gap concerns the lack of information regarding the impact of cyclist attitudes, experiences and training on cycle safety programmes.

Recommendations for crash monitoring

- Enhance the available data by improved exposure data on cyclists
- Enhance the data with more detailed information on the causes and outcomes of non-fatal cycle crashes
- Conduct routine evaluation studies of all measures to build the evidence base for future cycle safety policies both in London and elsewhere
- Continue to monitor collisions and casualties before and after schemes and at specific locations using the Traffic Accident Diary System
- Conduct further research into the key risk factors associated with cycling safety. For example what effect does age, gender, road position, cyclist observations etc. have on cycle safety
- Continue to develop the use of fatal crash files as a road safety data resource with the support of the Metropolitan Police Service

7. ACKNOWLEDGEMENTS

The authors would like to acknowledge the valuable contribution of the following groups:

Metropolitan Police: John Hartfree

Kerri Cheek and Ben Johnson of TfL

TSRC staff – in particular Martyn Chambers-Smith who assisted with the data collection and crash reviews

TfL Internal Cycle Safety Working Group

TfL External Cycle Safety Working Group

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