Development of a human factors road safety assessment tool: interim report

by D Basacik, T Luke and T Horberry

Published Project Report
PPR275

TRL Limited

PUBLISHED PROJECT REPORT PPR 275

DEVELOPMENT OF A HUMAN FACTORS ROAD SAFETY ASSESSMENT TOOL: INTERIM REPORT

Version: 3.0

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Prepared for:	**Project Record:**	**118(387)HTRL** **Development of a human factors road safety assessment tool**
	Client:	**Highways Agency** **(Sydney Xavier)**

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CONTENTS

Executive summary

This interim report is a mid-point deliverable to the Highways Agency of the project '*Development of a Human Factors Road Safety Assessment Tool'*. The task detailed within this interim report is executed under the Agency's National Framework Contract 118(387) HTRL for Research & Development Services. The work described in this interim report fully complies with the original task specification.

Overview

The report first presents a definition of human factors, and a justification of why it is important to explicitly consider such human element issues on the Highways Agency (HA) network (based largely on the number of highway accidents that have human error as a contributory factor). It then describes the human factors data collected during a comprehensive literature review, the human factors principles developed from this data, and the matrix structure used to display the principles (Phase A). Following that, it presents a review of existing HA design guidelines for the design of highways, highlighting gaps and conflicts between these documents and human factors principles. Then, the report proceeds to Phase B: a human factors assessment of a current HA site, including making suggestions to improve safety at this site based on the principles developed in Phase A. Finally, all the work to date is tied together by summarising the key findings and implications, and making recommendations for project continuation.

Phase A

Typically, human error is either a main or contributory factor in up to 90% of road traffic accidents[1]. Therefore, any decrease in the frequency of human error could lead to tangible reductions in accident rates. One means by which these reductions can be achieved is through the application of human factors to the design of highways.

Currently, the HA produces the Design Manual for Roads and Bridges (DMRB) which is used to ensure that the design/maintenance process of highways is completed to current standards. However, the extent to which the DMRB incorporates human factors knowledge is not completely clear.

Following the project inception, Phase A was executed in two steps: firstly a comprehensive list of human factors principles was developed; secondly, the extent to which the DMRB accommodated those principles was investigated.

A literature review was conducted to draw on current knowledge with regards to the application of human factors to the design of highways. This review resulted in a list of approximately 1,200 pieces of evidence of human factors 'best practice' which were distilled into 79 principles. Examples are:

"Minimise the number and severity of conflict points at junctions."

"Minimise variations in the curvature of the highway."

For clarity of presentation and comprehension, the principles were then arranged in a matrix according to the particular road situation which the engineer may be designing or trying to improve (e.g. roundabout, curved section, etc.) and the hierarchy of hazard control:

Eliminate hazards if possible,

If not, then minimise the likelihood of accidents,

If not, then reduce consequences of error.

[1] For example, Sanders, M. S., and McCormick, E. J. (1993). Human Factors in Engineering and Design, 7th Edition. Singapore: McGraw-Hill, Inc.

An analysis of 2005 accident data from England's highways was also conducted to ascertain the causal factors for accidents at specific types of locations. A comparison between these causal factors and the human factors principles developed shows that the application of the principles is likely to reduce the number of accidents to which human error is a contributing factor.

Following this, the DMRB was reviewed to ascertain the extent to which it incorporates the human factors principles developed. Firstly, any chapters which seemed to be of particular relevance to the principles were read in detail. Secondly, the on-line DMRB was searched for keywords using a search engine. This approach offered the best combination of thoroughness and efficiency. As Phase A progressed, it became apparent that several of the principles applied to the Traffic Signs Manual (TSM); therefore, the search was expanded to include this document.

The work on Phase A to date has produced a matrix of human factors principles for the design of highways. The examination of the DMRB and TSM has provided mixed evidence for the presence of these principles within the current design documents. Overall a large number of principles are covered (implicitly or explicitly) in the documents, however the following areas were notable absentees: removing distracting or obstructing stimuli, having gradual changes of ambient lighting, preventing signs being over-conspicuous, verifying the accuracy of signs/markings and providing drivers with opportunities for safe recovery from wrong route choices.

Overall, the work carried out in Phase A indicates that a human factors tool would be valuable in informing the highways design and operational processes.

Phase B

This report also outlines work carried out to survey a specific site which had been identified by the HA as presenting particular difficulties. This site was the A23/M23 southbound diverge junction in Hooley, Surrey.

This junction presents drivers with the options of bearing left onto the M23, or remaining on the A23. The main sources of potential difficulties for road users were identified as the presence of a cyclist crossing at a high speed location on a curved slip road, and the layout of the road which can:

- Limit the time available to make routing decisions (leading to late lane changing),
- Limit the time available to respond to hazards,
- Reduce the likelihood of safe recovery from errors.

Over the course of two visits, the junction was assessed by a team of human factors professionals who compiled a record of cyclist and motorist behaviour at the junction. Driver and cyclist behaviour and route choice was observed during peak and off-peak hours.

Several design suggestions are made within this report which could make the junction safer. These are based on the human factors principles produced in Phase A and are structured in line with the hierarchy of hazard control. These include, among others:

- Replacing the crossing with a cycle underpass,
- Modifications to signage (improved signage for motorists and cyclists),
- Ensuring signs are clean and not obscured by vegetation, etc.

The assessment of this site also allowed TRL to judge the applicability of human factors principles to a real-world situation.

In conclusion, the research to date has generated a large amount of useful information, and is well situated to produce a valuable deliverable in the second half of the project. Such a deliverable should be invaluable in helping to further improve safety on the Highways Agency network.

1 Introduction

The ultimate aim of this project is to develop a human factors tool to aid the Highways Agency both to consider human factors within new highway designs and to evaluate and improve current sites. The section below will first provide an overview of what is meant here by the term 'human factors', and then will describe the overall project aims and progress to date to meet those aims.

1.1 Project Overview: Definition of Highway Human Factors

It is vital to establish a commonly agreed definition of human factors at the outset. For this project human factors is defined as a branch of science that studies human abilities and limitations, and then applies that knowledge to improve people's interaction with products (e.g. vehicle design), environments (e.g. road environment design) and systems (e.g. the whole of the road transport system). It is concerned with both road user well being and overall highway system performance.

Human Factors is also called Ergonomics. Ergonomics is about 'fit': the fit between road users, the things they do, the objects they use and the environments they work and travel in. If good fit is achieved, the stresses on people are reduced. They are more comfortable, they can do things more quickly and easily, and they make fewer mistakes.

In the highway environment the human factors approach is mainly driver-centred; it explicitly considers the capabilities and limitations of drivers and other road users in the design and evaluation of road infrastructure. This work utilises an 'information processing' model to represent the driver's interactions with the road environment. This model is expanded below.

1.1.1 A road user as a processor of highway information

The driver takes in a large amount of information from a wide range of sources in order to interact with the highway system. Most of this information is visual; their eyes may scan the road in front of them, to their left and right, the rear view mirror and the dashboard display. If they are slightly more experienced they will be searching the environment outside for possible future hazards, traffic signs and other relevant visual information. Visual cues will be processed to inform the driver of the rate at which they approach other objects on the road such as other vehicles.

During an emergency situation such as a dog running in front of a vehicle, factors such as the rate at which the road environment changes around the driver, their past experience and knowledge of the road rules will be processed by the driver. As a result, they may (or may not) decide that the sensation(s) are sufficient to make them change their current course of action. Depending on this decision, they may take emergency action such as braking, swerving or simply honking their horn.

In this above case, the three broad information processing stages are:

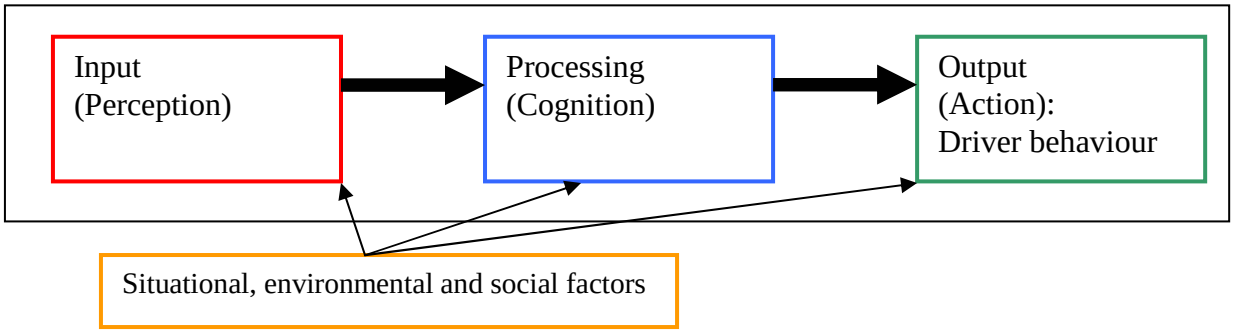
- **Perception** is the visual identification of the dog's trajectory intercepting the driver's own (which is the stimulus)
- **Cognition** is their decision-making about the estimated risk (based on vision, etc.)
- **Action** is their response to the situation (based on the risk level they estimate, etc.)

In the above example, a driver's reaction as the dog runs in front of them will also be dependent upon other information perceived from the environment. The choice to swerve may be made if there is no immediate threat of a collision with another vehicle and no other passengers in the car. The choice to brake heavily may be made if surrounding lanes are occupied. The choice to pump the brakes may be made in wet conditions. If the time frame is very short, these will not be conscious choices, but made on memory and a driver's ability to take in external information. This, in turn, will be limited by their ability to divide their attention and combine perceived information. As such, environmental, social and situational factors interact with a driver's perceptual and cognitive capabilities to influence their driving behaviour.

1.1.2 The three stage model

The above example shows driver information processing as a three-stage model. A simplified version of it (and the impact of other factors) is:

Figure 1: Three-stage model of road user information processing



Although the example above was for driving a vehicle, a similar information processing model can be applied to other road users such as cyclists or pedestrians. This overall model underpins the human factors approach presented in this report.

1.1.3 Overall project viewpoint

The general project philosophy is that the highway environment should be designed to consider driver strengths and weaknesses. Based on the three stage model introduced above, the guiding human factors elements in each of these stages to improve safety in the highway environment include:

Figure 2: Overall rationale behind the human factor approach

1. Perception
Design maximum visibility/ sight lines into the highway environment.
Give enough information to the driver to support the driving task. Provide relevant information to all other road users to support their task.
2. Cognition
Don't overload the driver/ other road users.
Don't distract the driver/ other road user.
Support decision making, and don't require too many judgements.
Obtain predictability and consistency (to follow driver and other road user expectations).
3. Action
Don't require overly complex manoeuvres that are above a typical driver/ road user's skill levels.
Use automatic 'skill' based behaviour as much as possible in all road users.
Drivers and other road users may be fatigued or distracted.
Expect driver and other road user violations (for example, where this is due to cost of compliance or behavioural adaptation).

1.1.4 Why consider human factors in the highway environment?

Human error is a contributory factor in the majority of highway accidents; the exact percentage depends on the specific road, but studies have attributed human behaviour as being either the dominant causal or contributory factor in up to 90% of accidents[2]. As such, consideration of the human element is a key consideration when aiming to further reduce accidents and improve safety on the HA network.

To explicitly consider such human factors, developing specific tools to quantify how they may contribute to accidents or incidents on the HA network is very valuable. A human factors tool for highways could provide an objective method of assessing a road layout, both to identify possible sources of driver error, and to help specify safety improvement measures.

Unlike some other transport domains (e.g. rail), highways are a highly complex environment: the range of drivers, the range of vehicle types, the types of accidents, the different types of driving tasks (e.g. driving along a familiar highway versus wayfinding in a unfamiliar road network) and the large number of specific road design variables all add to the complexity. As such, developing such a tool for the HA network will require human factors, accident analysis and road transport knowledge, highway authority contacts and proven tool development skills. The research methodology outlined in this report builds on TRL's proven expertise in these areas.

1.2 Project aims

The above section has presented an overview of human factors, and has shown why an explicit consideration of the human element is critical to further improve safety on the HA network. An overview of the project is presented below.

1.2.1 Task objectives and specification

The methodology presented in this report complies with the original task specification. The main objectives of the task are:

- Assess how drivers currently behave on the HA network and identify the factors that influence driver behaviour and performance.
- Review the existing road design and operational procedures in comparison to human factors information in terms of the extent to which human factors are currently incorporated to identify gaps and conflicts.
- Consult with the HA and other stakeholders to assess the appropriate scope and format for incorporating human factors consideration into current designs.
- If a human factors tool is ultimately required, to develop the tool and evaluate and refine it by reviewing it against some HA sites. The tool must include a guidance note on how to use it.
- To assess and report on the existing A23/M23 diverge road layout from a human factors viewpoint to identify potential concern areas. This includes proposing revisions to the existing site in order to minimise the risk to the cyclist and to reduce the quantity of late lane changing. Also it includes reviewing and assessing from a human factors perspective any proposed engineering/design solutions provided by the HA area performance manager or his Managing Agent Contractor.

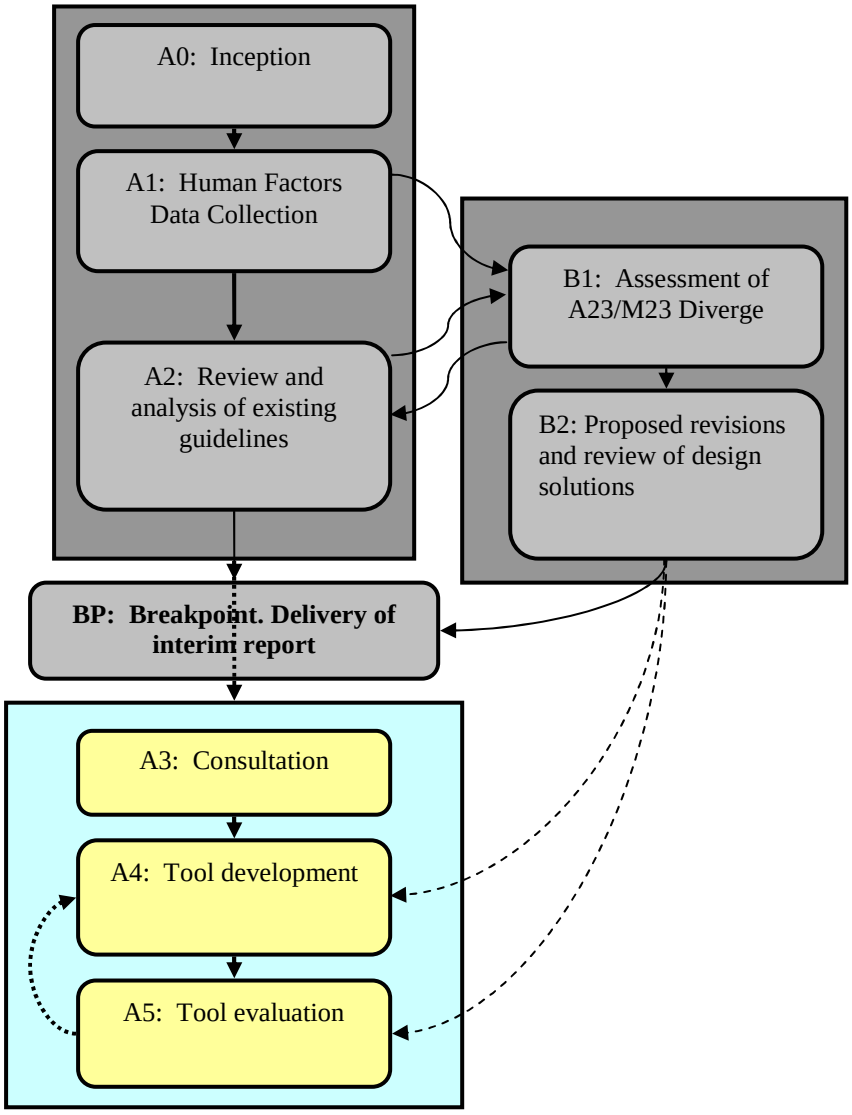
[2] For example, Sanders, M. S., and McCormick, E. J. (1993). Human Factors in Engineering and Design, 7th Edition. Singapore: McGraw-Hill, Inc.

1.2.2 Overview of work to date

This interim report describes the first half of the overall project. It provides the client with an understanding of what is 'human factors' and how it is important for the HA network (especially in terms of the number of accidents that have a human element as a contributory factor). It presents an overview of the human factors data collected and the key human factors principles developed. Also, it provides evidence of the extent to which current road design processes incorporate human factors, including areas where human factors is not adequately considered. Finally, it reports on the assessment of a real HA site, which will allow HA to understand the specific value of using a human factors approach.

Figure 3 below gives an overview of work to date (all items shown in grey have been completed and are described in the report below).

Figure 3: **Task progress to date, and the overview plan for the second half of the project**



2 Phase A1: Human factors data collection and development of Human Factors principles

2.1 Aims

Human factors data was collected in order to understand how drivers actually behave on the HA network and to focus on environmental factors which influence driver behaviour and performance. A review of previous literature was conducted to generate a list of road design factors which lead to good driver behaviour, and those which promote inappropriate or unsafe driving behaviour or impaired performance. A focussed analysis of accidents to which human error was a contributing factor was then conducted to establish underlying causal factors, as well as the relationship between these factors and the types of errors and violations made by drivers. The data collected was later compared to the current guidelines for the design and operation of roads, and will ultimately be used in the development of a human factors tool for the Highways Agency.

2.2 Method

2.2.1 Literature review

A systematic literature review focussed on four classic human factors texts on road safety, the design of highways and road elements. The following prominent texts by world experts in human factors and road safety were reviewed:

> Castro, C. and T. Horberry. (2004). The Human Factors of Transport Signs. London: CRC Press LLC.
>
> Dewar, R.E. and P.L. Olson. (2002). Human Factors in Traffic Safety. Tucson: Lawyers & Judges Publishing Company, Inc.
>
> Elvik, R. and T. Vaa. (2004). The Handbook of Road Safety Measures. Oxford: Elsevier Ltd.
>
> Fuller, R. and J.A. Santos. (2002). Human Factors for Highway Engineers. Oxford: Elsevier Science Ltd.

In addition, other important highway human factors references (such as key papers in scientific journals) were added as appropriate.

The review focussed only on those factors which are under the control of the Highways Agency, and omitted issues such as vehicle maintenance and driver training. The following categories were used to guide the review and categorise the evidence collected:

- Road width, alignment and design
- Signs, signals and traffic control
- Road markings
- Roadside items
- Junctions and roundabouts
- Divided roads (where a physical division exists between opposing traffic flows)
- Non-divided roads (where no physical division exists between opposing traffic flows)
- Cyclists
- Pedestrians
- Road workers

- New schemes
- Bridges, tunnels, pedestrian crossings
- Self explaining roads
- Maintenance zones
- Secondary safety measures (e.g. crash cushions)
- Lighting

The data collected were entered into a spreadsheet and referenced along with any supporting evidence. Duplicate entries were made if the evidence fitted into more than one category. Examples of the results of the literature review are presented in Section 2.3.2.

2.2.2 Accident analysis

The accident analysis was conducted using data from the STATS19 database. The database covers all injury road accidents (i.e. accidents in which one or more people were injured) which become known to the police. The information is collected and recorded on a standard form by the police officers who attended the accident scene. The form has developed and changed over time but generally collects a range of details about an accident including the date, time of day, road class, road type, speed limit, weather and light conditions (for an example of the STATS19 form for 2005 please see Appendix A).

Contributory factors were highlighted as an important part of the accident statistics for the purpose of this project. They are a list of factors which may contribute to the occurrence of an accident. In 2005, contributory factors were recorded nationally as part of STATS19. Each accident was assigned up to six contributory factors. They were not recorded in any order, but an indication was given as to whether each factor was 'very likely' or 'possible'. The vehicle or casualty to which the factor applies was also given. One contributory factor could be recorded for more than one vehicle or casualty, and each vehicle or casualty could have none, one or more contributory factors. The factors recorded reflect the opinion of the reporting police officer who attended the accident.

There are nine primary contributory factors. Each primary factor is divided into a number of sub-factors from which officers select those they feel were relevant to the cause of the accident.

Table 1 details the contributory factors available for use on the 2005 STATS19 form. The factors highlighted in green are those that are considered to be related to the design of the road, either in that they directly refer to road characteristics or that the road characteristics have the potential to influence the behaviour or error described. These factors are of particular importance because they are areas where good road design may influence the prevalence of the contributory factor and so potentially reduce the number of accidents. The relationship between the highlighted factors and the human factors design principles is discussed in Section 2.3.2.

The sample of data for all analyses was limited to the year 2005 and to Highways Agency roads only. The STATS19 data were analysed to determine the number of accidents associated with each contributory factor. The factors were then ranked according to these findings to establish the most common accident causes. This information may be used in future to target the human factors tool such that guidelines aimed at mitigating the most common causes can be given a higher priority than guidelines which target less common accident factors.

Table 1 – STATS19 contributory factors used in 2005 data

Primary factor	Sub factors									
Road environment contributed	101	102	103	104	105	106	107	108	109	
	Poor or defective road surface	Deposit on road	Slippery road (due to weather)	Inadequate or masked signs or road markings	Defective traffic signals	Traffic calming	Temporary road layout	Road layout	Animal or object in carriageway	
Vehicle defects	201	202	203	204	205	206				
	Tyres illegal, defective or under-inflated	Defective lights or indicators	Defective brakes	Defective steering or suspension	Defective or missing mirrors	Overloaded or poorly loaded vehicle or trailer				
Injudicious action	301	302	303	304	305	306	307	308	309	310
	Disobeyed automatic traffic signal	Disobeyed "Give Way" or "Stop" signs or markings	Disobeyed double white lines	Disobeyed pedestrian crossing facility	Illegal turn or direction of travel	Exceeding speed limit	Travelling too fast for conditions	Following too close	Vehicle travelling along pavement	Cyclist entering road from pavement
Driver/rider error or reaction	401	402	403	404	405	406	407	408	409	410
	Junction overshoot	Junction restart	Poor turn or manoeuvre	Failed to signal or misleading signal	Failed to look properly	Failed to judge other person's path or speed	Passing too close to cyclist, horse, rider or pedestrian	Sudden braking	Swerved	Loss of control

Primary factor	Sub factors									
Impairment or distraction	501	502	503	504	505	506	507	508	509	510
	Impaired by alcohol	Impaired by drugs	Fatigue	Uncorrected defective eyesight	Illness or disability, mental or physical	Not displaying lights at night or in poor visibility	Cyclist wearing dark clothing at night	Driver using mobile phone	Distraction in vehicle	Distraction outside vehicle
Behaviour or inexperience	601	602	603	604	605	606	607			
	Aggressive driving	Careless, reckless or in a hurry	Nervous, uncertain or panic	Driving too slow for conditions or slow vehicle	Learner or inexperienced driver/rider	Inexperience of driving on left	Unfamiliar with model of vehicle			
Vision affected by	701	702	703	704	705	706	707	708	709	710
	Stationary or parked vehicles	Vegetation	Road layout	Buildings	Dazzling headlights	Dazzling sun	Rain, sleet, snow or fog	Spray from other vehicles	Visor or windscreen dirty or scratched	Vehicle blind spot
Pedestrian only (casualty or uninjured)	801	802	803	804	805	806	807	808	809	810
	Crossing road masked by stationary or parked vehicle	Failed to look properly	Failed to judge vehicle's path or speed	Wrong use of pedestrian crossing facility	Dangerous action in carriageway	Impaired by alcohol	Impaired by drugs	Careless, reckless or in a hurry	Pedestrian wearing dark clothing at night	Disability or illness, mental or physical
Special codes	901	902	903	904						999
	Stolen vehicle	Vehicle in course of crime	Emergency vehicle on a call	Vehicle door opened or closed negligently						Other

Further analysis was conducted on the data to establish which of the contributory factors were more prevalent at different Highways Agency locations. The accident locations analysed were:

- Non junction (including bends)
- Bends specifically
- Junctions (including roundabouts)
- Roundabouts specifically

This analysis aimed to highlight particular considerations at different locations towards which the human factors guidelines and future human factors tool might be targeted.

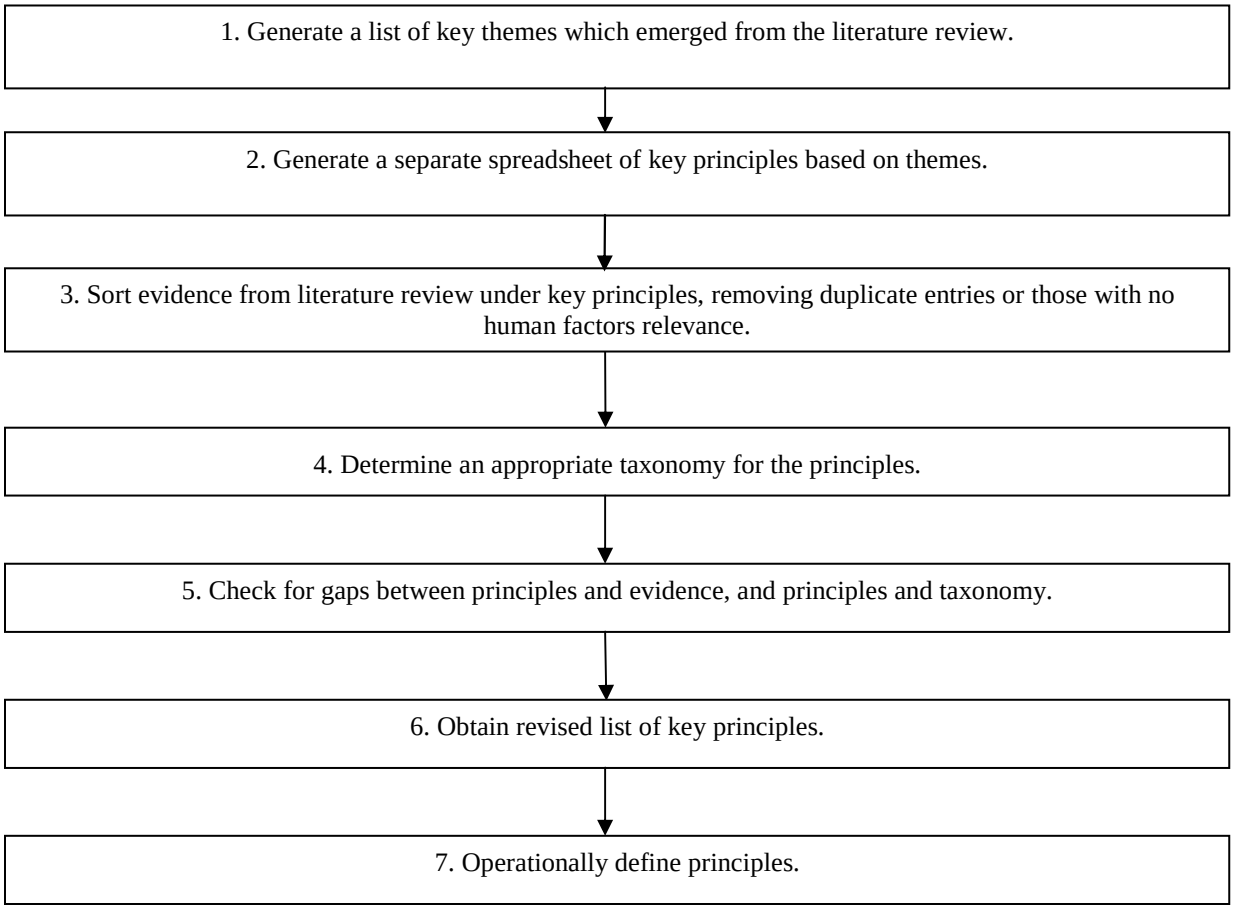
Finally, analysis was conducted to determine which other contributory factors were commonly linked to the most prevalent driver error contributory factors. The aim was to determine whether particular aspects (e.g. the road environment) were often associated with driver error factors (e.g. failure to look properly).

The results of the accident analysis are presented in Section 2.3.1.

2.2.3 Evidence review workshops

The human factors data collected during the literature review was reviewed by three Human Factors Researchers and one Chief Research Scientist during two workshop sessions. The first two steps of the process outlined in **Figure 4** were used to generate human factors principles during these sessions. The remainder of the process was conducted by two human factors researchers after the workshops.

Figure 4: Process for generating Human Factors principles from data collected.



The method used incorporates both a top-down and a bottom-up approach to generating human factors principles. This method ensures that obvious human factors principles not addressed by the literature could be flagged up, researched and developed further, whilst also making sure that all of the evidence collected is addressed by one of the principles generated. In this sense, the approach ensures that the resulting principles reflect the state of the art. The human factors principles generated as a result of this process are presented in Section 2.3.2.

2.3 Findings

2.3.1 Accident analysis

2.3.1.1 Overall prevalence of contributory factors on HA network in 2005

Overall, 13,800 out of 15,009 (92%) trunk road accidents were given at least one contributory factor and are included in the results.

There are nine primary categories of contributory factors as detailed in Table 1. Figure 5 shows the percentage of accidents associated with each primary category. The 'driver/rider error or reaction' category was the most frequent, involved in 71% of accidents.

Figure 5 - Contributory factor type by accident severity[3]

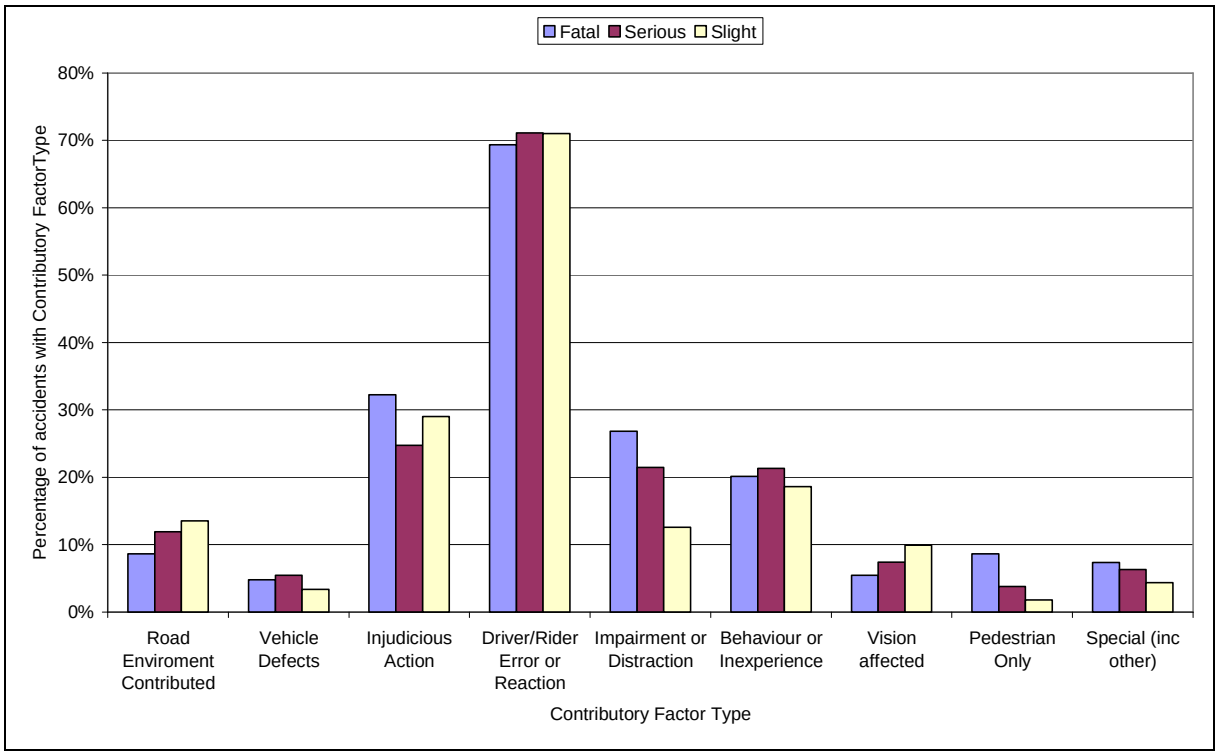


Table 2 shows the number and percentage of accidents coded with each contributory factor. The factors highlighted in green are those considered to refer to highway design or be influenced by highway design and are therefore factors which have the potential to be reduced through human factors design best practice. The top three contributory factors and many other highly prevalent factors are relevant; this represents a significant potential accident saving.

[3] Note: The individual percentages sum to more than 100% as accidents can have up to six Contributory Factors

Table 2 – Contributory factors in order of prevalence

Factor	Description	Primary category	Total	%
405	Failed to look properly	Driver/rider error or reaction	3,418	24.80%
406	Failed to judge other person's path or speed	Driver/rider error or reaction	3,411	24.70%
410	Loss of control	Driver/rider error or reaction	2,593	18.80%
308	Following too close	Injudicious action	2,292	16.60%
408	Sudden braking	Driver/rider error or reaction	1,707	12.40%
403	Poor turn or manoeuvre	Driver/rider error or reaction	1,683	12.20%
307	Travelling too fast for conditions	Injudicious action	1,582	11.50%
602	Careless, reckless or in a hurry	Behaviour or inexperience	1,590	11.50%
103	Slippery road (due to weather)	Road environment	1,183	8.60%
409	Swerved	Driver/rider error or reaction	1,057	7.70%
503	Fatigue	Impairment or distraction	652	4.70%
999	Other - please specify below	Special codes and other	563	4.10%
710	Vehicle blind spot	Vision affected by	552	4.00%
501	Impaired by alcohol	Impairment or distraction	495	3.60%
306	Exceeding speed limit	Injudicious action	430	3.10%
509	Distraction in vehicle	Impairment or distraction	426	3.10%
605	Learner or inexperienced driver/rider	Behaviour or inexperience	421	3.10%
601	Aggressive driving	Behaviour or inexperience	359	2.60%
707	Rain, sleet, snow or fog	Vision affected by	319	2.30%
201	Tyres illegal, defective or under-inflated	Vehicle defects	284	2.10%
603	Nervous, uncertain or panic	Behaviour or inexperience	263	1.90%
109	Animal or object in carriageway	Road environment	247	1.80%
510	Distraction outside vehicle	Impairment or distraction	241	1.70%
401	Junction overshoot	Driver/rider error or reaction	209	1.50%
402	Junction restart (moving off at junction)	Driver/rider error or reaction	212	1.50%
404	Failed to signal or misleading signal	Driver/rider error or reaction	203	1.50%
706	Dazzling sun	Vision affected by	203	1.50%
505	Illness or disability, mental or physical	Impairment or distraction	180	1.30%
107	Temporary road layout (e.g. contraflow)	Road environment	132	1.00%
108	Road layout (e.g. bend, hill, narrow carriageway)	Road environment	143	1.00%
708	Spray from other vehicles	Vision affected by	142	1.00%
102	Deposit on road (e.g. oil, mud, chippings)	Road environment	123	0.90%
302	Disobeyed "Give Way" or "Stop" sign or markings	Injudicious action	127	0.90%
606	Inexperience of driving on the left	Behaviour or inexperience	114	0.80%
607	Unfamiliar with model of vehicle	Behaviour or inexperience	113	0.80%
701	Stationary or parked vehicle(s)	Vision affected by	107	0.80%
802	Pedestrian failed to look properly	Pedestrian only	116	0.80%
803	Pedestrian failed to judge vehicle's path or speed	Pedestrian only	110	0.80%

Factor	Description	Primary category	Total	%
206	Overloaded or poorly loaded vehicle or trailer	Vehicle defects	96	0.70%
305	Illegal turn or direction of travel	Injudicious action	91	0.70%
808	Pedestrian careless, reckless or in a hurry	Pedestrian only	84	0.60%
203	Defective brakes	Vehicle defects	66	0.50%
104	Inadequate or masked signs or road markings	Road environment	54	0.40%
204	Defective steering or suspension	Vehicle defects	58	0.40%
301	Disobeyed automatic traffic signal	Injudicious action	57	0.40%
407	Passing too close to cyclist, horse rider or pedestrian	Driver/rider error or reaction	60	0.40%
502	Impaired by drugs (illicit or medicinal)	Impairment or distraction	49	0.40%
703	Road layout (e.g. bend, winding road, hill crest)	Vision affected by	62	0.40%
101	Poor or defective road surface	Road environment	43	0.30%
303	Disobeyed double white lines	Injudicious action	37	0.30%
508	Driver using mobile phone	Impairment or distraction	46	0.30%
604	Driving too slow for conditions, or slow vehicle (e.g. tractor)	Behaviour or inexperience	48	0.30%
805	Pedestrian dangerous action in carriageway (e.g. playing)	Pedestrian only	43	0.30%
806	Pedestrian impaired by alcohol	Pedestrian only	41	0.30%
901	Stolen vehicle	Special codes and other	41	0.30%
903	Emergency vehicle on a call	Special codes and other	36	0.30%
202	Defective lights or indicators	Vehicle defects	23	0.20%
809	Pedestrian wearing dark clothing at night	Pedestrian only	31	0.20%
902	Vehicle in course of crime	Special codes and other	21	0.20%
105	Defective traffic signals	Road environment	15	0.10%
106	Traffic calming (e.g. speed cushions, road humps, chicanes)	Road environment	9	0.10%
310	Cyclist entering road from pavement	Injudicious action	13	0.10%
504	Uncorrected, defective eyesight	Impairment or distraction	16	0.10%
506	Not displaying lights at night or in poor visibility	Impairment or distraction	18	0.10%
507	Cyclist wearing dark clothing at night	Impairment or distraction	14	0.10%
705	Dazzling headlights	Vision affected by	17	0.10%
709	Visor or windscreen dirty or scratched	Vision affected by	15	0.10%
801	Pedestrian crossing road masked by stationary or parked vehicle	Pedestrian only	17	0.10%
804	Pedestrian wrong use of pedestrian crossing facility	Pedestrian only	10	0.10%
810	Disability or illness, mental or physical	Pedestrian only	18	0.10%
904	Vehicle door opened or closed negligently	Special codes and other	8	0.10%
205	Defective or missing mirrors	Vehicle defects	1	0.00%
304	Disobeyed pedestrian crossing facility	Injudicious action	6	0.00%
309	Vehicle travelling along pavement	Injudicious action	5	0.00%
702	Vegetation	Vision affected by	6	0.00%

Factor	Description	Primary category	Total	%
704	Buildings, road signs, street furniture	Vision affected by	6	0.00%
807	Pedestrian impaired by drugs (illicit or medicinal)	Pedestrian only	6	0.00%

2.3.1.2 Prevalence of contributory factors according to location

The following tables list the top-ten most prevalent contributory factors for accidents which occurred during 2005 at the following HA locations:

- Roads excluding junctions
- Roads – bends only
- Junctions including roundabouts
- Roundabouts only

Factors highlighted in green are those considered to directly refer to highway design issues or to be factors that may be influenced by features of the highway.

Table 3 – Top ten contributory factors for HA roads excluding junctions

Contributory Factor		Fatal	Serious	Slight	Total
406	Failed to judge other person's path or speed	28	207	2020	2255
410	Loss of control	94	367	1644	2105
405	Failed to look properly	37	206	1770	2013
308	Following too close	9	102	1665	1776
408	Sudden braking	6	91	1204	1301
307	Travelling too fast for conditions	29	137	985	1151
403	Poor turn or manoeuvre	25	145	891	1061
602	Careless, reckless or in a hurry	25	140	864	1029
409	Swerved	26	130	723	879
103	Slippery road (due to weather)	13	83	767	863

Table 4 – Top ten contributory factors for accidents on HA roads, bends only

Contributory Factor		Fatal	Serious	Slight	Total
410	Loss of control	19	86	279	384
307	Travelling too fast for conditions	8	45	159	212
103	Slippery road (due to weather)	3	24	156	183
403	Poor turn or manoeuvre	3	33	107	143
602	Careless, reckless or in a hurry	5	22	97	124
405	Failed to look properly	4	19	71	94
406	Failed to judge other person's path or speed	3	12	69	84
306	Exceeding speed limit	9	16	55	80
501	Impaired by alcohol	7	19	50	76
409	Swerved	6	13	54	73

The top contributory factors for non-junction road sections were failure to judge another person's path or speed, loss of control and failure to look properly. The first and third factors imply faulty interactions with another road user. The top contributory factors for bends were loss of control and travelling too fast for the conditions. These results indicate that appropriate interactions are of primary concern on the highway in general (including curved sections) and that at curved sections there are additional issues of maintaining control of the vehicle.

Table 5 – Top ten contributory factors for accident at HA junctions (including roundabouts)

Contributory Factor		Fatal	Serious	Slight	Total
405	Failed to look properly	28	138	1239	1405
406	Failed to judge other person's path or speed	19	104	1033	1156
403	Poor turn or manoeuvre	16	88	518	622
602	Careless, reckless or in a hurry	11	71	479	561
308	Following too close	4	27	485	516
410	Loss of control	9	96	383	488
307	Travelling too fast for conditions	10	55	366	431
408	Sudden braking	2	21	383	406
103	Slippery road (due to weather)	1	30	289	320
402	Junction restart (moving off at junction)	2	19	181	202

Table 6 – Top ten contributory factors for accidents at HA roundabouts

Contributory Factor		Fatal	Serious	Slight	Total
405	Failed to look properly	2	33	569	604
406	Failed to judge other person's path or speed	1	23	470	494
602	Careless, reckless or in a hurry		21	200	221
403	Poor turn or manoeuvre	1	23	182	206
308	Following too close	1	3	200	204
307	Travelling too fast for conditions		21	128	149
408	Sudden braking		7	134	141
410	Loss of control	1	25	112	138
402	Junction restart (moving off at junction)		4	120	124
103	Slippery road (due to weather)		8	90	98

Table 5 and Table 6 show that failure to look properly and failure to judge another person's path or speed are the primary causes of accidents at junctions. Again, this points to the importance of appropriate interactions between road users. Poor turn or manoeuvre is also a common contributory factor at junctions. This factor is likely to be related to junction layout, priority of different traffic streams and driver information. Roundabouts have a very similar pattern of contributory factors to junctions in general which implies that a similar set of design principles may apply.

2.3.2 Key human factors principles

The review of the four human factors texts and supplementary material uncovered approximately 1200 pieces of evidence from research which can be used to make design recommendations for roads. Most of the research reported in these texts fell into the following three categories, which represent more than half of the data collected:

- Signs, signals and traffic control,
- Road, width, alignment and design,
- Maintenance zones.

It is important to note that this does include separate entries for similar experiments with confirming results. Thus, the number of entries under each category at the literature review stage does not correspond to the number of principles eventually generated from each category.

It is not practical to include all of the results of the literature review within this report; however, examples are provided in Table 7:

Table 7: Examples of evidence collected during the literature review.

Category	Evidence	Reference
Road Width, Alignment and Design	Rumble strips constructed transversely across the road on approaches to intersections reduce the number of injury accidents by 33% and property damage accidents by 25%.	Elvik & Vaa, Part.3, Section 3.12, p534
Signs, Signals and Traffic Control	Maximum search expectation and maximum visual acuity occur in a visual cone of 10°, but drivers tend to use no more than 5° vertically. With a 10m offset and a 10° cone, reading of a sign must be finished when it is 57m away.	Castro & Horberry, Section 3.2.2.1, p31
Road Markings	Progressively decreasing the spacing between transverse lines across the road creates the illusion that drivers are speeding up even when their speed remains constant. At a motorway exit ramp, this can reduce excessive speed (more than 18mph over posted limit) by 40%.	Dewar & Olson, Ch13, p440
Roadside Items	At curves, drivers pick up useful information at the inside edge of a road which is known as the tangent. Thus attention must not be attracted to the outside edge of the curve through other information.	Fuller & Santos Ch7, p112
Junctions and Roundabouts	Roundabouts with 4 entrances/exits have fewer conflict points (8 vehicle - vehicle and 8 vehicle - pedestrian) than 4-way crossroads (32 vehicle-vehicle and 24 vehicle-pedestrian).	Fuller & Santos Ch12, p398
Divided Roads	Medians on a divided highway reduce fatal (40%) and injury (30%) accidents, but increase property damage accidents. However, median crossing accidents are almost completely eliminated.	Elvik & Vaa, Part.3, Tables 1.15.3 and 1.15.4
Cyclists	Advanced stop lines for cyclists at intersections reduce accidents where vehicles turning left collide with cyclists who are going straight ahead. This leads to a 27% reduction in cyclist accidents and 66% reduction in vehicle accidents.	Elvik & Vaa, Part.3, Table 3.14.1
Pedestrians	Traffic islands on pedestrian crossings divide the road so that pedestrians can attend to one direction of traffic at a time. This reduces the number of both pedestrian (18%) and vehicle accidents (9%).	Elvik & Vaa, Part.3 Table 3.14.1
New Schemes	Environment prioritised streets can help reduce injury accidents by 30-50%, and property damage accidents by 15-35%. However, this is related to the speed reduction the measures lead to (on average from 54.9kph down to 46kph). Without reduction in speed, the number of injury accidents has been found to rise by 55%.	Elvik & Vaa, Part.3, Section 3.2, p478

Bridges, Tunnels and Crossings	Bridges with a shoulder width equal to that of the approaching road have a 20% lower accident rate than those with a narrower width than the approaching road.	Dewar & Olson, Ch12, p402
Self-explaining Roads	Road widths should be systematically narrower for lower order roads, as these elicit a lower driving speed.	Fuller & Santos, Ch4, p61
Maintenance Zones	Driving in a full contra flow reduces accidents by 23% in comparison to a partial contra flow - this is likely to be because drivers are forced to reduce their speed more and be more alert in a full contra flow. They may also be less confused about lanes.	Elvik & Vaa, Part 3, Section 2.9, p452-453
Secondary Safety Measures (e.g. crash cushions, safety barriers)	25% of crashes involve a collision with a fixed object. Thus, guard rails, breakaway light poles, barriers and crash cushions, should be considered.	Dewar & Olson, Ch 12, p383
Lighting	Analysis of the distances required in order to detect a pedestrian at night and stop before hitting them show that at 25mph, none of the drivers would have difficulty stopping before hitting the pedestrian. At 65mph, 40% would have been unable to stop in time for a pedestrian wearing a white top on the left hand side of the road, and 100% would be unable to stop for a pedestrian wearing a dark top on the right side of the road.	Dewar & Olson, Ch15, p499

Table 7 illustrates the wide range of evidence collected for this study. While some of the evidence quantifies percentage decreases in the number of accidents, other evidence is the result of experiments which have studied driver behaviour and human capabilities for information processing in the road environment (e.g. eye movements, mental workload). Whilst the safety benefit is not always quantified in terms of accident reduction, it is implicit in the argument.

The process defined in Figure 4 was used to generate human factors principles based on the evidence collected. A total of 79 principles were generated, covering a wide range of road elements and highways design issues. In order to grasp the spirit of the principles, it is important to consider the characteristics of the road users and road situations to which the principles will be applied. In addition to the information processing model presented in Section 1.1, the following section presents human factors considerations for the application of the principles.

2.3.2.1 Background on human factors principles

The principles apply to all types of road users who have different physical limitations. For example:

- Elderly drivers find it difficult to focus on objects a certain distance from the eye. This problem is worse in low light levels, where older people take longer to accommodate than younger people. Older drivers also take longer to recover from glare.
- Elderly pedestrians move more slowly and take longer to clear crossings, negotiate gradients, and climb onto kerbs.
- Truck drivers find it difficult to keep within the lane markings on narrow roads and have poor visibility of objects close to the vehicle.
- Truck drivers take longer to gather speed, and thus, to clear junctions at which they must come to a stop.

- Drivers' view out of their vehicle may be obstructed (the vehicle may be overloaded or poorly designed for drivers of that particular body size).

The principles apply to road users who may not think or behave in the way the designer expects. Human factors knowledge suggests that:

- Drivers do not always behave appropriately. They may drive too fast or aggressively, they may not use their mirrors, indicators or lights.
- Drivers may be intoxicated, fatigued or distracted by in-vehicle sources (passengers, mobile phones, reading documents, smoking, eating, grooming, in-car entertainment, etc), may be more interested in the scenery or other external factors than the road, may be inattentive, daydreaming or unaware of other road users.
- Drivers may not know where they are going, may miss signs, get lost or not understand geographical instructions (e.g. whether their direction is North)
- Drivers may drive poorly functioning vehicles (stalling, erratic acceleration, etc.), overloaded vehicles, and vehicles that have malfunctioning lights and indicators.

The principles apply to a wide variety of road conditions:

- Darkness and weather conditions such as rain and fog have a great impact on drivers' ability to see road elements and hazards.
- Maintenance zones are inherently hazardous and require strict adherence to the principles.

2.3.2.2 The principle matrix

A matrix structure was used to organise and present the principles in a logical and usable framework (see Appendix B). Figure 6 shows an outline of this structure.

One dimension of the matrix is based on the hierarchy of hazard control:

- Eliminate hazards on the highway.
- Minimise the likelihood of road user error by:
    - Minimising the opportunity for conflict between road users.
    - Informing the road user about:
        - Appropriate interactions with other road users.
        - Appropriate speed choice and control actions.
        - Appropriate route choice.
- Provide safe opportunities for error handling and promote recovery.

Hazard elimination is clearly the desired option when designing new roads or improving existing roads. For example, the principle "*Do not place junctions on curves*" advocates the removal of all junctions on a curved path. The flow of visual information for drivers on a curve is at a different rate for the left and right eyes. On a curve to the left, the flow of visual information is faster for the driver's right eye than for the left eye. As a result for this difference, drivers are less able to judge the relative speeds of cars on an intersecting road at the end of their curved path. The most desirable option is to remove the junction at the end of the curve.

Figure 6: Current structure of the matrix used to categorise principles.

Application category		A. Eliminate hazards	Minimise likelihood of error						G. Provide safe opportunities for error handling and promote recovery
			B. Minimise opportunity for conflicts between road users	C. Inform the road user					
				D. Appropriate interactions		E. Appropriate speed choice and control actions		F. Appropriate route choice	
Road geometry	All								
	Straight sections								
	Curved sections								
	Gradients								
Junctions/Interface Points	All junctions								
	Grade separated junctions								
	Staggered junctions								
	Cross roads & t-junctions								
VRU facilities	All								
	Pedestrians								
	Cyclists								
Methods	Lighting								
	Signs								
	Road markings								

There are, however, likely to be situations in which complete elimination of a hazard is not possible or practical. The remaining columns within the matrix contain principles which do not completely eliminate the hazard, but do minimise the likelihood of error, or provide safe opportunities for recovery if an error is committed. For example, if a hazard can not be removed, one of the principles recommends, "*Make the hazard itself visible if possible.*" Human factors knowledge suggests that drivers are likely to react to situations which are obviously hazardous and take appropriate actions to minimise the opportunity for error. If other improvements can not be made, or are thought to be inadequate, the matrix suggests providing safe opportunities for error handling and promoting recovery through, for example, the use of *"impenetrable barriers to prevent vehicles from leaving the road."*

The two examples above show how this dimension of the matrix divides the principles according to the different approaches which can be taken to hazards in the highway situation. The second dimension of the matrix groups the principles according to the different road situations or elements which the highways engineer may wish to consider. Examples include roundabouts, gradients and vulnerable road users.

There is also a hierarchy of principles within the matrix. The statements which define the hazard control dimension of the matrix are, in themselves, high-level human factors principles for highway design. Under each of these principles are further principles, all of which are labelled with the letter of the high-level principle to which they relate. For example, the principle "*Provide official and visible pedestrian crossings in safe places*" is labelled B8, meaning it is the eighth principle which relates to the high level principle B: "*Minimise the likelihood of error by minimising the opportunity for conflict between road users.*"

Some principles also contain sub-principles. Principle B8.4, "*Clearly indicate priority at pedestrian crossings*", is a sub-principle which goes towards achieving Principle B.8.

This structure provides a logical and usable front-end to the principles, which are in themselves fairly concise. The detail behind each principle can be presented in a one-page document, each containing the principle statement itself, an explanation of the principle including the human factors reasoning behind it, examples of ways in which the principle has been applied in the past, and a statement of situations to which the principle applies. Not all of the principles have been written up at this stage of the project. Since the ultimate aim is to provide the Highways Agency with a tool which meets their needs, a prototyping approach has been taken, providing samples of the work, receiving feedback and building on it rather than providing a finished product which may not be what the client requires. Examples of the principle documents are provided in Appendix C.

2.3.2.3 Human factors principles and rationale

The human factors principles generated as a result of the work outlined in the previous sections are presented in Table 8 along with a brief explanation of the human factors reasoning behind each one.

Table 8: Human factors principles and rationale.

A. Eliminate Hazards:

Principle	Explanation
A1. Minimise the number of variations in the design of the highway.	With each variation in the road situation, there is a chance the driver will fail to notice any change, or react inappropriately. Furthermore, drivers build up expectations as to the layout of the road ahead based on the layout of the previous road section. Large variations in the design of the highway can lead to violation of driver expectation, and increases in driver mental workload as they suddenly have to react to unexpected variations. In such situations, there is increased risk of the driver failing to respond in time, a general unpredictability in overall traffic behaviour and an increased risk to other road users as drivers take evasive control actions.
A1.1. Minimise variations in road width for the highway section.	It is important to ensure that the width of the road remains constant over a certain stretch of the highway, as changes in road width violate driver expectation and may increase driver workload. For example, studies have shown that bridges which are as wide as the road leading up to them have a 20% lower accident rate than bridges which are narrower than the approach road.
A1.2. Minimise sudden increases and decreases in driver mental workload for the highway section.	Driver mental workload refers to the perception of a wide range of information which the driver must take in from the environment, processing the information and potentially reacting to it. For example, at a junction, a driver may have to monitor signs to make a route choice, read lane markings to ensure that he is in the correct lane, monitor the movement of other vehicles around him to ensure that conflicts don't occur, monitor the junction and potentially traffic signals, and make decisions as to when it is safe to cross the junction. In addition, the driver may be processing visual information from advertising signs, audio information from the in-car radio and potentially responding to mobile telephone calls. If all of this processing must be carried out suddenly, it is likely that an error will occur. One example of such a situation would be if the junction and signage comes upon the driver suddenly over the brow of a hill. Sudden decreases in workload can also be a potential problem, as it may cause behavioural adaptation (where the driver might speed up in a suddenly less demanding environment) or may cause general unpredictability in overall traffic behaviour
A1.3. Minimise variations in the curvature of the highway.	Drivers on a particular stretch of road form expectations about the geometry of the road based upon the geometry of the sections which they have passed (as well as adjust their driving behaviour based on this). Sudden sharp curves are problematic (even following the use of curve warning signs) especially if the road up until that point has been straight or had only gentle curves. Increases and decreases in curvature should be linear if transition curves are constructed, as linear variations are easier for the driver to respond to than sudden changes.
A2. Avoid distracting or obstructing stimuli, particularly at high workload highway locations.	A high mental workload location refers to situations in which drivers have to take in, process and potentially respond to a large amount of information from the environment. Distractions such as advertisements or obstructions such as a trucks or road furniture which distract the driver's attention from important sources of information such as road signs or pedestrian crossings can cause deteriorations in driver performance. This distraction may be visual (e.g. the driver having more things to attend to, only some of which are relevant for the driving task) or cognitive (where the driver may, for example, be thinking about the contents of a recent billboard).

Principle	Explanation
A3. Replace level crossings with other measures.	A large number of perceptual and behavioural factors contribute to accidents at level crossings. Drivers sometimes violate signs, signals and at times even gated crossings. Due to the serious implications of colliding with a train, the best solution is to remove level crossings and replace them with other measures that focus on grade separation (e.g. tunnels or bridges). Where such crossings are necessary, the measures to control the risks should focus on engineering measures (such as barriers) rather than ones that rely purely on warnings and an absence of driver errors.
A4. Separate vehicle parking spaces from the flow of traffic.	Introducing parking restrictions on roads reduces the accident rate and improves traffic flow. Vehicles moving in and out of parking spaces can create dangerous situations and uneven traffic flows, while parked vehicles can obstruct drivers' view of pedestrians and potentially signs at the side of the road. Parked cars can also create dangerous situations when cyclists swerve around them. In order to avoid such situations, vehicle parking spaces should be separated from the flow of traffic.
A5. Avoid curves with a small radius.	Curves with a small radius require the driver to be alert and make accurate judgements well in advance, and have a high control workload requiring larger speed and steering adjustments. Especially if the driver is not primed by the layout of previous road sections to expect the curve, errors can be made, leading to near misses or accidents. Such issues are likely to be made worse where there is visual clutter around the highway, from visibility issues (e.g. fog or poor lighting), where a driver is fatigued or where some drivers (especially younger drivers) engage in sensation seeking by driving around the curve above the design speed.
A5.1. Provide straight on/off ramps rather than curved ones.	Drivers who have been driving on a motorway adapt to higher driving speeds and underestimate their speed. Poor judgement of speed can lead to dangerous situations on curved motorway on/off ramps. Furthermore, when driving on a curved road section, the rate of flow of visual information is different for the left and right eye of the driver. On a curve to the left, the flow of visual information is faster in the driver's right eye than his left eye. Because speed perception depends on the flow of visual information, the driver is less able to accurately predict the relative speed of a car approaching a junction at the end of the curved ramp that he is on. On the other hand, straight ramps allow the driver better visibility, so they can build up a more accurate picture of the approaching road/intersection, this is especially important when the vehicle needs to merge with other traffic.
A6. Avoid gradients greater than 2%.	Gradients lead to increased variation in speed in different vehicles, which can lead to impatience, risky overtaking manoeuvres and more rear end collisions. On downgrades, drivers can find it more difficult to control their speed and this leads to an increase in run-off the road accidents. Thus, steep gradients should be avoided, especially where slower moving vehicles are expected.
A6.1. Minimise gradients on approach to junctions.	Junctions are potentially high-workload situations in which drivers must react to a wide range of information. Gradients approaching a junction have an increased accident rate, as increased difficulty of speed control on downgrades or increased difficulty of hill-starts on upgrades only add to the workload of the driver. This can lead to dangerous situations. Furthermore, visibility on junctions with a gradient on their approach would be worse than for junctions on level ground.
A7. Do not place junctions on curves.	When driving on a curved road section, the rate of flow of visual information is different for the left and right eye of the driver. On a curve to the left, the flow of visual information is faster in the driver's right eye than his left eye. Because speed perception depends on the flow of visual information, the driver is less able to accurately predict the relative speed of a car approaching a junction at the end of the curved path that he is on. Furthermore, straight junctions allow the driver better visibility, so they can build up a more accurate picture of the approaching intersection.

B. Minimise opportunity for conflicts between road users:

Principle	Explanation
B1. Separate different types of road users.	Roads which contain a mixture of motorised and non-motorised traffic are less safe than roads on which different types of road user are separated for reasons which include differentials in speed, the difficulty of predicting each other's actions, visibility differences etc. Separation can be achieved through a range of measures including markings, timing (to allow different vehicles at different times- such as traffic lights for vehicles or cycle), dedicated pathways and physical barriers.
B1.1. Separate pedestrians from cyclists and motorised vehicles.	Conflicts between vehicles or cyclists and pedestrians can occur for a number of reasons including poor pedestrian conspicuity, drivers not expecting them to be where they are, and red light running and large differentials in speed. The unsafe situations created by mixed traffic can be avoided by a range of measures, ranging from providing completely different routes for pedestrians which are separated physically from the carriageway and where any crossings are grade-separated, to providing a raised pavement or marked pathway adjoining the carriageway.
B1.2. Separate cyclists from motorised vehicles.	Conflicts between cyclists and motorised road users can occur for a number of reasons including poor cyclist conspicuity, drivers not expecting them to be where they are, large differentials in speed and poor adherence to the rules of the road by drivers and cyclists. The unsafe situations created by mixed traffic can be avoided by a range of measures, from providing completely different routes for cyclists which are separated physically from the carriageway and where any crossings are grade-separated, to providing a marked lane within the carriageway.
B1.3. Separate faster moving motorised vehicles from slower ones.	On gradients, and where traffic flow is high enough to produce queues, drivers may get frustrated behind slow moving traffic. In such situations, there is an increased likelihood that they will attempt risky overtaking manoeuvres. Constructing passing lanes and informing drivers of the passing lane in advance using signing reduces the temptation to carry out risky overtaking manoeuvres. Similarly, the speed differentials may increase both the number and severity of rear/front end collisions.
B2. Separate opposing traffic flows by design (e.g. one way roads) or physical barriers.	Separation of opposing traffic flows minimises the opportunity for head-on collisions, creates a more orderly and predictable traffic flow, minimises driver workload and allows vulnerable road users to cross the road more safely. A number of different measures could accomplish this, including using medians and central reservations, impenetrable crash barriers, kerbstones or hatched areas between opposing traffic flows, and the construction of one-way streets.
B3. Design highway lanes wide enough for the official speed of the road.	At 48mph, and on 8ft wide roads, drivers show a significant increase in high-frequency steering adjustment. Furthermore, on narrow roads, drivers tend to drive closer to the centre of the road, increasing the danger of encroaching on the opposing lane. Roads should be designed to avoid high mental workload to accomplish lateral control of the vehicle at the design speed, and should take into account different road users including trucks. Roads should also be designed to be wide enough to tolerate driver error, particularly in high-workload situations. However, roads should not be designed to appear too safe even if in practice they are, as this may lead to increases in speed due to a perceived reduction in task difficulty on wider roads (especially at night).

Principle	Explanation
B4. Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely.	Large differentials in speed between traffic in a lane and traffic attempting to enter that lane, and inadequate opportunity for drivers in both lanes to see each other, decide when to merge, and react by making speed and steering adjustments can lead to high mental workload and poor decision making. Extension of short acceleration lanes results in a decrease in the number of accidents at such locations.
B5. Minimise the number and severity of conflict points at junctions.	The more opportunities for conflict between different traffic streams, the less safe is a roadway. Each conflict point potentially requires monitoring by the driver, and a decision as to whether conflict will or will not occur. Crossroads have a large number of conflict points (32 vehicle-vehicle and 24 vehicle-pedestrian). Roundabouts have fewer conflict points and grade separated junctions have fewest conflict points. The severity of conflict points is also important; if conflict points are head-on or at 90 degrees they result in more severe collisions than conflict points only slightly angled towards each other (as is often the case at roundabouts).
B6. Where it does not significantly impact on flow rates, provide traffic lights at cross roads and t-junctions.	Traffic lights explicitly state whether a driver can proceed through a junction or not, and reduce the monitoring tasks and decisions which must be made by the driver. This, in turn, reduces mental workload and the opportunity for the driver to make the incorrect decision which could lead to an accident.
B6.1. Introduce conflict-free control for junction users.	Conflict-free control refers to junctions at which signals give streams of traffic absolute right of way without requiring, for example, drivers turning right at the junction to additionally give way to oncoming drivers, or for left turning drivers to give way to pedestrians. Currently, some junctions are conflict-free and others are not. The meaning of the green light is therefore ambiguous, and drivers have the additional task, when they arrive at a junction, of deciding what the green light means. Conflict-free control removes the ambiguity, reduces visual and cognitive demand, increases predictability, and minimises the opportunity for drivers to make errors. This must be balanced with the possibility of increasing driver frustration and the likelihood of violation of the signal due to long red phases.
B6.2. If control is not conflict-free, provide channelisation.	When traffic signals show a green light, the actions which must be taken by road users will depend on their destination out of the junction, and differences can lead to conflicts and accidents. Channelisation ensures that drivers which have the same destination and must therefore negotiate the junction obeying the same set of rules (e.g. giving way to oncoming traffic) are separated from those who must use a different set of rules. This increases predictability, reduces the number and severity of accidents and reduces visual demand. Such channelisation may be particularly beneficial for older/less confident drivers.
B6.3. Discourage red and amber light running.	Red light running by pedestrians, cyclists and vehicles is an unexpected behaviour which limits the ability of other road users to react to it quickly and contributes to a high proportion of accidents. Discouraging such behaviour by installing red light cameras, phase development, reducing the waiting time at lights and other measures can lead to a reduction in the number of accidents. This may be particularly important at night time or in reduced visibility conditions.

Principle	Explanation
B7. Implement continuous and high quality provision for vulnerable road users.	Provision for vulnerable road users must be continuous. For example, if pedestrians are catered for by the installation of a pedestrian path, there must also be similar high quality provision where they must cross the carriageway. The provision must be of sufficient quality to encourage vulnerable road users to use it (as such, the 'cost of compliance' must be considered), and issues of cleanliness and drainage must be considered. High quality provision should have an advantage over the alternative unsafe route (e.g. be more attractive or perceived to be safer). Facilities which make a pedestrian cross the road unnecessarily or require a cyclist to dismount are not considered continuous, as the cost of compliance to the route increases with each unnecessary action (as does the number of violations). The provision must also take into account the capabilities of the road user, and in particular elderly pedestrians who may find it hard to negotiate gradients, high kerbs, and barriers. If the provision discourages pedestrians from using it, they will use the carriageway instead, taking drivers by surprise and leading to a potential increase in the number of conflicts.
B8. Provide official and visible pedestrian crossings in safe places.	A large proportion of pedestrian accidents occur while crossing the road. Official and visible crossings indicate to drivers that pedestrians are likely to cross at such locations, and can lead to increased vigilance by a driver. Official crossings also have clear and consistent rules for priority; this removes ambiguity with regards to who must yield. However, the crossing itself must also be placed in a safe location which allows the driver enough time to see and interpret the crossing, and make the necessary speed adjustments.
B8.1. Discourage crossing at places other than designated crossing points.	A large number of pedestrians cross the road in a zone 25m to either side of crossings. Crossing the road in these locations leads to an increase in the number of accidents, and violates driver expectation as to where pedestrians will be (so may reduce the effectiveness of the actual crossing). This may lead to sudden braking and evasive manoeuvres, which will also have an impact on accidents between vehicles. It is therefore important to discourage pedestrians from crossing at places other than designated pedestrian crossings. This is especially important under reduced visibility conditions (such as night or fog) where less light is available to assist the detection of pedestrians.
B8.2. Design crossing so that all parties have a good view of each other.	If pedestrian crossings or pedestrians at crossings are obscured from the driver's view (or poorly lit), the driver may fail to slow down or stop at the crossing. Potential obstructions which could block pedestrians or crossings from the driver's view include parked cars, A-pillars of vehicles as they come around a corner, and guard rails where the rails are placed too close together. Particularly young children are affected in such situations, both because they are more easily obscured from driver's view, and also because they only take into account visible dangers when making decisions. Thus, if approaching vehicles are obscured, they are likely to perceive the situation to be safe and cross the road.
B8.3. Provide crossings which allow pedestrians to negotiate one stream of traffic at a time.	Allowing pedestrians to cross one stream of traffic at a time allows them to monitor and process information from traffic coming in one direction at a time. This is an easier visual task, and reduces the likelihood of error (in part due to the predictability of the direction of traffic). Practical implementations of this include provision of pedestrian islands between opposing lanes, and implementation of one way streets. However, on highways with very low traffic flows such measures may encourage pedestrians to not use the crossing provided elsewhere.

Principle	Explanation
B8.4. Clearly indicate priority at pedestrian crossings.	Road users and pedestrians should be given clear cues as to who has priority at conflict points. If the situation is unclear, road users will try to control the situation in a way that they do not have to stop (the act of stopping has a high incurred cost in comparison to carrying on). This could potentially lead to conflicts where the pedestrian thinks they have priority.
B9. Do not mark cycle lanes within junctions used by mixed traffic.	Although marking cycle lanes generally has safety benefits, marking cycle lanes through junctions can lead to an increase in vehicle accidents. This may be due to the increased complexity of the junction due to markings, and also because the markings give the road user a false expectation of where the cyclist will go, and who has priority.
B10. Provide an advanced stop line for cyclists at junctions.	Advanced stop lines at junctions enable cyclists to be in full view in front of cars when they pull off rather than alongside cars where drivers may not notice them. If drivers are able to see cyclists, they are less likely to turn left or right into them at junctions. Thus, advanced stop lines for cyclists help to reduce such accidents, and may encourage cyclist to use cycle lanes more often.

C. Minimise the likelihood of error by informing the road user:

Principle	Explanation
C1. Provide sufficient sightlines for the design speed of the highway.	Sight distances must be sufficient for a driver to perceive potential hazards which may or may not be conspicuous, process the information, make a decision of how to react, and execute any necessary control actions safely, and in advance of the hazard. Sight distances can be improved by flattening roads and removing roadside objects. Increasing sight distances also leads to less risky overtaking manoeuvres when drivers are stuck behind slow moving traffic and can increase predictability in overall traffic behaviour. Maximisation of sight distances in the design of the roadway is especially important for conditions of reduced visibility.
C2. Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation.	Managing variations in the road situation is an important part of the driving task. Large variations in road geometry or unexpected hazards may not be detected if they violate driver expectation. Ideally the road environment design itself should alert drivers; however in other conditions (e.g. darkness) warnings will also be required. Drivers require clear warnings about hazards, and telling the driver the required response is also beneficial in reducing the time necessary to process the hazard information and determine the correct response and action it when necessary.
C2.1. Make the hazard itself visible if possible.	Making the hazard itself visible by marking it or removing visual obstacles increases the chance that the driver will see the hazard. Also, such visibility increases may be a cue to help the driver formulate the correct response to avoid an accident. However, care must be taken not to make a minor hazard too visible (as it may make other aspects less conspicuous)
C2.2. Provide cues or warnings to alert the driver to unseen/invisible hazards.	Where hazards are invisible or where they are likely to go unnoticed, cues and warnings in the form of signs, flashing lights, rumble strips or even sound signals can be used to alert the driver to their presence. Such measures increase the driver's awareness of a potential hazard and thus increase the chance that they will react quickly and correctly to the potential danger.
C3. Provide appropriate road lighting for the road situation. The best possible lighting should be used at transition points, natural hazards and abnormal situations.	Providing a good and uniform level of road lighting increases the visual performance of the driver, and particularly older drivers who take longer to accommodate in lower light levels. A good level of lighting enables drivers to see signs, the road ahead and any hazards. Lateral and longitudinal control of the vehicle improve as a result. Lighting is particularly important where pedestrians are likely to be present, and at transition points between different roads and different types of road (including tunnels). The spectral content of the light and the directionality of lighting must also be considered depending on the visual tasks of the driver (whether it is important that they see certain colours) and the direction of flow of traffic. However, lighting does not necessarily have to be as bright as possible- lighting costs, local light pollution concerns and possible glare effects need to be considered. As such, localised lighting on hazards and key driver information (e.g. signs) may be needed.

Principle	Explanation
C3.1. Ensure lighting is uniform, and that glare from the light source used and other potential sources of glare within the particular road situation are minimised.	Glare can lead to impaired visual performance, especially for older drivers who take longer to recover from glare. Excessively bright lights in a darker surrounding, poorly placed street lamps and headlights from the opposing carriageway are sources of glare which can affect driver visual performance. Minimising glare sources can have a beneficial effect, especially in sites which require high driver workload, judgement or concentration.
C3.2. Generate gradual changes in ambient light levels.	It takes time for drivers' eyes to adapt to large changes in the level of lighting. Driver visual performance is impaired while adaptation takes place. If ambient light levels are changed gradually, the decrease in visual performance is not as pronounced. Adapting to dark conditions is generally slower than light adapting, so additional lighting is often needed in such situations (such as the entrance to tunnels).
C4. All signs must be conspicuous, but not over-conspicuous.	Drivers usually cannot take in all of the visual information contained in the highway environment, so key information (e.g. traffic signs) needs to be conspicuous. The conspicuity of a sign determines whether a driver is likely to see it or not, particularly in a visually cluttered environment. However, overly-conspicuous signs reduce the likelihood that drivers will notice other signs or salient road elements in the vicinity.
C5. All signs must be legible from an appropriate distance.	Drivers must be able to complete the task of reading a sign at a distance which allows them to detect, read and process the information from the sign and react safely if necessary. The elements on the sign (symbols, numbers or letters) must be large enough to facilitate this for all road users driving at the expected speed of the road.
C6. All signs must be comprehensible.	Signs must be comprehensible both in terms of the message given and the response required so that they do not confuse the driver, particularly when the driver is under pressure. Using symbolic signs is generally recommended (especially where a large number of foreign drivers are expected).
C7. All signs must be accurate.	The information content of the sign must always accurately convey the required message for the road situation. If not, drivers may become confused as to the meaning of the sign and the required reactions, and may come to distrust and ignore the sign.
C8. Regularly check signs and do not assume they have the correct materials, content, placement, orientation and angle.	Studies have shown that a significant proportion of signs are not correct in terms of materials, content, placement, orientation and angle. It is important not to take for granted that signage is appropriate, and to carry out checks to ensure that it is. This is especially important after roadway maintenance.

Principle	Explanation
C8.1. Remove warning signs or replace them with more appropriate signs if the hazard has changed or no longer exists.	Warnings for hazards which have changed (e.g. new road layout) or no longer exist (e.g. roadworks signs which haven't been removed) can lead to drivers learning to ignore or distrust these types of signs. As a result, drivers would not be sensitised to the hazard and become less prone to making the necessary control adjustments for potential hazards until they become visible.
C9. Where physically possible, position signs where the driver expects them to be.	Drivers usually cannot take in all of the visual information contained in the highway environment, so key information (e.g. traffic signs) needs to be conspicuous. Visual search is partly led by drivers' previous experiences in similar situations (and partly by the current properties of the road environment). Thus, if signs tend to appear at a particular point in relation to a certain item of road geometry, moving the sign to another location (e.g. different side of the road) may contradict driver expectation and reduce the probability that drivers will see it. However, it must be noted that signs often need to be positioned in locations that are not optimal, so obtaining complete consistency in location is impossible.
C10. Where signs are unlit, position them so that they achieve headlight illumination.	Signs which rely on retroreflection of car headlights at night must be placed so that they achieve headlight illumination, otherwise the driver will be unable to see them. Generally an angle of 85 degrees to the driver allows retroreflection whilst minimising dazzle. This can be particularly difficult on curved road sections and for signs on the right hand side of the carriageway, signs placed high up and signs which are placed near objects which may prevent car headlights from illuminating them. Specific sign lighting may be a more appropriate option in such situations.
C11. Road markings must be conspicuous.	Drivers usually cannot take in all of the visual information contained in the highway environment, so key information (e.g. road markings) needs to be conspicuous. The conspicuity of road markings determines whether a driver is likely to see (and follow) them or not.
C12. Road markings must be legible.	Drivers must be able to clearly see which specific road markings are used for a particular stretch of road. Since road markings inform drivers of permissible actions for that stretch of road (and guide lateral control), illegible road markings can lead to inappropriate behaviour.
C13. Road markings must be comprehensible.	Road markings must be comprehensible both in terms of the message given and the response required so that they do not confuse the driver, particularly when the driver is under pressure. This applies to both marking messages (e.g. 'give way' markings painted on the road) and well as centre/edge marking to provide visual guidance.
C14. Road markings must be correct and accurate.	The road marking must be used correctly and apply to the road situation in which it is used. Since road markings inform the drivers of permissible actions for that stretch of road (and guide control actions), inaccurate road markings can misinform or mislead drivers, leading to potentially dangerous situations, inappropriate driving behaviour and/or confusion.

D. Minimise the likelihood of error by informing the road user of appropriate interactions:

Principle	Explanation
D1. Provide the driver with cues to inform them which areas of the road are for them, which are designated for other traffic and which are permissible in some circumstances.	Drivers require unambiguous information as to which part of the road is designated for them, which parts of the road they must share with other traffic and which parts of the road they are not allowed to use. Ambiguity in this area can lead to unexpected behaviour and conflicts between road users (including vulnerable users). Transition points such as junctions, hard shoulders and cycle lanes should be highlighted using methods ranging from road markings, texture, rumble strips and colours to signs in order to help the driver understand where in the road they are allowed to drive.
D1.1. Make the hard shoulder look and feel like "foreign territory" by distinct markings/texture.	Wide hard shoulders (which are appropriately marked) have a safety benefit in enabling drivers to drive closer to the edge rather than the centre of the road, and reducing head on and run off the road collisions. However, making the hard shoulder feel like 'foreign territory' can alert the driver that they are in a dangerous situation and must make steering and speed adjustments. A further benefit would be that it would discourage drivers from deliberately and unnecessarily stopping on the hard shoulder (especially where parking areas are provided, or where hard shoulder parking is illegal).
D2. Design junctions so that traffic from opposing streams has a good view of each other.	At junctions, drivers require a clear view of other vehicles at the junction and of those approaching the junction. This enables them to make a judgement based on their velocity and position as to whether it is safe to enter the junction or join a stream of traffic. Left-turn lanes at intersections, on street parking, negatively offset right turn lanes and other visual obstacles can reduce drivers' ability to make the correct decision by limiting the visual information they have about the road situation.
D3. Priority of one road over another should be clearly and consistently indicated through road design, markings and signs.	Ambiguity about the priority of one road over another at a junction can lead to conflicts. Drivers evaluate a number of cues to determine which road has priority, including their prior experience at similar junctions, signs, relative flow of traffic, rules of the road (e.g give way to oncoming traffic when turning right) and perceptual continuity of the road through the junction; these cues should all lead to the same conclusion in order to minimise conflicts.
D4. Give pedestrians clear instructions regarding interaction with traffic.	Directly specifying what the pedestrian must do can help both safety and mobility, decreasing the need for them to learn what the contingencies are through other means such as trial and error. Instructing pedestrians which way to look at crossings is one way of helping them to interact correctly with traffic.
D5. Provide street lighting where pedestrians are likely to be present.	Drivers find it difficult to see pedestrians at night in unlit areas, particularly if they are wearing dark clothing. Low beam headlights illuminate very little of the pedestrian's body until the vehicle is very close, and particularly if the pedestrian is on the right hand side of the road, as headlights are angled to the left. As a result, street lighting is especially important in unlit areas where pedestrians are likely to be crossing the road.

E. Minimise the likelihood of error by informing the road user of appropriate speed choice and control actions:

Principle	Explanation
E1. Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed.	It is desirable for safety reasons to ensure that the driver chooses an appropriate speed for the road (generally this is to prevent speeding, but occasionally driving far too slow for the road conditions may create hazards). Speed limit signs alone do not have the desired effect on speed choice, therefore other approaches must be considered. Drivers use environmental cues to determine safe speeds for the road on which they are travelling. The design of the road plays an important role in specifying the perceived speed limit for the road, whereas the rate of flow of visual stimuli across the retina provides the driver with cues about their own speed. These can both be manipulated to ensure that the driver selects an appropriate speed.
E1.1. Design the highway so that the task of vehicle control seems harder than it may actually be.	Drivers' perception of safe speeds for the road partly depends on the perceived effort it takes to keep the car in the lane. It is possible to manipulate certain aspects of the road to ensure drivers reduce their speed. Reducing road widths and sight distances, increasing the curvature of the road, implementing speed humps, environment prioritisation, variable message signs and road markings have had speed reducing effects in some locations. However, these measures must be used with caution and ensuring that the safety of drivers is not compromised; it is likely that these are more applicable to small roads (or accident black-spots) rather than high speed roads.
E1.2. To reduce vehicle speeds, present the driver with an increased flow of stimuli in the peripheral visual field.	The rate at which visual information flows across the retina can moderate the perception of speed. Putting rumble strips or transverse lines across the road with decreasing intervals can give the impression that the vehicle is speeding up, and lead to a reduction in speed. Similarly, placing roadside elements such as delineator posts close to the roadside can make the driver more aware of their speed (however, the delineator posts must not add to risk in the case of them being hit by a driver).
E1.3. Encourage drivers on major/priority road to slow down on approach to junctions.	Drivers generally control their relative speed and proximity to the junction in a way which aims to make other road users stop. However, from a safety point of view it is desirable for the driver on the major road to slow down to a certain degree, in order to increase the margin for error (or decrease accident severity) if the driver on the minor road misjudges the situation. Visually highlighting junctions as transition zones is one way of ensuring that drivers slow down in a predictable manner when approaching them.
E2. Provide road edge, lane and centre line delineation.	Road edge, lane and centre line delineation provides optical guidance for drivers, increasing their ability to accurately position the vehicle within the road, and enabling the driver to judge the layout of the road ahead. Delineation can be achieved through measures including road markings, cat's eyes, rumble strips and delineator posts. However, it must be noted that such measures sometimes increase the mean speed of travel at night.
E2.1. Align road edge delineation (including barriers, guard rails etc.) with the path of the road	Because road markings, barriers, cat's eyes, rumble strips and objects such as telegraph poles and trees are used by drivers to judge the layout of the road ahead, it is important that they are aligned with the path of the road (although, of course, trees and telegraph poles represent a significant hazard, so should not be too close to the roadway). If they are not aligned with the road, drivers may misjudge the layout and make lateral and longitudinal control adjustments which are inappropriate. This is a particular issue in roadworks where the layout of the road is temporarily changed.

Principle	Explanation
E3. Design curves so that their presence and characteristics are apparent on approach and throughout.	Drivers can underestimate curvature of the road particularly for sharp or partially obscured curves. As a result, they may not take the appropriate control actions and may be unable to remain within their lane. Such situations can be reduced by ensuring that the driver is able to clearly see the curve, including how sharp it is, is driving at the appropriate speed and is warned using a number of measures including signs and rumble strips.
E3.1. Provide cues to help the driver negotiate the curve.	Driver mental workload is usually higher on curves than on straight sections, and it is therefore important to ensure that drivers are given clear and unambiguous cues as to their lateral position within the road and the layout of the road ahead. Edge line motion is an effective cue for drivers in such situations. Other than road markings, delineator posts, rumble strips, guard rails and sometimes even telegraph poles and trees (despite their negative effects when hit) can help drivers in judging the radius of the curve and making the necessary speed and steering adjustments.
E4. Repeat warning signs when the hazard itself is not visible.	Once a sign is passed, the behaviour of the driver will be largely controlled by stimuli in the environment. Repetition of signs can provide another opportunity for the sign to be seen, understood and followed, and improve driver reaction times to hazards.

F. Minimise the likelihood of error by informing the road user of appropriate route choice:

Principle	Explanation
F1. At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination.	When driving an unfamiliar route, or at complex junctions, drivers can become confused as to which lane to use and which exit to take for their particular destination. This can lead to sudden braking and late lane changing, and is particularly dangerous at high workload situations where drivers are likely to make incorrect decisions where other traffic is present. Providing clear instructions, including signs and road markings can greatly reduce the chances of a driver committing errors in such situations, and can help maximise appropriate lane and speed choices.
F1.1. At junctions and other high workload situations, provide information at the correct time and place.	Driver mental workload is high at junctions as the driver must monitor the movements of pedestrians, cyclists and other vehicles around them as well as the flow of traffic which they wish to join. Furthermore, they must take in and process route information, and plan a course of action which will enable them to reach their destination. Providing information in advance of a junction can help the driver prepare for the junction beforehand and reduce the possibility of the driver being overloaded or distracted close to the junction.
F2. Provide information about the driver's current location and type of road they are currently on.	When driving an unfamiliar route, drivers can become apprehensive that they have taken the wrong route after they pass a junction. Reassurance direction signs and speed limit signs placed after junctions to inform drivers of their current route can improve journey planning, reduce driver uncertainty and also reduce unnecessary distance travelled.

G. Provide safe opportunities for error handling and promote recovery:

Principle	Explanation
G1. Minimise the severity of run-off situations.	Drivers can find themselves in run-off situations due to a number of reasons, including fatigue or impairment, misjudgement of the road layout or road conditions. It is important to ideally allow recovery from road run-offs (such as by road verges) that allow a vehicle to re-enter the lane safely. Also, it is important to reduce the severity of such situations, minimising the likelihood of injury (for example, trees are a particular hazard in road run-offs). Solid and wire barriers are possible solutions (although wire barriers can cause particular injuries for motorcyclists).
G1.1. Provide impenetrable barriers to prevent vehicles from leaving the road.	Driver fatigue, impairment and misjudgement can result in situations where the vehicle leaves the carriageway. Impenetrable barriers prevent the vehicle from leaving the road in such situations (although they can create hazards for other vehicles in the road).
G1.2. If barriers cannot be provided, provide alerting delineation and a safe run off area sufficient for the speed and layout of the road.	Delineation measures such as rumble strips can make the driver aware that they are leaving the carriageway, promoting recovery particularly in situations where they are fatigued or momentarily distracted. Furthermore, safe run off areas decrease the likelihood of injury in such situations. These should take into account the expected speed of the road (wider areas for faster roads), as well as the layout of the road (wider areas in curved sections).
G1.3. Design run-off areas which are generally flat and without hazards.	Driver fatigue, impairment and misjudgement can cause run-off situations. Run off areas should not contain steep slopes, as these are additional hazards which reduce the likelihood that the driver will be able to stop the vehicle safely after the car has left the road. Furthermore non-crashworthy sign mounts, utility poles, trees and other roadside objects are additional dangers which drivers must cope with when they have run off the road. Removal of these increases the chance that drivers will be able to recover from such situations.
G1.4. Provide secondary safety measures to minimise injury from run-off accidents.	Driver fatigue, impairment and misjudgement can cause run-off situations. Secondary safety measures such as guard rails and crash cushions can help to reduce the severity of such accidents, and may provide a visual cue to help drivers maintain appropriate lateral control.
G1.5.Provide tertiary safety measures (access to emergency and medical services).	Driver fatigue, impairment and misjudgement can cause run-off situations. Provision of tertiary safety measures such as telephones to access emergency and medical services can increase the chance of physical recovery from run-off situations.

Principle	Explanation
G2. Provide skid resistant surfaces in areas where drivers are prone to make late decisions.	Particularly in high workload situations, or in situations where there is a sudden increase in driver mental workload, drivers may make late decisions and require the vehicle to respond promptly to control inputs. Skid resistant surfaces can help to increase the chance that drivers will be able to maintain control over their vehicle in such situations, and reduce the likelihood of conflict. Although virtually all road surfaces should be skid resistant to some degree, regularly maintaining the surface in accident black-spots and similar may be especially important.
G3. Provide opportunities for safe recovery from wrong-route choices.	When drivers inadvertently make wrong route choices, they can become frustrated or anxious. This can lead to risky manoeuvres in an attempt to get back on route. In order to reduce the temptation for such manoeuvres, it is beneficial to provide opportunities for safe recovery. These may include U turn areas and additional signing to common points of interest.
G4. Provide safe pedestrian refuges for emergency use or in case of breakdown.	Providing well-maintained and signed pedestrian refuges for emergency and breakdowns is likely to increase the predictability of where pedestrians will wait in such situations, reducing the probability that they will be struck by drivers. It would also help emergency services find pedestrians.
G5. Place signs such that there is no risk of them being struck by vehicles or protect them using a barrier.	Driver fatigue, impairment and misjudgement can result in situations where the vehicle leaves the carriageway. In such situations, drivers may crash into signs. Signs should not be placed in the median of a divided highway unless they have particular relevance to drivers in that lane, especially as cars driving in the lane adjacent to the median are likely to have higher speeds. Signs should also be protected by crash cushions or barriers to minimise the likelihood of signs becoming hazardous. Where signs must be placed in potentially hazardous locations, they must be constructed of a material that minimise injury if struck (e.g. are non-rigid).

2.3.3 Relationship between accident data and human factors principles

Table 9 draws the relationship between the contributory factors and the human factors design principles. Each contributory factor is matched with principles which, when implemented, have the potential to reduce that accident cause. For example, following the principle "*Design junctions so that traffic from opposing streams has a good view of each other*" reduces the load on the driver when negotiating a junction and maximises their opportunity and ability to see and make judgements about other road users. This reduces the likelihood of the error where they fail to look properly and may have a positive impact on the incidence of this contributory factor. As a result it becomes less likely that this type of accident will occur.

Table 9 – Relationship between accident contributory factors and human factors design principles

Contributory factor		Total % prevalence	Relevant principles[4]	Rationale
405	Failed to look properly	24.8	A1.2: Minimise sudden increases and decreases in driver mental workload for the highway section. A2: Avoid distracting or obstructing stimuli, particularly at high workload highway locations. A5.1: Provide straight on/off ramps rather than curved ones. A7: Do not place junctions on curves. B4: Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely. B5: Minimise the number and severity of conflict points at junctions. B8.2: Design crossings so that all parties have a good view of each other. C1: Provide sufficient sightlines for the design speed of the highway. C3: Provide appropriate road lighting for the road situation. The best possible lighting should be used at transition points, natural hazards and abnormal situations. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road over another should be clearly and consistently indicated through highway design, markings and signs.	The relevant principles are those that aim to: 1. Reduce conflict opportunities and therefore the number of occasions where safety relies on driver decision making. 2. Provide the physical opportunity for drivers to look properly by the provision of good lighting, adequate sightlines and removal of obstructions. 3. Maximise the driver's ability to make judgements by making accurate perception easier and reducing driver workload.

[4] Note – Where a listed principle has sub-principles the sub-principles also apply and may have benefit in reducing the incidence of the accident contributory factor.

Contributory factor		Total % prevalence	Relevant principles	Rationale
406	Failed to judge other person's path or speed	24.7	A1.2: Minimise sudden increases and decreases in driver mental workload for the highway section. A2: Avoid distracting or obstructing stimuli, particularly at high workload highway locations. A5.1: Provide straight on/off ramps rather than curved ones. A7: Do not place junctions on curves. B1: Separate different types of road users. B4: Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely. B5: Minimise the number and severity of conflict points at junctions. B6: Where it does not significantly impact on flow rates, provide traffic lights at crossroads and t-junctions. B8: Provide official and visible pedestrian crossings in safe places. B9: Do not mark cycle lanes within junctions used by mixed traffic. C1: Provide sufficient sightlines for the design speed of the highway. C3: Provide appropriate lighting for the road situation. The best possible lighting should be used at transition points, natural hazards and abnormal situations. D1: Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road user over another should be clearly and consistently indicated through highway design, markings and signs. D4: Give pedestrians clear instructions regarding interaction with traffic.	The relevant principles are those that aim to: 1. Reduce conflict opportunities and therefore the number of occasions where safety relies on driver decision making. 2. Provide the physical opportunity for drivers to look properly by the provision of good lighting, adequate sightlines and removal of obstructions. 3. Maximise the driver's ability to make judgements by making accurate perception easier and reducing driver workload. 4. Increase the chance of accurate expectations through consistency and the provision of good information

Contributory factor		Total % prevalence	Relevant principles	Rationale
410	Loss of control	18.8	A1: Minimise the number of variations in the design of the highway. A5: Avoid curves with a small radius. A6: Avoid gradients greater than 2%. B3: Design highway lanes wide enough for the official speed of the road. C1: Provide sufficient sightlines for the design speed of the highway. C2: Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation. E1: Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed. E2: Provide road edge, lane and centre line delineation. E3: Design curves so that their presence and characteristics are apparent on approach and throughout. E4: Repeat warning signs when the hazard itself is not visible. G1.2: If barriers cannot be provided, provide alerting delineation and a safe run-off area sufficient for the speed and layout of the road. G2: Provide skid resistant surfaces in areas where drivers are prone to make late decisions.	The relevant principles are those that aim to: 1. Remove road features which may make it difficult for drivers to control their vehicle. 2. Alert drivers to the nature of the road and to hazards to increase their control readiness in response to difficult sections, hazards or variations. 3. Assist drivers in maintaining an appropriate speed for the road situation and conditions. 4. Assist drivers in regaining control before an accident occurs.

Contributory factor		Total % prevalence	Relevant principles	Rationale
408	Sudden braking	12.4	A1: Minimise the number of variations in the design of the highway. B1: Separate different types of road users. B5: Minimise the number and severity of conflict points at junctions. B7: Implement continuous and high quality provision for vulnerable road users. B8: Provide official and visible pedestrian crossings in safe places. C1: Provide sufficient sightlines for the design speed of the highway. C2: Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation. D1: Provide the driver with cues to inform them which areas of the road are for them, which are designated for other traffic and which are permissible in some circumstances. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road over another should be clearly and consistently indicated through highway design, markings and signs. D4: Give pedestrians clear instructions regarding interaction with traffic. E1: Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed. E4: Repeat warning signs when the hazard itself is not visible. G2: Provide skid resistant surfaces in areas where drivers are prone to make late decisions.	The relevant principles are those that aim to: 1. Remove road features or hazards that may cause drivers to brake unexpectedly, including minimising unexpected actions from other road users. 2. Alert drivers to the nature of the road and to hazards, including the likely actions of other road users, to promote early anticipation in order to reduce sudden braking. 3. Control drivers' speed to provide more opportunity for them to respond to hazards early and to respond to other road users appropriately. 4. Assist drivers in maintaining control when they or another road user brakes heavily or suddenly.

Contributory factor		Total % prevalence	Relevant principles	Rationale
403	Poor turn or manoeuvre	12.2	A1: Minimise the number of variations in the design of the highway. A1.2: Minimise sudden increases and decreases in driver mental workload for the highway section. A2: Avoid distracting or obstructing stimuli, particularly at high workload highway locations. A5.1: Provide straight on/off ramps rather than curved ones. A6.1: Minimise gradients on approach to junctions. A7: Do not place junctions on curves. B4: Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely. B5: Minimise the number and severity of conflict points at junctions. B6: Where it does not significantly impact on flow rates, provide traffic lights at crossroads and t-junctions. C1: Provide sufficient sightlines for the design speed of the highway. C2: Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation. C4: All signs must be conspicuous, but not over-conspicuous.. C5: All signs must be legible from an appropriate distance. C6: All signs must be comprehensible. C7: All signs must be accurate. C11: Road markings must be conspicuous. C12: Road markings must be legible. C13: Road markings must be comprehensible. C14: Road markings must be correct and accurate. D1: Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road over another should be clearly and consistently indicated through highway design, markings and signs. F1: At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination. G3: Provide opportunities for safe recovery from wrong-route choices.	The relevant principles are those that aim to: 1. Remove transitions that require the driver to manoeuvre in response to them. 2. Limit the road user's manoeuvring options in order to minimise the number of possible choices and errors. 3. Provide the driver with the opportunity to judge and control their manoeuvres accurately. 4. Provide the driver with good information to allow them to make appropriate decisions on where, when and how to manoeuvre to achieve their journey aims.

Contributory factor		Total % prevalence	Relevant principles	Rationale
307	Travelling too fast for conditions	11.5	A5: Avoid curves with a small radius. C1: Provide sufficient sightlines for the design speed of the highway. C2: Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation. E1: Manipulate road users' speed choice using environmental cues to ensure that they drive at the designated speed. E3: Design curves so that their presence and characteristics are apparent on approach and throughout.	The relevant principles are those that aim to: 1. Remove road features which require a large reduction in speed to safely negotiate. 2. Encourage appropriate speed choice through road design, including alerting drivers to variations or hazards that may require a reduction in speed.
103	Slippery road (due to weather)	8.6	*None of the individual principles specifically refer to the characteristics of the surface in different weather conditions. However, the premise of the principles is that they should apply equally in all weather conditions (see Section 2.3.2.1). Other factors which may have an influence on this factor, such as driver education, pavement design and vehicle characteristics are outside of the scope of this project.*	

Contributory factor		Total % prevalence	Relevant principles	Rationale
409	Swerved	7.7	A1: Minimise the number of variations in the design of the highway. B1: Separate different types of road users. B5: Minimise the number and severity of conflict points at junctions. B7: Implement continuous and high quality provision for vulnerable road users. B8: Provide official and visible pedestrian crossings in safe places. C1: Provide sufficient sightlines for the design speed of the highway. C2: Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation. D1: Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road over another should be clearly and consistently indicated through road design, markings and signs. D4: Give pedestrians clear instructions regarding interaction with traffic. E1: Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed. E4: Repeat warning signs when the hazard itself is not visible. G2: Provide skid resistant surfaces in areas where drivers are prone to make late decisions.	The relevant principles are those that aim to: 1. Remove road features or hazards that may cause drivers to swerve unexpectedly, including minimising unexpected actions from other road users. 2. Alert drivers to the nature of the road and to hazards, including the likely actions of other road users, to promote early anticipation in order to reduce swerving. 3. Control drivers' speed to provide more opportunity for them to respond to hazards early and to respond to other road users appropriately. 4. Assist drivers in maintaining control when they or another road user swerves.
306	Exceeding speed limit	3.1	E1: Manipulate road users' speed choice using environmental cues to ensure that they drive at the designated speed.	The relevant principle is aimed to manipulate road users' speed using a variety of measures, chosen according to what is appropriate for the particular road.

Contributory factor		Total % prevalence	Relevant principles	Rationale
603	Nervous, uncertain or panic	1.9	A2: Avoid distracting or obstructing stimuli, particularly at high workload highway locations. B4: Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely. B5: Minimise the number and severity of conflict points at junctions. C4: All signs must be conspicuous, but not over conspicuous. C5: All signs must be legible from an appropriate distance. C6: All signs must be comprehensible. C7: All signs must be accurate. C11: Road markings must be conspicuous. C12: Road markings must be legible. C13: Road markings must be comprehensible. C14: Road markings must be correct and accurate. D1: Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances. D2: Design junctions so that traffic from opposing streams has a good view of each other. D3: Priority of one road over another should be clearly and consistently indicated road design, markings and signs. D4: Give pedestrians clear instructions regarding interaction with traffic. F1: At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination. F2: Provide information about the driver's current location and type of road they are currently on.	The relevant principles are those that aim to reduce driver workload and stress in the driving situation through simplifying the driving task and providing good information to help the driver make appropriate and confident decisions.

3 Phase A2: Review of existing design documents

3.1 Aims

This phase of the project aimed to review the current Highways Agency design documents in comparison to human factors best practice as identified by the literature review in Phase A1. The Design Manual for Roads and Bridges (DMRB) was identified as the most relevant and comprehensive design document. This document was reviewed in comparison to the human factors principles in order to:

- Determine the extent to which human factors best practice is already incorporated into the design of roads.
- Identify any gaps where human factors is not currently considered.
- Identify any conflicts where existing guidelines are not consistent with human factors.

Where insufficient information was present in the DMRB to make a judgement as to whether human factors considerations were incorporated, references from this document to the Traffic Signs Manual (TSM) were followed up. Other documents such as the Manual of Contract Documents for Highway Works (MCHW), the Network Management Manual (NMM) and SUSTRANS National Cycle Network guidelines on the design of cycling infrastructure were not reviewed.

3.2 Method: Review of the DMRB and Traffic Signs Manual for Human Factors Principles

The work undertaken during this phase of the project focussed on finding statements within the DMRB and Traffic Signs Manual which could indicate the degree to which each human factors principle was (or was not) satisfied within these design documents. For each human factors principle, two methods were employed to produce a list of relevant quotes from the relevant document:

- The most relevant chapters were identified and methodically examined to find evidence of the principles.
- Key words and phrases were identified and a search engine was used to scan the manuals.

This combination of approaches was necessary due to the extensive nature of the manuals. It was not possible to read both manuals in their entirety for every principle in the timescales available. Neither was there an opportunity for the researchers to become expert users of the DMRB and Traffic Signs Manual. Therefore, it was confidently felt this approach was both sufficiently thorough and an effective use of time.

Each quote was recorded along with a rating of the degree to which it satisfied the principle. The rating categories used were: strong/moderate/weak evidence for the principle or a contradiction of the principle. If no evidence was found, this was also recorded. Notes were also included for some pieces of evidence when the researchers felt more clarification was necessary. Finally, if a piece of evidence was applicable to more than one principle it was duplicated for both. Table 10 provides one example of how the evidence was recorded for each principle.

The search for the principles was undertaken by three researchers, each of whom was given a portion of the principles to investigate. Once they had finished their individual searches a meeting was held where they reviewed each others' findings before conducting a final revision of the list in light of the points raised.

Table 10 – Format used for recording DMRB review findings

Principle	Section	*Quote*	Satisfies Principle? Strong	Moderate	Weak	Contradicts	Not Found	Notes
A1. Minimise the number of variations in the design of the highway	6.2.4 - 5.3 The Design of Major Interchanges	*"In general the most desirable interchange layout will be that option which has the minimum number of decisions and manoeuvres."*	☑	☐	☐	☐	☐	Narrow context
	6.1.3 - 2.39 Guidance on Minor Improvements to Existing Roads	*"Improving route consistency can assist in making drivers aware of the overall nature of the route."*	☐	☑	☐	☐	☐	
	6.1.1 - 5.47 Roads Geometry Links	*"…avoid frequent changes of patterns on long hills…"*	☑	☐	☐	☐	☐	
	6.2.3 - 2.31 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts	*"The number of straight ahead entry and exit lanes for a traffic stream should be balanced in order to reduce conflict…"*	☐	☐	☑	☐	☐	

3.3 Limitations

The DMRB was the primary focus of the review and was the only document that was reviewed in full. Where necessary, the reviewers also examined the Traffic Signs Manual for evidence relevant to some principles. The authors acknowledge that there may be other documents which were not reviewed that cover any outstanding issues.

The current version of DMRB was examined. The review therefore does not take into account any reviews or other research which may be underway at the time of this report.

The review was of the content of the DMRB and relevant sections of the Traffic Signs Manual. The content was reviewed at face value and the authors were not able to take into account the background or rationale of the guidance given unless it is stated explicitly in the text. The review was also limited by a lack of understanding of the users of the design documents and their training and background knowledge which may affect the way the guidance is interpreted during design.

Finally, the review was conducted by human factors specialists who are not trained engineers and had a limited understanding of some of the technical language in the design documents. In particular, there was no way to verify whether the engineering specifications provided constitute compliance or not.

3.4 Findings

The following section summarises the findings of the DMRB review. The full findings are listed in Appendix D in the format shown in Table 10. A summary of the findings is given in Table 11 below, showing that almost two thirds of the principles only had moderate, weak or no support in the DMRB.

Table 11 – Number of principles for which evidence was found/not found in the DMRB.

Strong	Moderate	Weak	Contradicts	Not Found	Total[5]
31	27	13	1	6	78

[5] Principle F2 is likely to be covered in TSM chapter 2; however, it was not possible to gain access to this document. This principle is not reflected in this total.

3.4.1 A: Eliminate hazards

The majority of the "*Eliminate hazards*" human factors principles apply to road geometry in general. Principle A1 and its sub principles are:

> *"A1: Minimise the number of variations in the design of the highway"*
>
> > *"A1.1: Minimise variations in road width for the highway section"*
> >
> > *"A1.2: Minimise sudden increases and decreases in driver mental workload for the highway section"*

This principle is aimed at reducing variation, because variations usually require a road user response and each one therefore creates an opportunity for error or failure to respond. Consistency in the road environment also helps to convey the message to the driver of what behaviour is expected of them and what features and actions from other road users they can expect.

The guidance provided in the DMRB is consistent with this principle to a reasonable extent. For example, the text discourages certain types of variations in the specific contexts of interchanges and long hills. The text also promotes increased consistency as a potential way to improve existing roads. Driver workload is referred to in the context of major interchanges. The guidance states that "practical drivability and driver workload" should be evaluated as part of the decision making process. This particular aspect is evidence of human factors thinking within the DMRB.

The DMRB demonstrates a certain level of awareness of principle A1; however, the guidance is limited to specific contexts rather than as a philosophy for the overall design of the road and the text does not often state the rationale of the guidance from a human factors perspective.

Principle A2: "*Avoid distracting or obstructing stimuli, particularly at high workload highway locations"* is aimed at minimising driver workload by removing items that may pull their attention from task related matters or obstruct their view of task-critical items, such as signs or other road users. Statements relevant to this principle could only be found in the design of major interchanges section of the DMRB and the guidance relates to the number and timing of decisions and manoeuvres rather than to the potential for distraction and obstruction of view by non-task related items. There is also no guidance regarding the relevance of context in terms of workload and how this relates to decisions about which features should be avoided. However, the guidance does show evidence of consideration of driver stress and workload.

Principle A3 recommends the replacement of level crossings with alternative measures. The DMRB referred the reader to another document, Departmental Requirement (Ref 56), for guidance on this matter. It was not possible to review the relevant document. However, it is assumed that level crossings would not be desirable on the HA network for both safety and capacity reasons and that new level crossings would not be sanctioned on any new road. This assumption is supported by the Office of Rail Regulation (2007) Policy on Level Crossings.

Principle A4 states: "*Separate vehicle parking spaces from the flow of traffic."* Vehicles parking at the side of the road present a hazard to road users for several reasons: they may obstruct the view of the road ahead and create hidden areas where pedestrians or other road users cannot be seen. Furthermore, actions such as opening doors or pulling into traffic create unexpected situations for other road users. Motorway regulations (DSA, 2007) prohibit stopping on the motorway except in an emergency and parking facilities are provided in special service areas. For motorways the principle is therefore considered to be satisfied. For all purpose trunk roads (APTR) the principle is also satisfied. The guidance mentions the need to avoid situations that lead people to park on APTR and the potential for obstruction of visibility by parked vehicles.

Principle A5 and its sub-principles are:

> *"A5: Avoid curves with a small radius"*
>
> > *"A5.1: Provide straight on/off ramps rather than curved ones"*

Curves with small radii should be avoided because they increase the difficulty of the vehicle control task and require large speed and steering adjustments. Tight curves are particularly undesirable on on/off ramps because drivers need to accelerate when joining a motorway or trunk road and are likely to underestimate their speed when exiting. A curved approach also limits drivers' ability to judge the path and speed of traffic on roads they are joining. Guidance consistent with principle A5 is provided in the Highway Link Design section of the DMRB. The need to make curves at interchanges "as generous as possible" is also clearly stated and in this case the guidance is justified in terms of the enhancement of sight distances.

Principle A6 states that gradients of greater than 2% should be avoided. The rationale and structure of this principle is similar to that for principle A5. Downward gradients increase the difficulty of vehicle control and upward gradients are associated with large speed differentials between vehicles which result in increased opportunity for conflict and may encourage unsafe manoeuvring. Principle A6.1 states that gradients should be minimised on approach to junctions in particular. The DMRB states maximum gradients for various types of road. All recommended maximum gradients exceed the amount that is recommended in the human factors literature. However, the design document acknowledges that steep gradients are undesirable and should be avoided where practical. The DMRB also states that grade separated junctions should not be sighted on hill-tops because of the problems that can be caused by approach gradients. However, this guidance only applies to grade separated junctions on hill-tops rather than all junction types in all terrain; this aspect is only partially satisfied.

The final principle under "*Eliminate hazards*" refers specifically to junctions:

"A7: Do not place junctions on curves"

When junctions are situated on curves drivers will find it more difficult to judge the path and speed of vehicles approaching the junction due to the difference in the rate of visual flow on their left and right side. The guidance provided in the DMRB is fully consistent with this principle.

In summary, the "*Eliminate hazards*" human factors principles are quite well satisfied in the DMRB. Removal of distracting or obstructing stimuli (principle A2) and minimising gradients on approach to junctions (principle 6.1) were the only human factors principles for which there was little evidence found in the design manual. In some cases the DMRB guidance has a more narrow application than would be recommended from a human factors perspective. Explanations for the guidance are not often provided, although there is limited evidence of human factors rationale in some of the sections.

3.4.2 B: Minimise the opportunity for conflicts between road users

3.4.2.1 Road geometry

The "*Minimise the opportunity for conflicts between road users*" principles aim to restrict the number of times that different road users can come into contact with each other and to structure their interactions such that the risk of conflict situations (e.g. collisions, evasive action) is controlled and reduced.

Principle B1 recommends the separation of different types of road user. The sub-principles include the separation of pedestrians and cyclists from motorised traffic, pedestrians from cyclists and fast vehicles from slower ones. The separation of different categories of road users (i.e. pedestrians, cyclists and motorised traffic) is of particular benefit for many reasons. Cyclists and pedestrians tend to have limited conspicuity, travel much slower than motorised traffic and the different groups may have a limited ability to anticipate each other's actions. In addition, pedestrians and cyclists are more vulnerable to injury than the occupants of motorised vehicles in a conflict situation.

Pedestrians, cyclists and horse riders are all prohibited from UK motorways (DSA, 2007). This is consistent with principles B1.1 and B1.2 which recommend the separation of pedestrians, cyclists and motorised road users. More generally, the DMRB states that facilities for non-motorised users should

be considered in accordance with the "Hierarchy of Provision." The hierarchy advocates proper consideration of the need for facilities based on road characteristics and non-motorised user needs and is therefore considered to be consistent with principle B1. In other sections of the DMRB specific examples of situations where separation is recommended and potential methods to achieve this are detailed.

Principle B1.3 recommends that faster moving motorised vehicles are separated from slower ones. This measure is aimed at reducing the incidence of unsafe overtaking by motorists who are frustrated by vehicles travelling much slower than their target speed. The DMRB acknowledges this issue and recommends clearly identifiable overtaking sections on single carriageways and steep gradients.

Principle B2 states that opposing traffic flows should be separated. This is designed to reduce the risk of head-on collisions. The DMRB describes some methods by which separation might be accomplished.

Principle B3 states "*Design highway lanes wide enough for the official speed of the road"*. Lanes should be wide enough to accomplish lateral control at the design speed of the road without excessive driver workload and stress. They should also be wide enough to tolerate a certain amount of lateral control error and to accommodate the majority of road users, including large vehicles. In the DMRB several specifications for lane width were found in reference to the design of roundabouts. No specifications were found for normal running lanes or the relationship between width and speed. This information may be contained in another document.

In summary, the principle of separating different types of road user was well incorporated (principle B1). The review of the DMRB found that guidance regarding separating opposing traffic flows and recommended lane widths (principles B2 and B3) was lacking. However, these fundamental factors are likely to be specified in another document.

3.4.2.2 Junctions

Principle B4 refers to the design of junctions:

> "*Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely"*

The principle aims to provide road users with the time and space to properly judge the path and speed of other road users and to take appropriate control actions. The DMRB provides a lot of detail on the design of junctions of various types. It was not possible to judge whether the specifications are consistent with principle B4 due to the high level of specificity and engineering detail in the text.

Principle B5 applies to all junctions and recommends that the number and severity of conflict points is minimised. Again, this is based on the rationale of reducing the opportunity for conflicting movements between road users. The DMRB is consistent with this principle only with reference to large signal controlled junctions.

Principle B6 recommends the use of traffic lights at cross-roads and t-junctions. Traffic lights can be beneficial because they remove some of the monitoring and decision making load from road users; therefore, they reduce the opportunity for errors to occur. The DMRB recognises the benefits of traffic lights in terms of potential enhanced efficiency at junctions and states that it should be considered for new junctions and the improvement of existing junctions. The human factors principles (Principle B6.1) advocate conflict-free signal control where, when given a proceed signal, road users are not required to give way to any other road user (e.g. as is often not the case when turning right at a crossroads). The DMRB was found to recognise the problem of conflicts between flows but not include any guidance on this matter.

There are two other sub principles under B6. B6.2 states: *"If control is not conflict-free, provide channelisation"*. This is where paths through the junction for different destinations are marked so that conflicting movements are discouraged and drivers on a particular path have a consistent set of rules to follow. The DMRB did not include any guidance on this matter. Principle B6.3 states that

red light running should be discouraged as this type of violation is associated with a large number of accidents. The DMRB refers to the need for traffic light warning signs which may decrease red light running by warning drivers they are approaching them. The traffic signs manual provides more specific guidance relating to this type of sign, including required sighting distances. However, the DMRB does not mention other measures to reduce red-light running, such as enforcement.

The DMRB is generally in agreement with the principle of reducing the number of conflict points at junctions and the benefits of signal control. Specific guidance on the design of signal control advocated in the human factors principles is less well incorporated, for example, the DMRB does not appear to include any guidance regarding channelisation at junctions.

3.4.2.3 Vulnerable road user facilities

Principle B7 recommends the provision of continuous and high quality facilities for vulnerable road users in order to aid with their separation from motorised road users. This principle does not apply to motorways where pedestrians and cyclists are prohibited. The DMRB was found to be in support of this principle. It refers to draft LTN 1/04 which is a DfT (2004b) document that advocates convenient, accessible, safe, comfortable and attractive facilities for non-motorised road users. The DMRB also shows some evidence of human factors rationale in that it acknowledges that indirect or fragmented routes are not likely to be widely used. Guidance on where to provide facilities appears to be limited to the suggestion that designers "take account" of opportunities to provide facilities.

Principle B8 states that official pedestrian crossings (e.g. zebra, pelican etc.) should be provided in safe locations. The sub-principles of B8 describe the characteristics of a good pedestrian crossing. Adoption of this principle reduces conflict between pedestrians and traffic by limiting pedestrian movements to expected locations and simplifying the decision making process for both parties by indicating priority and in some cases, by providing signal control. The DMRB was found to be strongly consistent with this principle and sub-principles and sets out the particular requirements, including reference to LTN 1/95 which is a DfT (1995) document on the assessment of pedestrian crossings.

Principles B9 and B10 refer to facilities for cyclists at junctions:

> *"B9: Do not mark cycle lanes in junctions used by mixed traffic."*
>
> *"B10: Provide an advanced stop line for cyclists at junctions."*

Marked cycle lanes in junctions were found in the literature review to be associated with increased accidents. This may be due to increased complexity in the junction or it may impose a false expectation of what the cyclist will do that when violated results in accidents. The DMRB guidance was found to be slightly inconsistent with principle B9: whilst the DMRB does acknowledge that alternative routes should be provided for cyclists, it does not prohibit their use at junctions altogether. Principle B10 was well incorporated into the DMRB including a good justification of the benefits of advanced stop lines for cyclists.

The DMRB recommends good consideration of pedestrians and cyclists. The majority of the guidance provided was consistent with the human factors principles. The only inconsistency identified was related to marking cycle lanes through junctions which is suggested in the DMRB but the human factors literature indicates may decrease safety.

3.4.3 C: Inform the road user

3.4.3.1 General principles

"Inform the road user" principles are aimed at providing road users with information to allow them to make accurate judgements and decisions in order to minimise the risk of inappropriate actions which may result in an accident. They include general principles which apply to all actions and all situations

and more specific principles which aim to promote appropriate interactions between road users; appropriate speed choice and control actions or appropriate route choice. The general "*inform the road users"* principles are discussed in this section and more specific principles in subsequent sections.

Principle C1:

> *"C1: Provide sufficient sightlines for the design speed of the highway."*

Is a basic principle designed to ensure that drivers have sufficient time to react to situations and hazards they see ahead. The DMRB provides tables of stopping sight distances for various design speeds. It was not possible to verify the distances recommended but it is assumed that they provide sufficient distance for drivers to stop in time for hazards that come into view at the limit of the sight distance. It is unclear whether the recommended distances take into account factors such as response times. This lack of awareness of the authors' rationale is a limitation of this review. Another potential weakness of the DMRB guidance is that it is based on design speed. Drivers are very likely to exceed the design speed and may therefore require longer sight distances.

Principle C2 aims to provide road users with the information they need to make an appropriate response to hazards, which includes knowing a hazard exists, knowing what it is and knowing how to respond to it. Providing this comprehensive information reduces the time needed by a driver to formulate their response and therefore may increase available reaction times and decrease the risk of error.

The DMRB and the Traffic Signs Manual describe numerous examples of ways to alert drivers to the presences of hazards through signs; however there is little mention of other methods. In this respect principle C2 is only partially satisfied. The need to alert drivers to hazards is implicit in the guidance and the need to alert road users to the nature of the hazard and the required action is less well covered. The recommendation that where possible the hazards themselves should be made visible is not specifically covered and is implicit within other guidance.

3.4.3.2 Lighting

The human factors principles on lighting state:

> *"C3: Provide appropriate road lighting for the road situation. The best possible lighting should be used at transition points, natural hazards and abnormal situations."*
>
> > *"C3.1: Ensure lighting is uniform and that glare from the light source used and other potential sources of glare within the particular road situation are minimised."*
> >
> > *"C3.2: Generate gradual changes in ambient light levels."*

These principles are based on an understanding of human visual capabilities. Providing lighting at night is known to increase visual performance and helps drivers to perceive hazards. Good lighting minimises glare which has the potential to impair performance, particularly in older drivers, and takes account of the time required for the eyes to adjust to different levels of light.

Regarding the appraisal and replacement of lighting on HA roads, the DMRB acknowledges that providing lighting can result in accident savings. The need for lighting at hazards and transition points is not specifically mentioned. However, the guidance states that evaluations should be based on costs and benefits at any particular location over a 30 year period. Guidance on the design of lighting is strongly consistent with principle C3.1, uniformity and glare control are specifically emphasised. The DMRB does not appear to include any recommendations relating to the need for gradual changes in ambient lighting.

3.4.3.3 Signing

Principle C4 is "*All signs must be conspicuous, but not over-conspicuous.*" This is to ensure that signs are noticed but to avoid signs distracting road users from other task related information. The Traffic Signs Manual describes several ways to increase conspicuity of signs but does not appear to explicitly state the need for signs to be conspicuous. The issue of "over-conspicuity" is not acknowledged.

Principle C5, "*All signs must be legible from an appropriate distance",* aims to ensure that drivers can read a sign and respond to it in time. The Traffic Signs Manual specifies minimum clear visibility distances for various speeds and is consistent with the human factors principle in this respect. The Traffic Signs Manual and the Traffic Sign Regulations and General Directions (2002) generally provides specific guidance on character size, contrast and colour which is likely to be aimed at ensuring legibility; however, this review does not include the rationale of the design documents so this cannot be verified.

Principle C6, "*All signs must be comprehensible*" is not explicitly referred to in the DMRB or the Traffic Signs Manual. There is a related reference for the need to ensure signing and markings are understandable in complex layouts. This demonstrates implicit awareness of the principle. The Traffic Signs Manual also specifies the form of all standard road signs and special approval is required to deviate from these forms. The specified forms may have been selected on the basis of easy comprehension but this cannot be verified.

Principle C7 states that all signs must be accurate. No explicit reference to this requirement was found in either the DMRB or the Traffic Signs Manual. However, following these design documents would result in accurate signs.

Principle C8 is:

> *"C8: Regularly check signs and do not assume they have the correct materials, content, placement, orientation and angle."*

There are some references in the Traffic Signs Manual (2004a) to the need to check signs under certain circumstances, for example, where the sign does not appear to be being noticed. The design documents do not refer to any regular maintenance or checking process. However, this may be included in other documents.

Principle C9 refers to the placement of signs and recommends that they are placed where the driver expects to find them. This is because drivers target their visual attention to areas where they expect to find relevant information based on previous experience. If signs are placed in an unexpected or inconsistent position then they are less likely to be seen. There was no specific mention of the role of expectation in the DMRB or the Traffic Signs Manual. However, the Traffic Signs Manual (Chapter 1[6]) does provide guidance on how to position different types of signs and if this guidance is followed it will result in consistency of placement which drivers would use to target the correct areas of the environment.

The final signing principle is:

> *"C10: Where signs are unlit, position them so that they achieve headlight illumination."*

The Traffic Signs Manual acknowledges that reflectorisation generally produces adequate levels of sign luminance and that the visibility and legibility of hazard markings should be checked at night. The Manual (Chapter 1) gives specific guidance about sign angle relative to the road, so this principle is largely covered.

[6] Chapter 1 of the Traffic Signs Manual was published by HMSO in 1982 but may no longer be in print.

3.4.3.4 Road markings

The human factors principles for road markings follow a similar structure to the signing principles. Principles C11 to C13 state that road markings should be conspicuous, legible and comprehensible.

There is evidence in Traffic Signs Manual that conspicuity, legibility and comprehensibility are considered to be important. For example, the manual describes factors that may impair the conspicuity of road markings and several methods to improve their conspicuity. Similarly to signs, the specifications for particular road markings, in terms of size and content probably take legibility into consideration. Regarding understanding of markings, there is no evidence that driver/road user comprehension testing of different types of marking has been undertaken. The Manual therefore implicitly acknowledges the importance of these attributes but does not explicitly state the requirements.

The final road markings principle states that "*Road markings must be correct and accurate*." As in the case of signs the need for accuracy of road markings is not explicitly stated in the DMRB or the Traffic Signs Manual. However, by following the existing guidelines fully, it is expected that the resulting signs and road markings will be accurate.

3.4.3.5 Summary

In summary, the DMRB and TSM often make reference to the importance of sightlines; however, many of the references seem to be implicit and the authors' rationale behind some of the advice is unclear (in particular, principles C1 and C2). The DMRB is in agreement with the importance of lighting mentioned in principles C3, C3.1 and C3.2, however, it advises the use of a formula based on the benefits versus costs of a lighting scheme when deciding where lighting is appropriate. Finally, only some of the principles for good signage and road markings (C4 to C14) were found. These tended to cover the principles related to legibility and comprehensibility, however, no evidence for the importance of accuracy was found (it would seem the DMRB and TSM take this requirement as rote). Overall, the principles designed to inform the road user are partially covered within the documents.

3.4.4 D: Inform the road user – Appropriate interactions

3.4.4.1 General highway design

Principles in this section of the matrix aim to provide information which allows drivers to make appropriate interactions with other road users. Principle D1 is:

> "D1: *Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances."*

This principle is intended to ensure that road users are aware of where within the road environment they are permitted or not permitted to travel and where they can expect to find others. This helps drivers to take appropriate actions by accurately conveying the relevant rules and expectations. The design manual makes many references to the need to delineate different areas of the road for different road users, particularly in junction situations. The DMRB also describes various methods of doing this. The DMRB does not appear to provide much specific guidance on how to deal with areas that are sometimes permissible, such as shared overtaking lanes, although this may be provided within the Traffic Signs Manual.

Principle D1.1 is a sub principle which specifically refers to discouraging drivers from entering the hard shoulder. This is an important principle as drivers commonly stop on the hard shoulder for trivial reasons and do not realise the risk of being struck by other vehicles. The DMRB refers to coloured surfaces as a method of discouraging encroachment onto particular areas. This method is only recommended for limited application on non-standard hard shoulders and there is no discussion of additional methods for standard hard shoulders.

3.4.4.2 Junctions

D2 and D3 are general human factors principles for the design of all junctions, including pedestrian crossings:

> *"D2: Design junctions so that traffic from opposing streams has a good view of each other."*
>
> *"D3: Priority of one road user over another should be clearly and consistently indicated through highway design, markings and signs."*

Principle D2 intends to ensure that road users in potentially conflicting streams can clearly see and evaluate each other's actions in order to adjust their own speed and path appropriately and anticipate future actions. The review did not find explicit evidence of this principle in the design documents. However, the documents do refer to factors that may impair visibility at junctions and it is likely that the specific guidelines for the design of junctions take this into account. The review did not include the rationale of such guidelines so this cannot be verified.

Principle D3 aims to provide road users with effective cues to the appropriate action to take at interface points and in particular whether they are required to give way or proceed. The DMRB states that the most effective form of interchange layout is that which has the minimum number of "clear unambiguous decision points." Decision points are likely to include opportunities to indicate user priority, although they are not specifically mentioned. Again, it is probable that the detail of the specifications for junction road markings, layout and signing have taken this issue into account.

3.4.4.3 Non-motorised road users

Principle D4, "*Give pedestrians clear instructions regarding interaction with traffic,"* is intended to provide information to pedestrians as to how to safely negotiate traffic (e.g. road markings which say "Look Right"). Instructions of this type are helpful because pedestrians may not have the necessary knowledge of traffic movements, may be children or may be impaired by alcohol or disability. The DMRB does not appear to provide any specific recommendation which is consistent with this principle.

Principle D5 recommends that street lighting should be provided where pedestrians are likely to be present. Street lighting is beneficial because pedestrians are difficult to see at night. They are often dressed in dark clothing and vehicle headlights are unlikely to illuminate them until they are very close. The design manual remains vague with respect to the importance of lighting for pedestrians. In the guidance on provision for non-motorised users, the DMRB states that their routes should be lit where appropriate and feasible.

3.4.4.4 Summary

The evidence for the presence of the principles designed to inform the road user about appropriate interactions can be summarised as ample for some principles and insufficient for others. For example, some principles which are well covered include principle D2. Also the DMRB is clear on the need to delineate different areas of the road (principle D1). However, some advice suffers from a degree of ambiguity (e.g. principle D3) whilst evidence for others are extremely weak (e.g. principle D4).

3.4.5 E: Inform the road user – Appropriate speed choice and control actions

Principles in this section of the matrix aim to provide road users with information that helps them to formulate and implement their own control actions within the limits intended by the designer and their journey aims.

The first of these principles relates to the manipulation of speed choice by various methods and in particular situations:

"E1: Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed."

"E1.1: Design the highway so that the task of vehicle control seems harder than it may actually be."

"E1.2: To reduce vehicle speeds, present the driver with an increased flow of stimuli in the peripheral visual field."

"E1.3: Encourage drivers on major/priority roads to slow down on approach to junctions."

The DMRB demonstrates good understanding of the principle of manipulating speed through environmental design. Various methods are described, including some which fall under principles E1.1 and E1.2. The design manual mentions junctions as locations where drivers may require warning but this is limited to signalised junctions on high speed roads and does not specifically mention whether the warning would be intended to slow drivers.

Principle E2 recommends that road edge, lane and centre line delineation is provided which is consistent with the path of the road. Delineation is useful because it provides optical guidance to the driver so that they may accurately position their vehicle within the road and judge the layout of the road ahead. It is also a method of marking different road territories as required in principle D1. The Traffic Signs Manual provides numerous specifications for road markings of different types but the requirement to provide them in the first place is not explicitly stated.

Principle E3 is:

"E3: Design curves so that their presence and characteristics are apparent on approach and throughout."

"E3.1: Provide cues to help the driver negotiate the curve."

This refers to the need to design curves so that they are visible and to provide cues that allow drivers to read the curve and project its future path. Drivers may underestimate the curvature of the road which could result in insufficient speed adjustment or control compensation. Suitable cues include curve edge delineation and vertical features on the outside of the curve. The DMRB acknowledges that curves can be "deceptively tight" although no explicit guidance could be found which was consistent with principle E3. Some signs commonly used on curves (e.g. arrows placed at regular intervals on the outside edges of curves) are clearly designed for this purpose so the principle is included in the design documents to a small extent.

3.4.5.1 Summary

In summary, the principles contained within the heading *inform the road user about appropriate speed choice and control actions*, are covered to differing degrees in the DMRB and TSM. Principle E1 is considered within the manuals to a large extent, with several suggestions for how drivers can be encouraged to drive at the design speed. On the other hand an awareness of other principles such as those regarding lane and central line delineation, and the design of curves (E2 and E3 respectively) is only implied.

3.4.6 F: Inform the road user – Appropriate route choice

Principles in section F of the matrix are designed to provide drivers with the information they need to safely navigate to their destination. Drivers often fail to plan their journey adequately and rely on signage for way-finding. When drivers are lost, uncertain or even panicking their behaviour may become erratic which presents a risk to themselves and other road users.

These principles are:

"F1: At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination."

"F1.1: At junctions and other high workload situations, provide information at the correct time and place."

"F2: Provide information about the driver's current location and type of road they are currently on."

The Traffic Signs Manual sets out the definition and requirements for direction signs and route confirmatory signs. Some guidance is provided on the required viewing distances for signs according to speed and the distances they should be from junctions. The advice appears to be largely consistent with principle F1 and F1.1. However, there is no way to verify in this review whether this guidance is correct from a driving task and navigation point of view and the guidance may not take into account subtle differences that exist between junctions and affect exactly when information may be required.

3.4.7 G: Provide opportunities for error handling and promote recovery

Principles in section G of the matrix are designed to minimise the negative consequences of errors by providing road users with opportunities to recover from errors before they escalate into an accident or by protecting them from serious injury in an accident situation.

The first of these principles is G1, "*Minimise the severity of run off situations"*. This principle has a number of sub principles which describe different levels of protection, from installation of an impenetrable barrier through to alerting delineation. According to the DMRB the provision of road restraints is governed by a risk assessment process which is currently being updated. The Road Restraint Risk Assessment considers various hazards which influence the decision of what kind of protection to implement, including the presence of solid obstacles such as trees at the side of the road. This procedure is considered to be consistent with principle G1.

The Road Restraint Risk Assessment also considers protection from signs at the side of the road and is consistent with principle G5, *"Place signs such that there is no risk of them being struck by vehicles or protect them using a barrier."*

Principle G2 advocates the use of skid resistance surfaces in areas where drivers may make late decisions. The measure is intended to help drivers to maintain control in these situations so that an accident is less likely to occur. The DMRB gives several examples of situations where high friction surfacing may be beneficial, such as approaches to bends and junctions. The principle is therefore adequately incorporated.

Principle G3 recommends that the designer should "*Provide opportunities for safe recovery from wrong route choices*". When drivers make a navigation error they are prone to become anxious or frustrated. This may lead to erratic or rash manoeuvres, such as u-turns or aggressive lane changing, and the provision of official and well marked routes which can be used to correct for mistakes can reduce this problem. No reference to this principle was found in the DMRB.

Principle G4 is designed to assist drivers in the event of accident or breakdown as they wait for recovery:

"Provide safe pedestrian refuges for emergency use or in case of breakdown"

Several references to facilities for stranded motorists were found in the review. These include staggered gaps in the safety barrier at points where pedestrians may have to cross it (e.g. near emergency telephones). Another example describes how stranded motorists may use the verge to walk to a telephone or to wait. The DMRB obviously intends for the area behind the safety barrier to be used by pedestrians in an emergency but does not explicitly state that it should be provided for this purpose.

To summarise, the DMRB provides good evidence that the importance of "*minimising the severity of run off situations*" (G1) has been taken into account via the Road Restraint Risk Assessment process

and good evidence was also found about the provision of skid resistant surfaces (G2). The evidence for principle (G4) regarding the importance of safe pedestrian refuges is less convincing and evidence for principle G3 (the need for opportunities to recover from wrong decisions) was not found.

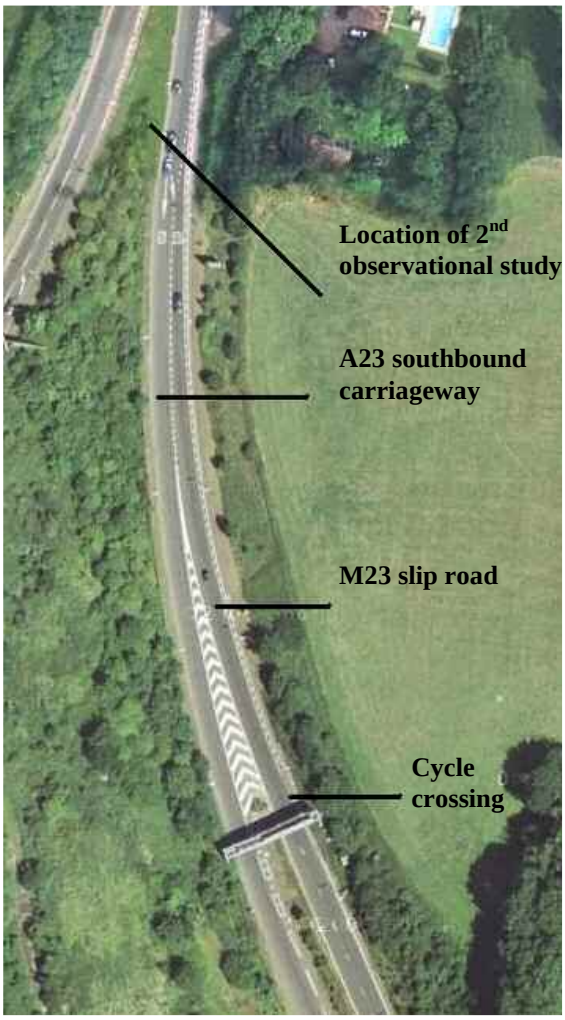
4 Phase B: Assessment of A23/M23 diverge

4.1 Introduction and aims

As part of the project, the Highways Agency required TRL to perform an assessment of one current site. The purpose of this assessment was three-fold. Firstly, the assessment would allow HA to see and judge the value of using a human factors approach at a real problem site. Secondly, the site would provide the TRL project team with an example of a potential application area for a human factors road safety assessment tool. Thirdly, the process of conducting the assessment could potentially provide insight regarding road-specific issues and practical constraints which could later feed into the development of the tool.

The A23/M23 southbound diverge junction (situated at Hooley, Surrey) was chosen by the Highways Agency as an example because it had been previously identified as a site with potential problems. At this point drivers can either join the slip road onto the M23 or pass the exit and continue on the A23. Cyclists are not permitted to join the M23. The specified path for them to take through this junction is to follow the cycle path onto the slip road, dismount, then cross the slip road into a refuge area, remount and continue on the A23. Concerns at the site include late lane changing by vehicles wishing to join the M23, the position of the cycle crossing and whether the refuge area provided for cyclists is sufficiently protected.

Figure 7 – Aerial View of A23/M23 Junction, from Google Maps, 2007



4.2 Method

The assessment of the A23/M23 diverge site was conducted in two stages. Firstly, a site visit was conducted to perform an initial review of the Human Factors issues at the diverge road. A more detailed data collection plan was then produced and a second site visit was conducted.

The initial site visit focussed on observation of general cyclist behaviour and safety, overall highway geometry, driver information and behaviour, and the protection provided to cyclists when crossing the M23 slip road section. Additionally, upon the request of the HA Assistant Route Manager, the Dean Lane junction was briefly examined. This is the point where drivers wishing to join the M23 southbound from the A23 northbound are required to perform a non-standard U-turn manoeuvre.

For the initial observations, four TRL human factors professionals visited the site on 23rd November 2006. Observations were made both on foot and from within a moving vehicle as described below:

1. The team walked southwards along the grass verge beside the cycle lane on the A23, from the 'Little Chef' at Dean Lane to the cycle crossing on the M23 slip road.

2. The team surveyed the junction from a moving car. The site was approached travelling southbound on the A23 and both the route continuing on the A23 towards Redhill and onto the M23 slip road were observed.
3. Initial observations of both cyclist and driver behaviour were made from various positions, these included: from within a stationary vehicle near where drivers performed the non-standard U-turn, from the 'Little Chef' restaurant and when parked in a lay-by off the A23 northbound.

In addition, digital photographs were taken to support the observations.

On the basis of the results of the initial observations, the team devised a more detailed data collection plan. This included more systematic observations of motorised traffic and cyclists, as well as questions for motorists to seek their experiences and opinion of the junction. Questions for cyclists were developed but it was felt that it was not safe or practical to attempt to stop cyclists at the site. Prior to the second site visit a researcher also attempted to identify a cycle club local to the junction which could be contacted for views on the junction. No suitable club was found.

The second site visit was conducted by two researchers on 1st February 2007. The researchers conducted observations of motorist and cyclist behaviour at the junction for approximately four hours in the morning, including during the peak period. Due to the large volume of traffic, a sampling strategy was employed whereby observations were made for 15 minutes out of every 30. The researchers noted the number of vehicles taking each route (i.e. continuing on the A23 or taking the M23), the incidence of late lane selection and the behaviour of any cyclists in terms of the path they chose through the junction.

Interviews were then conducted at a nearby service station. A total of ten people were questioned, including one person who also cycled the route on occasion. However, this method was not found to be very successful in eliciting useful information as people were unwilling to stop and take part.

Finally, measurements were taken of the position of signs and other features in relation to the cycle crossing and the available sightlines from the crossing to the approaching traffic.

4.3 Findings

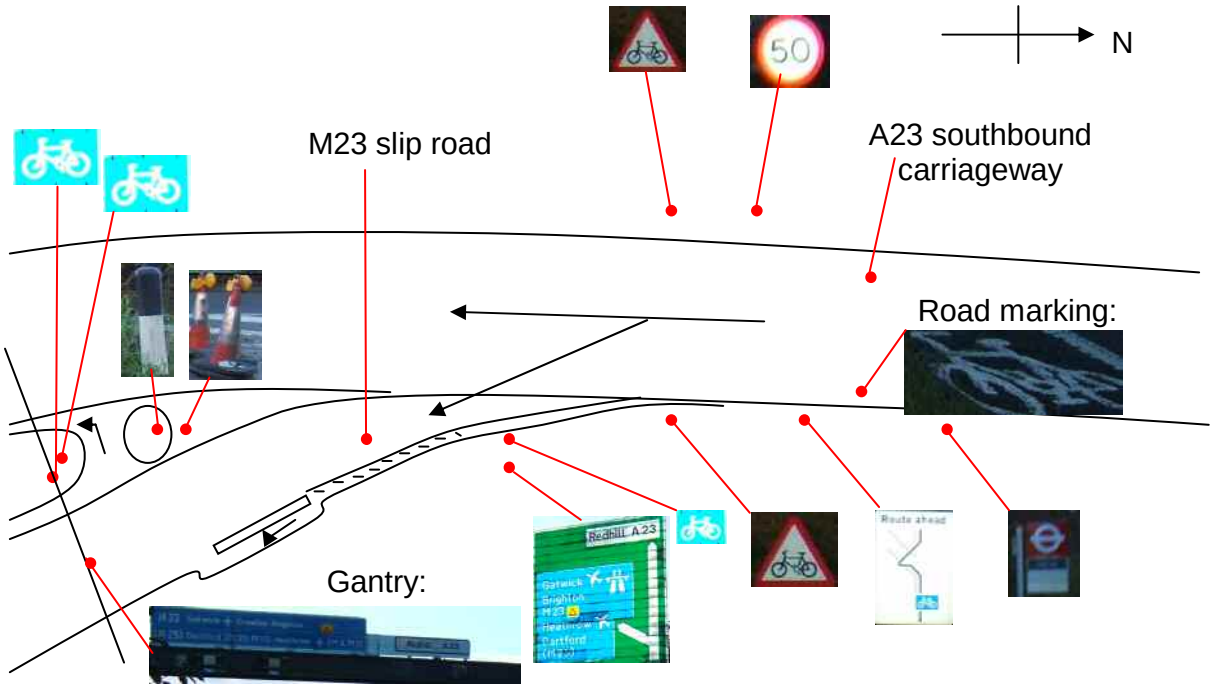
This section presents the key findings of the assessment. The information from the initial and second site visits is combined to present a comprehensive picture. The findings are broken down into six sections:

1. Site layout. This section presents an overview of the general layout of the site, including the signing and other key features.
2. Southbound A23 - This section discusses the southbound approach to the A23/M23 diverge and the southbound A23 after the M23 slip road.
3. Facilities for the cyclist – This section discusses the site from the point of view of cyclist safety on the approach to, and the passage across, the M23 slip road.
4. Cyclist protection – This section discusses the suitability of the refuge area where cyclists are expected to remount their bicycle before continuing on the southbound A23.
5. The Dean Lane junction – This section describes the human factors observations made about the Dean Lane junction.
6. General points – This section describes general aspects of the entire site that apply to all road users.

4.3.1 Site layout

During the site visits the location of all signs and key features was recorded. A representation of the layout of the southbound A23 and M23 slip road is shown in Figure 8.

Figure 8 – Representation of the layout of the southbound A23 and M23 slip road



4.3.2 The A23 southbound

On the A23 southbound carriageway, before the M23 slip road, the following issues were observed:

- Advanced signage (1/3mile for the motorway) is partially obscured by a tree (see Figure 9).
- This sign only has routing information for the motorway, not the A23. This may leave some drivers uncertain as to which direction to take until quite late, which may, in turn, account for some of the late decision making which has been observed. Overall, this increases the unpredictability of the traffic using this route.

Figure 9: Advanced route signage obscured by a tree.

- The approach to the M23 slip road is a single lane but is wider than standard width. It was observed that some drivers treated this single lane as two lanes when approaching the slip road and this inconsistency between behaviour and road markings could make it more difficult for all drivers to predict the actions of other road users.

On the A23 southbound, after passing the M23 slip road, the following points were observed:

- The following image shows that the cycle lane stops abruptly with simply “NO” and the cycle path icon signage. Markings are unclear. This occurs at a point where the road is narrowing. As such, presumably the termination of the cycle path is to maintain the road width for vehicular traffic. From a driver’s perspective this is understandable, but there would be increased risks to cyclists at this location.

Figure 10: End of cycle path on A23 southbound.

- The series of bridges under which the road passes as well as the morning sun shining directly at the driver means that visibility is poor (see Figure 11).

Figure 11: Poor visibility due to glare from morning sun.

4.3.3 Facilities for the cyclist

For a cyclist travelling south on the A23, it is assumed that the 'prescribed' behaviour for them would be:

- to use the cycle path (where available),
- come to a halt in the refuge bay before the slip road,
- dismount from their bikes,
- check that the road is clear,
- when clear, push their bikes quickly across the road,
- re-mount when in the refuge bay on the other side of the slip,
- continue on the A23 (in the cycle path, until it finishes)

Four cyclists were observed on the southbound carriageway of the A23 in a period of 1 hour during the morning rush hour (8-9am). This indicates that this route is frequently used by cyclists during peak periods. Three of these looked like cycling enthusiasts: they were riding high-speed bicycles and wearing cycling clothes. Two of these cyclists were observed crossing over to the right hand side of the A23 between Dean Lane and the M23 slip road without dismounting. From the observation position used, it was not possible to observe these cyclists beyond this point but presumably they would then have crossed the carriageway again at some point on the A23 to return to the left-hand side. It was not possible to observe, from the initial vantage point, how and where the remaining cyclists undertook the crossing. As such, generally cyclists do not currently seem to follow the 'prescribed' behaviour.

Figure 12 below shows the bus stop between Dean Lane and the M23 slip road which is on the cycle lane. Although this bus stop is a request stop only, if a bus pulled up it could directly obstruct the cyclists' path. The initial observations showed that some cyclists crossed onto the right hand side of the A23 before the M23 slip road; as such, the position of the bus stop may further add risk to this manoeuvre.

Figure 12: Bus stop on the cycle lane of the A23 southbound carriageway.

Figure 13 shows the refuge where cyclists must stop before crossing the slip road.

- From the information provided in the highway environment for cyclists, it is not clear that they must stop at the side of the slip road before crossing.
- The cycle path at this point is in poor condition, littered with debris and muddy. This could discourage cyclists from stopping and dismounting in the refuge as required.
- The refuge where cyclists must stand before crossing is narrow, and does not allow the bicycle to be positioned perpendicular to the road for crossing. Given that the M23 slip road at this point has traffic that would be accelerating up to speeds of 70mph to join the motorway then allowing the cyclist to cross as quickly as possible is vital. The current design does not facilitate this[7].

[7] During the observations, none of the TRL project team attempted to cross the slip road. Despite being comparatively mobile, wearing highly conspicuous clothing and having a colleague to help check for a gap in the traffic it was judged that the risks were too great. For a cyclist having to push a bike across the road, the risks would appear significantly higher.

Figure 13: The place where cyclists must stop and dismount before crossing.

Figure 14 and Figure 15 show the crossing from the points of view of the cyclist and the driver respectively. The following points are observed:

- Sight lines are not good at the crossing as it is located on a left-hand bend. Drivers have a late view of the crossing and cyclists would find it difficult to observe traffic approaching the crossing. Foliage may further obstruct driver and cyclist's views.
- The crossing is in an unexpected location where drivers will be concentrating on accelerating to join the motorway. This limits the ability of drivers to perceive and react to a cyclist crossing at this point. For example, the human factors literature shows that a driver's reaction time to respond to hazard he/she is expecting might be approximately 0.7 seconds, whereas reaction time for an unexpected hazard may be at least double that (Summala, 1981, who concluded *'it was recommended that, for safe operation, at least 3 s should be reserved for drivers to respond, by steering, to changes in the road environment'*).

  Timings were taken from the moment the driver was able to see the crossing to the moment the front of the vehicle crossed the crossing. For a vehicle travelling at 50mph it would be approximately 4.2 seconds, at 40mph it would be approximately 5.2 seconds and at 30mph it would be approximately 7 seconds. **So vehicles travelling significantly above 50mph might not have enough time (based on the 3 second recommendation mentioned above) to react to a cyclist on the crossing.**
- Even though the speed limit is 50mph, it is likely that drivers are travelling at higher speeds as they are about to join the motorway. Additionally, they would be accelerating rather than purely maintaining a constant speed. Again, this would increase the risk when a cyclist was crossing.

Figure 14: The place where cyclists must cross (cyclist's perspective, looking back along the A23).

Figure 15: The place where cyclists must cross (driver's perspective).

The warning signs for drivers of the cycle crossing could be improved. Figure 16 shows the only advanced warning of cyclists, which is a standard sign placed in close proximity to major route signage. This sign does not indicate a crossing, and the route sign is likely to divert attention away from the cyclist sign.

Figure 16: Sign for cycle path in close proximity to major route signage.

Figure 17 shows the route which the cyclist must take in order to cross the motorway slip road. The crossing is not marked.

Figure 17: The cyclist crossing.

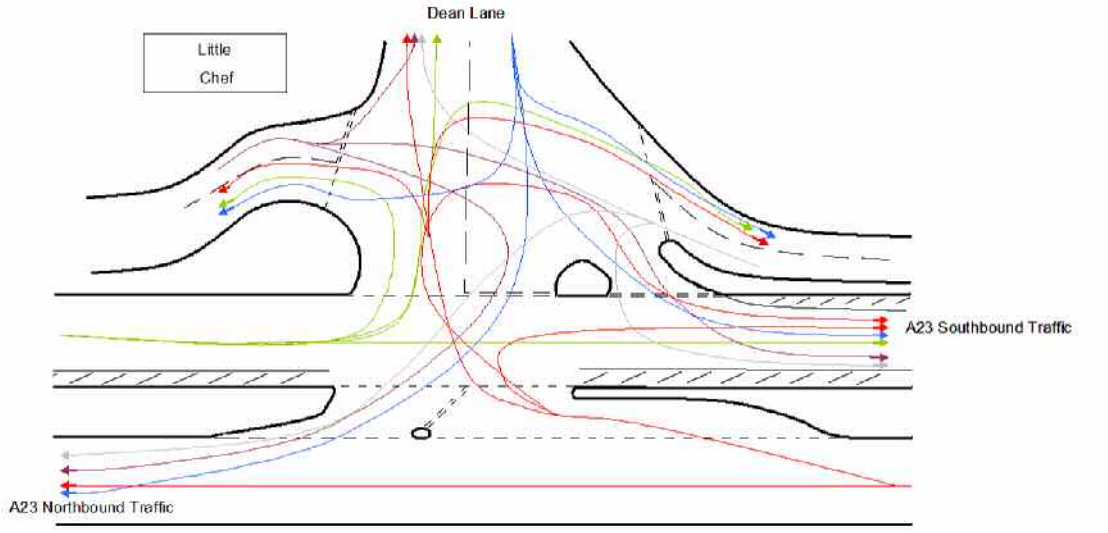
4.3.4 Cyclist protection

The current protection for cyclists waiting to join the A23 after crossing the M23 slip road is inadequate from a crash protection point of view and proposals have been made later in this report to modify it.

4.3.5 The Dean Lane junction

Figure 18 illustrates the manoeuvres that drivers approaching the Dean Lane junction can make. In order to simplify the diagram, the routes taken between the service road to the right of the diagram and the Little Chef have not been marked.

Figure 18: Conflicting interactions on the A23/Dean Lane junction for vehicular traffic



The following observations were made with regards to the Dean Lane junction illustrated above:

- The junction layout is complex, with many conflicting interaction points for vehicles.
- The road markings are worn which makes it even more unclear as to who has priority and who has to give way.
- The junction appears to be used by a large proportion of heavy vehicles which take longer and more space to manoeuvre creating an even greater hazard to vehicles approaching from the North. Also, these vehicles are more likely to be engaged in u-turns or other non-standard manoeuvres compared to cars.
- There are many methods of undertaking the u-turn from the northbound carriageway of the A23 to the southbound carriageway: a tight one directly onto the southbound A23, and a wider one going into and out of Dean Lane.
- When turning out of the "Little Chef" car park or the slip road onto Dean Lane in order to re-join the A23, visibility of the traffic travelling along Dean Lane to join the A23 is heavily restricted by the angle of the junction and surrounding foliage.
- During the visit, traffic conditions were fairly heavy, forcing drivers to leave small safety margins when pulling out.
- The wide road can be treated as 2 lanes on the A23 southbound carriageway. One car was observed overtaking another.
- Observations were only made during good daylight conditions; it is most likely the problems would be exacerbated during darkness/poor weather conditions.

4.3.6 General points

The following general issues were observed at the site:

- Road markings at all parts of the site are quite worn. This makes it more difficult for drivers and cyclists to understand and perform the correct course of action.
- The site is a high speed road (generally 50 mph) and this increases accident risk.
- The route is frequently used by large and heavy vehicles (including buses) which due to their size and shape pose an even greater risk to cyclists than cars.
- Likewise, there is a wide mix of vehicle types using the route; these include cars, buses, lorries and tractors. As such, their travel speeds and behaviour can be quite varied, further compounding the risks.

4.4 Suggestions to improve safety

Based on the observations, the project team developed the following suggestions based on a human factors version of the hierarchy of hazard control. Many variants of the hierarchy exist, but the version shown in Table 12 below has been successfully applied in transport human factors (and broadly reflects the human factors risk management approach used elsewhere in this project).

Table 12: Human Factors re-design suggestions

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
Minimise opportunity for conflict between road users.	1. Remove the cycle path	Unless adequate provision is made elsewhere, this option might result in cyclists simply using the road. As such, it is **not recommended**	**Not recommended**	N/A
	2. Remove the crossing hazard *Principle B1.2 "Separate cyclists from motorised vehicles."*	**Possible suggestion**. Without doubt grade separation is the safest option, and assuming that it does not inconvenience the cyclist it is likely that it would be used (unlike the current crossing). However, the costs of building the underpass which make this option the most expensive are likely to be a significant factor A bridge is a less-favourable option since the cost of compliance (effort required to ascend onto the bridge rather than stay on ground level or descend) for the cyclist would be high and therefore may not be used by many cyclists. Furthermore, the structure of the bridge is a potential crash hazard for motorists.	Remove the crossing hazard by building a cycle underpass (under the current location of the crossing)	Costs of building underpass would be high, but the benefits (in terms of removing accidents involving cycles at the crossing) would also be high. The underpass could also be used by pedestrians. Thus benefits would be to vehicles, cycles and pedestrians.

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
	3. Reduce the number of vehicles or cycles. 4. Reduce speed of vehicles to minimise risk. 5. Reducing road width at the crossing (so cyclist can cross quicker)	Given the nature of these highways, the options of reducing the number, or speeds, of vehicles are not viable. Likewise, reducing the number of cycles conflicts with governmental policy objectives of encouraging cyclist provision. Finally, reducing road width at the cycle crossing may have negative side effects for the safety of vehicular traffic. As such, **none of these options are recommended**	**None recommended**	N/A
Isolation/ Engineering controls	Better separation of all forms of traffic 1. Generally better separation of cycle and vehicular traffic. *Principle B1.2 "Separate cyclists from motorised vehicles."*	These constitute the core of our recommendations. **Possible suggestion**	Mark and maintain the cycle path up to the crossing better (for example, through the use of a green cycle lane, a wider hatched area with raised markings, and regular removal of debris). This would make cyclist behaviour more predictable as cycling over the raised markings would be uncomfortable. It would also sensitise the driver to the possibility of a cyclist being on the crossing ahead, so they may react quicker if a cyclist were present.	Painting additional markings for the cycle path (and regularly maintaining it) would primarily benefit the cyclist, increase the separation between them and fast-moving vehicles, and may make them less likely to violate the cycle path to cross the road earlier. Narrowing the carriageway through a wider hatched area may also result in slower speeds and less late merging behaviour.

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
	2. Better separation at cycle crossing (e.g. lighting, markings). *Principle B1.2 "Separate cyclists from motorised vehicles."*	**Possible suggestion**	Specifically signing the upcoming cycle crossing would sensitise vehicle drivers to a possible hazard, and make cyclists more likely to use the crossing (drawing 962.1 '*cycle track crossing road*' seems appropriate). However, marking the crossing on the roadway or installing a Toucan crossing is **not recommended** as such measures would not be expected by motorists, and may confuse or distract them when entering the slip road.	As above.
	3. Move crossing to an earlier point	Moving the crossing to an earlier point would mean that cyclists would have to cross the A23 twice, so is **not recommended**	**Not recommended**	N/A

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
	4. Better separation between vehicular traffic	**Possible suggestion**	Although the road before the intersection is probably wide enough to have two lanes, it is recommended that one lane is maintained. The road width could be reduced by putting marking (possibly raised markings) to prevent two lanes being formed.	More explicitly limiting the road to one lane would create more order and predictability, and merging problems would be removed. The main cost is re-marking the road. The main benefit is to vehicular traffic, but because the road is more predictable it would be less demanding, so safety benefits might also be present for cyclists.
	5. Better ambient lighting, especially near cycle crossing.	**Possible suggestion, but the benefits might not outweigh the costs**	Additional street lighting, especially at the crossing should be installed	The costs of installing and maintaining specific lighting would be high. Although this may benefit cyclists at night, the costs vs the possible benefits are likely to make this option unattractive.

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
	6. Better crash protection on either side of the crossing for cyclists	**Possible suggestion**	The design of the new barrier should allow the cyclists good observation of drivers approaching on the A23 to assist them with making decisions on when to join. The design of the new barrier should allow the drivers approaching the barrier good view of a cyclist waiting to join. The barrier should be designed to improve visibility of the barrier and driver anticipation of the crossing.	Crash protection would primarily benefit the cyclist. The cost is likely to be high, but the building of a crash area would further encourage cyclists to use the crossing rather than crossing the road earlier.
	7. Move the bus stop	If the cycle crossing was well designed then cyclists would not cross the A23 earlier As such, this option is **not recommended.** Although it should be acknowledged that the bus stop may still conflict with the cycle path.	Not recommended	N/A
Administrative controls	Restricting how, when and by who either the cycle path or roadway are used (e.g. no cyclists at night, no child cyclists).	Beyond the current licensing requirements, it is not practicable, nor desirable to try to impose such types of restrictions. As such, these options are **not recommended**.	Not recommended	N/A

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
Using warnings / having better information provision	1. Better signing for cyclists. 2. Better signing for motorists of the cycle path 3. Re-painting markings *Principles C4-C8 for signs, C11-C14 for road markings.*	**Possible suggestion** **Possible suggestion** **Possible suggestion** As discussed earlier, marking the crossing on the roadway is **not recommended** as it may confuse or distract a motorist entering the slip road (as priority must clearly be with the road user here) .	Signing is one of the weaker forms of risk reduction. The signing of the cycle path before the crossing is quite comprehensive, but the following signs are possible options (with diagram numbers from TSRGD, 2002): ▪ Sign 958.1 (with-flow cycle lane ahead) or 959.1 (with-flow cycle lane) ▪ Sign 966 (*Cyclists dismount*) at crossing ▪ Paint additional markings of the cycle lane (drawing 1057) ▪ Sign the crossing with drawing 962.1 (*cycle track crossing road*).	The improved signing would benefit both motorists (by informing them of the cycle path, and sensitising them of a possible cyclist on the crossing ahead) and cyclists (by informing them what to do, and where to cycle). The costs of the additional signing would be low, but the likely benefits might also be quite low.
Applying behavioural methods	1. Disciplining/prosecuting violating drivers. 2. Disciplining/prosecuting violating cyclists. 3. Encouraging cyclists to reduce the risk by means of personal protective equipment. *Not within scope of human factors principles.*	**Possible suggestion**, but outside scope of this work. **Possible suggestion**, but outside scope of this work. **Possible suggestion** (e.g. through helmets, or wearing conspicuous clothing), but outside scope of this work.	N/A N/A N/A	N/A N/A N/A

Control Measure	Overall HF design suggestions	Comment	Specific measure proposed	Summary of likely costs and benefits
Maintenance issues	1. Ensure signs are clean and not obscured by vegetation. *Principle C8. Regularly check signs and do not assume they have the correct materials, content, placement, orientation and angle.* 2. Maintain cyclist refuge (e.g. remove excess dirt, debris) *"Principle B7. Implement continuous and high quality provision for vulnerable road users."*	**Possible suggestion** **Possible suggestion**.	Regularly maintaining the road environment and cycle path, especially making sure signs are visible and the cycle path/refuge is clean and well marked. If the refuge contains debris and excessive dirt then it is likely that cyclists will not use them (for example to avoid punctures).	Benefits are for both drivers and cyclists. Drivers would be able to better see the information on signs. Cyclists would also be better informed, and would be more likely to use the cycle path if it was better maintained. The cost of such measures is likely to be reasonably low.

5 Discussion

5.1 Summary of key findings and implications

This task undertook research with the eventual aim of developing and evaluating a tool to incorporate human factors knowledge into the design of highways. The overall task is of 12 months duration, and the work contained in this interim report describes only the first half of this work; as such, some aspects are not yet finalised (for example, how the principles should be presented).

A wide range of research methods were used in this Task; a summary of these, and their key outcomes is given below.

1. **The Task provided a global definition of highway human factors and provided a justification of why it is important to explicitly consider such human element issues on the HA network**. This set the scene, introduced the general theoretical framework and provided a commonly-accepted definition of the human factors topic that was used throughout this project.
2. **Thereafter the Task described the human factors data collected and the human factors principles developed.** A massive amount of literature was reviewed, and then a systematic process was employed to generate a list of key principles. Further, a matrix of these principles was created to show which aspects of the road environment they address, and which level of hazard control they are directed at.

   Likewise, the analysis of the accidents that occurred in one full year on the HA network was performed to identify contributory factors that involved the human element. Finally, the human factors principles were mapped onto the accident data - this allowed the research to cross-check these developed principles. Also, this process allowed the work to establish a link between the general class of event (accident contributory factor), their underlying causes (overall rationale) and the possible human related countermeasures (principles).
3. **Following that, the work reviewed and analysed existing HA design guidelines** (DMRB) to determine the extent to which human factors best practice is already incorporated into the design of roads, identify any gaps where human factors is not currently considered, identify any conflicts where existing guidelines are not consistent with human factors best practice and show where the human factors principles are not covered. Overall a large number of principles are covered (implicitly or explicitly) in the documents, however the following areas were notable absentees: removing distracting or obstructing stimuli, having gradual changes of ambient lighting, preventing signs being over-conspicuous, verifying the accuracy of signs/markings and providing drivers with opportunities for safe recovery from wrong route choices.
4. **Finally, the report focused on a human factors assessment of a current HA site**, including making suggestions to improve safety at this site. The purpose of this assessment was three-fold: to allow HA to appreciate the value of using a human factors approach at a real problem site, to provide the TRL project team with an example of a potential application area for a human factors road safety assessment tool and to help provide insight regarding road specific issues and practical constraints which could later feed into the development of the tool.

   A number of re-design suggestions were proposed, these ranged from removing the crossing hazard completely (for example by an building an underpass), better separation of cycle and vehicular traffic, better crash protection around the cycle crossing, better warnings/information provision and improved cycleway maintenance. For each of these measures, the likely costs vs. benefits were outlined, and the benefits for different road user groups was summarised.

5.2 Recommendations for project continuation

It is been shown in this report that human failings are key contributory variables in a large number of accidents that occur on the HA network. As such, work to define the topic, identify the key human factors principles, show the extent to which they are currently covered in existing HA documents and show how they can be applied at a 'test' site (the A23/M23 intersection) was vital. It is argued here that this report has successfully addressed all of these elements.

Based on the original work specification (and the subsequent proposal by TRL) the three remaining items for the second half of the work are:

1. Consultation with HA personnel who might be the eventual users of a human factors road safety assessment tool,
2. Development of the tool, based on the work described in this report,
3. Evaluation of the tool at several HA sites, and amendment as necessary.

It is recommended that the work progresses as was described in the original HA work specification (and the subsequent proposal by TRL).

The form of the human factors road safety assessment tool, and the possible sites for its evaluation, are scheduled to be initially discussed with HA at the break-point meeting in April 2007 and finally determined on the basis of consultation with potential users. The project team recommend that the main focus of the tool should be to evaluate existing HA sites (such as the A23/M23 intersection). However, the information contained in it could also be used to inform the design of new HA roads and to help designers and HA staff gain a better understanding of human factors in general.

To conclude, we believe that the research to date has generated a large amount of useful information, and is well positioned to produce a valuable deliverable in the second half of the project. Such a deliverable should be a valuable tool to help further improve safety on the HA network.

Acknowledgements

The work described in this report was carried out in the Human Factors and Simulation Group of TRL Limited. The authors are grateful to Ian Burrow and Dr. Alan Stevens who carried out the quality review and auditing of this report.

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Appendix A. Example STATS 19 Form

Sept. 2004

MG NSRF/A

ACCIDENT STATISTICS

Incident URN

Other ref.

1.3 ACCIDENT REFERENCE

*FATAL / SERIOUS / SLIGHT

1.9 TIME H H M M DAY* Su M T W Th F S 1.7 DATE D D M M 2 0 Y Y

1st Road Class & No. or (Unclassified - UC) (Not Known - NK)

1st Road Name

Outside House No. or Name or Marker Post No.

at junction with / or metres N S E W * of

2nd Road Class & No. or (Unclassified - UC) (Not Known - NK)

2nd Road Name

Town

Sector /Beat No.

County or Borough

Parish No. or Name

1.10 Local Auth No. (if known)

1.11 Grid Reference E → N ↑

REPORTING OFFICER Name

Number

BCU/Stn

1.2 Force

Tel Number

1.5 Number of vehicles	
1.6 Number of casualties	

1.14 ROAD TYPE

		✗
Roundabout	1	
One way street	2	
Dual carriageway	3	
Single carriageway	6	
Slip road	7	
Unknown	9	

1.15 Speed Limit (Permanent)		

1.16 JUNCTION DETAIL

		✗
Not at or within 20 metres of junction	00	
Roundabout	01	
Mini roundabout	02	
T or staggered junction	03	
Slip road	05	
Crossroads	06	
Multiple junction	07	
Using private drive or entrance	08	
Other junction	09	

JUNCTION ACCIDENTS ONLY

1.17 JUNCTION CONTROL

		✗
Authorised person	1	
Automatic traffic signal	2	
Stop sign	3	
Give way or uncontrolled	4	

1.20a PEDESTRIAN CROSSING - HUMAN CONTROL

		✗
None within 50 metres	0	
Control by school crossing patrol	1	
Control by other authorised person	2	

1.20b PEDESTRIAN CROSSING - PHYSICAL FACILITIES

		✗
No physical crossing facility within 50m	0	
Zebra crossing	1	
Pelican, puffin, toucan or similar non-junction pedestrian light crossing	4	
Pedestrian phase at traffic signal junction	5	
Footbridge or subway	7	
Central refuge — no other controls	8	

1.22 WEATHER

		✗
Fine without high winds	1	
Raining without high winds	2	
Snowing without high winds	3	
Fine with high winds	4	
Raining with high winds	5	
Snowing with high winds	6	
Fog or mist — if hazard	7	
Other	8	
Unknown	9	

1.23 ROAD SURFACE CONDITION

		✗
Dry	1	
Wet / Damp	2	
Snow	3	
Frost / Ice	4	
Flood (surface water over 3cm deep)	5	

1.21 LIGHT CONDITIONS

		✗
Daylight: street lights present	1	
Daylight: no street lighting	2	
Daylight: street lighting unknown	3	
Darkness: street lights present and lit	4	
Darkness: street lights present but unlit	5	
Darkness: no street lighting	6	
Darkness: street lighting unknown	7	

1.24 SPECIAL CONDITIONS AT SITE

		✗
None	0	
Auto traffic signal out	1	
Auto traffic signal partially defective	2	
Permanent road signing or marking defective or obscured	3	
Roadworks	4	
Road surface defective	5	
Oil or diesel	6	
Mud	7	

1.25 CARRIAGEWAY HAZARDS

		✗
None	0	
Dislodged vehicle load in carriageway	1	
Other object in carriageway	2	
Involvement with previous accident	3	
Pedestrian in carriageway - not injured	6	
Any animal in carriageway (except ridden horse)	7	

1.26 Did a police officer attend the scene and obtain the details for this report?

		✗
Yes	1	
No	2	

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* Circle as appropriate

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VEHICLE RECORD

Sept. 2004

2.26 VEHICLE REGISTRATION MARK

Vehicle 001	
Vehicle 002	
Vehicle 003	
Vehicle 004	

2.28 FOREIGN REGISTERED VEHICLE ✗

		VEHICLE 1	2	3	4
Not foreign registered vehicle	0				
Foreign registered vehicle LHD	1				
Foreign registered vehicle RHD	2				
Foreign reg' vehicle-two wheeler	3				

2.5 TYPE OF VEHICLE ✗

Pedal cycle	01				
M/cycle 50cc and under	02				
M/cycle over 50cc and up to 125cc	03				
M/cycle over 125cc and up to 500cc	04				
Motorcycle over 500cc	05				
Taxi / Private hire car	08				
Car	09				
Minibus (8-16 passenger seats)	10				
Bus or coach (17 or more passenger seats)	11				
Other motor vehicle	14				
Other non-motor vehicle	15				
Ridden horse	16				
Agricultural vehicle (include diggers etc)	17				
Tram / Light rail	18				
Goods vehicle 3.5 tonnes mgw and under	19				
Goods vehicle over 3.5 tonnes mgw and under 7.5 tonnes mgw	20				
Goods vehicle 7.5 tonnes mgw and over	21				

2.6 TOWING AND ARTICULATION ✗

No tow or articulation	0				
Articulated vehicle	1				
Double or multiple trailer	2				
Caravan	3				
Single trailer	4				
Other tow	5				

2.21 SEX OF DRIVER ✗

Male	1				
Female	2				
Driver not traced	3				

2.22 AGE OF DRIVER (Estimate if necessary)

Vehicle 001		Vehicle 002	
Vehicle 003		Vehicle 004	

2.27 DRIVER HOME POSTCODE

or Code: 1- Unknown 2- Non UK Resident 3 - Parked & unattended

Vehicle 001	
Vehicle 002	
Vehicle 003	
Vehicle 004	

2.23 BREATH TEST ✗

		VEHICLE 1	2	3	4
Not applicable	0				
Positive	1				
Negative	2				
Not requested	3				
Refused to provide	4				
Driver not contacted at time of acc'	5				
Not provided (medical reasons)	6				

2.24 HIT AND RUN ✗

Not hit and run	0				
Hit and run	1				
Non-stop vehicle, not hit	2				

2.29 JOURNEY PURPOSE OF DRIVER / RIDER ✗

Journey as part of work	1				
Commuting to / from work	2				
Taking school pupil to/ from school	3				
Pupil riding to / from school	4				
Other/Not known	5				

2.9 VEHICLE LOCATION AT TIME OF ACCIDENT RESTRICTED LANE/ AWAY FROM MAIN C'WAY ✗

On main carriageway not in restricted lane	00				
Tram / Light rail track	01				
Bus lane	02				
Busway (inc. guided busway)	03				
Cycle lane (on main carriageway)	04				
Cycleway or shared use footway (not part of main carriageway)	05				
On lay-by / hard shoulder	06				
Entering lay-by / hard shoulder	07				
Leaving lay-by / hard shoulder	08				
Footway (pavement)	09				

2.10 JUNCTION LOCATION OF VEHICLE ✗

Not at or within 20m of junction	0				
Approaching junction or waiting /parked at junction approach	1				
Cleared junction or waiting / parked at junction exit	2				
Leaving roundabout	3				
Entering roundabout	4				
Leaving main road	5				
Entering main road	6				
Entering from slip road	7				
Mid junction- on roundabout or on main road	8				

2.7 MANOEUVRES ✗

Reversing	01				
Parked	02				
Waiting to go ahead but held up	03				
Slowing or stopping	04				
Moving off	05				
U turn	06				
Turning left	07				
Waiting to turn left	08				
Turning right	09				
Waiting to turn right	10				
Changing lane to left	11				
Changing lane to right	12				
O'taking moving veh on its offside	13				
O'taking stationary veh on its offside	14				
Overtaking on nearside	15				
Going ahead left hand bend	16				
Going ahead right hand bend	17				
Going ahead other	18				

2.11 SKIDDING AND OVERTURNING ✗

		VEHICLE 1	2	3	4
No skidding, jack-knifing or overturning	0				
Skidded	1				
Skidded and overturned	2				
Jack knifed	3				
Jack-knifed and overturned	4				
Overturned	5				

2.12 HIT OBJECT IN CARRIAGEWAY ✗

None	00				
Previous accident	01				
Roadworks	02				
Parked vehicle	04				
Bridge-roof	05				
Bridge-side	06				
Bollard / Refuge	07				
Open door of vehicle	08				
Central island of roundabout	09				
Kerb	10				
Other object	11				
Any animal (except ridden horse)	12				

2.13 VEHICLE LEAVING CARRIAGEWAY ✗

Did not leave carriageway	0				
Left carriageway nearside	1				
Left carriageway nearside and rebounded	2				
Left carriageway straight ahead at junction	3				
Left carriageway offside onto central reservation	4				
Left carriageway offside onto central reserve and rebounded	5				
Left carriageway offside and crossed central reservation	6				
Left carriageway offside	7				
Left carriageway offside and rebounded	8				

2.14 FIRST OBJECT HIT OFF CARRIAGEWAY ✗

None	00				
Road sign / Traffic signal	01				
Lamp post	02				
Telegraph pole / Electricity pole	03				
Tree	04				
Bus stop / Bus shelter	05				
Central crash barrier	06				
Nearside or offside crash barrier	07				
Submerged in water (completely)	08				
Entered ditch	09				
Other permanent object	10				

2.16 FIRST POINT OF IMPACT ✗

Did not impact	0				
Front	1				
Back	2				
Offside	3				
Nearside	4				

2.17 FIRST CONTACT BETWEEN EACH VEHICLE

Example: In a 3 car collision vehicle 1 collides with the rear of vehicle 2 pushing it into vehicle 3.

Example Code:			
Vehicle 001 first collides with vehicle 002	0	0	2
Vehicle 002 first collides with vehicle 003	0	0	3
Vehicle 003 first collides with vehicle 002	0	0	2

Vehicle 001	0			Vehicle 002	0		
Vehicle 003	0			Vehicle 004	0		

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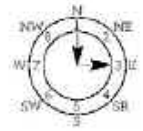
2.8 DIRECTION OF VEHICLE TRAVEL

1. Using the Example shown complete the FROM and TO boxes for the vehicles concerned, indicating direction of travel FROM and TO
2. If PARKED enter '00'

Vehicle 001		Vehicle 002	
FROM	TO	FROM	TO
Vehicle 003		**Vehicle 004**	
FROM	TO	FROM	TO

EXAMPLE

FROM	TO
1	3



CASUALTY RECORD

3.4 VEHICLE REFERENCE NUMBER
Enter VEH No. which CASUALTY occupied (for pedestrians, code vehicle that struck them) e.g. 001,002 etc.

Casualty 001	0	Casualty 002	0
Casualty 003	0	Casualty 004	0
Casualty 005	0	Casualty 006	0

3.18 CASUALTY HOME POSTCODE
or Code: 1- Unknown
2- Non UK Resident

Casualty 001		Casualty 002	
Casualty 003		Casualty 004	
Casualty 005		Casualty 006	

		CASUALTY					
		1	2	3	4	5	6
3.7 SEX OF CASUALTY ✗							
Male	1						
Female	2						
3.8 AGE OF CASUALTY (Estimate if necessary) For children less than a year enter 00							
Casualty 001							
Casualty 002							
Casualty 003							
Casualty 004							
Casualty 005							
Casualty 006							
3.6 CASUALTY CLASS ✗							
Driver/Rider	1						
Veh./pillion Passenger	2						
Pedestrian	3						
3.9 SEVERITY OF CASUALTY ✗							
Fatal	1						
Serious	2						
Slight	3						

		CASUALTY					
		1	2	3	4	5	6
3.13 SCHOOL PUPIL CASUALTY ✗							
School pupil on journey to or from school	1						
Other	0						
3.15 CAR PASSENGER (not driver) ✗							
Not a car passenger	0						
Front seat passenger	1						
Rear seat passenger	2						
3.16 BUS OR COACH PASSENGER ✗ (17 passenger seats or more)							
Not a bus or coach passenger	0						
Boarding	1						
Alighting	2						
Standing passenger	3						
Seated passenger	4						

PEDESTRIAN CASUALTIES ONLY

3.10 PEDESTRIAN LOCATION ✗		CASUALTY 1	2	3	4	5	6
In carriageway, crossing on pedestrian crossing facility	01						
In carriageway, crossing within zig-zag lines at crossing approach	02						
In carriageway, crossing within zig-zag lines at crossing exit	03						
In carriageway, crossing elsewhere within 50m of pedestrian crossing	04						
In carriageway, crossing elsewhere	05						
On footway or verge	06						
On refuge, central island or central reservation	07						
In centre of carriageway, not on refuge, island or central reservation	08						
In carriageway, not crossing	09						
Unknown or other	10						

3.11 PEDESTRIAN MOVEMENT ✗		CASUALTY 1	2	3	4	5	6
Crossing from driver's nearside	1						
Crossing from driver's nearside-masked by parked or stationary veh	2						
Crossing from driver's offside	3						
Crossing from driver's offside-masked by parked or stationary veh	4						
In carriageway, stationary - not crossing (standing or playing)	5						
In carriageway, stationary - not crossing (standing or playing), masked by parked or stationary veh	6						
Walking along in carriageway-facing traffic	7						
Walking along in carriageway-back to traffic	8						
Unknown or other	9						

3.12 PEDESTRIAN DIRECTION ✗		CASUALTY 1	2	3	4	5	6
Standing still	0						
Northbound	1						
Northeast bound	2						
Eastbound	3						
Southeast bound	4						
Southbound	5						
Southwest bound	6						
Westbound	7						
Northwest bound	8						
Unknown	9						
3.19 PEDESTRIAN INJURED IN THE COURSE OF 'On The Road' WORK Work actively carried out on public road (e.g. delivery services, road maintenance, postal delivery, traffic control etc.) ✗							
No	0						
Yes	1						
Not known	2						

LOCAL STATISTICS

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CONTRIBUTORY FACTORS

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1. Select up to six factors from the grid, relevant to the accident.
2. Factors may be shown in any order, but an indication must be given of whether each factor is **very likely (A)** or **possible (B)**.
3. Only include factors that you consider contributed to the accident. (i.e. do NOT include "Poor road surface" unless relevant).
4. More than one factor may, if appropriate, be related to the same road user.
5. The same factor may be related to more than one road user.
6. The participant should be identified by the relevant vehicle or casualty ref no. (e.g. 001, 002 etc.), preceded by "V" if the factor applies to a vehicle, driver/rider or the road environment (e.g. V002), or "C" if the factor relates to a pedestrian or passenger casualty (e.g. C001).
7. Enter U000 if the factor relates to an uninjured pedestrian.

Road Environment Contributed	101 Poor or defective road surface	102 Deposit on road (e.g. oil, mud, chippings)	103 Slippery road (due to weather)	104 Inadequate or masked signs or road markings	105 Defective traffic signals	106 Traffic calming (e.g. speed cushions, road humps, chicanes)	107 Temporary road layout (e.g. contraflow)	108 Road layout (e.g. bend, hill, narrow carriageway)	109 Animal or object in carriageway	
Vehicle Defects	201 Tyres illegal, defective or under-inflated	202 Defective lights or indicators	203 Defective brakes	204 Defective steering or suspension	205 Defective or missing mirrors	206 Overloaded or poorly loaded vehicle or trailer				
Driver/Rider Only (Includes Pedal Cycles and Horse Riders) — Injudicious Action	301 Disobeyed automatic traffic signal	302 Disobeyed 'Give Way' or 'Stop' sign or markings	303 Disobeyed double white lines	304 Disobeyed pedestrian crossing facility	305 Illegal turn or direction of travel	306 Exceeding speed limit	307 Travelling too fast for conditions	308 Following too close	309 Vehicle travelling along pavement	310 Cyclist entering road from pavement
Driver/Rider Only — Driver/Rider Error or Reaction	401 Junction overshoot	402 Junction restart (moving off at junction)	403 Poor turn or manoeuvre	404 Failed to signal or misleading signal	405 Failed to look properly	406 Failed to judge other person's path or speed	407 Passing too close to cyclist, horse rider or pedestrian	408 Sudden braking	409 Swerved	410 Loss of control
Driver/Rider Only — Impairment or Distraction	501 Impaired by alcohol	502 Impaired by drugs (illicit or medicinal)	503 Fatigue	504 Uncorrected defective eyesight	505 Illness or disability, mental or physical	506 Not displaying lights at night or in poor visibility	507 Cyclist wearing dark clothing at night	508 Driver using mobile phone	509 Distraction in vehicle	510 Distraction outside vehicle
Driver/Rider Only — Behaviour or Inexperience	601 Aggressive driving	602 Careless, reckless or in a hurry	603 Nervous, uncertain or panic	604 Driving too slow for conditions or slow vehicle (e.g. tractor)	605 Learner or inexperienced driver/rider	606 Inexperience of driving on the left	607 Unfamiliar with model of vehicle			
Driver/Rider Only — Vision Affected by	701 Stationary or parked vehicle(s)	702 Vegetation	703 Road layout (e.g. bend, winding road, hill crest)	704 Buildings, road signs, street furniture	705 Dazzling headlights	706 Dazzling sun	707 Rain, sleet, snow or fog	708 Spray from other vehicles	709 Visor or windscreen dirty or scratched	710 Vehicle blind spot
Pedestrian Only (Casualty or Uninjured)	801 Crossing road masked by stationary or parked vehicle	802 Failed to look properly	803 Failed to judge vehicle's path or speed	804 Wrong use of pedestrian crossing facility	805 Dangerous action in carriageway (e.g. playing)	806 Impaired by alcohol	807 Impaired by drugs (illicit or medicinal)	808 Careless, reckless or in a hurry	809 Pedestrian wearing dark clothing at night	810 Disability or illness, mental or physical
Special Codes	901 Stolen vehicle	902 Vehicle in course of crime	903 Emergency vehicle on a call	904 Vehicle door opened or closed negligently						*999 Other – Please specify below

	1st	2nd	3rd	4th	5th	6th
Factor in the accident						
Which participant? (e.g. V001, C001, U000)						
Very likely (A) or Possible (B)						

* If 999 Other, give brief details .....

(Note: Only use if another factor contributed to the accident **and include it in the text description of how the accident occurred**)

These factors reflect the reporting officer's opinion at the time of reporting and may not be the result of extensive investigation

UNCLASSIFIED

Appendix B. Current Layout of Principles within Matrix

Application category	Applications	A. Eliminate hazards	B. Minimise opportunity for conflicts between road users	C. Inform the road user: D. Appropriate interactions	C. Inform the road user: E. Appropriate speed choice and control actions	C. Inform the road user: F. Appropriate route choice	G. Provide safe opportunities for error handling and promote recovery
Road geometry	All	A1. Minimise the number of variations in the design of the highway	B1. Separate different types of road users.	C1. Provide sufficient sightlines for the design speed of the highway.			G1. Minimise the severity of run-off situations.
		A1.1. Minimise variations in road width for the highway section.	B1.1 Separate pedestrians from cyclists and motorised vehicles.	C2. Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation.			G1.1. Provide impenetrable barriers to prevent vehicles from leaving the road.
		A1.2. Minimise sudden increases and decreases in driver mental workload for the highway section.	B1.2 Separate cyclists from motorised vehicles.	C2.1. Make the hazard itself visible if possible.			G1.2. If barriers cannot be provided, provide alerting delineation and a safe run off area sufficient for the speed and layout of the road.
			B1.3 Separate faster moving motorised vehicles from slower ones.	C2.2. Provide cues or warnings to alert the driver to unseen/invisible hazards.			G1.3. Design run-off areas which are generally flat and without hazards.
		A2. Avoid distracting or obstructing stimuli, particularly at high workload highway locations.		D1. Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances.	E1. Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed.		G1.4. Provide secondary safety measures to minimise injury from run-off accidents.
		A3. Replace level crossings with other measures.	B2. Separate opposing traffic flows by design (e.g. one way roads) or physical barriers.	D1.1. Make the hard shoulder look and feel like "foreign territory" by distinct markings/texture.	E1.1. Design the highway so that the task of vehicle control seems harder than it may actually be.		G1.5.Provide tertiary safety measures (access to emergency and medical services).
		A4. Separate vehicle parking spaces from the flow of traffic.	B3. Design highway lanes wide enough for the official speed of the road.		E1.2. To reduce vehicle speeds, present the driver with an increased flow of stimuli in the peripheral visual field.		G2. Provide skid resistant surfaces in areas where drivers are prone to make late decisions.
	Straight sections				E2. Provide road edge, lane and centre line delineation.		G3. Provide opportunities for safe recovery from wrong-route choices.
	Curved sections	A1.3. Minimise variations in the curvature of the highway.			E2.1. Align road edge delineation (including barriers, guard rails etc.) with the path of the road.		
		A5. Avoid curves with a small radius.					
					E3. Design curves so that their presence and characteristics are apparent on approach and throughout.		
					E3.1. Provide cues to help the driver negotiate the curve.		
	Gradients	A6. Avoid gradients greater than 2%.					

Application category	Applications	A. Eliminate hazards	B. Minimise opportunity for conflicts between road users	C. Inform the road user: D. Appropriate interactions	C. Inform the road user: E. Appropriate speed choice and control actions	C. Inform the road user: F. Appropriate route choice	G. Provide safe opportunities for error handling and promote recovery
Junctions/ interface points	All junctions	A6.1. Minimise gradients on approach to junctions.	B4. Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely.	D2. Design junctions so that traffic from opposing streams has a good view of each other.	E1.3. Encourage drivers on major/priority road to slow down on approach to junctions.	F1. At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination.	
		A7. Do not place junctions on curves.	B5. Minimise the number and severity of conflict points at junctions.	D3. Priority of one road over another should be clearly and consistently indicated through highway design, markings and signs.		F1.1. At junctions and other high workload situations, provide information at the correct time and place.	
	Grade separated junctions	A5.1. Provide straight on/off ramps rather than curved ones.					
	Staggered junctions						
	Cross roads and t-junctions		B6. Where it does not significantly impact on flow rates, provide traffic lights at cross roads and t-junctions.				
			B6.1. Introduce conflict-free control for different types of junction users.				
			B6.2. If control is not conflict-free, provide channelisation.				
			B6.3. Discourage red and amber light running.				

Application category	Applications	A. Eliminate hazards	Minimise likelihood of error: B. Minimise opportunity for conflicts between road users	Minimise likelihood of error: C. Inform the road user: D. Appropriate interactions	Minimise likelihood of error: C. Inform the road user: E. Appropriate speed choice and control actions	Minimise likelihood of error: C. Inform the road user: F. Appropriate route choice	G. Provide safe opportunities for error handling and promote recovery
VRU facilities	All		B7. Implement continuous and high quality provision for vulnerable road users.				
	Pedestrians		B8. Provide official and visible pedestrian crossings in safe places.	D4. Give pedestrians clear instructions regarding interaction with traffic.			G4. Provide safe pedestrian refuges for emergency use or in case of breakdown.
			B8.1. Discourage crossing at places other than designated crossing points.	D5. Provide street lighting where pedestrians are likely to be present.			
			B8.2. Design crossing so that all parties have a good view of each other.				
			B8.3. Provide crossings which allow pedestrians to negotiate one stream of traffic at a time.				
			B8.4. Clearly indicate priority at pedestrian crossings.				
	Cyclists		B9. Do not mark cycle lanes within junctions used by mixed traffic.				
			B10. Provide an advanced stop line for cyclists at junctions.				

Application Category	Applications	A. Eliminate hazards	B. Minimise opportunity for conflicts between road users	Minimise likelihood of error: C. Inform the road user — D. Appropriate interactions	E. Appropriate speed choice and control actions	F. Appropriate route choice	G. Provide safe opportunities for error handling and promote recovery
Methods	Lighting			C3. Provide appropriate road lighting for the road situation. The best possible lighting should be used at transition points, natural hazards and abnormal situations.			
				C3.1. Ensure lighting is uniform, and that glare from the light source used and other potential sources of glare within the particular road situation are minimised.			
				C3.2. Generate gradual changes in ambient light levels.			
	Signs			C4. All signs must be conspicuous, but not over-conspicuous.			G5. Place signs such that there is no risk of them being struck by vehicles or protect them using a barrier.
				C5. All signs must be legible from an appropriate distance			
				C6. All signs must be comprehensible.			
				C7. All signs must be accurate.			
				C8. Regularly check signs and do not assume they have the correct materials, content, placement, orientation and angle.			
				C8.1. Remove warning signs if the hazard no longer exists.			
				C9. Where physically possible, position signs where the driver expects them to be.			
				C10. Where signs are unlit, position them so that they achieve headlight illumination.			
					E4. Repeat warning signs when the hazard itself is not visible.	F2. Provide information about the driver's current location and type of road they are currently on.	
	Road markings			C11. Road markings must be conspicuous			
				C12. Road markings must be legible.			
				C13. Road markings must be comprehensible.			
				C14. Road markings must be correct and accurate.			

Appendix C. Example Principle Statement Documents

Principle B1.2:

Separate cyclists from motorised vehicles.

Explanation:

Mixing different types of traffic increases the potential for conflict between them, and makes the roadway less safe. Heterogeneous traffic, where one mode does not compose more than 85% of the on-street traffic during a peak period results in increased traffic fatalities. Different methods can be used to separate cyclists from motorised road users; however, the more comprehensive the separation, the greater the reduction in accidents.

Examples:

The following methods have been used to separate modes of traffic:

Method Used	Result
Raised pavements (10-20cm) separated from motorised traffic by kerbstones.	30% reduction in accidents involving bicycles. 1-13% reduction in total number of accidents.
A cycle lane.*	10% fewer cyclist accidents 30% fewer pedestrian accidents. 40% fewer accidents for other vehicles.
Kerbstones (in the city) or segregators (in rural areas) to separate cycle lanes from motorised traffic and pedestrian tracks.	4% reduction in injury accidents.

* Marking bicycle lanes in red stresses the distinction between lanes and communicates the possibility of encountering this type of traffic.

Applicability:

This principle applies to all roads on which cyclists are allowed to travel along with motorised vehicles.

Principle B8.1:

Discourage crossing at places other than designated crossing points.

Explanation:

25% of pedestrians cross the road away from crossings, in a zone 25m to either side. Crossing the road away from the crossing at up to 50m to either side increases the accident rate for that particular stretch of road. For example, when a crossing is signalised, the number of rear-end collisions for vehicles increases. For pedestrians, the decrease in the number of accidents is 27%, however, there is a tendency for a slight increase in accidents up to 50m away.

When driving in the dark, drivers can detect pedestrians at twice the distance at night if they are where they expect them to be. Thus, applying this principle is likely to result in a reduction in night time collisions with pedestrians.

There are also safety benefits for young children in discouraging them from crossing the road away from dedicated crossings. Young children only take into account directly visible dangers; they can not anticipate dangers in the way that adults have learned to. Brows of hills and sharp bends are almost always regarded by them as safe places to cross, because cars are not immediately visible at these locations. Thus, there is a safety benefit in specifying where young pedestrians cross the road, and discouraging them from crossing elsewhere.

Although the literature does not mention safety benefits of discouraging cyclists from crossing the road away from crossings, it is likely that this principle would apply to all vulnerable road users.

Examples:

The following methods have been used to discourage pedestrians from crossing the road at places other then the dedicated crossing points:

Method Used	Result
Guard rails between the pavement and carriageway.*	24% reduction in accidents involving pedestrians. 8% reduction in vehicle accidents. A reduction from 18% to 7% in the number of pedestrians crossing the road away from the crossing.

* The problem of the rails obstructing drivers' ability to see pedestrians who are about to step into the road at the end of the rails can be reduced by removing some of the rail posts - the reduction in accidents then becomes 33% for pedestrians and 50% for vehicles.

Applicability:

This principle applies to all roads on which crossings exist.

Principle E1.2:

To reduce vehicle speeds, present the driver with an increased flow of stimuli in the peripheral visual field.

Explanation:

Perception of speed is related to the rate of flow of visual stimuli within the field of vision. It is thus possible to manipulate drivers' perceptions of their speed using visual cues. A high rate of flow of visual stimuli may be a cue to the driver that they are driving fast; an increasing rate of flow of stimuli is a cue to the driver that they may be speeding up.

Examples:

The following methods have been successfully used to manipulate road user speed:

Method Used	Rationale
Painting transverse lines across the road.	Provides fast and regular flow of visual stimuli across the peripheral visual field.
Decreasing the interval between transverse lines painted across the road.	Gives the illusion that drivers are speeding up even when their speed remains constant. At a motorway exit ramp, this can reduce excessive speed (more than 18mph over posted limit) by 40%.
Placing roadside elements closer to the edge of the motorway.*	Closer roadside elements result in an increased flow of visual stimuli within the peripheral visual field.
Decreasing road width.*	Elements at the edge of the road become closer, and lead to an increased rate of flow of visual stimuli.
Using a 9:3 mark - gap ratio on road markings.	Urges caution and lower driving speed.

* Whilst these methods are successful, they may be considered undesirable on high speed roads as they may increase the opportunity for conflict between vehicles, or between vehicles and roadside elements.

Applicability:

This principle applies to all roads on which it is desirable to slow drivers in preparation for a potential hazard, a variation in the road situation, and particularly when leaving a motorway to combat the effects of speed adaptation.

Appendix D. Findings from DMRB Review

Principle	Section	*Quote*	Satisfies Principle? Strong	Moderate	Weak	Contradicts	Not Found	Notes
A1. Minimise the number of variations in the design of the highway	6.2.4 - 5.3 The Design of Major Interchanges	*"In general the most desirable interchange layout will be that option which has the minimum number of decisions and manoeuvres."*	☑	☐	☐	☐	☐	Narrow context
	6.1.3 - 2.39 Guidance on Minor Improvements to Existing Roads	*"Improving route consistency can assist in making drivers aware of the overall nature of the route."*	☑	☐	☐	☐	☐	
	6.1.1 - 5.47 Roads Geometry Links	*"avoid frequent changes of patterns on long hills…"*	☑	☐	☐	☐	☐	
	6.2.3 - 2.31 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts	*"The number of straight ahead entry and exit lanes for a traffic stream should be balanced in order to reduce conflict…"*	☐	☐	☑	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
A1.1. Minimise variations in road width for the highway section.	5.1.3 - D.3 Traffic Flow Ranges for Use in the Assessment of New Rural Roads	*"...the width factor Wf should always be unity for motorways as there is no evidence to suggest that the maximum hourly throughput of motorway links is affected by minor changes in lane width."*	☑	☐	☐	☐	☐	
	5.1.3 - D.3 Traffic Flow Ranges for Use in the Assessment of New Rural Roads	*"The majority of dual carriageways will have lane widths of 3.65 metres and hence a width factor of unity. Some will have reduced lane widths, generally those built to older design standards, and in these cases the width factor can be less than unity."*	☐	☑	☐	☐	☐	

	5.1.3 - D.3 Traffic Flow Ranges for Use in the Assessment of New Rural Roads	*"Roads built to modern designs usually have 7.3 metre or 10 metre carriageways, that is, a width factor of unity or 1.46. The width of older roads can vary significantly…"*	☐	☑	☐	☐	☐	Broad agreement with principle
	Overall Rating		☑	☐	☐	☐	☐	
A1.2. Minimise sudden increases and decreases in driver mental workload for the highway section.	6.2.4 - 5.4 the Design of Major Interchanges	*"...alternative layouts also need to be appraised for their practical driveability and driver workload. All driving tasks which may increase driver stress and discomfort or lead to safety problems on the interchange must be listed and evaluated when comparing options."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
A1.3. Minimise variations in the curvature of the highway.	6.1.1 - 8.7 Highway Link Design	*"Desirable Minimum radii" & "Short curves and straights shall not be used. Adjacent curves shall be similar in length."*	☐	☑	☐	☐	☐	
	6.1.1 Highway Link Design	*"Short curves and straights shall not be used. Adjacent curves shall be similar in length."*	☐	☑	☐	☐	☐	
	6.1.1 Highway Link Design	*"Small changes of direction shall not be made, as they give the perspective of the road ahead a disjointed appearance."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
A2. Avoid distracting or obstructing stimuli, particularly at high workload highway locations.	6.2.4 - 2.33 The Design of Major Interchanges	*"Driver stress and driver comprehension of the layout will depend on the number and timing of decisions and manoeuvres required."*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☐	☑	☐	☐	

A3. Replace level crossings with other measures	6.3.3 - 12.1 Roadside Features	*"The Railway Construction and Operation Requirements of level crossings for all road categories are covered by a current Departmental Requirement (ref 56)"*	☑	☐	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
A4. Separate vehicle parking spaces from the flow of traffic.	6.2.7 - 2.18 Vehicular Access to All Purpose Trunk Roads	*"Dangerous conditions arise if vehicles obstruct visibility by parking within visibility splays. Where necessary, parking and access shall be controlled to prevent this."*	☑	☐	☐	☐	☐
	6.2.7 - 4.6 Vehicular Access to All Purpose Trunk Roads	*"It will be important to ensure that developments serviced by a new direct access do not lead to parking on the trunk road"*	☑	☐	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
A5. Avoid curves with a small radius.	6.1.1 - 5.19 Highway Link Design	*"Factors which help to create a safer road environment include the avoidance of sharp bends…"*	☑	☐	☐	☐	☐
	6.1.1 - 8.7 Highway Link Design	*"Flowing alignment can most readily be achieved by using large radius curves rather than straights."*	☐	☐	☑	☐	☐
	6.1.1 - 8.7 Highway Link Design	*"Desirable Minimum radii" & "Short curves and straights shall not be used. Adjacent curves shall be similar in length."*	☑	☐	☐	☐	☐
	6.1.1 Highway Link Design	*"Short curves and straights shall not be used. Adjacent curves shall be similar in length."*	☑	☐	☐	☐	☐

	6.1.1 Highway Link Design	*"Small changes of direction shall not be made, as they give the perspective of the road ahead a disjointed appearance."*	☐	☑	☐	☐	☐	
	6.1.1 - 8.7 Highway Link Design	*"Horizontal and vertical curves shall be made as generous as possible at interchanges in order to enhance sight distances."*	☐	☑	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
A5.1. Provide straight on/off ramps rather than curved ones	6.1.1 - 8.7 Highway Link Design	*"Horizontal and vertical curves shall be made as generous as possible at interchanges in order to enhance sight distances."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
A6. Avoid gradients greater than 2%	6.1.1. - 4.1 Highway Link Design	*"The desirable maximum gradient for design shall be: Motorways 3%; AP Dual Carriageways 4%; AP Single Carriageways 6%. However, in hilly terrain steeper gradients will frequently be required…"*	☐	☑	☐	☐	☐	Maximum' (but not necessarily recommended) gradients are higher
	Overall Rating		☐	☑	☐	☐	☐	
A6.1. Minimise gradients on approach to junctions	6.2 Part 1 TD 22/06 5.3	*"The siting of a grade separated junction on a hill top should be avoided if possible as approach gradients can cause operational problems in the diverge area, even when the percentage of LGVs is small…There is also the risk of drivers being blinded when the sun is low in the sky"*	☐	☐	☑	☐	☐	Narrow context
	Overall Rating		☐	☐	☑	☐	☐	
A7. Do not place junctions on curves.	6,2, Part 6 TD42/95 3.4 and 3.5- Horizontal Alignment	*"Ideally, major/minor priority junctions should not be sited where the major road is on a sharp curve."*	☐	☑	☐	☐	☐	

		"Junctions on the inside of sharp curves are most undesirable."	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
B1. Separate different types of road users	5.2.4 Provision for Non-Motorised Users	*"It is recommended that options are considered in accordance with the 'Hierarchy of Provision'"*	☑	☐	☐	☐	☐	Hierarchy implies pedestrians and cyclists should be separated
	Overall Rating		☑	☐	☐	☐	☐	
B1.1 Separate pedestrians from cyclists and motorised vehicles	6.2.3 - 5.1 Geometric Design of Roundabouts	*as above. Also:"Separate pedestrian routes with crossings away from the flared entries to roundabouts are preferable."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
B1.2 Separate cyclists from motorised vehicles	6.2.3 - 5.1 Geometric Design of Roundabouts	*as B1. Also:"Roundabouts are a particular hazard for pedal cyclists… [solved by] the use of with flow cycle lanes around the circulatory carriageway, conversion of peripheral …" Roundabouts with ... significantly higher speeds on entry, exit and on the circulatory carriageway, and are of greatest risk to cyclists. In these cases it is recommended that cyclists are provided with an alternative route such as an off-carriageway cycle track..."*	☐	☑	☐	☐	☐	
	5.2.4 - 7.12: Crossings		☐	☑	☐	☐	☐	
	5.2.4 Provision for Non-Motorised Users	*"Cycle lanes are provided to… help to ensure a safe separation between motor vehicles and cyclists."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	

B1.3 Separate faster moving motorised vehicles from slower ones	6.1.1 - 7.2 Highway Link Design	*"Clearly identifiable Overtaking Sections for either direction of travel are required to be frequently provided throughout the single carriageway according to the design flow, so that vehicles can maintain the Design Speed…"*	☑	☐	☐	☐	☐	
	6.1.1 - 5.8 Highway Link Design	*"…additional lane added to single or dual carriageway in order to improve capacity and/or safety because of the presence of the steep gradient. The steep gradient is the primary reason for adding a lane."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
B2. Separate opposing traffic flows by design (e.g. one way roads) or physical barriers	6.2.6 - 7.28 Geometric Design of Major/Minor Priority Junctions	*"Cutting, merging and diverging movements can usefully be separated by physical or painted guide islands…"*	☐	☐	☑	☐	☐	Not necessarily for opposing flows
	6.3.4 - 2.5 Coloured Surfacing in Road Layout (Excluding Traffic Calming)	*"Red is commonly used to supplement prescribed markings to discourage vehicles from encroaching on an area of the road."*	☐	☐	☑	☐	☐	Only loosely related
	6,2, Part 1 TD22/06-4.13	*"Measures to maintain safety are necessary, and measures to consider include…physical separation of opposing traffic streams"*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
B3. Design highway lanes wide enough for the official speed of the road.	6.2.3 - 7.15 Geometric Design of Roundabouts	*"Lane widths at the "Give Way" line shall be not less than 3.0m."*	☐	☐	☑	☐	☐	Only at roundabouts
	6.2.3. - 2.22 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts	*"Where new junctions are being designed as signal controlled, entry lane widths should be between 3m and 3.65m, unless there are specific reasons to justify the use of narrower or wider lane widths."*	☐	☑	☐	☐	☐	Prescribe dimensions at junctions - assume these are 'wide enough?'

	6.2.3 - 4.5 Geometric Design of Roundabouts	*"The reduction of excessive entry width by hatching or physical means"*	☐	☑	☐	☐	☐	
	5.1.3 - Annex D, note 2 Traffic Flow Ranges for Use in the Assessment of New Rural Roads	*"...there is no evidence to suggest that the maximum hourly throughput of motorway links is affected by minor changes in lane width."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
B4. Provide ample opportunity (e.g. merging lanes and acceleration areas) for vehicles to enter the flow of traffic safely.	6.2.1 - 2.25 Layout of Grade Separated Junctions	*"If joining flows are greater than one lane capacity then an additional lane should normally be added to the mainline as a lane gain"* *then an additional lane should normally be added to the mainline as a lane gain"*	☐	☐	☑	☐	☐	Limited evidence - majority focuses on specifics of junction design rather than describing a relationship between rate of flow and what constitutes 'ample' opportunities to enter the flow of traffic
	Overall Rating		☐	☐	☑	☐	☐	
B5. Minimise the number and severity of conflict points at junctions.	6.2.8 - Annex C Layout of Large Signal Controlled Junctions	*"The minority flows may need to be diverted to enable the number of conflicting movements at any one individual junction to be kept to a minimum."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
B6. Where it does not significantly impact on flow rates, provide traffic lights at cross roads and t-junctions	6,2, Part 3 1.8 and 5.7	*"Introducing signal control at a junction, including measures to provide the maximum degree of safety and convenience for all road users, can enhance efficiency by reducing congestion and conflict between different vehicle movements, within the available road space."*	☑	☐	☐	☐	☐	
		"The use of signal control should therefore be considered as an option at the scheme assessment stage for new junctions and the improvement of existing junctions."	☑	☐	☐	☐	☐	

	Overall Rating		☑	☐	☐	☐	☐	
B6.1. Introduce conflict-free control for different types of junction users.	6,3, Part 5 TA90/05 7.16	*"The potential for conflict between users increases where flows of more than one group are high. In this case, it is normally necessary to have some form of segregation along the route"*	☐	☑	☐	☐	☐	Does not specify 'form of segregation', not a great enough level of detail to satisfy principle completely
	Overall Rating		☐	☑	☐	☐	☐	
B6.2. If control is not conflict-free, provide channelisation.			☐	☐	☐	☐	☑	
	Overall Rating		☐	☐	☐	☐	☑	
B6.3. Discourage red and amber light running.	8,1, Part 1 TA12/81	*"Advanced warning signs are necessary on each approach in accordance with requirements given in chapter 4 of the Traffic Signs Manual (Ref 2)"*	☐	☐	☑	☐	☐	
	Traffic Signs Manual Chapter 4, Part 8- 8.2	*"The (traffic signals warning) sign may be used with all three-aspect traffic signals, including Pelican, Toucan and Puffin crossings and portable traffic signals used at roadworks"*	☐	☐	☑	☐	☐	
	Traffic Signs Manual Chapter 4, Part 8- Table 8.1	*Visibility distance criteria for traffic signals warning signs*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☐	☑	☐	☐	
B7. Implement continuous and high quality provision for vulnerable road users.	5.2.4:3.15 - Scheme development and assessment	*"Facilities for NMUs should offer positive provision that reduces delay, diversion and danger. Five core principles common to NMU routes have been identified in draft LTN 1/04, as follows:* ***• Convenient: Accessible: Safe: Comfortable:• Attractive***	☐	☑	☐	☐	☐	

	6.2. Junctions	*Scheme designs should take account of opportunities to provide safe and attractive provision"*	☐	☑	☐	☐	☐	
	6.3.5:	*4.1 "NMU routes need to be practical to use. NMUs will avoid routes that include diversions, frequent obstacles and fragmented facilities."*	☐	☑	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
B8. Provide official and visible pedestrian crossings in safe places	2.2.8: 11.1-11.2 - Design Criteria for Footbridges	*"Although numerical calculations of the degree of conflict between pedestrians and vehicles (PV2) provide a basis for assessing the need for a pedestrian crossing all the other factors set out in the sections on site and option assessment in LTN 1/95 must also be taken into account."*	☐	☑	☐	☐	☐	limited to one type of crossing.
	Overall Rating		☐	☑	☐	☐	☐	
B8.1. Discourage crossing at places other than designated crossing points	5.2.6:6.5	*"If delays between gaps become too high, users are likely to either take risks or be discouraged from using the crossing at all."*	☑	☐	☐	☐	☐	
	5.2.4: 6.6 Crossing	*6.6 "It is desirable in some cases to restrict the crossing of certain approaches at an intersection and guard rails can be used to prevent pedestrians crossing at dangerous places.*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
B8.2. Design crossing so that all parties have a good view of each other	5.2.4:6.1 Crossings	*"For any at-grade crossing provision of adequate visibility is very important for safety reasons."*	☑	☐	☐	☐	☐	
		8.3 "the use of guardrails should be kept to the minimum necessary, and where used, designs should avoid obstructing inter-visibility between drivers and pedestrians"	☐	☑	☐	☐	☐	

	6.3.5: Visibility	*3.6 "Any crossing of a trafficked road should be located such that drivers of vehicles have full visibility of NMUs wishing to use the crossing point." & 3.1 "The following require consideration: the visibility at junctions or crossings, to enable both the NMU to see approaching traffic, and for other users on the main route to see NMUs about to cross."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
B8.3. Provide crossings which allow pedestrians to negotiate one stream of traffic at a time.	6.2.3 - 4.5 the Geometric Layout of Signal Controlled Junctions and Signalised Roundabouts	*"TA 15 (DMRB 8.1.1) sets out the measures which can be adopted to assist pedestrians to cross carriageways at signal-controlled junctions and provides guidance on the overall requirements (and dimensions) for staggered and displaced pedestrian crossing facilities. TA 68 (DMRB 8.5.1) outlines the requirements for refuge islands and staggered crossings."*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☐	☑	☐	☐	
B8.4. Clearly indicate priority at pedestrian crossings.	5.2.4:2.18 NMU Requirements	*"Design Organisations should[1] aim to provide appropriate facilities that balance the needs of each group."*	☐	☐	☑	☐	☐	
	5.2.4:6.1 Crossings	*6.32 Zebra crossings are relatively low cost facilities which offer immediate response to pedestrian demand and provide priority to the pedestrian across the whole crossing.*	☐	☑	☐	☐	☐	Only one type of crossing
	Overall Rating		☐	☑	☐	☐	☐	
B9. Do not mark cycle lanes within junctions used by mixed traffic	5.2.4 - 6.14: Crossings	*"...the special marking is necessary because cyclists' route through the junction would not otherwise be obvious"*	☐	☐	☐	☑	☐	Cycle lane markings can be used in junctions but only under protection of signals
	5.2.4 - 6.22: Crossings	*6.26 "Alternatively cycle tracks may be 'bent in', moving the cycle track onto the carriageway across the mouth of the junction. However, this may require some junction treatment to narrow the road to provide protection to the cyclist and pedestrians to use the same crossing."*	☐	☐	☐	☑	☐	Cycle lanes can be present at the entrance to junctions

	Traffic signs manual 5.16 Cycle Markings	*"At side road junctions the mandatory lane should change to an advisory one"*	☐	☐	☑	☐	☐	Acknowledges the danger presented to cyclists in junctions but does not prohibit their use
	Overall Rating		☐	☐	☐	☑	☐	
B10. Provide an advanced stop line for cyclists at junctions	5.2.4:7.2-7.3 Provision for Non-Motorised Users	*7.2 "Cyclists wishing to turn right or travel straight ahead at signalised junctions can often find themselves in conflict with motorised traffic, particularly at junctions with left turn only arms" & 7.3" ASLs can be used in these situations to hold motor vehicles back while allowing cyclists to take up a position nearer the signals. This puts the cyclists where drivers can clearly see them,"*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
C1. Provide sufficient sightlines for the design speed of the highway	6.1.1 - 1.12 Highway Link Design	*"designers should normally aim to achieve at least Desirable Minimum values for stopping sight distance"*	☐	☑	☐	☐	☐	Stopping sight distance is not ideal.
	6.1.1 - 2.1 Highway Link Design	*"Table 3 shows the stopping sight distance (SSD) appropriate for each Design Speed."*	☐	☑	☐	☐	☐	
	6.1.1 - 1.23 Highway Link Design	*"Values for sight distance, horizontal curvature and vertical curvature shall not be less than those given in Table 3 for 50kph design speed."*	☐	☑	☐	☐	☐	
	6.2.3 - 7.44 Geometric Design of Roundabouts	*"Drivers of all vehicles approaching the Give Way line shall be able to see the full width of the circulatory carriageway ahead of them for a distance (measured along the centre line of the circulatory carriageway) appropriate to the size of the roundabout..."*	☐	☐	☑	☐	☐	Partial - for roundabouts

	6.2.6 - 7.3 Geometric Design of Major/Minor Priority Junctions	*"...essential that minor road drivers have adequate visibility…"*	☐	☑	☐	☐	☐	
	Traffic Signs Manual 5.1.12 Road Markings	*"Recent collaborative European research has shown that drivers need to be able to detect guidance markings at a distance equivalent to a minimum of two seconds of travel time"*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
C2. Through the design of the road, or by using warning signs, alert drivers to the presence, nature and required response to hazards or variations in the road situation.	Traffic Signs Manual 4.1.6 Warning Signs	*"Warning signs are used to alert drivers to potential danger ahead. They indicate a need for special caution by road users and may require a reduction in speed or some other manoeuvre."*	☐	☑	☐	☐	☐	
	Traffic Signs Manual 4.17.1 Warning Signs	*"Although prescribed mainly for temporary use to warn of transient or occasional hazards such as "Dust cloud" or "Census", diagram 562 is also used for certain permanent features not easily represented symbolically, e.g. "Hidden dip"."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
C2.1. Make the hazard itself visible if possible	6.2.7 - 2.17 Vehicular Access to All Purpose Trunk Roads	*"Visibility splays shall be provided to enable emerging drivers using the direct access to have adequate visibility in each direction to see oncoming traffic in sufficient time to make their manoeuvre safely without influencing the major road traffic speed."*	☐	☑	☐	☐	☐	Implies awareness of principle
	Overall Rating		☐	☑	☐	☐	☐	
C2.2. Provide cues or warnings to alert the driver to unseen/invisible hazards	6.3.5 - 3.48 Traffic Calming on Trunk Roads: A Practical Guide	*"Changes in surface texture can be used on the approaches to hazards or gateways."*	☐	☑	☐	☐	☐	

	6.1.3 - 5.13 Guidance on Minor Improvements to Existing Roads	*"rumble areas provide a physical warning of the approaching hazard"*	☐	☑	☐	☐	☐	
	6.3.5 - 2.10 Traffic Calming on Trunk Roads: A Practical Guide	*"Increasingly, trunk road traffic calming has been used as a "route" treatment… Particular objectives of route based schemes could be to: ...enhance drivers' awareness of road hazards;"*	☐	☑	☐	☐	☐	
	6.1.3 - 4.14 Guidance on Minor Improvements to Existing Roads	*"improvement measures include: … providing authorised advisory speed signs, speed roundels or bend warning markings on approaches to the hazard;"*	☐	☑	☐	☐	☐	
	Traffic Signs Manual 5.4.22 Warning Signs	*The principal purpose of the marking is to warn drivers of the risk of unseen vehicles emerging.*	☐	☑	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
C3. Provide appropriate road lighting for the road situation. The best possible lighting should be used at natural hazards and transition points.	8.3 Appraisal of New and Replacement Lighting on Trunk Roads and Trunk Road Motorways.	*NIGHT-TIME ACCIDENT SAVINGS...When calculating expected accident cost savings…Costs and benefits should be evaluated over a 30 year period…"*	☐	☐	☑	☐	☐	Defines 'appropriate' in terms of costs vs. benefits
	Overall Rating		☐	☐	☑	☐	☐	
C3.1. Ensure lighting is uniform, and that glare from the light source used and other potential sources of glare within the particular road situation are minimised.	8.3 - 4.1 Design of Road Lighting for Motorway Trunk Roads	*"Road lighting for motorway trunk roads shall be designed in accordance with the general principles… The objective shall be to achieve compliance with respect to...Glare control…"*	☑	☐	☐	☐	☐	
	8.3 - 3.1.2. Design of Road Lighting for All Purpose Trunk Roads	*The objective is to achieve:- (a) The quantifiable requirements of luminance level, luminance uniformity (overall and longitudinal) and glare control.*	☑	☐	☐	☐	☐	

	Overall Rating		☑	☐	☐	☐	☐	
C3.2. Generate gradual changes in ambient light levels.			☐	☐	☐	☐	☑	
	Overall Rating		☐	☐	☐	☐	☑	
C4. All signs must be conspicuous, but not over conspicuous.	Traffic Signs Manual Chapter 4: Warning Signs 1.31	*"To improve conspicuity against a complex or dark background, a warning sign may be mounted on a grey or yellow backing board…"*	☐	☑	☐	☐	☐	
	Traffic Signs Manual Chapter 4: Warning Signs 1.34	*"In areas of street lighting, however, much higher levels of luminance are required to ensure that signs are always adequately conspicuous."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
C5. All signs must be legible from an appropriate distance	Traffic Signs Manual Chapter 4: Warning Signs 1.20	*"...in general, the greater the speed of approach, the further in advance of the hazard the sign needs to be placed."*	☐	☐	☑	☐	☐	
	Traffic Signs Manual Chapter 4: Warning Signs 1.22	*"Appendix A specifies minimum clear visibility distances."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
C6. All signs must be comprehensible.	Traffic Signs Manual Chapter 5: Road Markings 10.1	*"When designing a complex layout, it should be borne in mind that it must be capable of being signed and marked in a way that drivers can readily understand."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	

C7. All signs must be accurate.		*Accomplished through strict adherence to the Traffic Signs Manual.*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
C8. Regularly check signs and do not assume they have the correct materials, content, placement, orientation and angle.	Traffic Signs Manual Chapter 4: Warning Signs 1.31	*"Where it seems that a sign is not being noticed by drivers, it should be checked to ensure that it is well-sited, not obscured by foliage or other obstructions, and is of the appropriate size and in good condition."*	☐	☑	☐	☐	☐	Not a regular event; more of a response to an identified problem
	Traffic Signs Manual Chapter 4: Warning Signs 16.6	*"Care should be taken to ensure that hazard markers do not appear confusing at night. This may occur for example if headlights (with raised or dipped beams) are reflected from markers delineating more than one bend. It is recommended that, following installation, they are checked at night from a moving vehicle."*	☐	☐	☑	☐	☐	Limited scope
	Overall Rating		☐	☑	☐	☐	☐	
C8.1. Remove warning signs if the hazard no longer exists.	Traffic Signs Manual Chapter 4: Warning Signs 6.4	*"...any existing signs which are not being respected should be removed."*	☐	☐	☑	☐	☐	Several similar examples. All refer to temporary road conditions; no examples of the necessity of reviewing established signs
	Overall Rating		☐	☐	☑	☐	☐	
C9. Where physically possible, position signs where the driver expects them to be.		*Accomplished through consistent adherence to the Traffic Signs Manual.*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
C10. Where signs are unlit, position them so that they achieve headlight illumination.	Traffic Signs Manual Chapter 4: Warning Signs 1.34	*"On unlit roads, reflectorisation generally produces an adequate level of sign luminance in the illumination from a vehicle's headlamps."*	☑	☐	☐	☐	☐	Assumes they will reflect adequately as a consequence of being mounted correctly

	Overall Rating		☑	☐	☐	☐	☐	
C11. Road markings must be conspicuous	Traffic Signs Manual Chapter 5: Road Markings 1.7	*"They may be completely obliterated by snow. Their conspicuity is impaired when wet or dirty…"* *"Because of the oblique angle at which they are viewed, road markings appear heavily foreshortened. This effect is countered in the case of worded markings, e.g. SLOW, by elongating the legend… Similarly, longitudinal lines need to be wider and longer where speeds are high, in order to maintain adequate conspicuity."*	☐	☐	☑	☐	☐	Acknowledges the importance of conspicuousness but does not say how to achieve a sufficient degree
	Traffic Signs Manual Chapter 5: Road Markings 1.9		☐	☐	☑	☐	☐	Narrow context
	Traffic Signs Manual Chapter 5: Road Markings 7.11	*Coloured surfacing may be used under the hatched marking to improve conspicuity and discourage encroachment.*	☐	☐	☑	☐	☐	Narrow context
	Overall Rating		☐	☐	☑	☐	☐	
C13. Road markings must be legible.	Traffic Signs Manual Chapter 5: Road Markings 1.7	*"Road markings have their limitations. They may be completely obliterated by snow. Their conspicuity is impaired when wet or dirty, and their effective life is reduced if they are subjected to heavy trafficking."*	☐	☑	☐	☐	☐	
	Traffic Signs Manual Chapter 5: Road Markings 1.7	*"For road markings to be effective, they must be clearly visible both by day and by night."*	☐	☐	☑	☐	☐	
	Traffic Signs Manual Chapter 5: Road Markings 1.12	*"Recent collaborative European research has shown that drivers need to be able to detect guidance markings at a distance equivalent to a minimum of two seconds of travel time."*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☐	☑	☐	☐	

C14. Road markings must be comprehensible.	Traffic Signs Manual Chapter 5: Road Markings 10.1	*"When designing a complex layout, it should be borne in mind that it must be capable of being signed and marked in a way that drivers can readily understand."*	☑	☐	☐	☐	☐
	Traffic Signs Manual Chapter 5: Road Markings 13.4	*"Although abbreviations may be used, these must be understandable..."*	☑	☐	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
C15. Road markings must be correct and accurate.		*Achieved through strict adherence to the Traffic Signs Manual*	☑	☐	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
D1. Provide the driver with cues to inform them which areas of the highway are for them, which are designated for other traffic and which are permissible in some circumstances	6.2.1 - 2.4 Layout of Grade Separated Junctions	*"Advance notification of the layout on the approach to a junction; • conspicuous junction locations and layouts; • understanding of permitted changes to the direction of travel; • understanding of other traffic movements; • avoidance of potential hazards."*	☐	☑	☐	☐	☐
	6.2.3 - 4.5 Geometric Design of Roundabouts	*"Measures that have been found to be useful in reducing accidents at existing roundabouts…repositioning or reinforcement of warning signs…"*	☐	☑	☐	☐	☐
	6.2.3 - 2.13 Design of Road Markings at Roundabouts	*"Markings can reduce confusion on wide circulatory carriageways, and provide drivers with well defined paths through the junction."*	☐	☑	☐	☐	☐

	6.2.3. - 5.4 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts	*"When designing signal-controlled junctions the designer should ensure that drivers * a. have sufficient advance warning to know exactly which route to take at the junction; * b. are then guided into the intended lane (or lanes) by road markings and signs..."*	☐	☑	☐	☐	☐	
	6.2.8 - 3.55 Layout of Large Signal Controlled Junctions	*"This type of junction [hamburger] is not very common and drivers will require clear direction signing if they are to appreciate the 'roundabout' nature of the right turns from the main through route to the side roads"*	☐	☑	☐	☐	☐	
	6.3.4 - 2.6 Coloured Surfacing in Road Layout (Excluding Traffic Calming)	*"Green or red is commonly used to supplement prescribed signs/ markings to highlight an area of the road for use by buses or cycles."*	☐	☑	☐	☐	☐	
	Traffic Signs Manual 5.4.1 Road Markings	*"The 1994 Regulations introduced new markings intended for use as centre lines separating opposing flows of traffic on single carriageway roads."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
D1.1. Make the hard shoulder look and feel like "foreign territory" by distinct markings/texture	6.3.4 - 2.16 Coloured Surfacing in Road Layout (Excluding Traffic Calming)	*"...the colour should increase driver awareness and encourage caution by highlighting the area of road excluded… limited application on non-standard hardshoulders"*	☐	☑	☐	☐	☐	
	6.3.4 - 2.5 Coloured Surfacing in Road Layout (Excluding Traffic Calming)	*"Red is commonly used to supplement prescribed markings to discourage vehicles from encroaching on an area of the road."*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
D2. Design junctions so that traffic from opposing streams have a good view of each other.	6.2.3 - 7.44 Geometric Design of Roundabouts	*"Drivers of all vehicles approaching the Give Way line shall be able to see the full width of the circulatory carriageway ahead of them for a distance (measured along the centre line of the circulatory carriageway) appropriate to the size of the roundabout..."*	☐	☑	☐	☐	☐	Partial - for roundabouts

	6.2.6 - 7.3 Geometric Design of Major/Minor Priority Junctions	*"...essential that minor road drivers have adequate visibility…"*	☑	☐	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
D3. Priority of one road over another should be clearly and consistently indicated through highway design, markings and signs.	6,2, Part 4 TD 39/94 2.12	*"The most efficient form of interchange layout is that which presents drivers with both the minimum number of clear unambiguous decision points and with adequate time/distance between decisions to ensure that the path through the interchange is easily understood."*	☐	☑	☐	☐	☐
	Overall Rating		☐	☑	☐	☐	☐
D4. Give pedestrians clear instructions regarding interaction with traffic	5.2.:8 General considerations	*"… road markings can be hazardous to NMUs if they: • stand excessively proud of the surface; • become slippery when wet; • are used to excess, which adds to visual impact and future maintenance requirements, and can distract horses.*	☐	☐	☑	☐	☐
	Overall Rating		☐	☐	☑	☐	☐
D5. Provide street lighting where pedestrians are likely to be present	5.2.4: 8.12 - Provision for Non-Motorised Users	*"…recommended that where appropriate and feasible, routes should be lit..." & "...routes within or adjacent to the highway verge will often benefit from lighting spillage."*	☐	☑	☐	☐	☐
	Overall Rating		☐	☑	☐	☐	☐
E1. Manipulate road users' speed choice using environmental cues to ensure they drive at the designated speed.	6.1.3 - 2.28 Guidance on Minor Improvements to Existing Roads	*"In some circumstances landscaping may be introduced to restrict excessive forward visibility on bends"*	☐	☑	☐	☐	☐
	6.1.3 - 2.33 Guidance on Minor Improvements to Existing Roads	*"Changes to the road layout can significantly influence the control of speed..."*	☐	☑	☐	☐	☐

	6.1.3 - 2.35 Guidance on Minor Improvements to Existing Roads	*From research (TRL Contractors Report 319), references to design features which may influence speed include: …[various environmental factors]"*	☐	☑	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
E1.1. Design the highway so that the task of vehicle control seems harder than it may actually be.		*as above*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
E1.2. To reduce vehicle speeds, present the driver with an increased flow of stimuli in the peripheral visual field.		*as above*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
E1.3. Encourage drivers on major/priority road to slow down on approach to junctions	8.1 - 2.2 Traffic Signals on High Speed Roads	*"Because of the increased braking distances required at high speeds, drivers need adequate warning that they are approaching a signalled junction."*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
E2. Provide road edge, lane and centre line delineation	Traffic Signs Manual 5.4.1 Road Markings	*"The 1994 Regulations introduced new markings intended for use as centre lines separating opposing flows of traffic on single carriageway roads."*	☐	☑	☐	☐	☐	
	6.2.3 - 2.10 Design of Road Markings at Roundabouts	*"Many of the problems at such junctions are caused by driver uncertainty. Approach markings and circulatory division lines and markings can reduce this uncertainty…"*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	

E2.1. Align road edge delineation (including barriers, guard rails etc.) with the path of the road	Traffic Signs Manual 5.4.33 Road Markings	*"The marking should be laid with a gap of approximately 225 mm to the near side edge of the carriageway."*	☐	☑	☐	☐	☐	
	2.2 - 5.2 Safety Fences and Barriers	*"The set-back is the dimension between the traffic faces of safety fences and edge of the trafficked carriageway shown in Fig 1 and shall normally not be less than 1.2m"*	☐	☑	☐	☐	☐	
	Overall Rating		☐	☑	☐	☐	☐	
E3. Design curves so that their presence and characteristics are apparent on approach.	6.1.1 - 8.7 Highway Link Design	*"Horizontal and vertical curves shall be made as generous as possible at interchanges in order to enhance sight distances."*	☐	☐	☑	☐	☐	
	6.2.3 - 4.13 Geometric Design of Roundabouts	*"The problem of large goods vehicles overturning or shedding their loads at roundabouts… [is caused by] Long straight sections of circulatory carriageway leading into deceptively tight bends."*	☐	☐	☑	☐	☐	
	6.1.1 - 3.1 Highway Link Design	*"On sections of road with radii greater than that shown in Table 3, the crossfall or camber should be 2.5%..."*	☐	☐	☑	☐	☐	Details curve radii without mentioning principle
	Overall Rating		☐	☐	☑	☐	☐	
E3.1. Provide cues to help the driver negotiate the curve.			☐	☐	☐	☐	☑	
	Overall Rating		☐	☐	☐	☐	☑	
E4. Repeat warning signs when the hazard itself is not visible.			☐	☐	☐	☐	☑	
	Overall Rating		☐	☐	☐	☐	☑	

F1. At junctions drivers should be provided with information to tell them how to negotiate it for their particular destination	Traffic Signs Manual Chapter 3, 3.1	*"Direction signs are signs placed at a junction and point along specific routes….Route confirmatory signs are those placed after a junction giving confirmation as to the route being followed and in most cases, destinations that can be reached, together with the appropriate distances"*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
F1.1. At junctions and other high workload situations, provide information at the correct time and place.			☐	☐	☐	☐	☑	Possibly ties in with F1?
	Overall Rating		☐	☐	☐	☐	☑	
F2. Provide information about the driver's current location and type of road they are currently on.		*Need to consult Traffic Signs Manual, chapter 2, Directional Informatory Signs on Motorways and All-Purpose Roads*	☐	☐	☐	☐	☐	
	Overall Rating		☐	☐	☐	☐	☐	
G1. Minimise the severity of run-off situations.	2.2.8 - 2.26 Requirement for Road Restraint System	*"The RRRAP will highlight if the risk is 'broadly acceptable', 'tolerable', or 'unacceptable'. It will not state how the risk should be mitigated, but will allow options to eliminate or control the hazards and/or to mitigate the risk to be tested and their impact on the risk level assessed and recorded. Options might include: removing or relocating the hazard; a change in, or redesign of, a hazard to make it less aggressive..."*	☑	☐	☐	☐	☐	
	Overall Rating		☑	☐	☐	☐	☐	
G1.1. Provide impenetrable barriers to prevent vehicles from leaving the road.	6.3 - 1.6 Roadside Features	*"On roundabouts... the use of… barrier-type safety kerbs can be particularly effective in preventing overrunning of footways by heavy vehicles."*	☐	☑	☐	☐	☐	Limited application
	Overall Rating		☐	☑	☐	☐	☐	

G1.2. If barriers cannot be provided, provide alerting delineation and a safe run off area sufficient for the speed and layout of the road.	6.3.5 - 4.31 Traffic Calming on Trunk Roads: a Practical Guide	*"Rumble devices are designed to alert drivers to approaching hazards or gateways through noise, vibration and visual effect."*	☐	☑	☐	☐	☐	Principle includes a reference to audible delineation
	Overall Rating		☐	☑	☐	☐	☐	
G1.3. Design run-off areas which are generally flat and without hazards.	6.3 - 6.2.1 Roadside Features	*"On existing hills where there is a history of accidents involving runaway vehicles consideration should be given to the provision of arrester beds."*	☐	☐	☑	☐	☐	Loosely related
	Overall Rating		☐	☐	☑	☐	☐	
G1.4. Provide secondary safety measures to minimise injury from run-off accidents.	2.2.8 - 3.12 Requirement for Road Restraint System	***Road Restraint Risk Assessment Process*** *"The Design Organisation must identify local hazards [secondary]… The following is a list of hazards that must be identified within the RRRAP: [list of 20 hazards, e.g. trees]…The RRRAP must be used to determine if a safety barrier is required..."*	☑	☐	☐	☐	☐	
	6.3 - 6.1.2 Roadside Features	*"The purpose of arrester beds is to stop, without serious injury or serious damage to vehicles or to adjacent property or other road users, those vehicles whose brakes fail on long downhill gradients."*	☐	☑	☐	☐	☐	Limited scope
	Overall Rating		☑	☐	☐	☐	☐	
G1.5.Provide tertiary safety measures (access to emergency and medical services).	2.2 BD 78/99 Tunnels	*"shall accommodate emergency points at intervals along the tunnel."*	☐	☑	☐	☐	☐	
		" consideration be given at the design stage to the safety of maintenance operations and the safety of all who may be required to work on or near the highway in the course of their duties, e.g. emergency service personnel."						
	Volume 6 Section 1 Part 2 TD 27/05	*"The hardshoulder"…"provides access for emergency vehicles."*	☐	☑	☐	☐	☐	

	Volume 5 Section 2 Part 2 HD 19/03	*Audit brief should contain: Any relevant factors which may affect road safety such as adjacent developments (existing or proposed), proximity of schools or retirement/ care homes and access for emergency vehicles.*	☐	☑	☐	☐	☐
	Overall Rating		☐	☑	☐	☐	☐
G2. Provide skid resistant surfaces in areas where drivers are prone to make late decisions	8.1 - 8.1 Traffic Signals on High Speed Roads	*"Skid resistant surfaces should always be considered on the approaches to signal controlled junctions on high speed roads."*	☐	☑	☐	☐	☐
	6.2.3 - 4.5 Geometric Design of Roundabouts	*"The provision of appropriate levels of skidding resistance on the approaches to roundabouts and on the circulatory carriageways"*	☐	☑	☐	☐	☐
	6.2.3 - 3.11 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts	*HD 28 (DMRB 7.3.1) is used to determine the need for HFS on the carriageway approaches to a junction.*	☐	☑	☐	☐	☐
	6.3.4 - 2.6 Coloured Surfacing in Road Layout (Excluding Traffic Calming)	*"High friction surfacing has been applied to carriageways on the approach to bends...Although this is often of a Light Colour...its primary purpose is to reduce the risk of skidding…"*	☐	☑	☐	☐	☐
	Overall Rating		☑	☐	☐	☐	☐
G3. Provide opportunities for safe recovery from wrong-route choices.			☐	☐	☐	☐	☑
	Overall Rating		☐	☐	☐	☐	☑
G4. Provide safe pedestrian refuges for emergency use or in case of breakdown	2.2: requirement for Road restraint systems	*"A staggered overlapped gap for NMUs must be provided where possible in any verge safety barrier at emergency telephones and opposite a central reserve NMU crossing gap as shown in Figure 3-14"*	☐	☐	☑	☐	☐

	5.2: Annex 2.6 Route type F - Minor Highway	*On motorways, stranded motorists may use the verge on foot to reach the emergency telephones or await the arrival of a rescue vehicle.*	☐	☐	☑	☐	☐	
	Overall Rating		☐	☐	☑	☐	☐	
G5. Place signs such that there is no risk of them being struck by vehicles or protect them using a barrier	2.2.8 - 3.12 Requirement for Road Restraint System	***Road Restraint Risk Assessment Process*** *The following is a list of hazards that must be identified within the RRRAP (xv)* ***Sign and signal gantry supports****. (xvi)* ***Sign posts*** *not meeting the requirements of BS EN 12767 which exceed the equivalent section properties of a tubular steel post having an external diameter of 89 mm and a nominal wall thickness of 3.2 mm. (xvii)* ***Large signs*** *(typically those higher than 2 m) located in a position where the fascia could be struck by an errant vehicle... The RRRAP must be used to determine if a safety barrier is required..."*	☑	☐	☐	☐	☐	Explains how to provide barriers protecting motorists from signs
	Overall Rating		☑	☐	☐	☐	☐	

Abstract

This interim report is a mid-point deliverable to the Highways Agency of the project '*Development of a Human Factors Road Safety Assessment Tool'*. The task detailed within this interim report is executed under the Agency's National Framework Contract 118(387) HTRL for Research & Development Services. The work described in this interim report fully complies with the original task specification.

The report first presents a definition of human factors, and a justification of why it is important to explicitly consider such human element issues on the Highways Agency (HA) network (based largely on the number of highway accidents that have human error as a contributory factor). It then describes the human factors data collected during a comprehensive literature review, the human factors principles developed from this data, and the matrix structure used to display the principles (Phase A). Following that, it presents a review of existing HA design guidelines for the design of highways, highlighting gaps and conflicts between these documents and human factors principles. Then, the report proceeds to Phase B: a human factors assessment of a current HA site, including making suggestions to improve safety at this site based on the principles developed in Phase A. Finally, all the work to date is tied together by summarising the key findings and implications, and making recommendations for project continuation.