THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR913

Towards Zero: 2014 to 2016 fatal collisions

Highways England Fatality Research

Adam Barrow, Nicola Hylands and Siobhan O'Connell

Report details

Report prepared for:	Highways England		
Project/customer reference:			
Copyright:	© TRL Limited		
Report date:	28th June 2019		
Report status/version:	Final		
Quality approval:			
Mike Maskell (Project Manager)		Mike McCarthy (Technical Reviewer)	**23/05/2019**

Disclaimer

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
V1.0	24/05/19	Draft V1.0	AB	MM
V2.0	18/07/19	Final version	NH	DH
V3.0	30/07/19	Final version – amended	NH	AB

Document last saved on:	22/08/2019 11:30
Document last saved by:	Maskell, Mike

Executive Summary

The project was devised by Highways England, who negotiated with the National Police Chiefs Council (NPCC) through the National Roads Policing Intelligence Forum (NRPIF). TRL was commissioned to undertake an examination of the fatal collisions on the Strategic Road Network (SRN) to better identify the cause and potential countermeasures of the most serious collisions that led to fatality.

The principle of this project was to utilise the tremendous amount of information that is contained within police collision investigation reports, but which is not used for any research or safety learning purposes. TRL examined the collisions and applied a safe-systems based approach to identifying the root cause of the collision and identifying the systems failures that led to the fatal collision. These examinations then form the evidence base for countermeasures that could have prevented the loss of life, either by avoiding the collision entirely or mitigating the severity of the injuries.

Importantly, codifying the information into the Highways England Fatality database increases the functionality and accessibility of the data by enabling a range of analysis types. These can include:

- **Network-level analysis** of the entire population of collisions on the SRN[1]
- **Thematic analysis**, e.g. of particular collision types or road user groups
- **Hotspot analysis** of collision loci where clusters of collisions can occur
- **Case-by-case analysis** of individual collisions

The Highways England Fatality database is a permanent dataset that is continuing to grow in size and will enable future safety analyses. The range of information enables more powerful road safety learning to be drawn compared to individual reports of single collisions. This project is providing a valuable evidence base supporting the STATS19 review and the Road Collision Investigation Project.

Network-level countermeasures

450 fatal collisions that occurred on the SRN between 2014 and 2016 were reviewed. The known causation factors always involved a 'people' component'; however, the countermeasures assigned to the collision encompassed all aspects of the safe-systems model. The majority of collisions had countermeasures in all three categories ('people', 'vehicle', 'road'), indicating a range of possible approaches to avoid the fatal collision occurring or to reduce the severity of the collision, despite the human-centric causation.

The largest proportion of fatalities with a known age were between 25 and 34 years old (16.1%) followed by fatalities between 35 and 44 years (14%). There was a large proportion (22%) of fatalities which had no reported age in the source information and have been coded as 'unknown'. This is recognised as a limitation of this work and it is recommended

[1] Strategic Road Network

that future studies collate the STATS19[2] information with the police fatal files to address this and other unknowns.

Highways England Countermeasures

The Highways England Fatality dataset can support cost-benefit analysis of specific countermeasures by identifying the target population and ultimately be used as the evidence base for casualty benefit analysis. Highways England has multiple countermeasures that are being considered for implementation. Many of the countermeasures address the same collision types, so two were selected to demonstrate how the Highways England Fatality dataset can be used in the process of selecting which countermeasures Highways England should take forward.

Recommendations for countermeasures to address Poor Tyre Condition

Improve driver awareness of the importance of tyre condition for safety in all journeys and the potential consequences of poor tyres through education measures. The majority of tyre defects related to fatal collisions were found on passenger cars, which may indicate that other road users have a greater awareness of the importance of tyre condition and maintenance. Further research should examine the prevalence of tyre defects in passenger cars to inform education strategies.

Part of the educational measure should promote the knowledge on how to assess tyre condition. This should include the simple measurements on tyres that are essential for tyre condition (e.g. tyre tread depth and pressure) but should also include how to find other safety related information (e.g. age of the tyre, operational temperatures, seasonality of the tyre). The equipment to take these basic measurements is readily available and relatively cheap. A future study should examine if providing this equipment to road users for free would improve the uptake and use of the equipment and, therefore, increase user awareness of their tyre condition.

The importance of tyre condition could be reinforced through an enforcement programme. However, the necessary resources to effectively support and the response from road users should be assessed in detail. Tyre checks to appraise vehicles on the road in order to raise awareness may be a viable alternative to enforcement.

Recommendations for countermeasures to address Medical Episode Collisions

Due to the often undetectable and unpredictable nature of medical episodes, measures to reduce the likelihood of one occurring while in control of a vehicle are likely to be the most effective at preventing these collisions. Improved detection of people at high risk of medical episodes will identify the potential target population of drivers at risk of this particular collision type. The majority of medical episodes occurred in drivers aged 35 to 54 years old. Detection of high risk individuals could include mandatory health screening for professional

[2] National data on reported accidents and casualties on public roads in GB (see https://www.gov.uk/government/collections/road-accidents-and-safety-statistics)

drivers or routine health screening for all drivers. Further research is required to identify the conditions that are most risky for medical episode collisions.

Better detection must be combined with a mechanism that enables and incentivises reporting of the conditions to the necessary agencies. There may be a perception that reporting these kinds of conditions will negatively impact the person's quality of life as they will have their licence revoked or suspended. Further research should focus on defining a mechanism that enables and incentivises reporting of potential high risk medical conditions while minimising the impact on personal mobility. This may be partially achieved by improving awareness and education of how dangerous the consequences of medical episode collisions can be. Mental health related collisions (including suicides) have extremely complex root causes and require further research to derive effective and evidence-based countermeasures.

The influx of Advanced Driver Assistance Systems in the vehicle fleet, such as Lane Keep Assist and Autonomous Emergency Braking systems will also aid these collisions. Although they may not be able to completely avoid the collision or result in a secondary collision further along the carriageway they will have a positive effect by keeping the vehicle on the carriageway and/or reducing the collision energy.

Hotspot countermeasures

Plotting the location of fatal cases has enabled collision clusters to be identified which may indicate localised and repetitive failures in the safe-system at those collision loci. **Analysis of two of the largest hotspots, each comprising of several collision clusters, has not revealed any critical failures in the road environment at either hotspot**. While the collision types and root causes of the collisions varied within both hotspots, there were some collision mechanisms that repeatedly occurred. It is recommended that further hotspot analysis is carried out to investigate geographically-clustered SRN collisions to determine whether there are common failures that could be addressed.

The full hotspot analysis is provided in Appendix A as demonstration of how the database can be used to provide regional safety recommendations.

Recommendations for Hotspot 1: Motorway

- Encourage the uptake and fitment of key vehicle ADAS[3] technologies that:
    - Reduce collision speeds and operate at motorway travelling speeds
    - Warn and/or prevent driver's being inattentive or fatigued
    - Warn and/or prevent vehicles from deviating from their lane
- Remove the critical launch risk and review the safety of the roadside in conjunction with the infrastructure instalments

[3] Advanced Driver Assistance Systems

- Encourage measures to prevent impaired drivers from starting their journey when they are too impaired to drive safely; the use of 'alco-lock' when the driver is above the drink drive limit, for example.
- Install measures that relay to drivers when there is slow traffic or congestion ahead – particularly in low visibility conditions
- Review the speed limit of the collision locus within the context of reducing the speed limit. This could lower the impact energy of future collisions by reducing the average travel speed of vehicles through the locus

Recommendations for Hotspot 2: A-class road

- Review the speed limit of the collision locus within the context of reducing the speed limit. This should reduce the average travel speed of vehicles through the locus. The purpose of the SRN is to enable fast travel so this should be reviewed as an assessment of the locus' overall safety – while reducing the collision energy may have prevented these collisions, this may not be locus specific
- Work with stakeholders (e.g. Department for Transport and Driver and Vehicle Standards Agency) to develop, implement training and provide information regarding how vehicle occupants should behave in certain situations. For example, an explanation of what to do when a vehicle breaks down on the SRN.
- Promote vehicle maintenance and educate drivers in essential vehicle safety checks
- Install measures that relay to drivers when there is a temporary hazard ahead (i.e. stationary vehicle)
- Improve licencing has been noted multiple times; however, each time it is for different reasons. These range from illnesses, to older drivers and inexperienced drivers

Table of Contents

1 Introduction

1.1 Purpose of the study

The government's road investment strategy[4] and the Highways England strategic business plan[5] set out the plan and targets for major roads and motorways over the period 2015 to 2020. This includes a target of reducing killed and seriously injured (KSI) road casualties 40% by 2020 and a focus on safety with a vision that 'no one should be harmed when travelling or working on our network.'

In response, this project aims to determine and analyse the causes of fatal collisions on the strategic road network (SRN) in order to assess the potential countermeasures that could have been deployed to either avoid or reduce the severity of these collisions, such that pre-emptive action could influence the outcome of future collisions on the SRN that have similar characteristics.

In reviewing and analysing existing fatal collision information to understand the causes of fatal collisions and predictively assessing ways in which the collision could have be avoided or mitigated, this project aims to populate an in-depth database for fatal road collisions on the SRN, identify the collision causation factors and identify the countermeasures that could have prevented or mitigated the fatal road collisions from occurring.

1.2 Information sources

The project used existing collision information collected by the Police and made available to Highways England to retrospectively review and assess the circumstances of fatal collisions on the SRN in the years 2014, 2015 and 2016. The fatal collisions which occurred on the SRN in 2017 are currently being analysed. Further information can be found in the 2016 Highways England Fatality Research report (McCarthy & Barrow, 2016).

1.3 Highways England Fatality Database

The objectives of this project, namely to determine the causation factors/cause and related countermeasures considering 'people, vehicle, and road' aspects, demand that the full picture of the collision circumstances are considered. Although this project used the same collision information as the police and Highways England, it analysed aspects of 'people' and 'vehicle' typically absent from Highways England information, and assessed the fatal file information to provide an evidence base for understanding why collisions are occurring and what can be done to prevent them, rather than focussing on aspects that meet the higher burden of proof for legal enforcement.

Following the success of the pilot study and continued cooperation from police forces, the project has continued to generate an analysable dataset from the police fatal files using a

[4] https://www.gov.uk/government/collections/road-investment-strategy

[5] https://www.gov.uk/government/publications/highways-england-strategic-business-plan-2015-to-2020

safe-systems approach. As Highway's England's database asset continues to grow in sample size the evidence base to inform safety recommendations and strategies strengthens. The database has provided the evidence base for safety recommendations directly from the analysis of the dataset and is increasingly being used to generate intelligence in other forms as demonstrated in Figure 1.

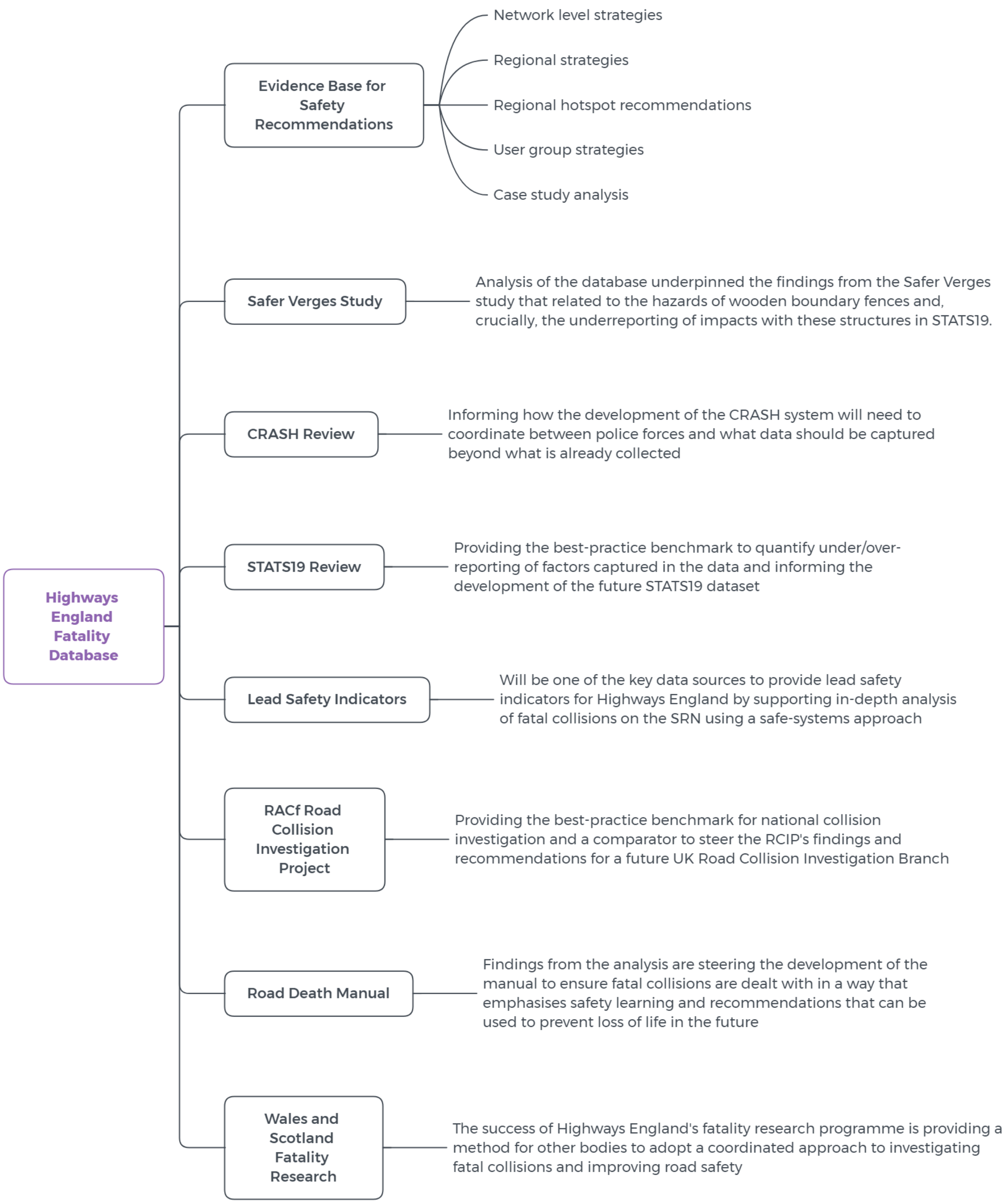


Figure 1: Intelligence generation process from raw information captured in police fatal files coded into the Highways England Fatality Database which forms the evidence base for multiple projects, safety initiatives and reviews.

2 Method

A detailed outline of the research methodology is available in the 2016 Highways England Fatality Research report (McCarthy & Barrow, 2016). The principle of the method is to utilise the tremendous amount of information that is often contained within police collision investigation reports but are not used for any research or safety learning purposes. TRL examined the collisions and applied a safe-systems based approach to identifying the root cause of the collision and identifying the systems failures that led to the fatal collision. These examinations then form the evidence base for countermeasures that could have prevented the loss of life either by avoiding the collision entirely or mitigating the severity of the injuries.

2.1 Data sources

TRL requests all police fatal files from collisions which occur on the SRN. The size and content of a police fatal file varies with the complexity and type of collision. TRL requested specific parts of the 'fatal file' to support our review of fatal SRN collisions; these were: the Collision Investigation Unit (CIU) fatal report, case photographs, scene plan and the 'collision booklet' front page – STATS19[6].

2.2 Data coding and storage

A team of experienced collision investigators reviewed each fatal file and coded the information into the Highways England Fatality Database. With agreement with Highways England and the UK Department for Transport, this database was housed within the Road Accident In-Depth Studies (RAIDS) database[7] which brings together different types of collision investigation into a single, compatible, and comprehensive database.

On receipt, cases were logged and stored securely. After completion of coding, the case was signed-off by the investigator in the database. The data was then subject to a quality review by a senior member of the team to ensure that the case had been coded completely and appropriately. Once any amendments had been made to the case, it was released into the database and available for analysis.

2.3 Data analysis

The investigation team reviewed and coded over 1,000 data fields for each case which records a multitude of information on the collision and outcomes, including information about the:

- Collision (weather conditions, contribution of the environment, road type/layout);

[6] Road accidents reported to the police – see https://www.gov.uk/government/collections/road-accidents-and-safety-statistics

[7] https://www.gov.uk/government/publications/road-accident-investigation-road-accident-in-depth-studies/road-accident-in-depth-studies-raids

- Vehicles (number and type involved, defects/condition of components, safety system fitment including the benefits and impact on collision avoidance);
- Occupants (characteristics, injury severity);
- Infrastructure (road condition, barrier type/condition, lighting type);
- Collision dynamics (Collision Deformation Classification (CDC), speed);
- Road environment (junction, sightlines, visibility, signs);
- Human factors (distraction, experience);
- 'Paths' (the point of view of each participant through the collision); and
- Causation factors and countermeasures.

In this process, the TRL team used the same base information as the police, but interpreted information from evidence (e.g. case photographs) and other sources using different aims and focus to that of the police investigation.

Importantly, by codifying the information into the Highways England Fatality database, it increases the functionality and usability of the data by enabling a range of analysis types. These can include:

- **Network-level analysis** of the entire population of collisions on the SRN;
- **Thematic analysis**, e.g. of particular collision types or road user groups
- **Hotspot analysis** of collision loci where clusters of collisions can occur
- **Case-by-case analysis** of individual collisions

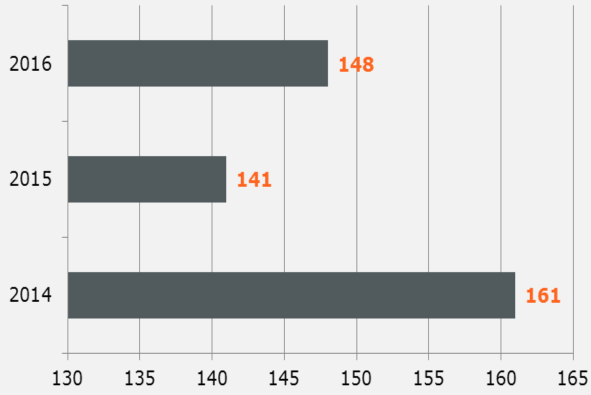
The Highways England Fatality database is a legacy dataset that is continuing to grow in size and the range of analyses support more powerful road safety learnings to be drawn compared to individual reports of single collisions.

The following sections provide the findings from novel analysis of the Highways England Fatality database. The analysis used in previous reports and presentations has also been redone and is provided in the Appendices to this document.

3 Sample Analysis

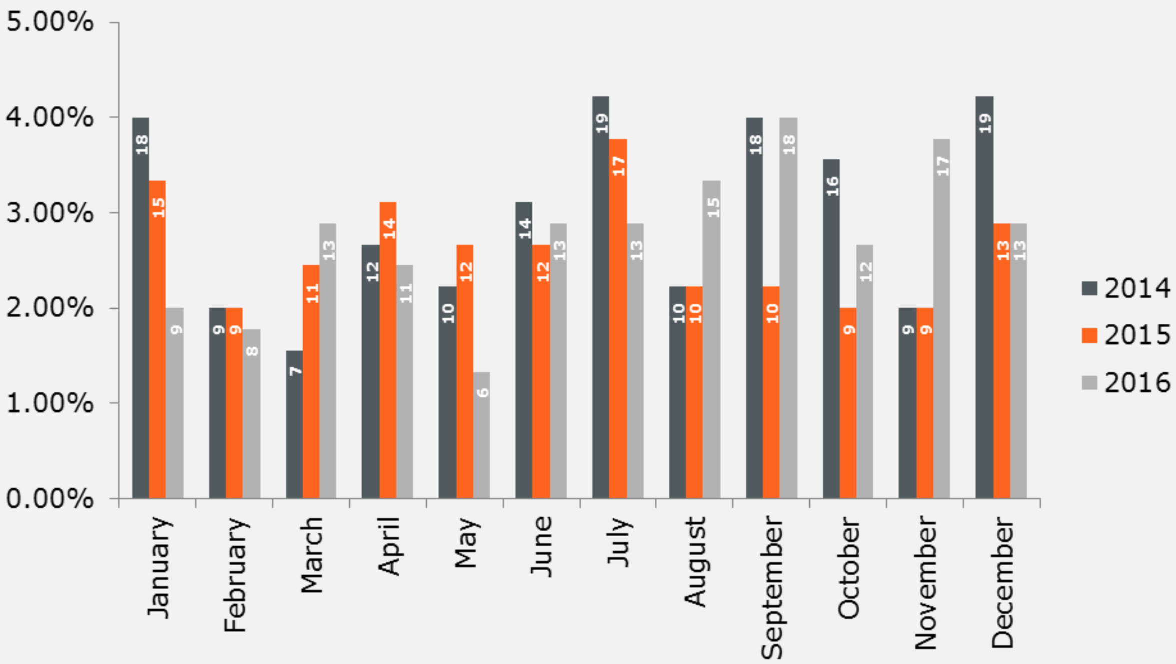
450 fatal collisions that occurred on the SRN between the years 2014 and 2016 have been examined and are available for analysis in the Highways England Fatality database. The table below details the amount of fatal collisions and fatal casualties coded in the database.

Fatal collisions which occurred in 2017 are currently being examined and coded. The following analysis considers fatal collisions that occurred between 2014 and 2016 only.



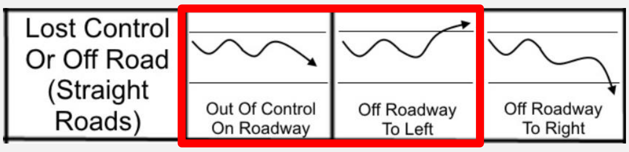
Sample description:

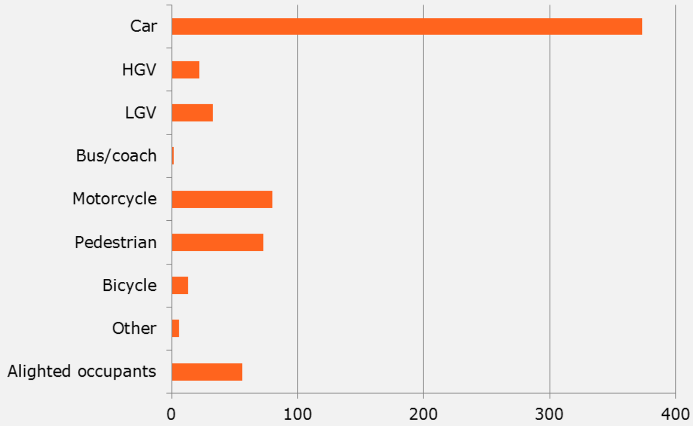
Total number of:	2014	2015	2016	2017
Fatal collisions on the SRN	192	202	211	203
Police collision files requested	192	202	211	203
Police collision files received and analysed	161	141	148	Currently 33
Fatal casualties coded into the database	233	203	222	Coding on-going



The figure above shows the monthly distribution of fatal collisions which have been coded into the database for the years 2014, 2015 and 2016. The greatest amount of collisions occurred in the month of July (n=49, 11%).

Key Collision Types: 21% of the collisions resulted in a vehicle losing control or the vehicle running off the road whilst on a straight road.



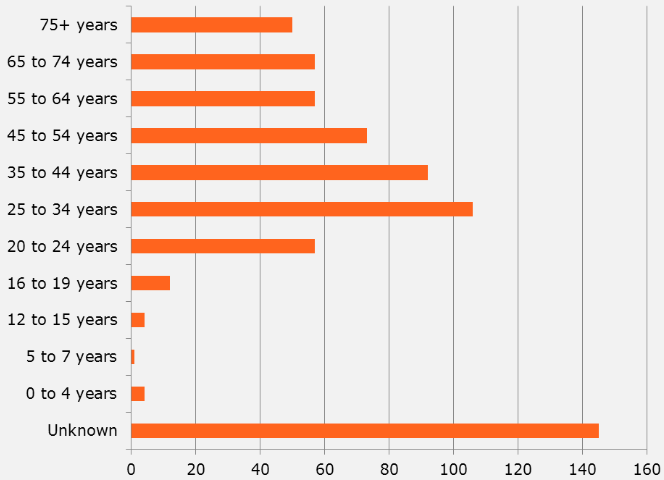


There are **658 fatal casualties** recorded in the database.

The graph shows the vehicle type and the count of occupants who sustained fatal injuries.

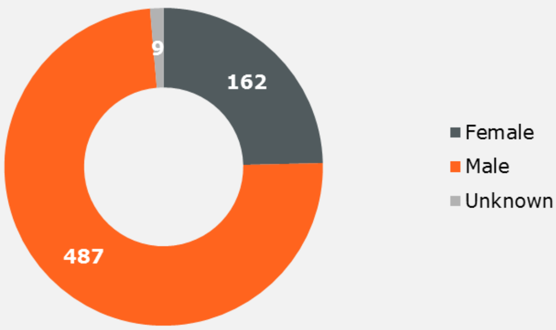
Note that only road users who were injured or who influenced the collision are coded.

Passenger car occupants are the most frequently killed people on the SRN (n=373). Car occupant fatalities account for 57% of all fatalities.



- The largest proportion of fatalities with a known age are between 25 to 34 years old (16.1%) followed by fatalities between 35 to 44 years (14%)
- People of all ages are killed, including nine children less than 16 years old

- 74% of occupants who sustained fatal injuries were male
- Females were primarily killed in passenger cars (80% of all female fatalities) and account for 19.6% of all passenger car fatalities

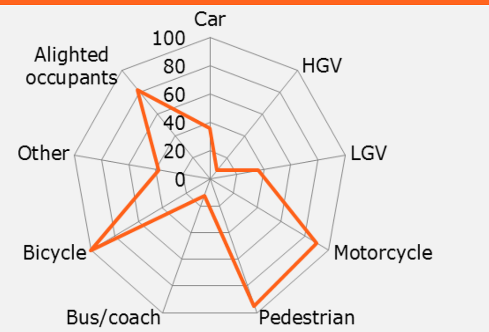


Vulnerable Road Users

The proportion of Vulnerable Road Users (VRUs) who are killed is substantially greater than any other road user class.

VRUs include:

- Motorcyclists
- Cyclists
- Pedestrians (including alighted occupants).



Graph showing %fatality by vehicle type (%)

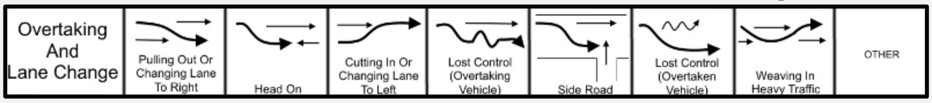
Vehicle type	Total number of occupants	Number of fatalities	Fatality rate %
Car	1047	373	36
HGV	266	22	8
LGV	91	33	36
Motorcycle	89	80	90
Pedestrian	77	73	95
Bicycle	13	13	100
Alighted occupants	68	56	82
Bus/coach	17	2	12
Other	16	6	38
Total	1710	658	38

Motorcyclists

66 motorcycles involved in fatal collisions

79% of motorcycle collisions included multiple vehicles

31% of motorcycle collisions occurred during an overtake or lane change



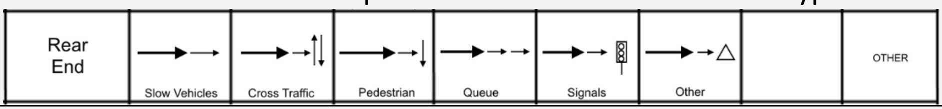
*Collision type diagrams taken from the Collision Matrix (Section 7B.1.1.1)

Cyclists

13 cyclists involved in fatal collisions

All collisions involving a pedal cycle included multiple vehicles

50% of pedal cycle collisions were rear end collision types

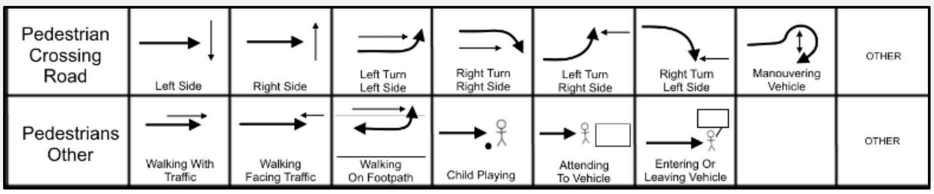


Pedestrians

77 pedestrians and **68 alighted occupants** involved in fatal collisions

All collisions involving a pedestrian (including those alighted from a vehicle) included another vehicle

35% of all pedestrian collisions (including alighted occupants) occurred when the pedestrian crossed a road or another scenario

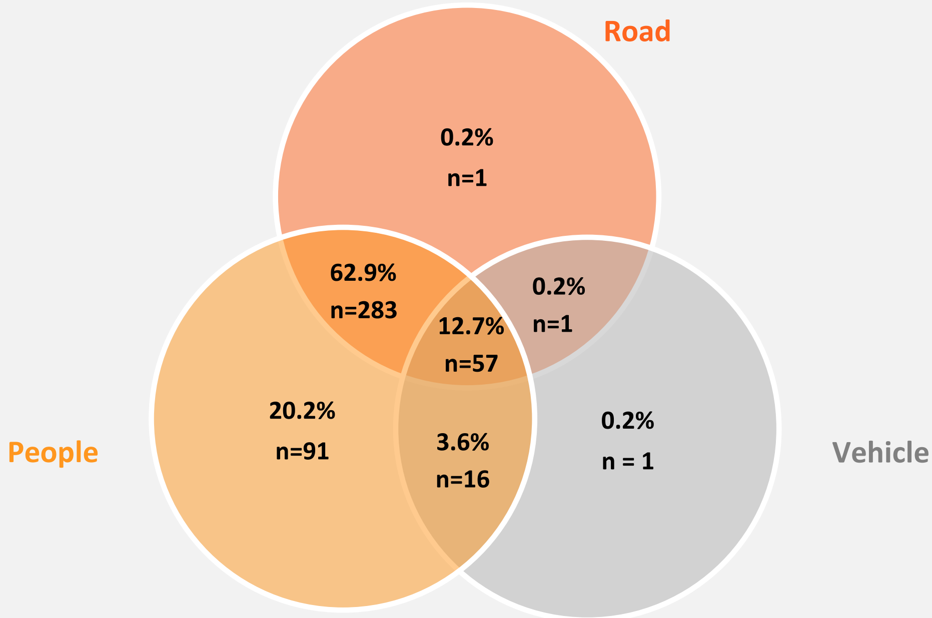


Causation Factors

A safe-systems approach was used to identify the causation factors that led to the fatal outcome of the collisions and identified the countermeasures that could have prevented or mitigated the fatal road collisions on the SRN.

The Venn diagram below shows the distribution of fatal collisions by the presence and combination of causation factors identified.

Each case is assigned causation factors. The factors are divided into three groups: road, human and vehicle. Overlapping causation factors will influence the occurrence or outcome of a collision due to inter-relationships.



Traditionally, causation factors were assigned solely to the driver/rider of the vehicle. This research has enabled the understanding that causation can be made up of multiple factors, and that the blame does not lie solely with the person.

Top 3 causation factors by category:

	Vehicle factors	People factors	Road factors
1	Defective tyres	Carelessness/ thoughtlessness	Poor or no street lighting at site
2	Defective brake system	Error of judgement	Bend or winding road at site
3	Defective suspension	Lack of attention	Slippery road at site

There were 3,103 people causation factors assigned across the 450 fatal collisions in the HE fatality database. The top three people causation factors account for 27% of all assigned people causation factors.

4 Highways England Countermeasure Assessment

Each collision coded into the fatality database is assigned countermeasures which aim to either avoid the collision or reduce the injury severity. This allows prioritisation of possible solutions to take pre-emptive action and influence the outcome of future collisions on the SRN that have similar characteristics. The countermeasures are based on the Haddon Matrix: the most frequently used concept in the injury prevention domain (see Figure 2). This shows how countermeasures can be assigned according to the stage of the collision and the category of the countermeasure.

	People	Vehicle	Road
Pre-crash	Improved driver training Driver awareness	Better maintenance Primary safety (e.g. tyres and brakes)	Improved road surface Improved highway layout/design
Crash	Use of safety systems (e.g. helmet or seatbelt)	Secondary safety Presence and performance of safety systems	Remove road side hazards Barrier performance
Post-crash	Incident response eCall systems	Fuel system Safety pyrotechnics Vehicle design standards	Infrastructure performance (e.g. access for emergency services)

Figure 2: The Haddon matrix (with example countermeasures)

The holistic recording of collision causation factors results in a strong evidence base with which to determine collision countermeasures: actions that can avoid the collision itself, or mitigate its injury outcome. These can be directly linked to the safe systems approach to provide an evidence base for the design of a safer overall transport system and provide an understanding of specific countermeasures and in which categories of 'people, vehicle, road' the countermeasures lie.

This information can inform ways in which Highways England could most effectively meet their strategic plan for a reduction in network KSIs of at least 40% by the end of 2020 against the 2005-09 baseline. In order to meet this criteria, Highways England implements interventions to reduce the fatalities on the SRN. The interventions can be grouped into categories, as different interventions all aim for the same outcome. For example; providing improved access to tyre tread monitors and research into quick scanning vehicles for roadworthiness both aim to improve vehicle roadworthiness. This ultimately prevents collisions relating to poor vehicle maintenance.

The data coded into the fatality database can be used to verify and validate the target population and the effects of the interventions. The data is able to inform on whether the correct countermeasures are being implemented, and if not, then what needs to be done instead. Sections 4.1 and 4.2 discuss the issue of tyre defects and medical episodes, and identify what countermeasures could be implemented to reduce the amount of fatalities relating to these issues.

4.1 Tyre countermeasures

Vehicle defects and mechanical failures may be contributory to the cause of collisions. More specifically, tyre defects caused by a lack of, or incorrect, vehicle maintenance can result in a fatal collision. Defective tyres was the most coded vehicle based causation factor in the fatality database (n=22) (see Appendix Figure 24).

The following section will identify who is involved in these collisions and what level of injury they are sustaining, how the collision is happening and how these collisions could potentially be prevented in the future. The Highways England countermeasures that are applicable to this analysis include:

- *Improved access to tyre tread monitors – tyre tread checkers in baby boxes*
- *Research and promote tyre safety and roadworthiness with partners*
- *Increased role of TOS – identification of defective tyres*
- *Fire and Rescue Service to assist with tyre safety readings*
- *Free tyre checks provided by National Tyre Repair Centres*
- *Pilot: drive-through sensor stations similar to those which have been trialled for HGV tyre management (* (WheelRight, 2019)*.*

These countermeasures can be found in the Highways England Safety Intervention Summary Toolkit (Highways England, 2018).

4.1.1 The collision: who is involved?

There are 100 vehicles listed in the fatality database as having a known or suspected defect or mechanical failure; 65% of these vehicles were passenger cars (Figure 3).

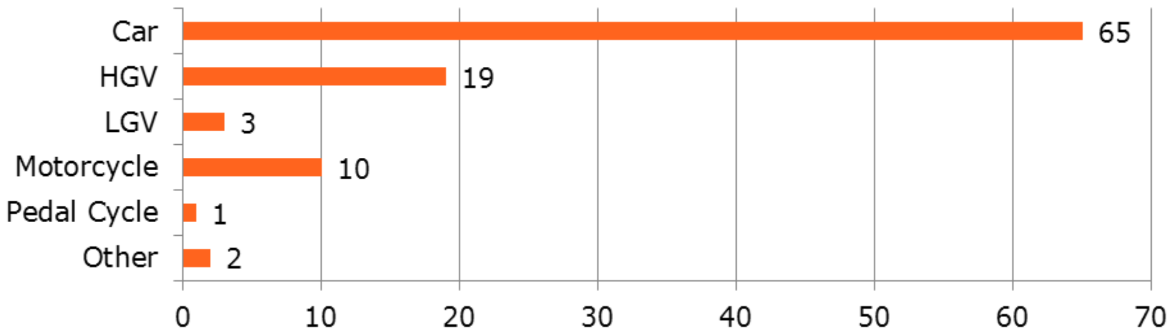


Figure 3: Number of vehicles with a known or suspected defect or mechanical fault by vehicle type (n=100)

Nearly half of the vehicles (49 of the 100) were found to have tyre defects. Tyre defects can include over or under inflation, and insufficient tread depth; these defects can affect the handling and control of the vehicle. **71% of these vehicles were coded as the vehicle at fault in the collision (the initial cause)**, the majority of which were passenger cars (73%).

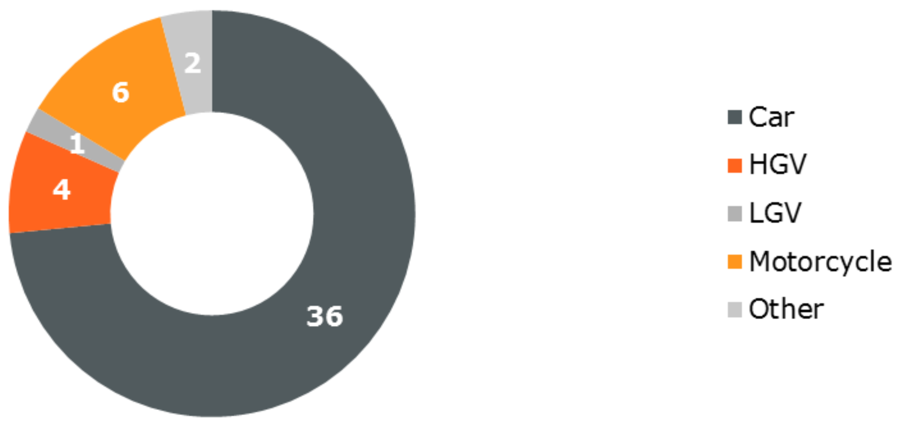


Figure 4: Vehicle types noted as having tyre defects (n=49)

4.1.2 *Who is sustaining fatal injuries?*

In total, there were 90 vehicles and 146 occupants involved in collisions where at least one of the vehicles had defective tyres. Of these 90 vehicles, 49 were listed as having tyre defects.

There were 76 occupants in these vehicles: 35 of these occupants sustained fatal injuries, as well as six occupants sustaining serious injuries and 15 with slight injuries. Table 1 shows the injury severity of the occupants by vehicle type in vehicles with a recorded tyre defect. The highest amount of fatalities and injuries occurred in passenger cars.

Table 1: Injury severity by vehicle type (n=76) – tyre defect present

	Injury Severity				
Vehicle Type:	**Fatal**	**Serious**	**Slight**	**Uninjured**	**Total**
Car	26	6	14	14	**60**
HGV	2	0	0	3	**5**
LGV	0	0	0	3	**3**
Motorcycle	6	0	1	0	**7**
Other	1	0	0	0	**1**
Total	**35**	**6**	**15**	**20**	**76**

Within the other 41 vehicles (which did not have the tyre defect), there were 70 occupants; 21 of which sustained fatal injuries as a result of the collision (Table 2).

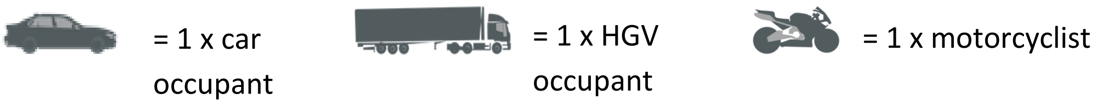
Table 2: Injury severity by vehicle type (n=70) – tyre defect not present

	Injury Severity					
Vehicle type:	**Fatal**	**Serious**	**Slight**	**Uninjured**	**Unknown**	**Total**
Car	6	5	8	7	4	**30**
HGV	0	0	1	5	0	**6**
LGV	1	0	0	1	1	**3**
Bus	0	0	0	4	0	**4**
Motorcycle	3	0	0	0	0	**3**
Pedestrian	10	0	0	0	0	**10**
Other	1	0	2	0	0	**3**
Unknown	0	0	0	0	11	**11**
Total	**21**	**5**	**11**	**17**	**16**	**70**

4.1.3 Tyre defects: are they causing the collision?

Of the 49 vehicles coded as having tyre defects, there were **ten vehicles that had a tyre defect which was a direct cause of the collision**.

In the collisions involving these vehicles, there were a total of 14 vehicles and 21 occupants. There were ten recorded fatalities: nine of the fatalities were the drivers/riders in the vehicle which was at fault (V1) and had defective tyres. The remaining fatality was a rear nearside passenger. The majority of the involved vehicles were passenger cars (n=16).



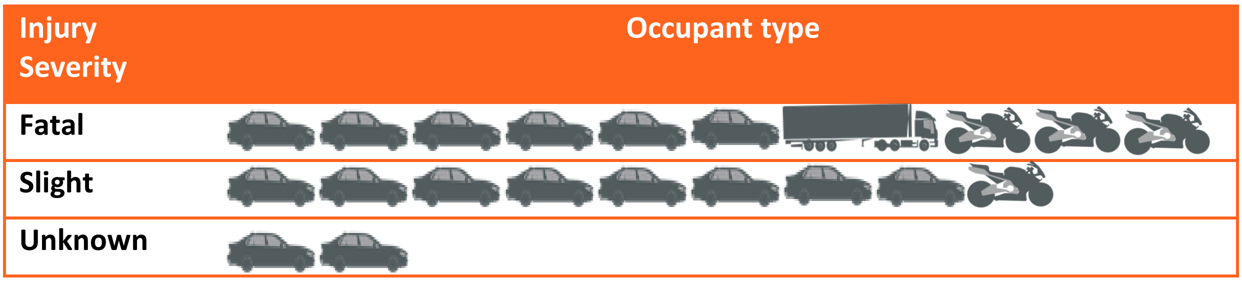


Figure 5: Occupant injury severity by vehicle type (n=21)

A case by case analysis was conducted to highlight the tyre defects for each of the ten vehicles. Table 3 shows the vehicle type, the tyre defect and how this defect was caused. The defects varied from over/under inflation, worn tyres and insufficient tread depth, and deflated tyres before impact. It is apparent that a lack of/incorrect maintenance was the underlying issue with the majority of the defective tyres.

Table 3: Contributory tyre defects

Case	Vehicle type	Tyre defect	Cause of tyre defect
1	Car	Tyre deflated before impact Tyre pressures wrong	Lack of maintenance/neglect
2	Car	Tyre worn or insufficient tread	Lack of maintenance/neglect
3	Motorcycle	Tyre pressures wrong	Lack of maintenance/neglect
4	Car	Tyre pressures wrong Tyre worn or insufficient tread	Lack of maintenance/neglect
5	Motorcycle	Tyre deflated before impact	Faulty maintenance: slow puncture
6	Motorcycle	Tyre pressures wrong	Faulty maintenance: over inflated
7	HGV	Tyre pressures wrong	Faulty maintenance
8	Car	Tyre deflated before impact Tyre pressures wrong	Faulty maintenance
9	Car	Tyre worn or insufficient tread	Lack of maintenance/neglect

10	Car	Tyre worn or insufficient tread	Lack of maintenance/neglect

4.1.4 *Driver demographic*

The drivers and riders of the vehicles where a tyre defect was contributory varied in age, however the majority were male. There is not one specific age group to target in regards to the promotion of vehicle maintenance.

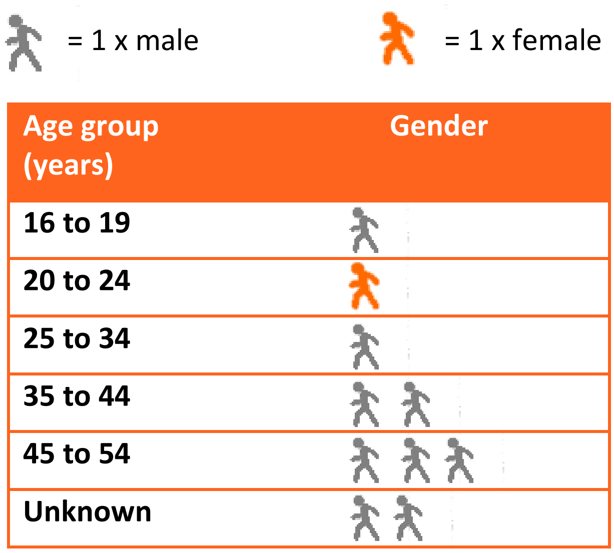


Figure 6: Age and gender of driver/rider (n=10)

4.1.5 *Collision type: what is happening?*

Of the ten collisions where the tyre defect was contributory, half occurred when the driver/rider lost control of the vehicle or the vehicle left the carriageway. Other collision types included cornering, overtaking/lane change and head on collisions.

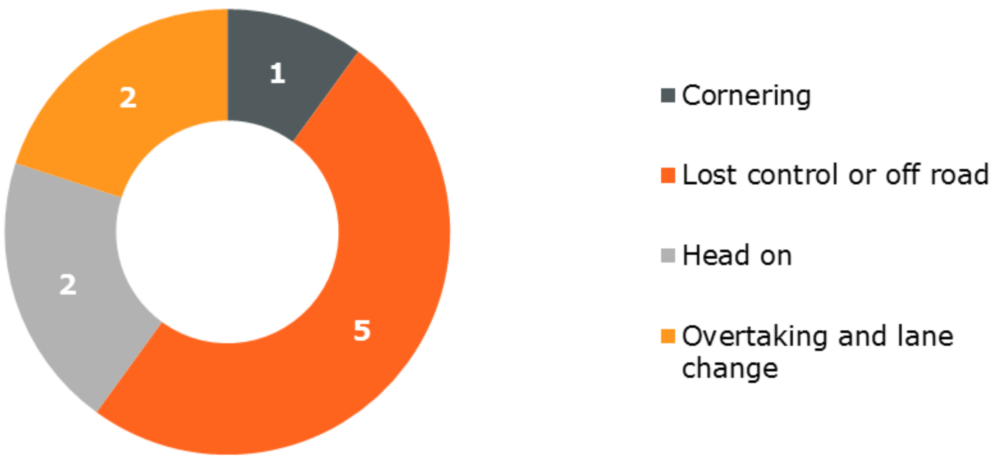


Figure 7: Collision type (n=10)

4.1.6 Prevention: tyre defect collisions

The ten cases in which a vehicle was found to have a tyre defect contributory to the collision could have been potentially avoided or had a reduced severity if the vehicle had been maintained correctly. The countermeasure 'better maintenance of vehicle consumables/features' was applied to all of these collisions. Vehicle maintenance is key to ensuring that a vehicle is safe and roadworthy. A lack of maintenance or faulty maintenance can lead to more serious issues with the vehicle, and as in these instances – a fatal collision.

Defective tyres can be prevented by conducting regular checks. This includes checking the tread depth, sidewall and the tyre pressure. **In total, there were 49 vehicles with defective tyres – 1 in 5 of these vehicles had tyre defects which were a contributory factor to the fatal collision. This indicates that poor tyre condition is a recurrent failure in the safe-system, even though it may not always lead to a fatality. This would be visualised as a persistent 'hole' in the Swiss-Cheese model.**

4.1.6.1 *Swiss-Cheese Model Explanation*

Reason's Swiss-Cheese Model visualises system failures as holes in planes, representing categories or groups of hazards. In its application in the Highways England Fatality Research, the model has been organised so the planes represent the safe-system by categorising failures into vehicle, people and environment. The model can be used to understand the root cause for a single collision or for multiple collisions, where the holes represent common or persistent failures.

The presence of a single failure does not necessarily result in a collision, only when there are failures in enough of the planes that the holes 'align' does the collision occur (Figure 8). Therefore, the size of the holes represents the likelihood or risk of the failure occurring. Using the example of vehicle speed, the size of the 'hole' will increase with speed as the risk of a collision increases. Furthermore, failures can be persistent, meaning that they reoccur in multiple models or are present in models that represent multiple collisions. These failures represent a particular danger as they increase the likelihood of a collision occurring by the same mechanism.

Tyre defects are a persistent system failure in fatal collisions occurring on the SRN. This is evidenced by the prevalence of the defects found in vehicles, even though these defects only aligned with other holes in the Swiss-Cheese model in one in five of the collisions.

Conducting in-depth investigations has revealed this recurrent systems-failure; however, this has only been done for a sample of fatal collisions. It is possible that tyre defects represent an even greater persistent failure in all vehicles travelling on the SRN.

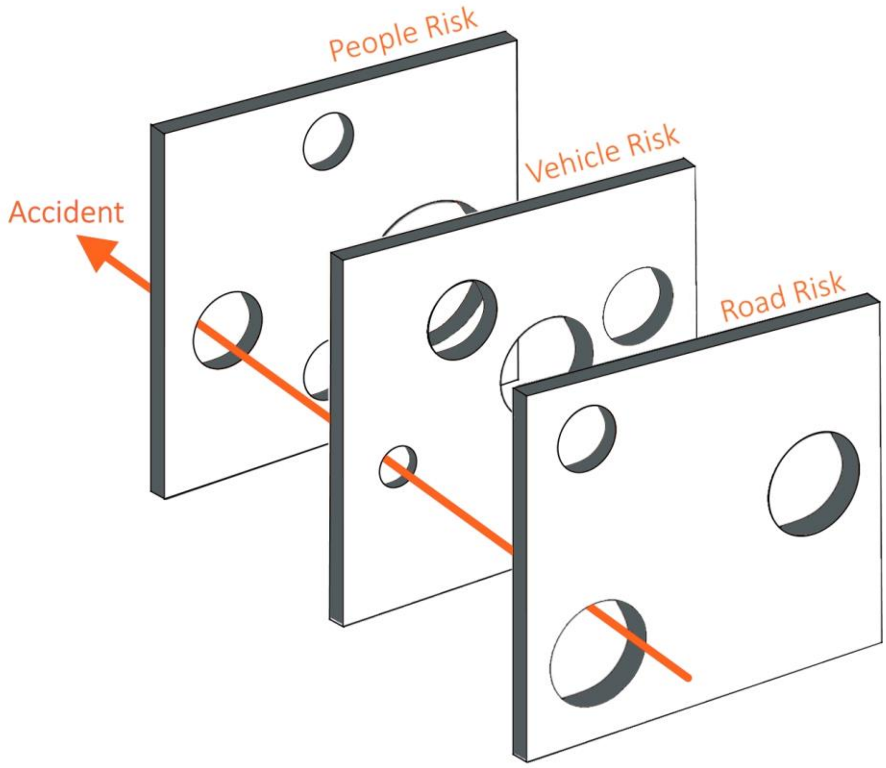


Figure 8: Swiss-Cheese Model (Adapted from Reason, 1990) showing how when failures align they result in a collision. Failures can also occur and not result in a collision.

RECOMMENDATION

Improve driver awareness of the importance of tyre condition for safety in all journeys and the potential consequences of poor tyres through education measures. The majority of tyre defects were found on passenger cars which may indicate that other road users have a greater awareness of the importance of tyre condition and maintenance. Further research should examine why passenger cars are over represented with tyre defects to inform education strategies.

Part of the educational measure should promote the knowledge on how to assess tyre condition. This should include the simple measurements on tyres that are essential for tyre condition (e.g. tyre tread depth and pressure) but should also include how to find other safety related information (e.g. age of the tyre, operational temperatures, seasonality of the tyre). The equipment to take these basic measurements is already readily available and relatively cheap. Further research should examine if providing this equipment to road users for free would improve the uptake and use of the equipment and, therefore, increase user awareness of their tyre condition.

Highways England previously conducted a study which used WheelRight's drive-over tyre management system to identify tyre issues on HGVs (WheelRight, 2019). The system was installed in three locations in the UK (Milton Keynes, Penrith and Cuerden). The tyre inspection system automatically checks tyres when the vehicle drives over it. It is already proving its significant potential as a fleet management tool within the HGV sector and assisting enforcement.

Although this trial targeted HGV tyres, the Fatality Research data has highlighted an issue with passenger cars, and therefore a similar procedure should be considered for these vehicles. The WheelRight system can be used by any vehicle and has previously been used in a year-long pilot study conducted by Highways England at a service station on the M6 (WheelRight, 2019). Within this year, the system automatically measured more than 155,000 tyre pressures as vehicles passed through the fuel forecourt. An expansion on this study, including implementing the technology in more locations and also changing the scope to include tread depths as well as pressures, would not only improve awareness of tyre condition, but it is also an easy task to undertake to check tyres. The inspection can occur at any time, day or night, without stopping any vehicle, or manually touching a tyre or valve

The importance of tyre condition could be reinforced through an enforcement programme. However, the necessary resources to effectively support and the response from road users should be assessed in detail. Random tyre checks to appraise vehicles on the road in order to raise awareness may be a viable alternative to enforcement.

4.2 Medical episode countermeasures

Within the years 2014 to 2016, there were 64 fatal collisions on the SRN where a known or suspected medical episode was a factor. These cases were identified by applying a selection of filters. These included identifying collisions where an occupant was known or suspected to have suffered an illness, or where a countermeasure identifying medical/health related issues was assigned. It is important to note that within this filter selection other illnesses were included; mental health and deliberate acts (suicide) as a result of mental health.

This section will identify who is having the medical episodes and what the outcomes of these collisions are. This includes identifying who is sustaining fatal injuries and whether or not these types of collisions could be prevented in the future.

The Highways England Safety Intervention Summary Toolkit (Highways England, 2018) outlines interventions that are applicable to this analysis. These include:

- *Carry out research on catastrophic claims made in relation to older drivers*
- *DVLA should require evidence of a recent eyesight test*
- *Nottingham Dementia Drivers Screening Assessment/Mental State assessment*
- *Investigation to ascertain GPs and Health Services developed role in driver appraisal and referral*
- *Referral Course: alternative to prosecution for careless driving targeting older drivers*

4.2.1 *Collision type: what is happening?*

Medical episode collisions are occurring in a variety of scenarios (see Figure 9). The top three collision types recorded for the 64 collisions involving a medical episode are;

- Head on collisions
- Collisions where the driver has lost control of the vehicle or it exited the carriageway
- Pedestrian 'other' collisions

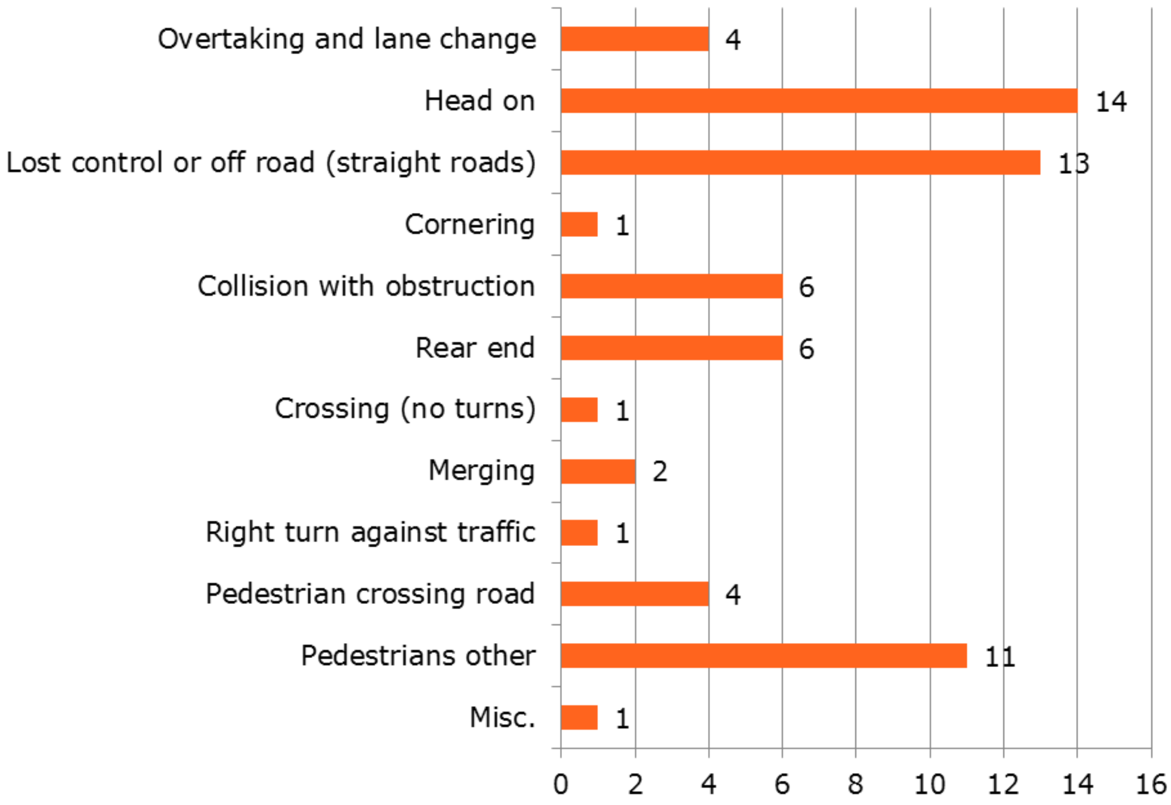


Figure 9: Collision type for medical episode cases (n=64)

Head on collisions:

When an individual suffers a medical episode whilst driving, they lose control of the vehicle. The vehicle veers/drifts across the carriageway and often enters the opposing lane of traffic. This is where a head on collision would occur.

Lost control/off road collisions:

Similar to head on collisions, the individual loses control of the vehicle and veers/drifts off of carriageway. These types of collisions can involve vehicles entering verges and ditches, and striking barriers, trees and fences.

Pedestrian 'other' collisions:

These collision types not only include pedestrians, but also occupants who have alighted from their vehicles. This collision type can include many scenarios:

- Walking with traffic
- Walking facing traffic
- Walking on footpath
- Playing
- Attending to vehicle
- Entering or leaving vehicle

4.2.2 Who is sustaining fatal injuries?

A total of 68 people suffered fatal injuries as a result of a medical episode collision. Figure 10 shows the injury severity for all occupants (n=192) involved in these collisions. **57 of the 68 fatalities were the drivers/riders who suffered the initial medical episode.** The remaining 11 fatalities were occupants in other vehicles involved in the collision. These included pedestrians, motorcyclists and car occupants.

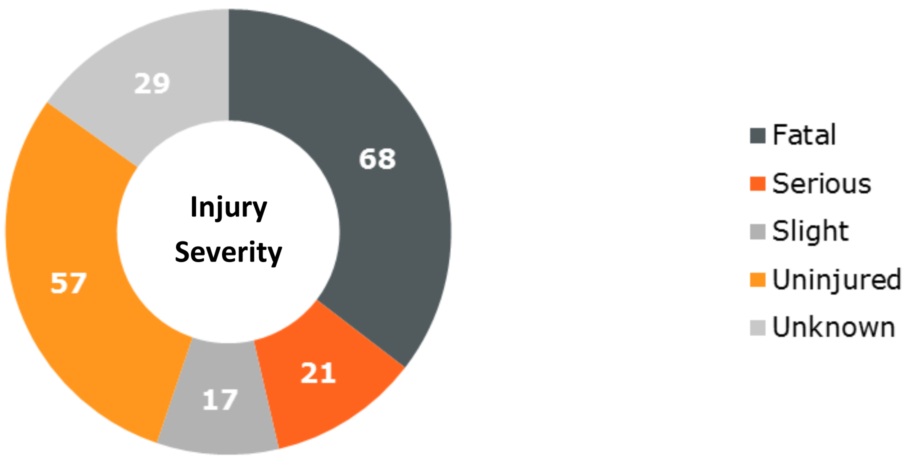


Figure 10: Injury severity for all occupants (n=192)

In medical episode collisions, there are cases where the individual has died as a result of the illness rather than injuries sustained in the collision. A case by case analysis was conducted to determine what medical conditions are causing these episodes. The investigators are not always provided with this information, and therefore there was not a clear answer. One case did highlight that the driver had blacked out as a result of diabetes, and another stated that a pedestrian had fainted and fallen into the path of a vehicle.

4.2.3 The collision: who is involved?

4.2.3.1 Vehicles

There were a total of 133 vehicles involved in medical episode collisions; with 51 of the vehicles recorded as having an occupant who sustained a fatal injury (Table 4). This amounts to 38% of all included vehicles.

Table 4: Maximum injury severity by vehicle (n=133)

	Most severely injured occupant in vehicle						
Vehicle type	Fatal	Fatal %	Serious	Slight	Uninjured	Unknown	Total
Car	40	54%	4	7	17	6	**74**
LGV	3	50%	0	0	2	1	**6**
HGV	2	7%	2	2	23	1	**30**
Motorcycle	3	100%	0	0	0	0	**3**
Bus/Coach	0	0%	1	0	1	0	**2**
Taxi/Private Hire	0	0%	0	0	1	0	**1**
Pedestrian	2	13%	0	0	0	13	**15**
Other	1	100%	0	0	0	0	**1**
Unknown	0	0%	0	0	0	1	**1**
Total	**51**	**38%**	**7**	**9**	**44**	**22**	**133**

There were 83 vehicles in which an occupant was noted as having or suspected of having a medical episode. The majority of the vehicles in this group were passenger cars (64%) (Figure 11). Other vehicles included HGVs, LGVs, motorcycles and pedestrians. There was also one 'other' vehicle which was an ambulance van.

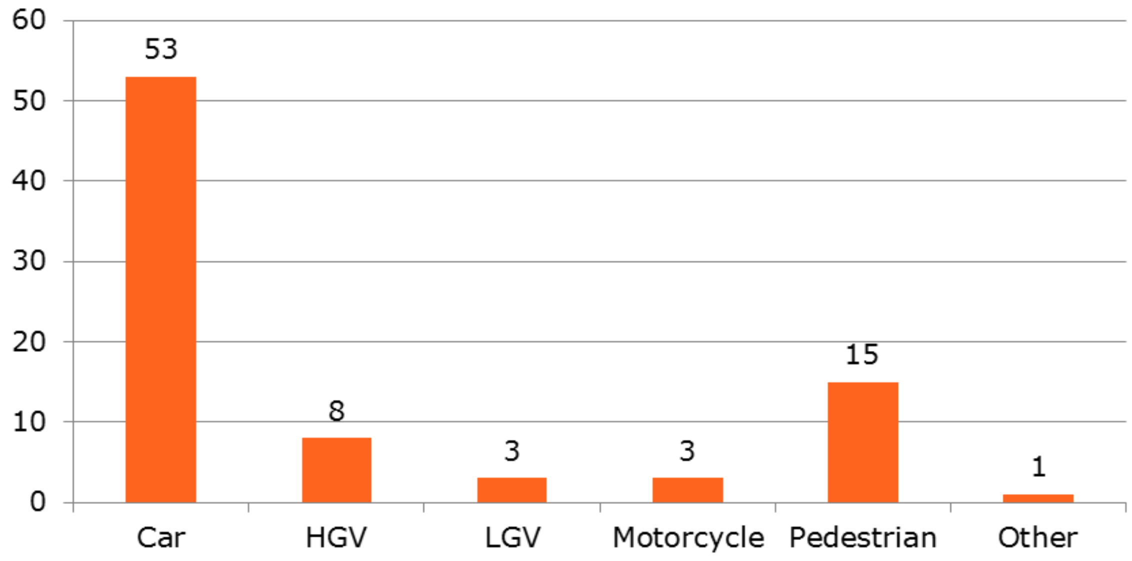


Figure 11: Vehicle type where the driver/rider was known/suspected to have suffered a medical episode (n=83)

4.2.3.2 Occupants

In total, there were 192 occupants involved. 63% (n=43 of 68) of fatal injuries were sustained by passenger car occupants (Table 5).

Table 5: Injury severity of all occupants by occupant type (n=192)

	Injury Severity						
Occupant type	**Fatal**	**Fatal %**	**Serious**	**Slight**	**Uninjured**	**Unknown**	**Total**
Car	43	36%	17	14	30	17	**121**
HGV	3	11%	2	2	20	1	**28**
LGV	2	29%	0	1	4	0	**7**
Bus	0	0%	1	0	3	0	**4**
Motorcycle	3	100%	0	0	0	0	**3**
Pedestrian	9	90%	1	0	0	0	**10**
Alighted occupant	7	100%	0	0	0	0	**7**
Other	1	100%	0	0	0	0	**1**
Unknown	0	0%	0	0	0	11	**11**
Total	**68**	**35%**	**21**	**17**	**57**	**29**	**192**

Of the 192 occupants, 84 were assigned as either having (or suspected to be having) a medical episode at the time of the collision. Table 6 shows the seating position of the occupants. Car drivers were the largest group of occupants within this data set. The majority of occupants were seated in the driver/rider position (n=82) – the individual in control of the vehicle. Note that pedestrians and alighted occupants have been coded as a 'vehicle' due to the database organisation.

Table 6: Seating position of occupant by occupant type (n=84)

	Position in vehicle			
Road user / Occupant type	**Driver/rider**	**Rear offside passenger**	**Unknown**	**Total**
Car	53	1	1	**55**
HGV	7	0	0	**7**
LGV	2	0	0	**2**
Motorcyclist	3	0	0	**3**
Pedestrian	9	0	0	**9**
Alighted occupant	7	0	0	**7**
Other	1	0	0	**1**
Total	**82**	**1**	**1**	**84**

Table 7 shows the gender and age group of the 82 drivers/riders. Overall, there were more male occupants who suffered a medical episode than females. Occupants aged between 35 to 54 years were most likely to be recorded as suffering a medical episode.

Table 7: Age group and gender of drivers/riders (n=82)

	Gender		
Age group	Female	Male	Total
12 to 15 years	0	1	**1**
16 to 19 years	0	1	**1**
20 to 24 years	0	2	**2**
25 to 34 years	0	6	**6**
35 to 44 years	2	11	**13**
45 to 54 years	3	10	**13**
55 to 64 years	1	7	**8**
65 to 74 years	2	9	**11**
75+ years	1	8	**9**
Unknown	3	15	**18**
Total	**12**	**70**	**82**

4.2.4 Prevention: medical episode countermeasures

It is not possible to determine one countermeasure which could prevent all medical episode related collisions occurring, as each case differs in many ways.

A pattern in collision types cannot be identified, as there are multiple types which occur at a similar rate. The top two collision types all included the vehicle drifting or veering off of the carriageway or into the path of an opposing vehicle. This was a result of the driver losing control due to the medical episode. As the fatality most often occurred in the 'medical episode' vehicle, countermeasures could be implemented to reduce the severity of the collision.

These countermeasures should aim to keep the vehicle from exiting the carriageway and the designated lane. For example, appropriate safety barriers. In cases where the vehicle cannot be prevented from exiting the carriageway, ensure that road side furniture is passively safe. Improved passive safety could also reduce the severity of the collision. In order to prevent these collisions from initially occurring, a system could be fitted to the vehicle to determine when the driver is not in control. This could ultimately bring the vehicle to a stop. However, if the collision did still occur, an eCall system would notify the emergency services if the vehicle was involved in a collision and inform them that the driver had been unresponsive for a certain amount of time.

The influx of Advanced Driver Assistance Systems in the vehicle fleet, such as Lane Keep Assist and Autonomous Emergency Braking systems will also aid these collisions. Although they may not be able to completely avoid the collision or result in a secondary collision further along the carriageway they will have a positive effect by keeping the vehicle on the carriageway and/or reducing the collision energy.

The data show that the drivers/riders most likely to suffer a medical episode are aged between 35 to 54 years old. It may be that the individuals are unaware of their medical condition and that is the reason why they haven't taken the appropriate medication, etc. The implementation of a mandatory health check when the individual reaches this age bracket could identify any unknown illnesses, and therefore ensure the appropriate action is taken. However, there are scenarios in which a medical episode could not have been previously identified. Further work could be conducted to improve awareness of the risks of medical episodes, from the perspective of the driver and the DVLA, to ensure that appropriate measures are taken to lower the risk of this collision mechanism occurring and that individuals can still be mobile to minimise the impact on quality of life.

RECOMMENDATIONS

Due to the undetectable and unpredictable nature of medical episodes, countermeasures to reduce the likelihood of an episode occurring whilst in control of a vehicle are likely to be the most effective at preventing these collisions. Improved detection of people at high risk of medical episodes will identify the potential target population of drivers at risk of this particular collision type. This could include mandatory health screening for professional drivers or routine health screening for all drivers. Further research is required to identify the conditions that are most risky for medical episode collisions.

Better detection must be combined with a mechanism that enables and incentivises reporting of the conditions to the necessary agencies. There may be a perception that reporting these kinds of conditions will negatively impact the person's quality of life as they will have their licence revoked or suspended. Further research should focus on defining a mechanism that enables and incentivises reporting of potential high risk medical conditions while minimising the impact on personal mobility.

This may be partially achieved by improving awareness and education of how dangerous the consequences of medical episode collisions can be.

If the medical episode is not avoidable then the implementation of measures that can prevent vehicles leaving the carriageway, either to the offside (resulting in crossover collisions) or to the nearside (resulting in run-off-road collisions) will improve the outcome of the incident by mitigating the severity of the impacts. This can include road infrastructure (e.g. the installation of central reservations or the improvement of roadside safety) or vehicle technologies (e.g. distraction monitoring systems with braking function or automated post-impact braking). However, the vehicle technologies run the risk of inducing negative secondary impacts without the driver's control or a highly autonomous capability. Due to the nature of the loss of control, countermeasures that address driver alertness are not suitable (e.g. lane keep assist or distraction monitoring).

Post-collision response is vital for the preservation of life with potentially life-threatening medical complications. Investigate how measures that can reduce the response time of emergency services could have a substantial impact on the survivability of casualties, particularly in combination with measures to mitigate the severity of the impacts.

Mental health related collisions (including suicides) have extremely complex root causes and require further research to derive effective and evidence-based countermeasures.

5 Regional Hotspot Analysis

The Highways England Fatality database contains precise grid coordinates of the collision loci. This can be used to examine location and surrounding road infrastructure as well as the approach for the road users involved. It also enables the identification of collision hotspot on the SRN based on clustering of fatal collisions which may indicate there is a systems failure or combination of failures, occurring in any part of Haddon's matrix/the Safe-System that is leading to repeated collisions culminating in the loss of life.

Figure 12 shows the geolocation of the sample of fatal collisions analysed in this report that occurred on the SRN from 2014 to 2016. **A detailed analysis of two hotspots is provided in Appendix A to demonstrate how the database can be used to provide safety recommendations to improve specific collision loci and regional safety strategies.**

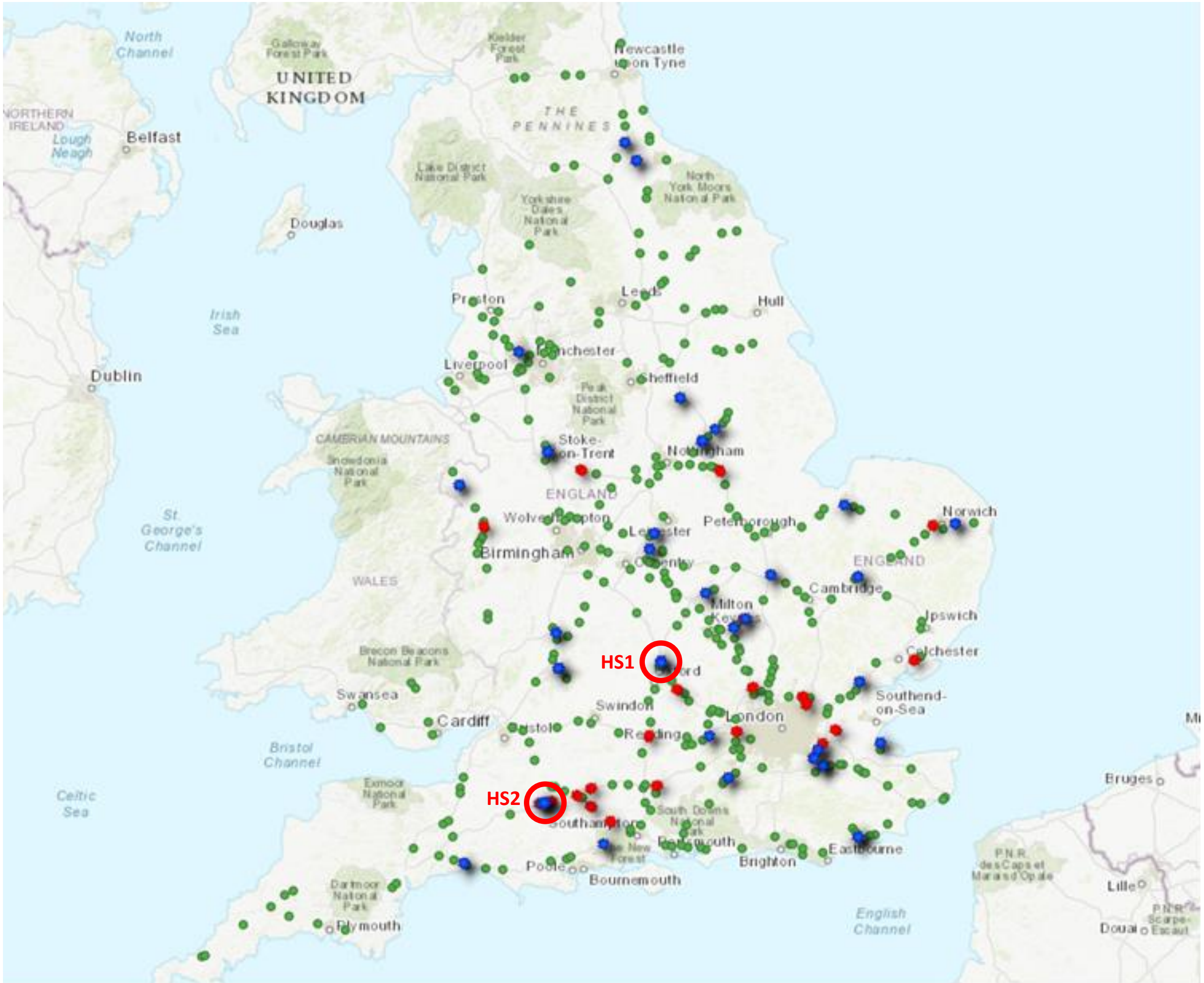


Figure 12: Geolocation of individual fatal collisions that occurred on the SRN between 2014 and 2016 (green) with collision clusters where multiple collisions occurred within a 1 mile radius (red) or 0.5 mile radius (blue). Two hotspots used in further analysis are ringed in red.

6 Summary and Conclusions

6.1 Sample analysis

This work has successfully examined and coded 450 police fatal cases from fatal collisions that occurred on the SRN in the years 2014, 2015 and 2016. The examination and coding of 2017 collisions is currently underway, but does not form part of the analysis in this report. The study successfully identified the causation factors and predictive countermeasures for these collisions, such that the findings could be used to prioritise solutions to prevent or mitigate the injuries of future collisions with similar characteristics. The main conclusions can be summarised as:

- Police fatal files typically contain data that allow collision causation and countermeasures to be identified from existing information and photographs. The most important information in the police report was the Collision Unit Investigation (CUI) report and scene and vehicle photographs.
- TRL coded information from the file (both directly and from additional data derived from the information in the file) and coded the information into a database. The strengths of this approach are that the information can be easily analysed and can respond to a range of very different research questions, therefore making it a powerful resource with which to examine fatal collisions in terms of their characteristics, causation factors and countermeasures. The data can be examined at a high level to show trends, or can be used for in-depth case-by-case analysis.
- Based on the 450 fatal collisions reviewed, the known causation factors always involved a ‘people’ component. However, the countermeasures assigned to the collision encompassed all aspects of the safe systems model. The majority of collisions had countermeasures in all three categories (‘people’, ‘vehicle’, ‘road’) indicating a range of possible approaches to avoid or reduce the resulting fatalities despite the human-centric causation.
- The largest proportion of fatalities with a known age are between 25 and 34 years old (16.1%) followed by fatalities between 35 and 44 years (14%). There is a large proportion (22%) of fatalities which had no reported age in the source information and have been coded as ‘unknown’. This is recognised as a limitation of this work and there is opportunity for future improvement. It is recommended that future studies collate the STATS19 information with the police fatal files to address this and other unknowns.
- The depth of the data captured enables detailed analysis that far exceeds the detail and robustness of analysis of macro datasets (e.g. STATS19). Furthermore, the Highways England Fatality database has a substantial sample size and is being used more routinely by analysts within Highways England to provide evidence for other analyses. This includes statistical analysis of network-level trends down to individual case-by-case reviews.

6.2 Highways England Countermeasure Assessment

The first step in evaluating the potential effectiveness for road safety countermeasures is to quantify the target population to which it applies. Highways England has multiple countermeasures that are being considered for implementation and were provided to TRL to undertake an initial assessment of their applicability. Many of the countermeasures address the same collision types, so two were selected to demonstrate how the Highways England Fatality dataset can be used in the process of selecting which countermeasures Highways England should take forward.

6.2.1 Countermeasures addressing collisions as a result of: Tyre Condition

The Highways England countermeasures (Highways England, 2018) that are applicable to this analysis include:

- *Improved access to tyre tread monitors – tyre tread checkers in baby boxes*
- *Research and promote tyre safety and roadworthiness with partners*
- *Increased role of TOS – identification of defective tyres*
- *Fire and Rescue Service to assist with tyre safety readings*
- *Free tyre checks provided by National Tyre Repair Centres*
- *Pilot: drive-through sensor station*

It is evident that a lack of, or incorrect, vehicle maintenance is a major factor in the cause of vehicle defects and mechanical failures. The ten cases in which a vehicle was found to have a tyre defect contributory to the collision could have been potentially avoided or had a reduced severity if the vehicle had been maintained correctly. The investigators highlighted this in the cases by coding a countermeasure of 'better maintenance of vehicle consumables/features'.

Of the 450 collisions in the fatality database, there were 50 vehicles with tyre defects. In 10 of those vehicles, the defect was a direct cause of the fatality. This indicates that poor tyre condition is a recurrent failure in the safe-system. This would be visualised as a persistent 'hole' in the Swiss-Cheese model, where one in five collisions involving a vehicle with a defective tyre, the hole aligns with other aspects of the system to result in a fatal collision.

Therefore, the evidence base to carry forward the countermeasures addressing tyre condition is clear in the Highways England fatality database. All of the proposed measures address one or more of the key mechanisms to prevent tyre condition related collisions:

- **Improving driver education and awareness**
- **Providing necessary equipment and skills**
- **On the spot checking of tyre condition**

The purpose of this study was to identify if tyre condition is a persistent system failure and provide the evidence-base for pursuing countermeasures to address the issue. Further research should now focus on identifying which countermeasures would most effectively address this failure and how they should be implemented on the SRN.

6.2.2 Countermeasures addressing collisions as a result of: Medical Episodes

The Highways England Safety Intervention Summary Toolkit (Highways England, 2018) outlines interventions that are applicable to this analysis. These include:

- *Carry out research on catastrophic claims made in relation to older drivers*
- *DVLA should require evidence of a recent eyesight test*
- *Nottingham Dementia Drivers Screening Assessment/Mental State assessment*
- *Investigation to ascertain GPs and Health Services developed role in driver appraisal and referral*
- *Referral Course: alternative to prosecution for careless driving targeting older drivers*

The top two collision types all included the vehicle drifting or veering off the carriageway or into the path of an opposing vehicle. This was a result of the driver losing control due to the medical episode. As the fatality most often occurred in the 'medical episode' vehicle, countermeasures could be implemented to reduce the severity of the collision.

The primary aim for countermeasures should be to prevent the vehicle from leaving the carriageway. If a collision is inevitable, it is likely to be more favourable if it occurs on the carriageway where the environment is usually safer. This can be achieved with road side structures such as barriers and vehicle technology, including lane keep assist, which is a more targeted countermeasure than roadside structures as these collisions can occur anywhere on the road network.

The data show that the drivers/riders most likely to suffer a medical episode are aged between 35 to 54 years old.

It may be that the individuals are unaware of their medical condition and that is the reason why they haven't taken the appropriate medication, etc. The implementation of a mandatory health check when the individual reaches this age bracket could identify any unknown illnesses, and therefore ensure the appropriate action is taken. However, there are scenarios in which a medical episode could not have been previously identified. Furthermore, if a driver/rider is aware of their medical condition, then a more stringent procedure could be implemented by the DVLA when undertaking driving licence reviews. Drivers should not be punished for their illnesses and it is important to ensure that these individuals can still be mobile.

Therefore, the evidence base to carry forward the countermeasures addressing medical episodes is clear in the Highways England fatality database. The measures proposed by Highways England address some, but not all of the key mechanisms for this collision type:

- **Prevention through improved screening and detection**
- **Method to incentivise reporting of high risk drivers**
- **Improving driver awareness of the risks of underlying medical conditions**

Furthermore, the analysis has shown that the age groups that most commonly suffered medical episodes leading to a fatal collision were younger than the ages targeted in some of the countermeasures. Importantly, none of the proposed measures provide a clear method to incentivise the reporting of high risk drivers without negatively impacting their

personal mobility. Without this, it is possible that road users will evade and undermine the screening and detection measures.

Further research should focus on identifying a specific method of implementation and assessing the expected effectiveness of the measures to identify which should be further considered for implementation by Highways England.

6.3 Regional Hotspot Analysis

The data can be analysed to identify potential collision hotspots and provide safety recommendations and inform regional safety strategies to improve the safety at those locations. An example of how this analysis can be used to generate safety recommendations for two potential hotspot locations is provided in Appendix A.

It is recommended that more hotspot analysis is done to further investigate the potential presence of resident road safety failures on the SRN.

6.4 Limitations

There are some general caveats that should be considered when interpreting the results of this study. In this study, the coding of the collision data was based on a subset of information contained within the police fatal file and although investigators examined information in the file, and in some cases gleaned additional information from photographs or other additional information sources, the information was mostly limited to that available in the file. While the extent and quality of information in the files was found to be good and generally consistent, any bias in the recording of source data has not been assessed. Some aspects of collision information are also genuinely more difficult to record and this may have influenced how often certain data or evidence was collected. For example, information on vehicle defects may be easily established for tyres, but may be more difficult, or less likely to be detected, for other mechanical defects. If this is the case for certain aspects of the case, these will not have been considered fully when the causation and countermeasures were assessed. Therefore, the results reflect the existing data rather than necessarily the full picture. The extent of missing data has been assumed to be small, but again this has not been investigated. To collect information about every aspect would require a dedicated data collection study collecting data at the scene in parallel with police data. This would be resource intensive, but would deliver benefit over and above that available from police file data.

We assessed countermeasures by applying a feature that wasn't present in the collision and theoretically assessing the outcome based on assumed performance characteristics. However, this predictive approach is fundamentally subject to a level of uncertainty since the assessment is limited by the detail of the data available from the fatal file and assumptions on how well the countermeasure would work in the specific circumstances. However, we attempted to minimise the effects of this by using experienced collision investigators and by developing consistent guidance rules for the function and performance of each countermeasure. This approach aimed to standardise the predictive assessment, but even with this in place, it is possible that the effectiveness of the countermeasure may have been overestimated in some circumstances. In addition, each Highways England Fatality

Research case was reviewed by another member of the team prior to being released into the database for analysis.

We assumed that any one of the countermeasures judged to be effective could have avoided or reduced the fatality as per the model of risk proposed by Reason (1990). However, in practice it may be that the countermeasure would not have been as effective as predicted, or that more than one intervention would have been required to prevent the fatality. Therefore, the predictions made by the method employed may overestimate the fatality savings to an unknown degree.

In this assessment process, we have not considered cost or implementation feasibility of potential measures. This is because these aspects can change over time, but primarily because it is necessary to determine the most objective picture of which countermeasures might influence the outcome. Only once this step has been completed can the cost effectiveness of the measure be identified. If potential measures are excluded at the onset on the grounds of cost, measures that might eventually be cost effective for implementation would not available for consideration. Thus, these results should be interpreted with this in mind; that the implementation cost-benefit for the measures has not been included in the prioritisation. Therefore, more work is required to determine the most cost effective and feasible implementation strategy should any subsequent action be taken.

7 Bibliography

Highways England. (2018). Safety Intervention Summary Toolkit. Retrieved May 14, 2019

McCarthy, M., & Barrow, A. (2016). *Towards Zero: Study on fatal collisions on the SRN during 2014.* TRL Ltd, Wokingham, Berkshire.

Reason, J. (1990, April 12). The Contribution of Latent Human Failures to the Breakdown of Complex Systems. *Philosophical Transactions of the Royal Society of London*, pp. Series B, Biological Sciences. 327 (1241): 475–484.

WheelRight. (2019). *Case Studies*. (WheelRight) Retrieved July 30, 2019 , from WheelRight: http://www.wheelright.co.uk/case-studies/

Appendix A Regional Hotspot Analysis

Figure 13 shows the geolocation of the sample of fatal collisions analysed in this report that occurred on the SRN from 2014 to 2016. Clusters of two or more collisions that occurred within a 1 mile radius are shown in red, and a 0.5 mile radius in blue. In total, 47 clusters with a 1 mile radius and 31 clusters with a 0.5 mile radius were identified. Hotspots can be made up of multiple clusters.

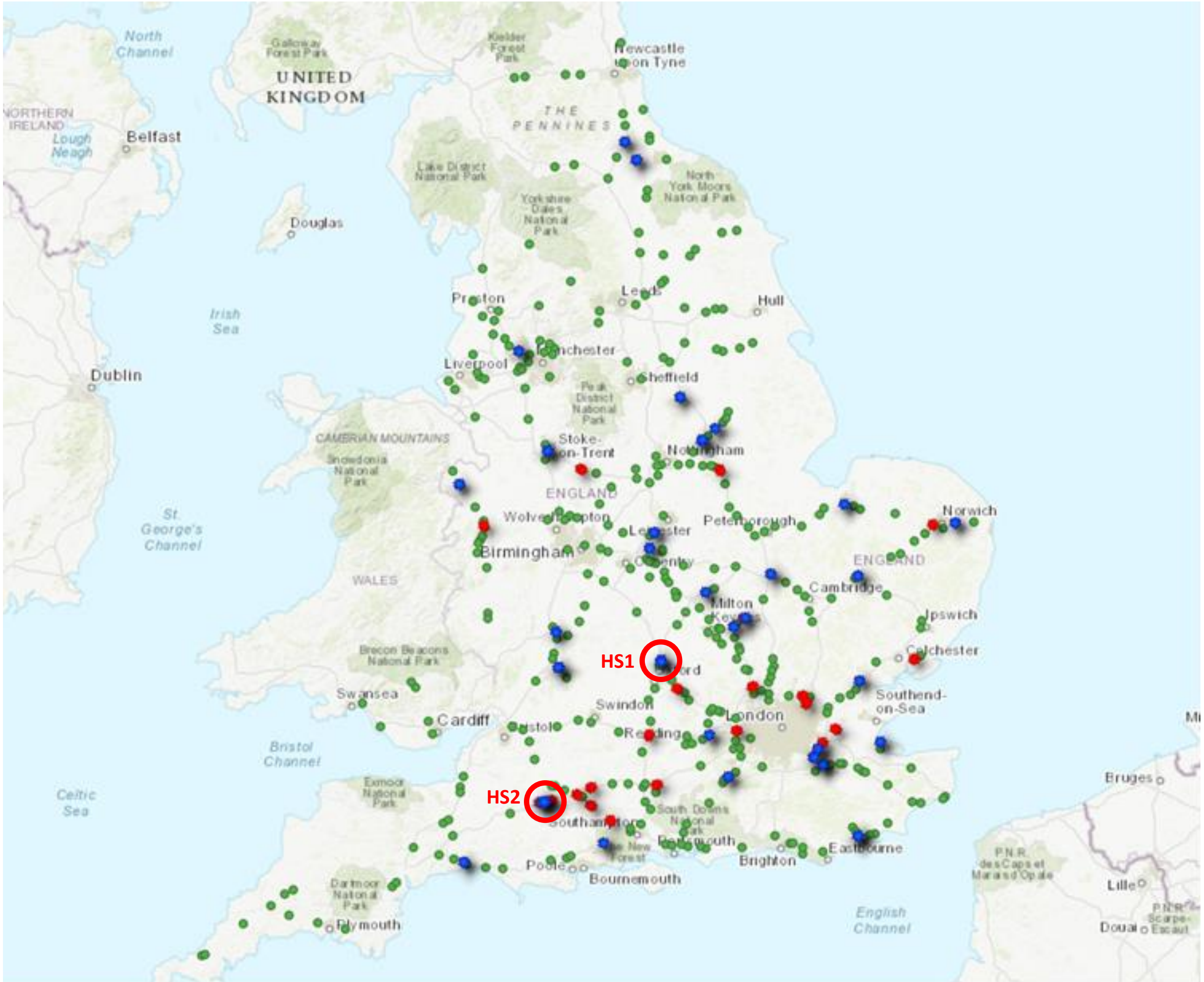


Figure 13: Geolocation of individual fatal collisions that occurred on the SRN between 2014 and 2016 (green) with collision clusters where multiple collisions occurred within a 1 mile radius (red) or 0.5 mile radius (blue). Two hotspots used in further analysis are ringed in red.

The collisions for two hotspots (both containing multiple collision clusters) were analysed to identify common causation factors and countermeasures between the collisions that occurred at the same hotspot (shown in red rings in Figure 13). Each collision was reviewed in detail and presented in the subsequent section which summarises the overall findings and recommendations for the hotspot followed by a one page summary of each collision.

For each collision a summary description of the events is provided based on the reconstruction. The collision reconstruction identifies the events from the final resting position of the road users as far back as the evidence captured at the scene will support. The **critical intervention points** are shown sequentially for each collision with the key **collision mechanism** that, if altered, would have prevented the fatality. The specific Highways England Fatality **countermeasures** that can execute the required influence at each critical are also shown.

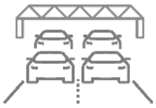
The critical intervention points are drawn from the Swiss-Cheese model (Reason, 1990) of identifying causation factors. In the events leading up to, during and after a collision there are moments where, had the circumstances been slightly different, the collision could have been avoided or the fatality prevented. These points represent the greatest likelihood of changing the outcome of the collision and equate to the largest holes in the Swiss-Cheese model and should be the principal target for countermeasures. The intervention points can occur at any point in the collision sequence and can influence any part of the safe-system (road, vehicle or people).

The type of interventions and how often they were applicable to the collisions that occurred at the hotspot are summarised after the description of the hotspot. The types of countermeasures that could enable the interventions to the hotspots are also summarised after the description of the hotspot. The combination of critical intervention points and mechanisms that occurred those points are the evidence base for the recommendations applicable to the hotspot.

Analysing collision hotspots will provide a finer level of detailed recommendations that can be implemented on a region-by-region basis. However, it is possible that the collisions making up a hotspot do not share common systemic failure and, therefore, do not have hotspot-specific recommendations.

COLLISION HOTSPOT 1

MOTORWAY



SPEED LIMIT

Locus description:

- Three lane motorway with hard shoulder
- If travelling southbound there is a slight right hand bend followed by a slight left hand bend
- South East England

Collision description:

- Four collisions occurred over 1.25km of carriageway
- Five fatalities occurred
- One collision occurred in 2014, two in 2015 and one in 2016

Of the four collisions that comprise this hotspot, there are several critical intervention types that could have avoided the collision or prevented the fatality some of which are common to multiple collisions. These provide the evidence base to inform the safety recommendations for the hotspot.

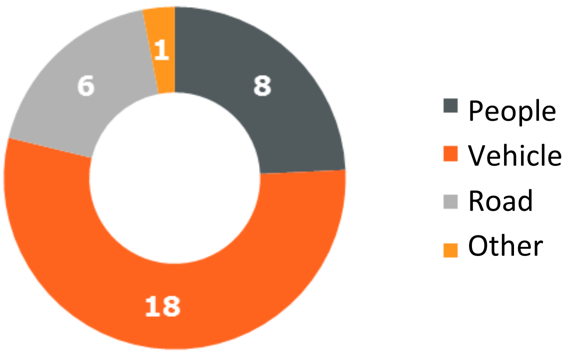
The critical interventions are shown below, ranked by the number of collisions to which they apply. The distribution of existing countermeasures that are able to achieve the critical interventions are shown in the chart by their type: vehicle tech, human behaviour or road environment countermeasures. The individual case studies that informed these data are summarised after the recommendations.

SUMMARY OF CRITICAL INTERVENTIONS

The four collisions have varied root causes and, therefore, the interventions required to prevent the collision or fatalities are also varied in nature.

Intervention type	% Distribution in collisions (n = 4)
Reduce collision energy	75%
Prevent inattentive/impaired driving	50%
Prevent run off road collision types	25%
Improve VRU visibility	25%
Prevent vehicle fire occurring	25%
Safer roadside design	25%
Improved vehicle occupant safety	25%
Prevent impaired driver from starting their journey	25%
Change driver behaviours in specific situations	25%
Prevent pedestrians entering the carriageway	25%

TYPES OF COUNTERMEASURES



Many of the critical interventions can be addressed with existing or new **vehicle technologies**. As with all vehicle technologies the real world performance is unlikely to be perfect, therefore the **human behavioural** and **infrastructure** based countermeasures, although less numerous, are potentially more effective for the avoidance of collisions and prevention of fatalities.

RECOMMENDATIONS FOR HOTSPOT 1

Although the collisions occurred in close proximity there are limited similarities between the root causes of the collisions and therefore the recommendations relating to the collision locus differ.

HE Specific Recommendations:

- Promote the uptake and fitment of key vehicle ADAS technologies that:
  - Reduce collision speeds and operate at motorway travelling speeds
  - Warn and/or prevent driver's being inattentive or fatigued
  - Warn and/or prevent vehicles from deviating from their lane
- Remove roadside furniture that presents critical launch risk and review the safety of the roadside in conjunction with the infrastructure instalments (i.e. look at the safety of the whole roadside)
- Take measures to prevent impaired drivers from starting their journey when they are too impaired to drive safely
- Install measures that relay to drivers when there is slow traffic or congestion ahead – particularly in low visibility conditions.
- Review the speed limit of the collision locus within the context of reducing the speed limit. This should reduce the average travel speed of vehicles through the locus. The purpose of the SRN is to enable fast travel so this should be reviewed as an assessment of the loci overall

Hotspot 1 – Case study 1

SINGLE VEHICLE

BARRIER IMPACT AND LAUNCH

VEHICLE FIRE

DAYLIGHT

FINE AND DRY

V1 (car) was travelling at 75 mph in lane 1 and continuously strayed into lane 2. V1 eventually veered left at a shallow angle into an angled concrete safety barrier terminal causing the vehicle to launch into the air.

V1 flipped over (back over front) until the front nearside corner impacted the concrete road sign pillar the barrier was intended to protect. The cars' fuel (and occupant's fire accelerant) ignited and there was an explosion.

The driver and passenger were fatally injured.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent high risk driver from starting their journey	Driver was under the influence of **drugs**	Training/education to reduce risky pre-driving behaviour
		Drug lock
	Driver was possibly **fatigued**	Training/education to reduce risky pre-driving behaviour
Prevent inattentive/ impaired driving	Driver was possibly **fatigued**	Fatigue monitoring
	Driver was possibly **inattentive/distracted** whilst driving which resulted in driving above the speed limit	Distraction monitoring
		Intelligent Speed Assist
Prevent run off road collision types	Vehicle continuously strayed across the offside lane line and then **exited the carriageway** to the nearside	Lane departure warning/lane keep assist
		Instalment of rumble strips on lane lines
Improve safety of roadside design	Vehicle was **launched into air** as a result of the ramped end barrier terminal	More effective barrier type – remove launch risk
	Vehicle **impacted concrete road sign pillar**	Make hazards passively safe
Prevent vehicle fire occurring	Vehicle **caught alight** after impacting the road sign. There was fire accelerant stored within the vehicle at time of impact. The vehicle's fuel also caught alight.	Implement more stringent rules regarding the transportation of fire accelerant in a passenger car

Hotspot 1 – Case study 2

MULTIPLE VEHICLES

LOW VISIBILITY

EARLIER COLLISION ON PATH

BARRIER IMPACT

DAYLIGHT

FOGGY AND DAMP

The collision occurred during early morning daylight hours. Road conditions were damp and there was patchy fog present - visibility was down to 20 ft. An earlier accident had caused stationary traffic.

V1 (car) was travelling in lane 3 of 3 at 50mph as it entered into the fog. V2 (car) was travelling at 70mph when it impacted the rear nearside of V1. V1 span and impacted the central barrier, rebounded and impacted the offside of V2 and then impacted the barrier for a second time, fatally injuring the front seat passenger and seriously injuring the driver of V1. V2 impacted V3 (car) which caused subsequent impacts between another 4 vehicles.

Critical Intervention	Collision Mechanism	Countermeasure
Change driver behaviours in specific situations	Many vehicles **did not have fog lights on** at the time of the collision	Training/education for appropriate use of lights
Reduce collision energy	Due to the **low visibility** caused by the fog the drivers were unable to see the queue of traffic ahead	Add interactive signage leading up to the congested area
		Hazard alert system in vehicle
	V1 was **travelling too fast for the conditions** and **following too close** to vehicles ahead	Training to improve hazard perception skill
		AEB (vehicle-to-vehicle)

Hotspot 1 – Case study 3

HGV VS PEDESTRIANS

INCONSPICUOUS

DARKNESS

FINE AND DRY

Early one morning in the hours of darkness V1 (HGV) was travelling in lane 1 and impacted three pedestrians walking along the side of the carriageway in the direction of traffic.

The pedestrians were wearing dark clothing and there was no street lighting present. One pedestrian sustained fatal injuries.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent pedestrians entering the carriageway	Pedestrians are **prohibited from entering the motorway**	Implement training/education programs to reduce dangerous actions in the carriageway
		Install a physical barrier and warning signage
Improve VRU visibility	Pedestrians **wearing dark clothing at night**	Training/education programs regarding VRU visibility – encouraging and/or supplying high-visibility clothing
		Installation of VRU camera/sensor systems on vehicles
		Improved vehicle lighting to increase time frame in which the driver could see the VRUs
		Improve street lighting – installation, ensure turned on in problematic areas, etc.
Reduce collision energy	Driver of vehicle **failed to see** the pedestrians and therefore was unable to react (apply braking/steering)	Pedestrian AEB
		Training/education program to Improve hazard perception skills
		Installation of a driver alert when approaching a temporary hazard (pedestrians on motorway)
		Installation of VRU camera/sensor systems on vehicles

Hotspot 1 – Case study 4

CAR VS HGV

SLOW MOVING TRAFFIC

DAYLIGHT

FINE AND DRY

V2 (HGV) was travelling in lane 1 of 3 and slowed due to a build-up of traffic ahead. The matrix signs displayed a speed limit of 40mph.

V1 (car) was travelling at 70mph in lane 2 and reacted to the slow moving traffic by steering into lane 1. There were no signs of braking from V1 and the front of the vehicle impacted the rear of V2.

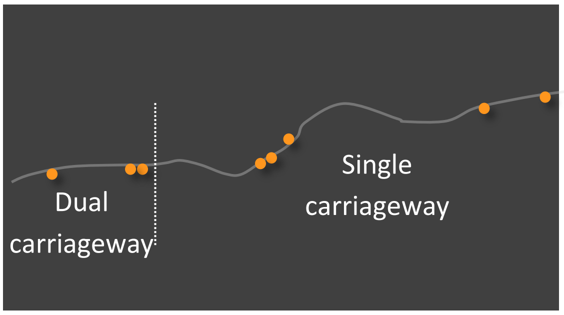
The driver of V1 was fatally injured.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent inattentive/impaired driving	V1 was **travelling too fast for the conditions**	Training/education programs to improve hazard perception skills
	Driver of V1 was possibly **distracted** which resulted in **excessive speed** and **failure to judge** other persons path or speed	Training/education program to reduce risky driving manoeuvres (e.g. speeding)
		Distraction monitoring
		Intelligent Speed Assist
Reduce collision energy	The driver **failed to react** (braking) before impact occurred	Driver alert for approaching temporary hazard (queuing traffic)
		AEB (vehicle to vehicle)
Improved vehicle occupant safety	The front of car collided with the rear of the HGV which caused **substantial intrusion**	Improved rear under-run guards for HGV

COLLISION HOTSPOT 2

DUAL CARRIAGEWAY + SINGLE CARRIAGEWAY

SPEED LIMIT
60 70



Locus description:
- Complex road geometry
- Many bends and hills to negotiate
- The road changes from a single carriageway to a dual carriageway.
- South West England

Collision descriptions:
- Eight collisions occurred over 6 miles
- Eight fatalities occurred
- One collision occurred in 2014, five in 2015, and two in 2016

Of the eight collisions that comprise this hotspot, there are several critical intervention types that could have avoided the collision or prevented the fatality some of which are common to multiple collisions. These provide the evidence base to inform the safety recommendations for the hotspot.

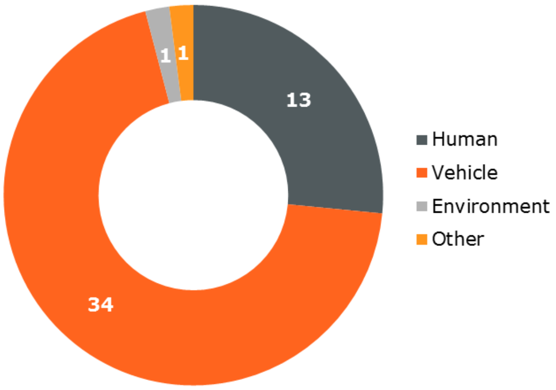
The critical interventions are shown below, ranked by the number of collisions to which they apply. The distribution of existing countermeasures that are able to achieve the critical interventions are shown in the chart by their type: vehicle tech, human behaviour or road environment countermeasures. The individual case studies that informed these data are summarised after the recommendations.

CRITICAL INTERVENTIONS

The eight collisions have varied root causes; however there are two critical interventions which are recurrently noted: reduce collision energy and prevent inattentive/impaired driving. Improvements to driving licencing and better vehicle maintenance

Intervention type	% Distribution in collisions (n = 8)
Reduce collision energy	88%
Prevent inattentive/impaired driving	75%
Improve licencing	50%
Promote vehicle maintenance	38%
Change driver behaviours in specific situations	25%
Improved vehicle occupant safety	13%
Prevent careless/dangerous driving	13%
Safer roadside design	13%

SPECIFIC COUNTERMEASURES



Many of the critical interventions can be addressed with existing or new **vehicle technologies**. As with all vehicle technologies the real world performance is unlikely to be perfect, therefore the **human behavioural** and **infrastructure** based countermeasures, although less numerous, are potentially more effective for the avoidance of collisions and prevention of fatalities.

RECOMMENDATIONS FOR HOTSPOT 2

Although the collisions occurred in close proximity, there are only a few similarities between the root causes. Therefore, there is not one recommendation which relates to all collisions.

HE Specific Recommendations:

- Promote the uptake and fitment of key vehicle ADAS technologies that:
  - Reduce collision speeds and operate at motorway travelling speeds
  - Warn and/or prevent driver's being inattentive or fatigued
  - Warn and/or prevent vehicles from deviating from their lane
- Review the speed limit of the collision locus within the context of reducing the speed limit. This should reduce the average travel speed of vehicles through the locus. The purpose of the SRN is to enable fast travel so this should be reviewed as an assessment of the loci overall safety – while reducing the collision energy may have prevented these collisions, this may not be locus specific.
- Implement training and provide information regarding how vehicle occupants should behave in certain situations. For example, an explanation of what to do when a vehicle breaks down on the SRN.
- Promote vehicle maintenance and educate drivers in carrying out essential vehicle safety checks.
- Install measures that relay to drivers when there is a temporary hazard ahead (i.e. stationary vehicle).
- Better licencing has been noted multiple times, however each time it is for different reasons. These range from illnesses, to older drivers and inexperienced drivers.

Hotspot 2 – Case study 1

CAR VS HGV

ASSISTING EARLIER COLLISION

INATTENTIVE

DARKNESS

RAINING

V2 (car) came to a stop in lane 1 of 2 on a dual carriageway section to give assistance to a vehicle that had just come off the road to the nearside and rolled.

The driver of V2 displayed their hazard warning lights and unbuckled their seatbelt to get out of the vehicle.

V1 (HGV) was travelling in lane 1 of 2, and despite having a view of V2 for at least 16 seconds, the driver was inattentive and failed to brake in time.

The front of V1 impacted the rear of V2 causing the driver of V2 to sustain fatal injuries.

Critical Intervention	Specific Behaviour	Countermeasure
Change driver behaviours in specific situations	The driver of V2 initially stopped to assist with another collision The driver of V2 **unbuckled their seat belt**; however they **remained in the vehicle**. The use of a seat belt at this time may have reduced injury severity	Training/education program explaining the risks of stopping on the live carriageway and instructions on how to do so correctly and safely
Prevent inattentive driving	Driver of V1 was **inattentive** Driver of V1 was possibly **distracted** by an occurrence/object either inside or outside of the vehicle	Distraction monitoring
		System design to reduce distraction from in-vehicle devices
		System design to reduce distraction from out-of-vehicle sources
Reduce collision energy	The driver of V1 failed to avoid a collision with the rear of V2 due to **lack of attention/distraction**	AEB (vehicle-to-vehicle)
		Driver alert for approaching temporary hazard (road works, broken down vehicle, queuing traffic)
Improve vehicle occupant safety	There was **substantial crush to the rear of V2** as a result of the impact – up to the B-pillars.	Improved occupant secondary safety (relative to current typical level) in high energy rear impacts

Hotspot 2 – Case study 2

CAR VS HGV

BROKEN DOWN VEHICLE

INATTENTIVE

DAYLIGHT

FINE AND DRY

V1 (HGV) was travelling in lane 1 of 2 on a dual carriageway and impacted the rear of V2 (car) which had broken down and was stationary in lane 1.

V2 was unable to display their hazard lights due to electronic failure; however there were no other visibility issues.

The driver of V1 may have been inattentive or distracted.

The occupant of V2 sustained fatal injuries.

Critical Intervention	Collision Mechanism	Countermeasure
Promotion of vehicle maintenance	V2 had broken down and was **unable to display hazard lights** due to an electronic fault	Better maintenance of vehicle consumables/features (brakes, tyres, lights etc.)
Change driver behaviours in specific situations	The driver of V2 **remained in the vehicle** as it was stationary in lane 1 of the live carriageway	Training/education program explaining the risks of stopping on the live carriageway and instructions on how to do so correctly and safely
Prevent inattentive/impaired driving	The driver of V1 either **failed to look** properly or **failed to judge** the path/speed of V2 The driver of V1 was possibly **distracted** by an occurrence/object inside or outside of the vehicle	Distraction monitoring System design to reduce distraction from in-vehicle devices System design to reduce distraction from out-of-vehicle sources
Reduce collision energy	The driver of V1 **failed to take avoiding action** and the front of V1 collided with the rear of V2	AEB (vehicle to vehicle) Driver alert for approaching temporary hazard (road works, broken down vehicle, queuing traffic)

Hotspot 2 – Case study 3

SINGLE MOTORCYCLE

LOSS OF CONTROL

PUNCTURE

INEXPERIENCED

DAYLIGHT

FINE AND DRY

V1 (motorcycle) was travelling between 60 and 70mph in lane 1 of the dual carriageway, with a driver and pillion passenger.

V1 appeared to wobble and weave in lane 1 of the carriageway until there was a total loss of control. This was found to be due to an under inflated rear tyre caused by a puncture.

The rider sustained fatal injuries and the pillion sustained slight injuries.

The rider on V1 had recently returned to motorcycling and had only just completed a course designed for those returning to motorcycling after a time lapse. This was their first journey since completed the course.

Critical Intervention	Collision Mechanism	Countermeasure
Promotion of vehicle maintenance	The **rear tyre** on V1 was **underinflated** which resulted in the rider **losing control of the vehicle**	Better maintenance of vehicle consumables/features (brakes, tyres, lights etc.)
		Tyre Pressure Monitoring system for motorcycles
		Training/education program on vehicle maintenance
Better licencing	The rider on V1 has only recently returned to motorcycling after a substantial break The rider was **not experienced riding** the vehicle and **lacked on-road experience**	Increase on-road experience
		Further training/education program to develop driving experience in different scenarios

Hotspot 2 – Case study 4

MOTORCYCLE VS CAR

BAD OVERTAKE

LOSS OF CONTROL

DAYLIGHT

FINE, DAMP ROAD SURFACE

V1 (scooter) was travelling downhill along a sweeping left hand bend and overtook a campervan.

V1 lost control and crossed the solid white centreline onto the opposing lanes and impacted the safety barrier. V1 rebounded and impacted V2 (car) which was travelling uphill.

The rider suffered fatal injuries and the driver of V2 suffered slight injuries.

V1 was found to be greatly modified with many non-standard parts. This might have caused the geometry of the vehicle to change, causing the handling characteristics to change.

Critical Intervention	Collision Mechanism	Countermeasure
Promotion of vehicle maintenance	As V1 overtook another vehicle, the rider **lost control** and crossed the carriageway towards the offside This may have been due to **defective steering** on the vehicle The vehicle was also **modified** with many non-standard parts	Better maintenance of vehicle consumables/ features (brakes, tyres, lights etc.) Implementation of more stringent laws regarding vehicle modifications
Prevent careless/dangerous driving	The rider of V1 **lost control** of the vehicle as they were **driving carelessly** It is possible that the vehicle was **travelling too fast** for the conditions	Fitment of ABS to motorcycle to reduce loss of control Training or education to reduce other risky behaviours while driving (e.g. speeding)
Safer roadside design	V1 **collided with the offside safety barrier** and rebounded back into the carriageway	Add appropriate barrier – motorcycle protection
Reduce collision energy	V2 was travelling in the opposite direction and **collided with V1**	Fitment of AEB (vehicle-to-vehicle) to V2 may have lowered the impact speed

Hotspot 2 – Case study 5

CAR VS MOTORCYCLE

FAILED TO LOOK
POOR TURN

DAYLIGHT

FINE AND DRY

V1 (car) was travelling eastbound turned right across the path of V2 (motorcycle) travelling westbound. V1 impacted V2.

The rider of V2 catapulted over V1 and was fatally injured.

V3 travelling westbound behind V2 swerved to the offside to avoid a further collision but collided with rear of V1 which was almost stationary across the westbound lane.

The drivers of V1 and V3 were uninjured.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent inattentive/impaired driving	The driver of V1 either **failed to look** or **failed to judge** the path/speed of V2	Training/education program to improve hazard perception skill
	The driver was driving **carelessly** and performed a **poor manoeuvre**, as well as **failing to signal** with the vehicle indicators	Intersection assistance system
		Training or education to reduce risky driving manoeuvre
Better licencing	The **driver of V1 was elderly** and it may be possible that the careless driving was a result of **age-related issues**	Better licencing (medical/health related)
Reduce collision energy	Dependent on the distance between V1 and V2, the fitment of a collision warning system to V1 may have given the rider a **greater opportunity to apply braking**	Forward collision warning (motorcycles only)
		ABS (motorcycles only)
	The front of **V3 collided with the rear of v1**	Fitment of AEB (vehicle-to-vehicle) to V3 – this would not alter the collision severity

Hotspot 2 – Case study 6

MULTIPLE VEHICLES

CROSSOVER INTO OPPOSING LANE

FATIGUE

DISTRACTION

DAYLIGHT

FINE AND DRY

V1 (car) was travelling westbound on a single carriageway. V2 (car) and V3 (van) were travelling eastbound. V1 drifted towards the opposite lane and momentarily drifted back to the nearside before drifting fully into the opposing lane.

The driver of V2 braked and steered to the left but was unable to avoid the collision. V1 collided with the front of V2. The driver of V3 reacted promptly and stopped the vehicle with relatively minor contact with V2.

The driver of V1 suffered fatal injuries and died at the scene. The driver and passenger of V2 suffered injuries requiring hospital treatment.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent inattentive/impaired driving	The driver of V1 **lost control** of the vehicle and **drifted into the opposing lane**	Fitment of Lane Departure Warning/Lane Keep Assist to V1 would have prevented the collision from initially occurring
	There are multiple possibilities as to why this occurred - the driver may have been **distracted by an object inside the vehicle**	Distraction monitoring
		System design to reduce distraction from in-vehicle devices
	The driver may have been suffering from **fatigue**	Fatigue monitoring
Better licencing	The **driver of V1 was diabetic** – it is unknown whether this directly influenced the collision	Ensure that all relevant medical issues are declared to the DVLA
Reduce collision energy	The driver of V1 **failed to take any avoiding action** before the collision occurred	Fitment of AEB (vehicle-to-vehicle) to V1

Hotspot 2 – Case study 7

CAR VS CAR

CROSSOVER INTO OPPOSING LANE

FATIGUE

ILLNESS

DAYLIGHT

FINE AND DRY

V1 (car) was travelling at the posted speed along a stretch of single carriageway. The driver of V1 fails to negotiate a gradual left hand bend and crosses into the opposing carriageway into the path of V2 (car).

The front offside corners of V1 and V2 impact each other.

The elderly driver of V1 sustained fatal injuries and the three occupants in V2 sustained serious injuries.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent inattentive/impaired driving	The driver of V1 **lost control** of the vehicle and **crossed into the opposing carriageway**	Fitment of Lane Departure Warning/Lane Keep Assist to V1 would have prevented the collision from initially occurring
	It is possible that the driver was **fatigued**	Fatigue monitoring
Better licencing	The **driver of V1 was elderly** and it may be possible that the collision was a result of **age-related issues**	Ensure that all relevant medical issues are declared to the DVSA
Reduce collision energy	The front of **V1 collided with the front of V2**	Fitment of AEB (vehicle-to-vehicle) to both vehicles may have reduced the impact speed

Hotspot 2 – Case study 8

CAR VS HGV

FATIGUE

DISTRACTION

DAYLIGHT

FINE AND DRY

V1 (car) was travelling on a single carriageway at approximately at 65 mph. V2 (HGV) was parked in the layby on the nearside.

V1 overtook another vehicle in lane 2 and moved back into lane 1. The driver of V1 continued to move to the nearside and entered into the layby, colliding with the rear of V2.

The driver of V1 sustained fatal injuries.

Critical Intervention	Collision Mechanism	Countermeasure
Prevent inattentive/impaired driving	The driver of V1 lost control of the vehicle and performed **a poor manoeuvre** – the driver may have been **fatigued**	Fatigue monitoring
		Lane keeping
	The driver of V1 may have also been **distracted** by an occurrence/object inside or outside of the vehicle	Distraction monitoring
Reduce collision energy	The front of **V1 collided with the rear of V2** and the driver of V1 **failed to take any avoiding action**	AEB (vehicle-to-vehicle)
Improved vehicle occupant safety	The driver of V1 was killed in the impact with the trailer rear underrun guard. The **impact configuration was particularly severe**	Improved rear under-run guards for HGV

A.3 Hotspot analysis conclusions

Plotting the fatal cases has enabled collision clusters to be identified which may indicate localised and repetitive failures in the safe-system at those collision loci. Analysis of two of the largest hotspots, each comprising several collision clusters, has not revealed any critical failures in the road environment at either hotspot. While the collision types and root causes of the collisions varied within both hotspots, there were some collision mechanisms that repeatedly occurred. As a result, there are common critical interventions and specific countermeasures capable of producing the required effect to prevent the loss of life in these collisions. The interventions represent opportunities in which the fatality could have been avoided.

Geographic hotspots do not always have common root causes and may be due to random clustering. However, this type of analysis could identify clusters that do have a common root cause and would enable the appropriate countermeasures to be identified and implemented.

It is recommended that more hotspot analysis is done to further investigate the potential presence of resident road safety failures on the SRN.

A.3.1 Hotspot 1: 70 mph Motorway located in the South East of England.

The four fatal collisions were varied in the specific mechanisms and root causes that led to the collisions occurring and the types of road users involved. However, there were some intervention types that were common to multiple collisions at the locus despite differing root causes. The distribution of all intervention types are shown in Table 8.

Table 8: Critical intervention type and distribution within collisions that occurred at Hotspot 1

Intervention type	% Distribution in collisions (n = 4)
Reduce collision energy	75%
Prevent inattentive/impaired driving	50%
Prevent run off road collision types	25%
Improve VRU visibility	25%
Prevent vehicle fire occurring	25%
Safer roadside design	25%
Improved vehicle occupant safety	25%
Prevent impaired driver from starting their journey	25%
Change driver behaviours in specific situations	25%
Prevent pedestrians entering the carriageway	25%

A.3.2 Hotspot 2: Single and Dual Carriageway A-road in South West England

The collision locus is far less consistent than Hotspot 1 because the road undulates, changes carriageway class and has multiple bends. The eight fatal collisions also have a variety of collision types, road user types and root causes. However, the collisions shared fewer critical intervention types and the majority of the collisions had the same two critical interventions as the collisions in Hotspot 1. The distribution of all intervention types are shown in Table 9.

Table 9: Critical intervention type and distribution within collisions that occurred at Hotspot 2

Intervention type	% Distribution in collisions (n = 8)
Reduce collision energy	88%
Prevent inattentive/impaired driving	75%
Improve licencing	50%
Promote vehicle maintenance	38%
Change driver behaviours in specific situations	25%
Improved vehicle occupant safety	13%
Prevent careless/dangerous driving	13%
Safer roadside design	13%

The specific recommendations for each hotspot are focused around these intervention types and the existing countermeasures that can potentially achieve them. Further research is required to assess and quantify the potential effectiveness of the specific countermeasures recommended. The Highways England Fatality dataset can support cost-benefit analysis of specific countermeasures by identifying the target population and ultimately be used as the evidence base for casualty benefit analysis.

Appendix B Sample Analysis

B.1 Results

There are currently 450 fatal collisions which have occurred on the SRN available on the fatality database (Figure 14). These collisions occurred between 2014 and 2016. The police files for fatal collisions which occurred in 2017 are currently being collected and analysed.

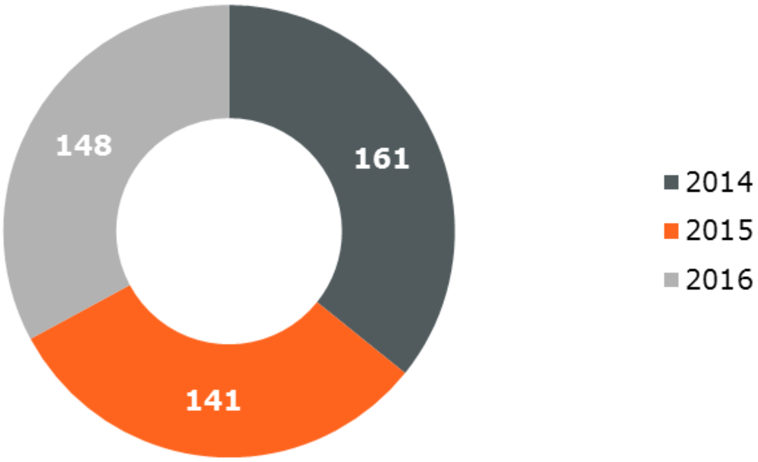


Figure 14: Total number of fatal collisions in the fatality database (n=450)

Total number of:	2014	2015	2016	2017
Fatal collisions on the SRN	192	202	211	203
Police collision files requested	192	202	211	203
Police collision files received and analysed	161	141	148	Currently 33
Fatal casualties coded into the database	233	203	222	Coding on-going

Figure 15 shows the monthly distribution of the fatal collisions for the years 2014, 2015 and 2016. The greatest amount of collisions occurred in the month of July.

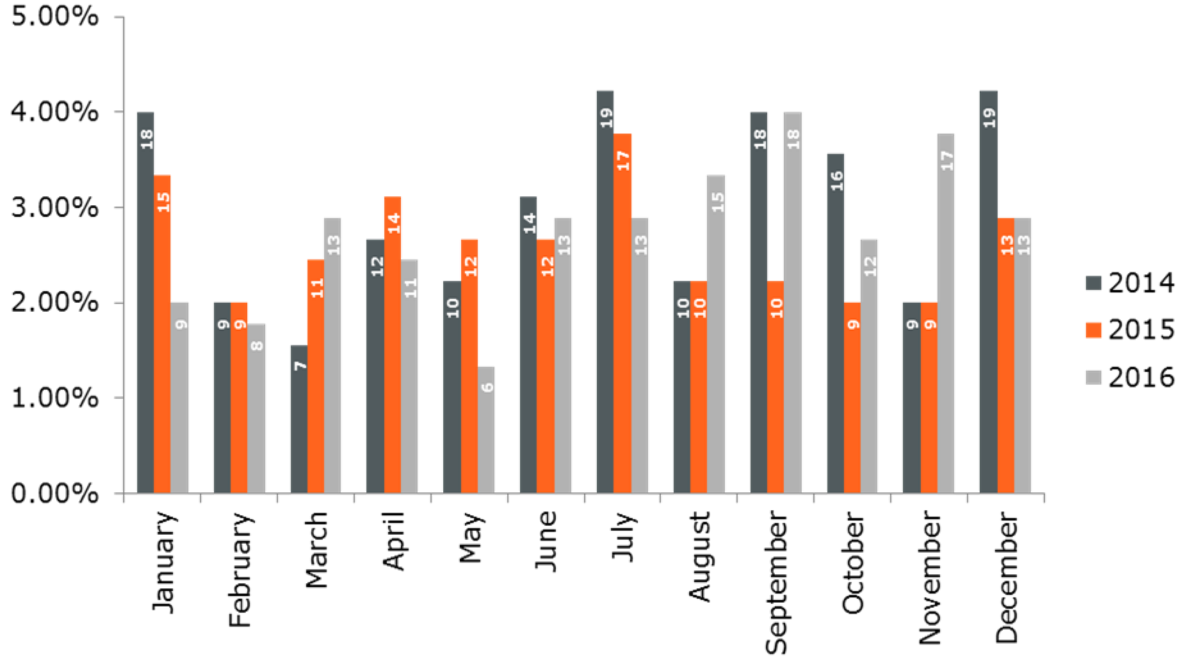


Figure 15: Monthly occurrence of fatal collisions occurring on the SRN (n=450)

B.1.1 Analytics

B.1.1.1 Collision type

Each case is assigned a collision code. This code determines the scenario in which the collision has occurred. 21% of the collisions included a vehicle losing control or the vehicle travelling off road whilst on a straight road.

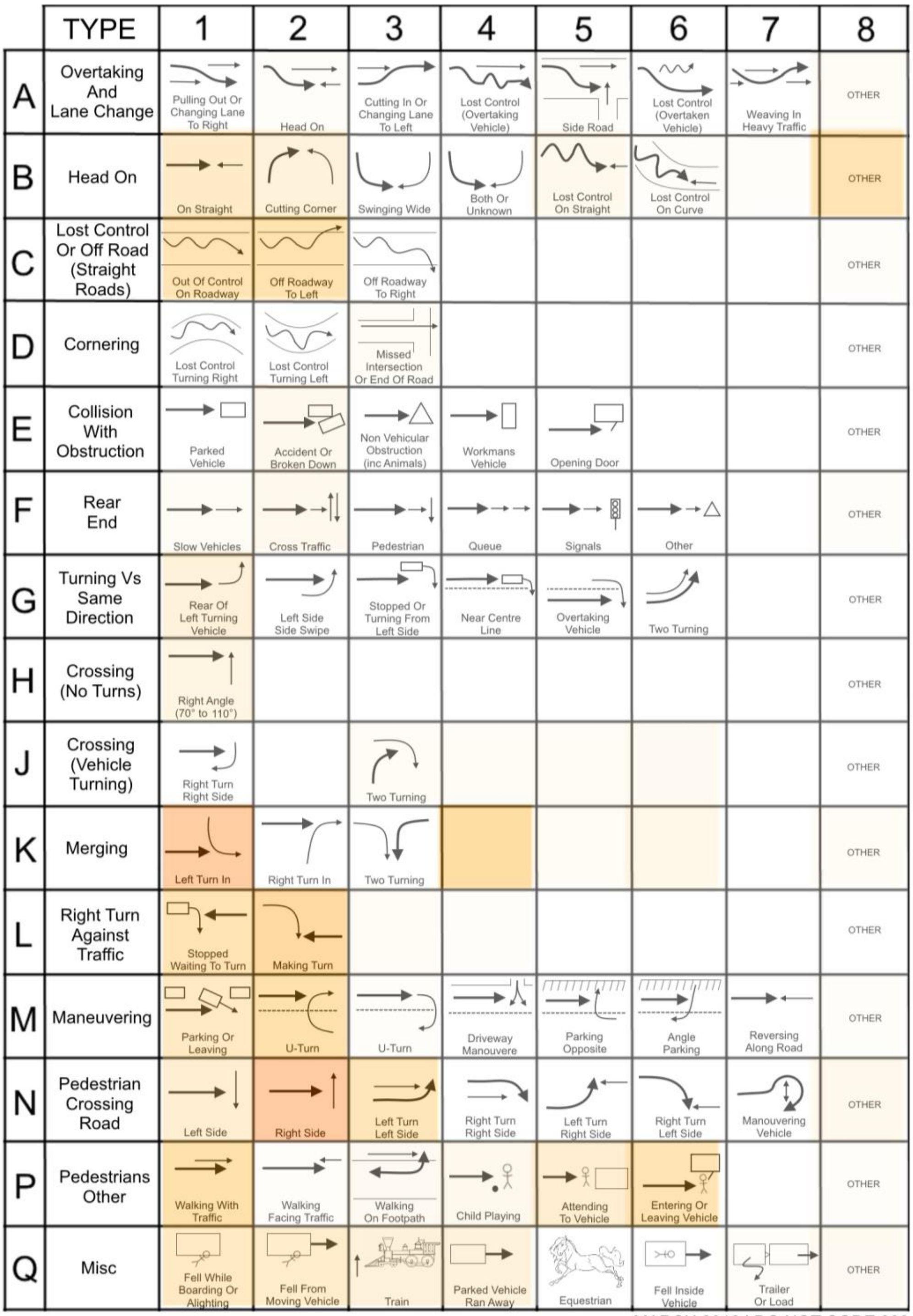


Figure 16: Heat map showing the most frequent collision types (n=450)

B.1.1.2 Demographics

There are 658 fatalities recorded in the database. The demographic information of the fatalities is presented in this section.

Figure 17 presents the fatalities in their road user class by their gender and shows:

- 74% of all fatalities in the sample are males from all road user classes
- Females were primarily killed in passenger cars (80% of all female fatalities) and account for 19.6% of all passenger car fatalities
- The gender of seven car occupant fatalities and one alighted occupant fatality were not reported in the source information and as a result they have been coded as an unknown gender

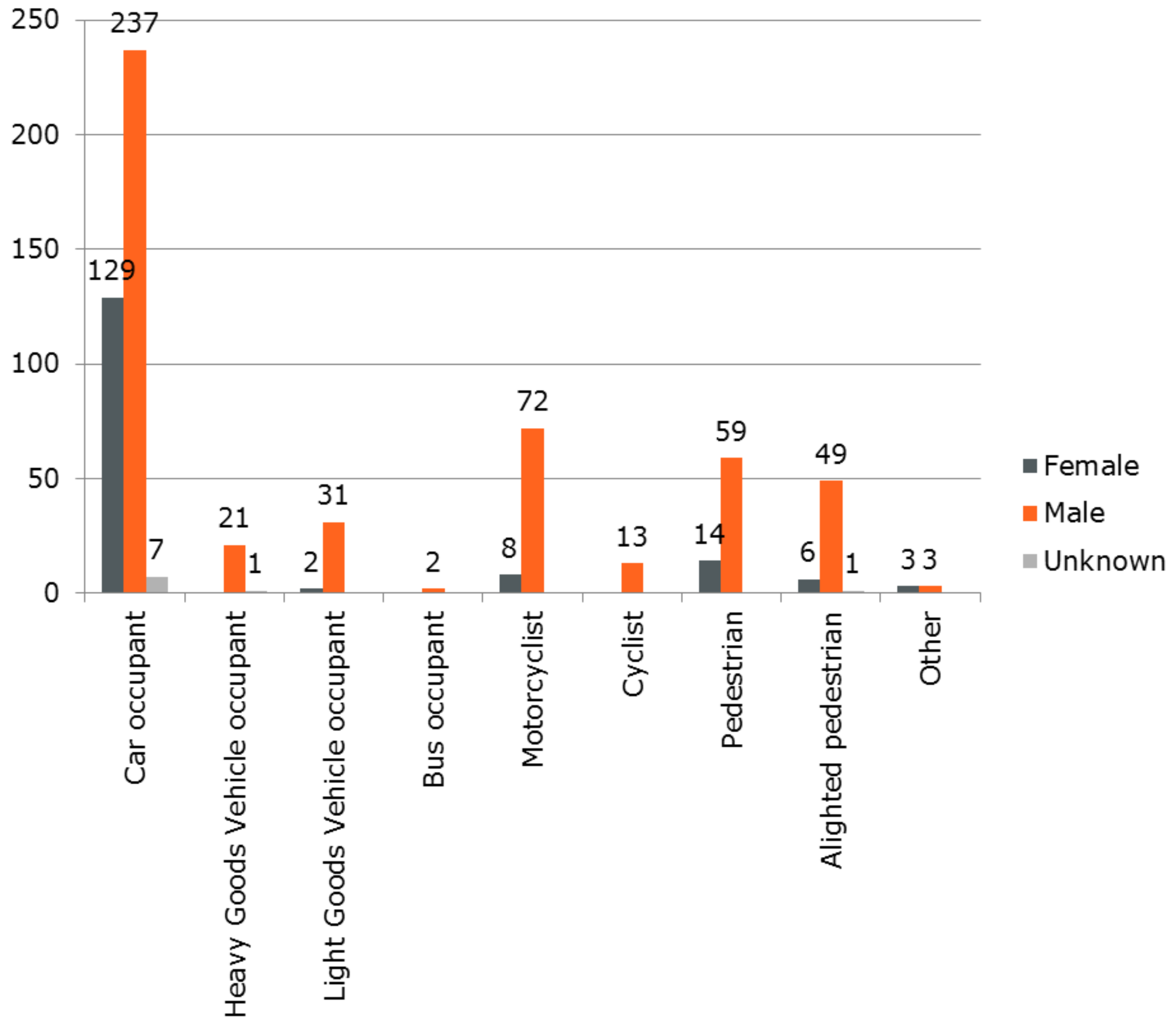


Figure 17: Occupant type and gender of all fatalities (n=658)

The age distribution of all fatalities is present in Figure 18.

- There is a large proportion (22%) of fatalities which had no reported age in the source information and have been coded as ‘unknown’. This is recognised as a limitation of this work and it is recommended that future studies collate the STATS19 information with the police fatal files to address and other unknowns
- The largest proportion of fatalities with a known age are between 25 to 34 years old (16.1%) followed by fatalities between 35 to 44 years (14%)
- People of all ages are killed, including nine children less than 16 years

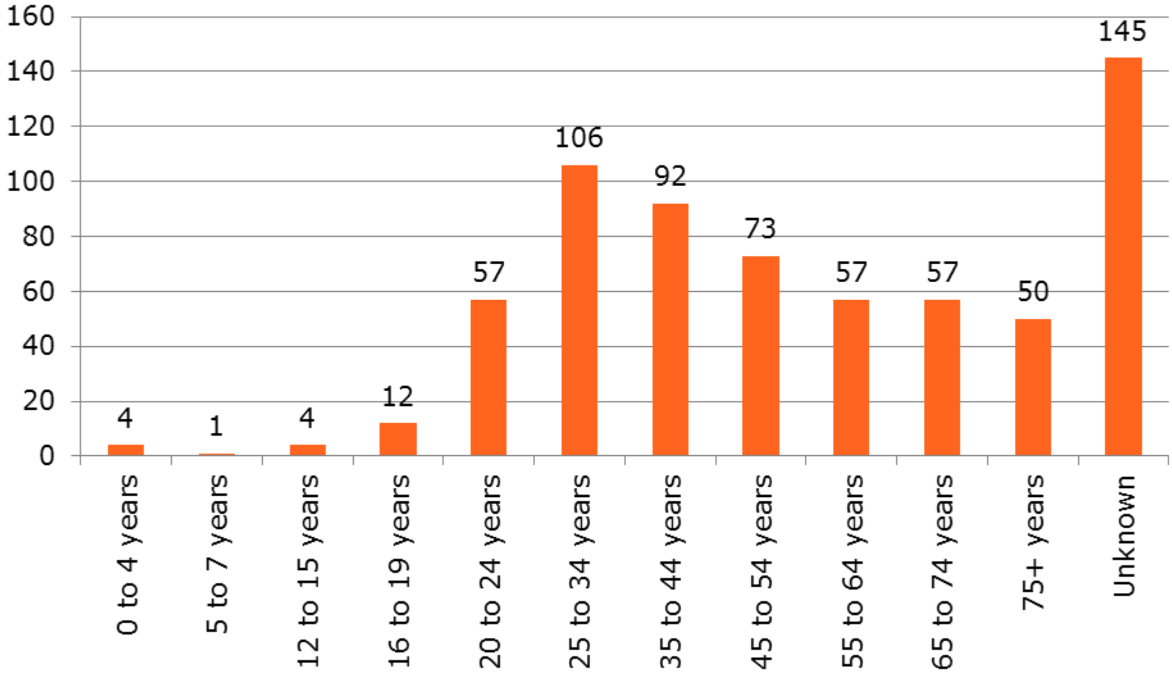


Figure 18: Age group distribution of all fatalities (n=658)

A further breakdown of the fatalities showing road user class as well as age group is present in Table 10:

- Of the nine child fatalities (0-16 years old) seven were killed in cars and two were alighted occupants.
- Killed occupants who alighted from their vehicles and entered the carriageway were from a wide spread of age bands. The most recorded age band was 25 to 34 year olds.
- This was a similar finding for pedestrians killed in the carriageway.

Table 10: Occupant type and age of all fatalities (n=658)

Age group (years)	Car	HGV	LGV	Bus	Motorcyclist	Cyclist	Pedestrian	Alighted Occupant	Other	Total
0 to 4	3	0	0	0	0	0	0	1	0	**4**
5 to 7	1	0	0	0	0	0	0	0	0	**1**
12 to 15	3	0	0	0	0	0	0	1	0	**4**
16 to 19	6	0	0	0	0	0	4	1	1	**12**
20 to 24	35	0	3	0	10	0	4	5	0	**57**
25 to 34	50	1	9	0	19	1	14	12	0	**106**
35 to 44	47	6	7	0	7	3	14	6	2	**92**
45 to 54	35	6	4	2	16	3	2	5	0	**73**
55 to 64	31	2	0	0	10	3	4	7	0	**57**
65 to 74	44	0	3	0	4	0	3	3	0	**57**
75+	37	0	0	0	0	0	10	0	3	**50**
Unknown	81	7	7	0	14	3	18	15	0	**145**
Total	**373**	**22**	**33**	**2**	**80**	**13**	**73**	**56**	**6**	**658**

B.1.1.3 Vehicle occupants

Table 11 shows the number of occupants in each vehicle type and the fatality rate. Note that only road users who were injured or who influenced the collision are coded.

Table 11: Vehicle type and fatality rate

Vehicle type	Total number of occupants	Number of fatalities	Fatality rate %
Car	1047	373	36
HGV	266	22	8
LGV	91	33	36
Motorcycle	89	80	90
Pedestrian	77	73	95
Bus/coach	17	2	12
Bicycle	13	13	100
Other	16	6	38
Untraced/not coded	26	0	0
Alighted occupants	68	56	82
Total	1710	658	38

B.1.1.4 Vulnerable Road Users

Clearly, passenger car occupants are the most frequently killed people on the SRN. However, the proportion of Vulnerable Road Users (VRUs) who are killed is substantially greater than any other road user class. VRUs include motorcyclists, cyclists and pedestrians (including alighted pedestrians).

The lowest fatality rate was for HGV occupants at 8%, followed by bus/coach occupants at 12%.

B.1.1.5 Motorcyclists

There were 61 fatal collisions involving motorcycles analysed and coded into the fatality database. 31% of the motorcycle collisions occurred during an overtake or lane change.

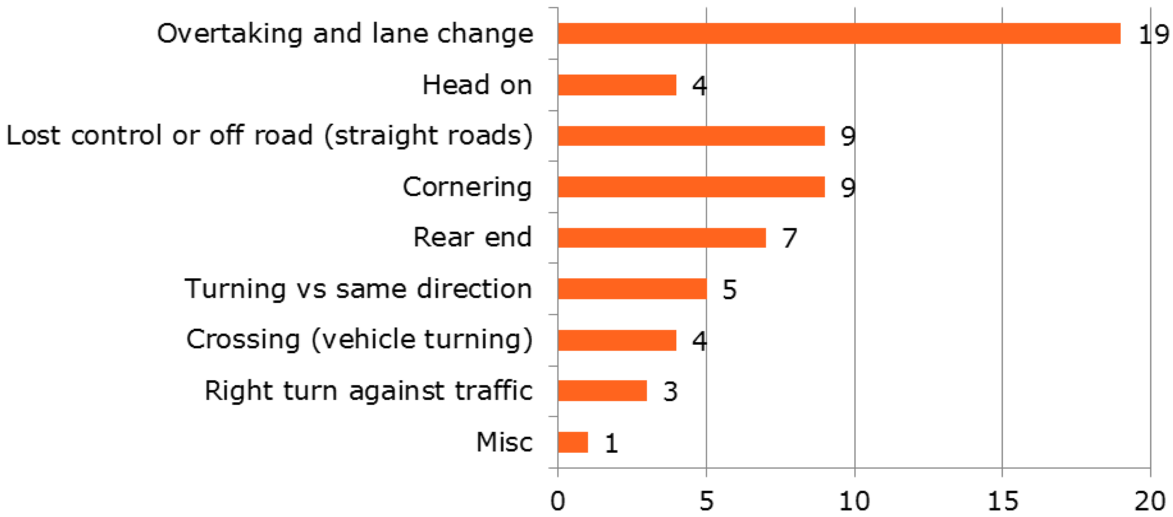


Figure 19: Collision type for motorcycle collisions (n=61)

B.1.1.6 Cyclists

There were 12 fatal collisions involving pedal cycles: 50% of the collisions involved the pedal cycle being struck from behind by another vehicle.

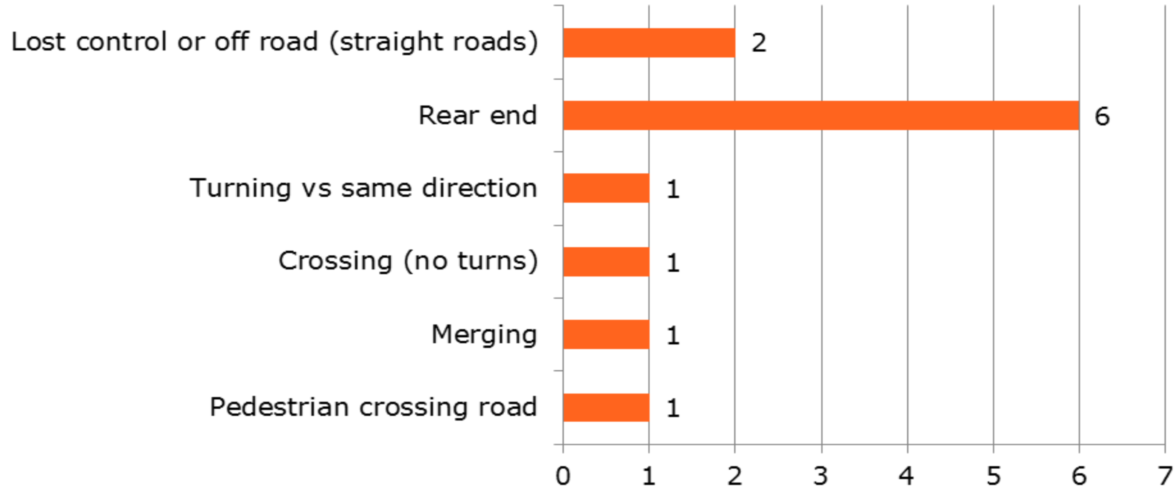


Figure 20: Collision type for cyclist collisions (n=12)

B.1.1.7 Pedestrians

There were 103 fatal collisions where 77 pedestrians and 68 alighted pedestrians were involved.

The alighted occupant group was devised to avoid confusion about which road users were genuinely pedestrians on the carriageway and which were originally vehicle occupants. Similarly, those road users who are in the process of alighting or have recently alighted from their vehicles and entered the carriageway but were not perceived as pedestrians by the other road users. This also avoids discrepancies when coding a person as either an occupant or a pedestrian.

Figure 21 shows the collision types in which pedestrians and alighted pedestrians were involved.

- 41% of the 103 collisions were classified as 'pedestrian other'
- 67% of 'pedestrian other' collisions were assigned to pedestrian cases

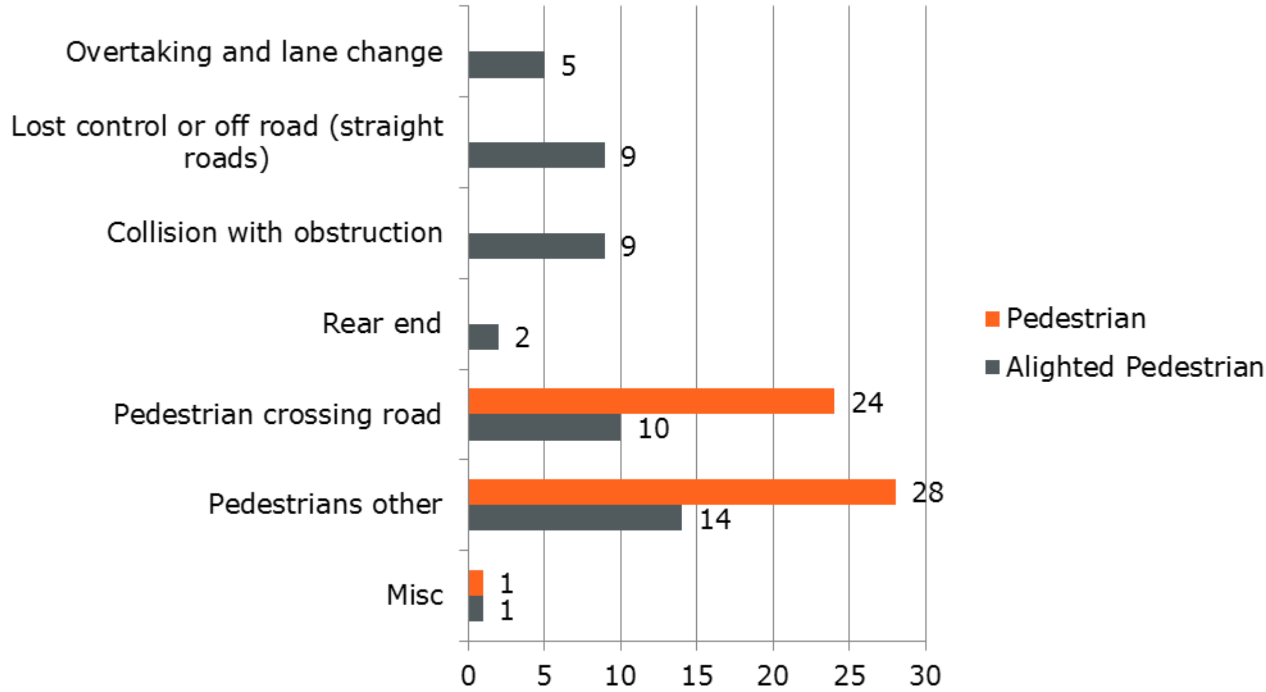


Figure 21: Collision type for pedestrians and alighted occupants (n=103)

B.2 Causation Factors

Each case within the fatality database is assigned causation factors. These are based on the codes used by the police outlined in STATS19. A collision can have any number of causation factors attributed to them; for example a case may consist of multiple environmental causation factors. The investigator uses their knowledge and experience of collision investigation to assign any other causation factors which haven't been assigned by the police. The causation factors are divided into three groups: road, human and vehicle. Overlapping causation factors will influence the occurrence or outcome of a collision due to inter-relationships.

Environment Factors

- Weather
- Highway design
- Roadside features

Human Factors

- Distraction
- Fatigue
- Vehicle operation

Vehicle Factors

- Vehicle condition
- Maintenance
- Stability

Figure 22 shows the overlap of the grouped causation factors:

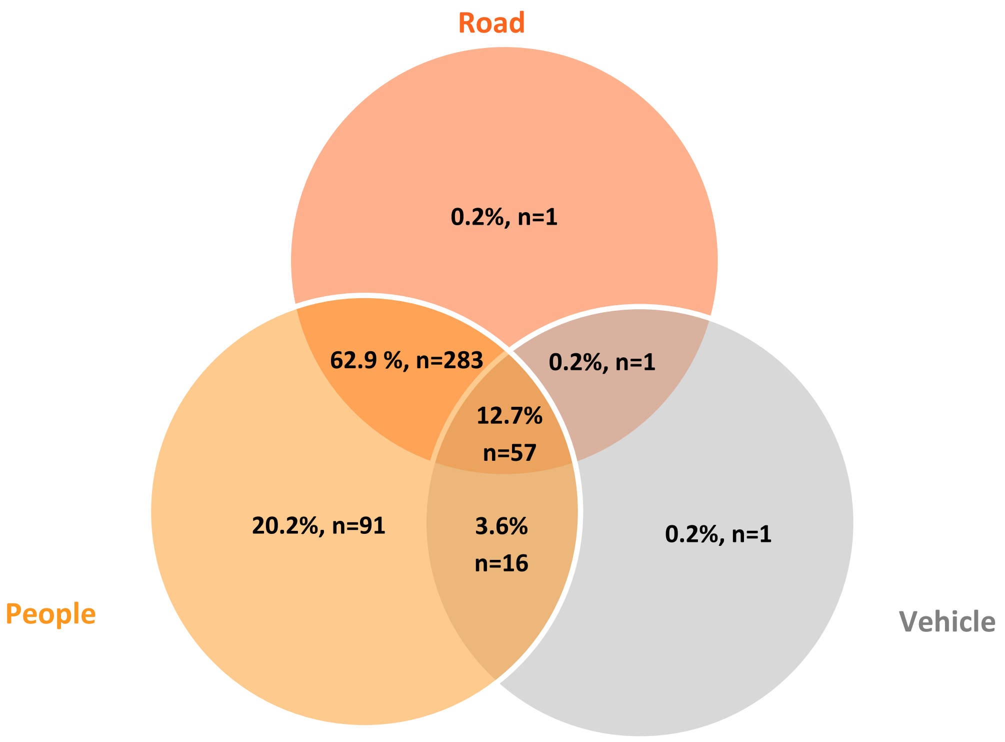


Figure 22: Venn diagram showing assigned causation factors by group at case level (n=450)

B.2.1.1 Road Causation Factors

There were 271 road factors assigned within the 450 fatal collisions with the fatality database. The most recorded road factor was poor or no street lighting at site (n=83).

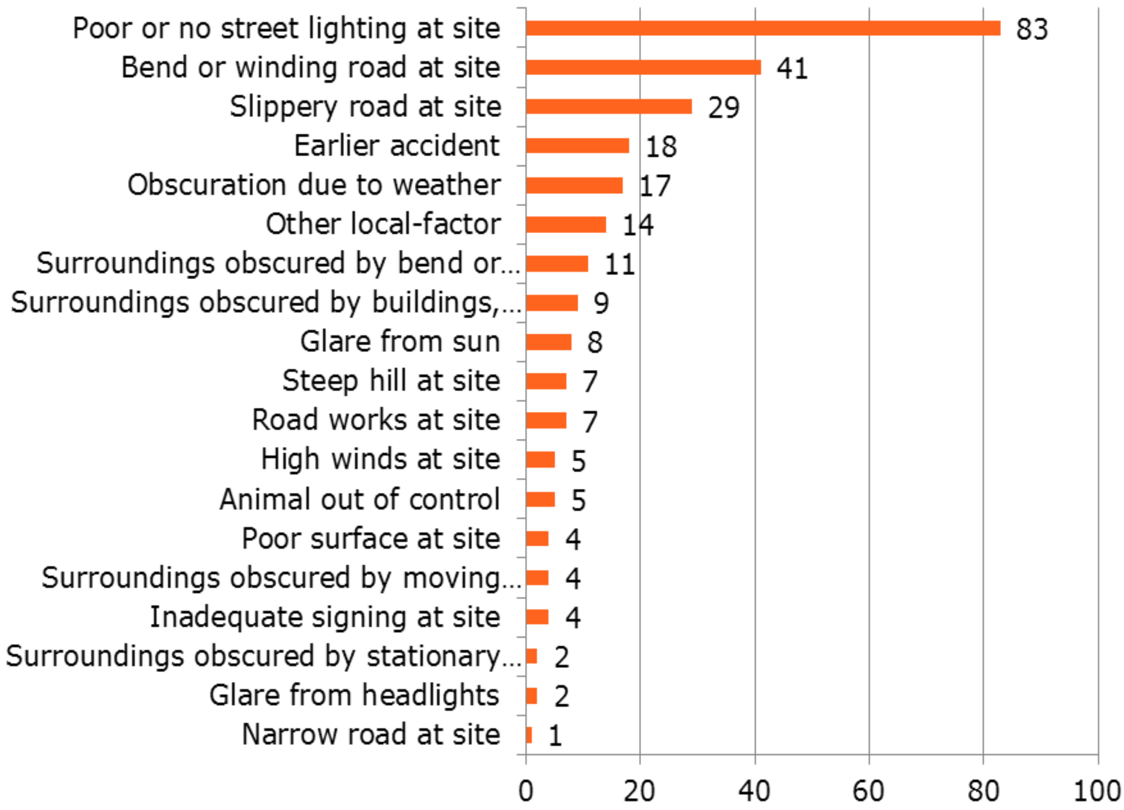


Figure 23: Environment causation factors (n=271). Note that a collision can have any number of environment causation factors attributed to them

B.2.1.2 Vehicle Causation Factors

There were 43 vehicle factors assigned within the 450 fatal collisions coded into the fatality database. The most recorded vehicle factor was defective tyres (n=22). Other defects include:

- A vehicle where the bonnet detached from the latch and smashed into the windscreen
- A vehicle that suffered catastrophic clutch failure inducing loss of control

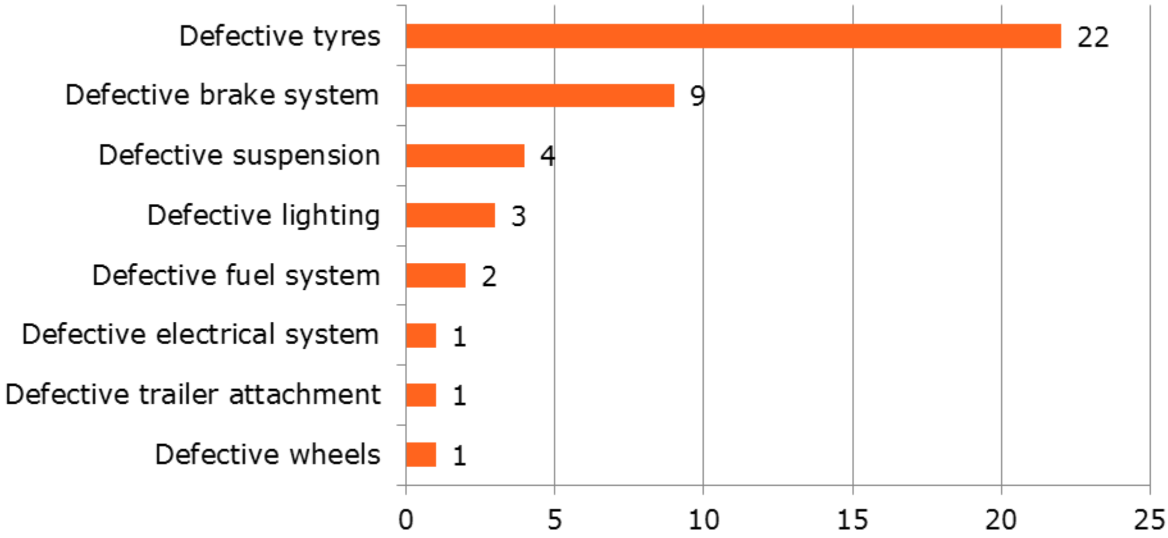


Figure 24: Vehicle causation factors (n=43). Note that a collision can have any number of vehicle causation factors attributed to them

B.2.1.3 Human Causation Factors

There were 3,103 human factors assigned within the 450 fatal collisions in the fatality database. The top six occupant causation factors account for 48% of all assigned human causation factors.

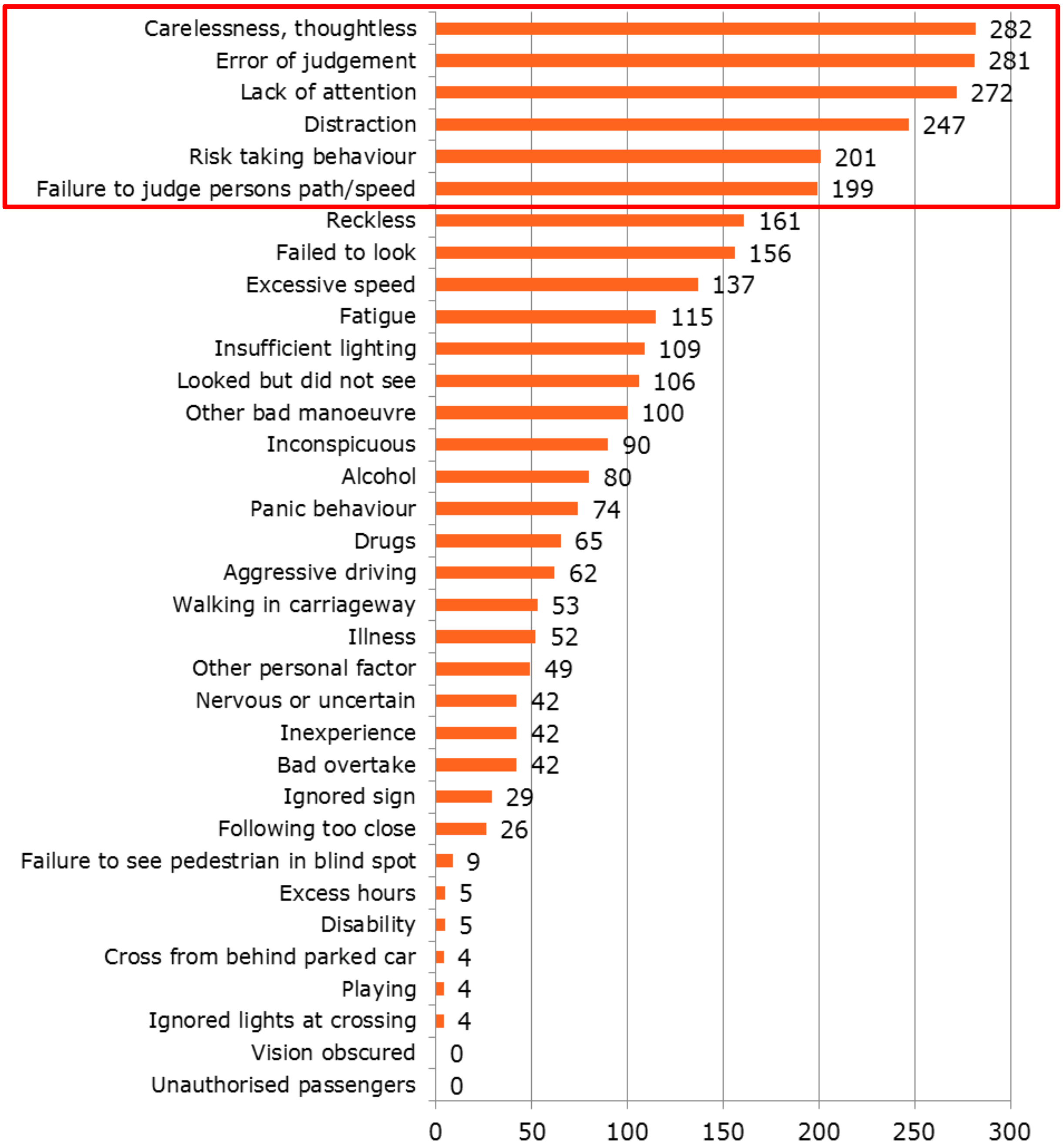


Figure 25: Human causation factors (n=3103). Note that a collision can have any number of occupant causation factors attributed to them

Appendix C Countermeasures

All road users are exposed to a variety of risks at all times. The Swiss Cheese Model (Figure 26) shows that the alignment of one or more of these risks can result in a collision. This is important to understand the nature of collision causation, as it may be any combination of factors that result in a collision and any combination of factors that result in a fatality.

Changing the risk in any layer can mitigate the severity of the collision or prevent it entirely. The fatality database uses this model to record all of the factors influencing the occurrence and outcome of a fatal collision.

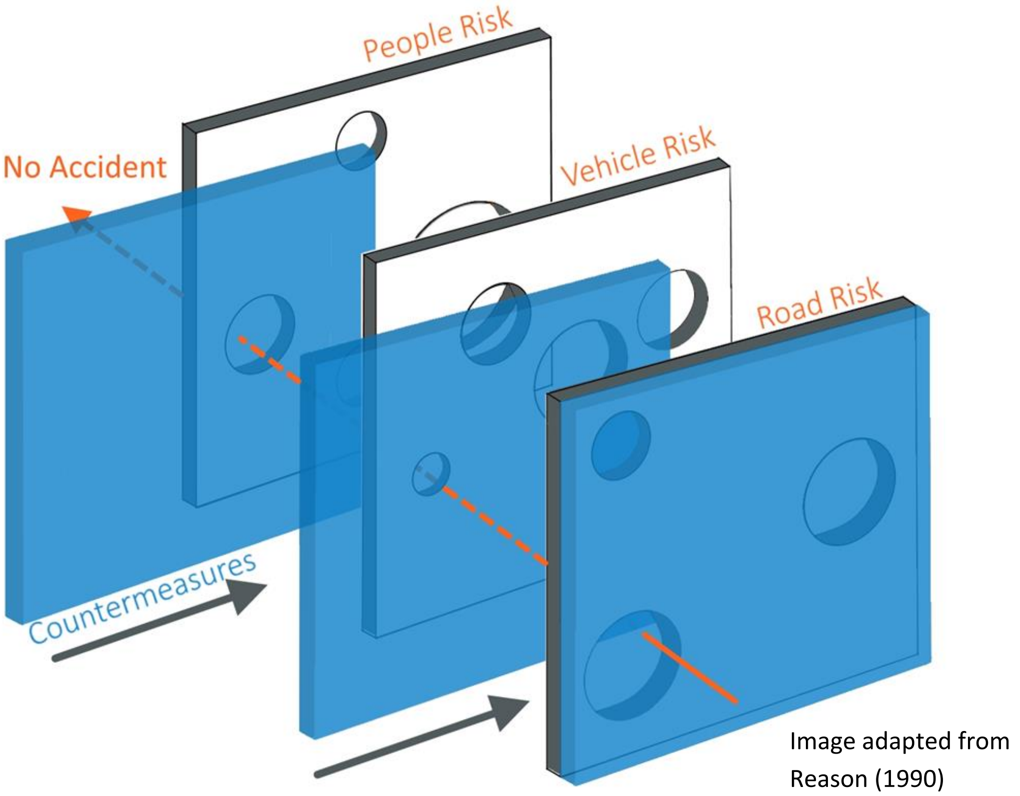


Figure 26: Countermeasures Swiss cheese model

Countermeasures are identified to intervene and alter the root causation factors that resulted in the fatal collision. Each individual countermeasure can influence the people, vehicles or road environment involved in each collision. Any number or combination of countermeasures can be applied based on their effectiveness or likelihood of preventing the fatality which is graded with high, medium or low confidence.

The Haddon Matrix is the most frequently used concept in the injury prevention domain (see Figure 27). This shows how countermeasures can be assigned according to the stage of the collision and the category of the countermeasure. The holistic recording of collision causation factors results in a strong evidence base with which to determine collision countermeasures: actions that can avoid the collision itself, or mitigate its injury outcome. These can be directly linked to the safe systems approach to provide an evidence base for the design of a safer overall transport system and provide an understanding of specific countermeasures and in which categories of 'people, vehicle, road' the countermeasures lie. This information can inform ways in which Highways England could most effectively meet their stragetic plan for a reduction in network KSIs of at least 40% by the end of 2020 against the 2005-09 baseline.

	People	Vehicle	Road
Pre-crash	Improved driver training Driver awareness	Better maintenance Primary safety (e.g. tyres and brakes)	Improved road surface Improved highway layout/design
Crash	Use of safety systems (e.g. helmet or seatbelt)	Secondary safety Presence and performance of safety systems	Remove road side hazards Barrier performance
Post-crash	Incident response eCall systems	Fuel system Safety pyrotechnics Vehicle design standards	Infrastructure performance (e.g. access for emergency services)

Figure 27: The Haddon matrix (with example countermeasures)

36.4% of the 450 collisions coded in the HE Fatality database included environment, vehicle and human countermeasures. Eight cases had unknown countermeasures, this is primarily due to the suspected deliberate nature of the collisions in which no meaningful countermeasures could be applied. The interesting comparison is with the causation Venn diagram (Figure 18) where the majority of cases were centred on human and vehicle factors, where the countermeasures can be applied to humans, vehicles or the environment.

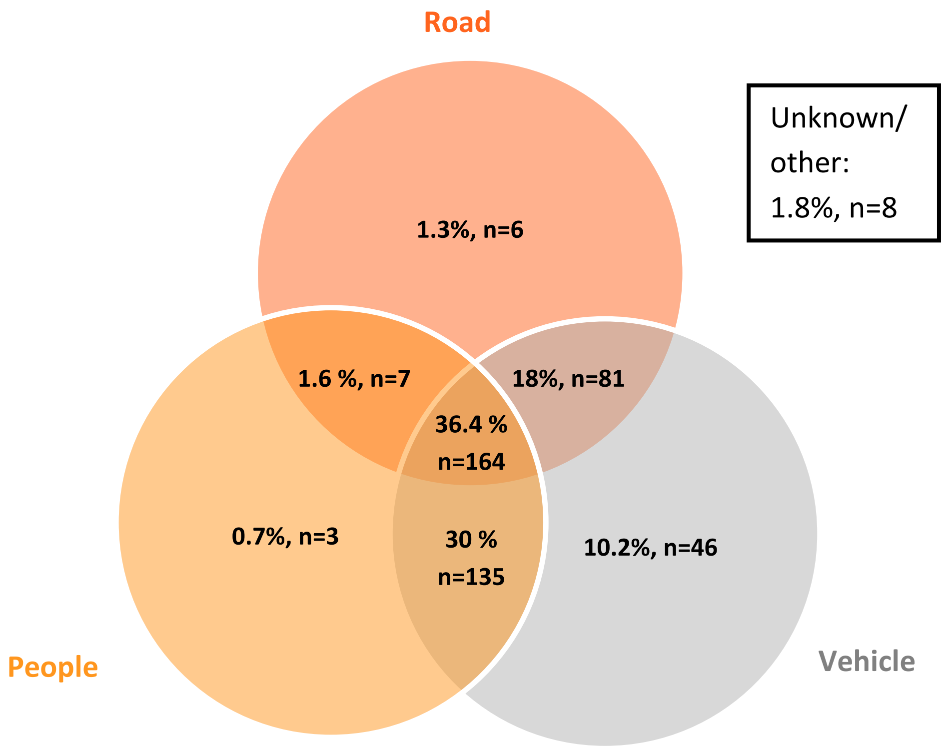


Figure 28: Venn diagram showing assigned countermeasures by group at case level (n=450)

In total there were 2,249 possible countermeasures applied to the coded cases. The collision investigators assess the countermeasure's ability to either avoid the collision entirely or mitigate the severity of the injuries and prevent the fatalities. The investigator's confidence enables the countermeasures to be graded, and those with high or medium confidence for avoidance or mitigation are defined as potentially the most effective countermeasures to the fatal collisions. Figure 29 shows all countermeasures by their effectiveness to avoid and/or mitigate the collision. The measures within the red boundaries are the most effective (n=1397), as they are rated as either medium and/or high for both categories.

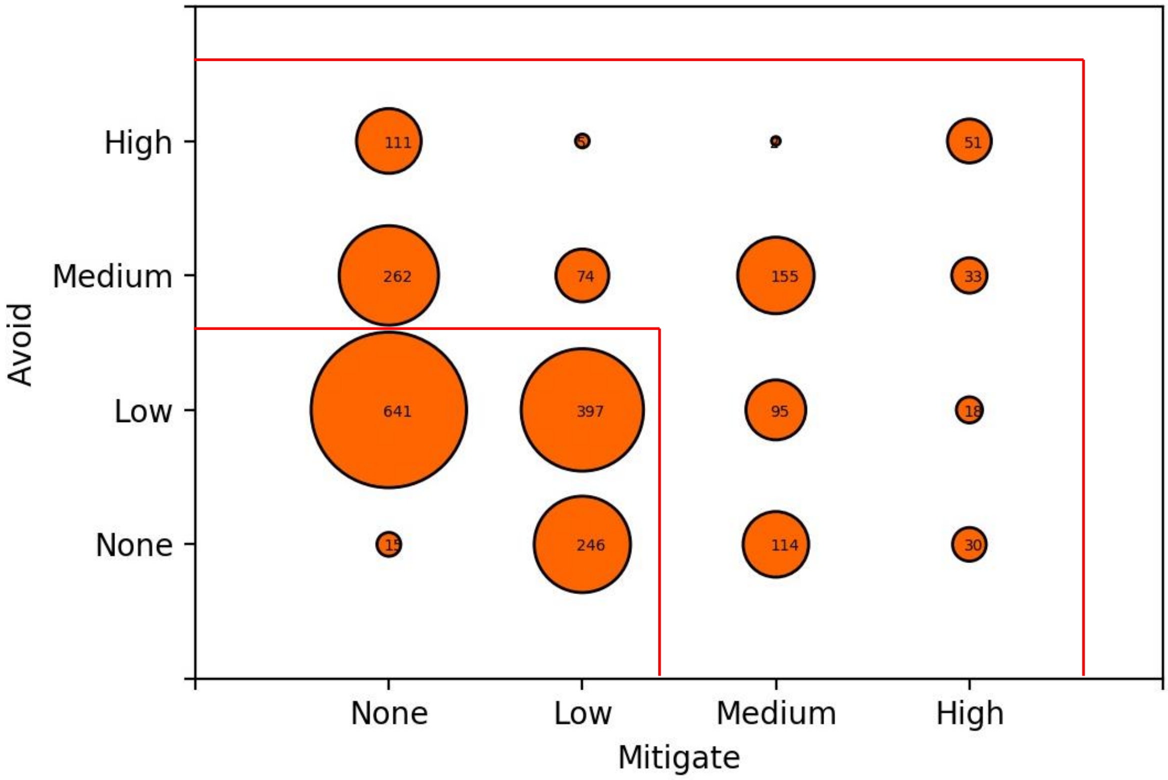


Figure 29: Bubble chart showing all countermeasures by effectiveness (n=2249)

C.1.1.1 Effective Road Countermeasures

There were 436 road countermeasures assigned to the 450 fatal collisions coded with the fatality database. The highest two coded countermeasures were to 'add street lighting' (n=111) and to 'shield hazard with a vehicle restraint system or improve the system' (n=109). The assessment of roadside protection follows the forgiving roadside principals. When assessing countermeasures to prevent striking roadside hazards the priorities are to:

1. Remove the hazard from the clear zone
2. Relocate the hazard beyond the clear zone
3. Make the hazard passively safe
4. Shield the hazard with a vehicle restraint system
5. Delineate the hazard

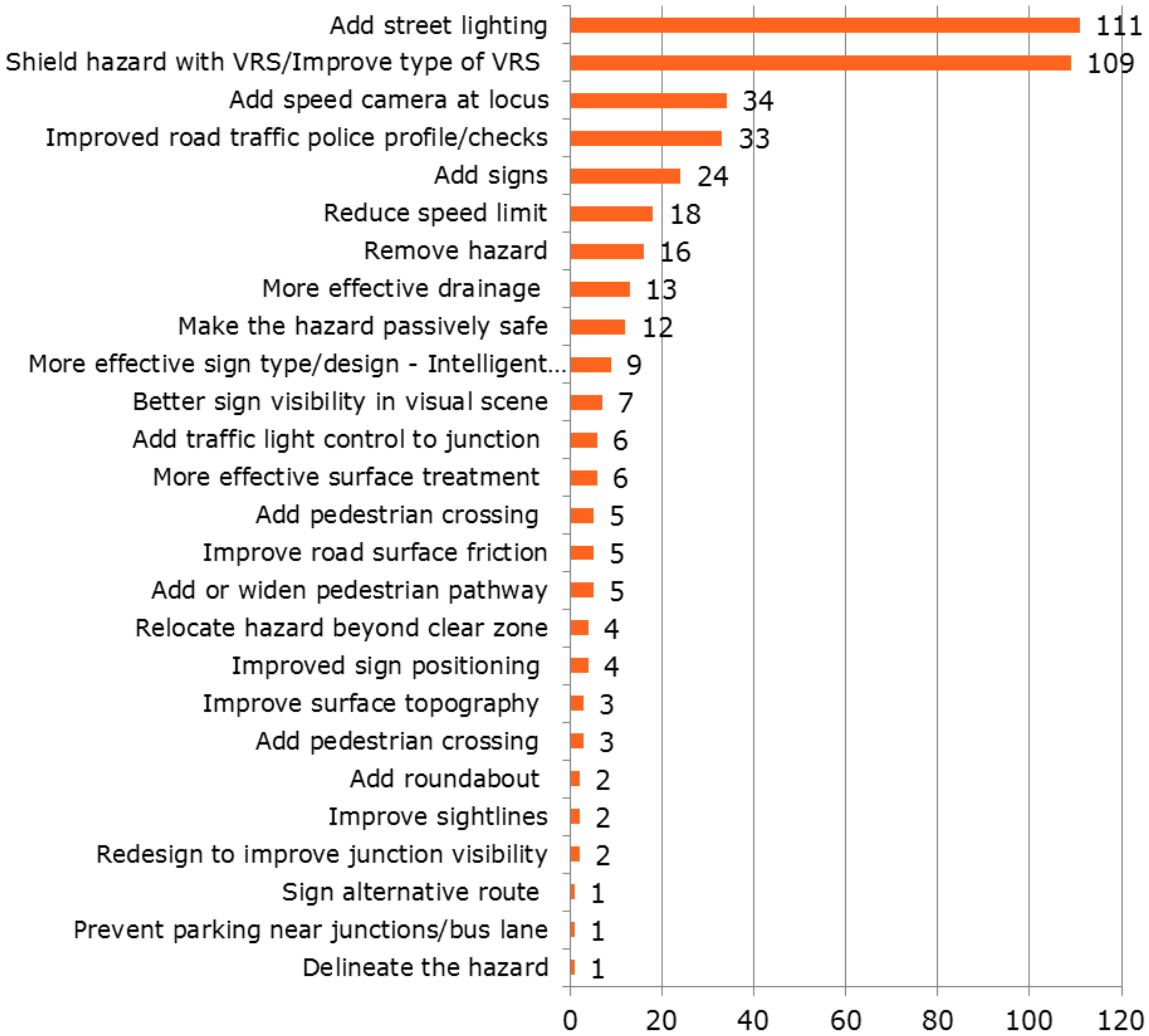


Figure 30: Effective environment countermeasures (n=436)

C.1.1.2 Effective Vehicle Countermeasures

There were 1,375 vehicle countermeasures assigned. The highest coded vehicle measure was Autonomous Emergency Braking (AEB – vehicle-to-vehicle) (n=209).

Figure 31: Effective vehicle countermeasures (n=1375)

C.1.1.3 *Effective Human Countermeasures*

There were 350 human countermeasures assigned to the cases. The top four human measures included training for various aspects of driving; hazard perception, pre-driving behaviour, risky driving manoeuvres and risk behaviours whilst driving. These four measures account for 71% of all human countermeasures.

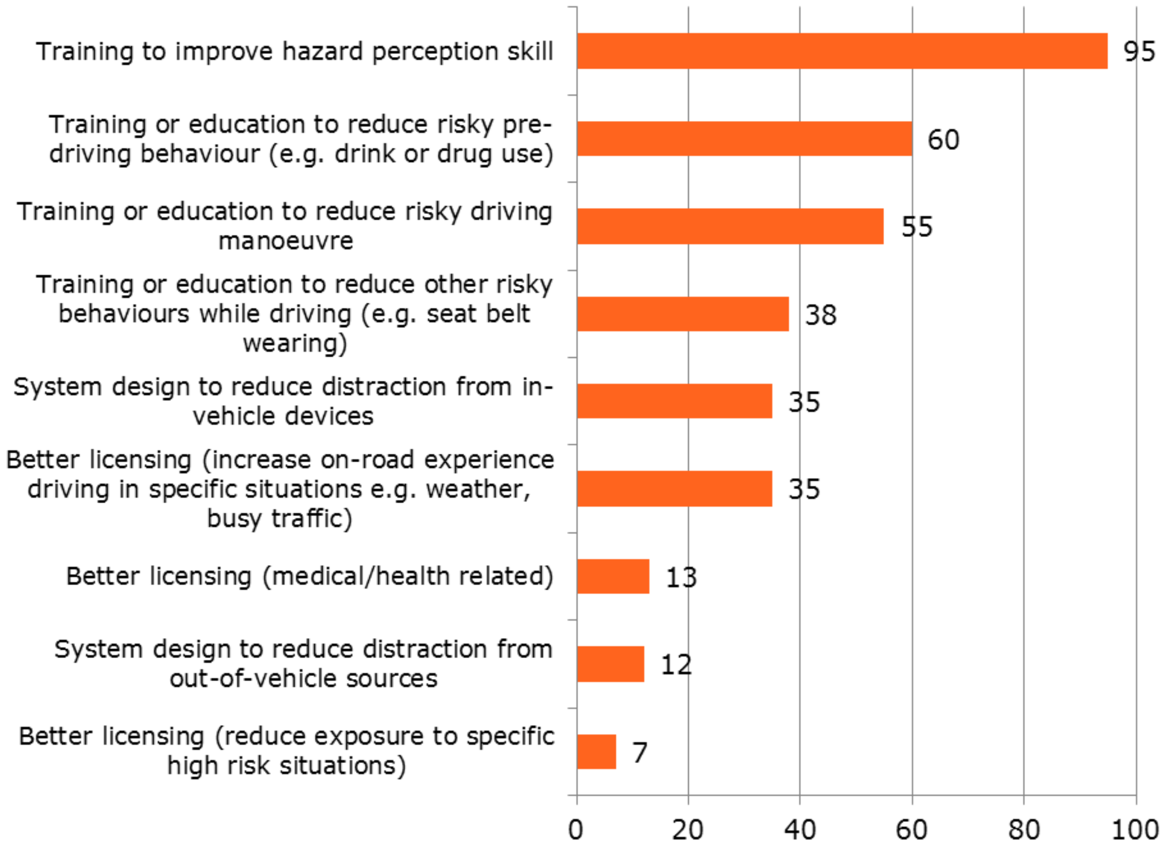


Figure 32: Effective human countermeasures (n=350)

The remaining 88 countermeasures were classified as 'Other'. This category is used by the investigator to describe measures which haven't been listed. Examples include traffic light recognition and improve HGV frontal crashworthiness.

Towards Zero: 2014 to 2016 fatal collisions

The Highways England Fatality Research programme collects police collision investigation reports of fatal collisions that occurred on the Strategic Road Network. The collisions are reinvestigated with a safe-systems approach and coded into the Highways England Fatality database, hosted within the RAIDS database. Analysis of the fatal collisions (that occurred in 2014 to 2016) shows that their root cause is often a result of more complex interactions between the people, vehicles and road environment than analysis of less detailed datasets has previously shown. Countermeasures that could prevent the loss of life can apply to all facets of the safe-system. Thematic and Hotspot analysis was also conducted to provide more focused recommendations on how these collisions could have been avoided or their severity mitigated.

Other titles from this subject area

PPR808	The methodology and initial findings for the Road Accident In Depth Studies (RAIDS) Programme. Richard Cuerden and Mike McCarthy. 2016
PPR896	RAIDS Year 2 Annual Report, Adam Barrow, Mike McCarthy and Rahul Khatry, 2018
CPPR2264	Towards Zero: Study on fatal collisions on the SRN during 2014. Michael McCarthy and Adam Barrow. 2016

TRL

Crowthorne House, Nine Mile Ride

ISSN 2514-9652

ISBN 978-1-912433-95-7

PPR913