THE FUTURE OF TRANSPORT

PUBLISHED PROJECT REPORT PPR2051

Motorcyclists and Barriers on the National Highways Road Network

C Erginbas, J Hammond, C Collis

Report details

Report prepared for:	National Highways		
Project/customer reference:	T0389		
Copyright:	© TRL Limited		
Report date:	30 November 2020		
Report status/version:	1.0		
Quality approval:			
Alison Kaminski (Project Manager)		David Hynd (Technical Reviewer)	

Disclaimer

Table of Contents

Executive summary

The aim of this report is to use findings from a review of literature and detailed incident data analysis to make recommendations to National Highways to help them develop a risk reduction policy specifically for motorcyclist to barrier incidents.

This report is an update of work done previously by TRL for Highways England in 2014. The previous work comprised a literature review, review of available motorcyclist protection systems on the market and their testing. It also included quantitative data analysis and statistics. In this report, the analysis and statistics have been updated using the most recent available data, but the literature review and testing sections remain unchanged from the 2014 work.

The risks posed to motorcyclists impacting roadside barriers have been raised by motorcyclists' groups throughout Europe and have become a focus in road safety research. The risks arise largely because a vast majority of the vehicle restraint systems installed along the roads today are not designed with motorcyclists in mind and motorcyclists impacting them are at risk of severe injury due to the sharp edges of exposed posts.

A literature review was carried out to understand the nature of motorcycle-to-barrier incidents, how different countries across the world are addressing this problem, and what solutions are available and how these solutions are being used in the UK. The review found that there is clear evidence within existing published literature that motorcycle-to-barrier impacts are infrequent, but high severity incidents. Additionally, it was found that current Motorcyclist Protection Systems (MPS), designed to reduce risk of injury to a motorcyclist when impacting a safety barrier, are only likely to reduce injury risk in around half of cases because they are only designed for impacts where a motorcyclist is sliding along the ground.

Casualty data for the Strategic Road Network (SRN) was analysed to understand the scale of motorcycle-to-barrier incidents on National Highways's network. This showed that the number of motorcycle-to-barrier incidents was small (accounting for only 0.2% of all SRN casualties). However, the need to make barriers safer for motorcyclists was highlighted by the fact that 76% of motorcycle-to-barrier impacts resulted in killed or seriously injured (KSI) casualties between 2014 and 2018 compared with 16% for non-motorcycle-to-barrier impacts. When distance travelled per year is accounted for, the figures show that motorcycles are heavily overrepresented in high severity incidents. More specifically, motorcycles (with 2.33 fatal collisions per billion vehicle kilometres) are roughly 33 times more likely to become involved in a fatal single vehicle barrier incident than cars (with 0.07 fatal collisions per billion vehicle kilometres).

There were 174 motorcycle-to-barrier incidents on the SRN between 2014 and 2018 which were analysed in detail to investigate the common characteristics of these types of incidents. The results showed that motorcycle-to-barrier incidents are most common at junctions and particularly within grade-separated junctions. Slip roads accounted for almost a quarter of motorcycle-to-barrier incidents, the largest proportion of any single road type. Cluster analysis of the incident data supported this finding, with seven out of ten identified clusters including at least one incident on a tightly curving slip road or loop within a grade-separated junction.

It was also found that there were a similar number of motorcycle-to-barrier incidents on slip roads with a curve radius less than 100 m as there were on straight link road sections. This indicates that installing smaller lengths of MPS on curved slip road sections could provide similar benefits to installing longer lengths on a straight road, which is known to be more difficult and costly.

Recommendations have been made for a risk reduction policy and for how to prioritise locations to assess for motorcycle risk. The recommended policy is as follows:

- Investigate the methods that would decrease the probability of a motorcyclist leaving the carriageway (e.g. improving road surface, improved signage or better visibility).
- Where possible, remove any existing hazard(s).
- Where possible, move any existing hazard(s) further from the carriageway.
- Where possible, make the hazard(s) passively safe for an impact by a motorcyclist (as there is no published testing standard to ascertain the passive safety performance of roadside hazards through an impact by motorcyclist, engineering judgement should be used to make this assessment).
- With consideration of the safety for all road users, remove any unnecessary lengths of barrier.
- If the hazard cannot be removed, relocated or made passively safe for motorcyclists, then installation of an MPS, compliant with TS 1317-8, should be considered.
- If the installation of an MPS cannot be justified (for example due to a cost-benefit analysis), then a review of the proximity of any remaining hazards to the front face of the barrier should be carried out to ascertain whether the working width of the system could be increased by the removal of posts from the barrier system. The removal of the posts would decrease the probability of an impact by a motorcyclist, and thus reduce the risk of injury.

The main recommendations for prioritising locations to assess are listed below. These are based on the common characteristics of locations where motorcycle-to-barrier incidents occur.

- At grade-separated junctions, slip roads and loops should be prioritised, especially where there are curves with a radius of less the 100 m or a left-hand bend.
- Merge or diverge points and weaving areas should also be high priority locations within grade-separated junctions.
- On link roads, left-hand bends, sections with a curve radius of less than 100 m and straight sections are the most likely to have motorcyclist to barrier incidents occur.

1 Introduction

The risk from incidents involving roadside barriers has been raised by motorcyclists' groups throughout Europe and has become an area of focus in road safety research.

This report is an update of work done previously by TRL in 2014 (Erginbas & Williams, 2014). The aim of the previous work was to assist National Highways to develop their MPS policy by:

- Reviewing the state-of-the-art research from around the world to develop a better understanding of the problem;
- Reviewing the applications and legislation related to MPS, across Europe;
- Reviewing the MPS available on the market and their test methodologies;
- Reviewing the national statistics and understanding the scale of the motorcycle-to-barrier incidents;
- Analysing in detail, the motorcycle-to-barrier incidents recorded on the SRN and understanding the common properties of the locations where this type of incident occurs;
- Developing recommendations to with regards to an MPS policy.

This report contains an update of all the analysis and statistics elements of the previous work. New recommendations have been made using these results together with the output from the reviews of literature, testing methodologies and available systems done previously. Section on testing methodologies have not been updated, as there have not been any significant improvements in this area since the delivery of the original report in 2014. Section on available MPS on the market have been removed.

The majority of the vehicle restraint systems installed along the roads today are not designed with motorcyclists in mind. These systems are not designed to stop errant riders from reaching the hazards behind but the barriers themselves may pose a risk to motorcyclists due to exposed posts, sharp edges and corners.

As detailed within this report, there is clear evidence in the literature that motorcycle-to-barrier impacts are high severity incidents. However, it is important to understand the scale of the problem, so that the possible countermeasures can be prioritised in an effective and cost-efficient manner.

There were 77,023 casualties on the SRN between 2014 and 2018, of which 8,726 (11%) were from vehicles which hit barriers. Table 1 shows a summary of the number of casualties on the SRN from vehicles hitting barriers between 2014 and 2018 and what proportion of these are from motorcycles. As can be seen from the table, the number of motorcycle-to-barrier casualties on the SRN is small but they are likely to be severe with motorcyclists accounting for 14% of all fatalities from barrier incidents.

Table 1: Summary of casualties from vehicles hitting barriers on the SRN (STATS19, 2014-18)

	Fatal	Serious	Slight	All severities
All barrier casualties	152	1,059	7,515	8,726
Motorcycle to barrier casualties	21	102	61	184
% Motorcycle to barrier	**14%**	**10%**	**1%**	**2%**

When distance travelled per year is accounted for, the figures also show that motorcycles are heavily overrepresented in high severity incidents. More specifically, motorcycles (with 2.33 fatal collisions per billion vehicle kilometres) are roughly 33 times more likely to become involved in a fatal single vehicle barrier incident than cars (with 0.07 fatal collisions per billion vehicle kilometres).

Being aware of the potential risk to motorcyclists from barrier systems, several manufacturers have designed MPS. These systems are usually in the form of adjuncts that are attached to the current barrier systems on the roads and are mostly designed to decrease the severity of barrier impacts for errant motorcyclists who are sliding on the ground, having fallen off their motorcycles.

As the number of MPS available on the market increased, the European test houses LIER and CIDAUT developed their own testing methodologies so that a standardised performance evaluation could be developed. These methodologies later led to a European Technical Specification: TS1317 Part-8.

There are now over 30 MPS available on the market, which have been successfully tested to either one of these methodologies. However, MPS installation to existing barriers require additional funds and therefore, a careful evaluation is needed to ensure public funding is utilised to achieve the highest benefit-to-cost ratio among many possible alternative safety measures.

2 Methodology

The flowchart shown in Figure 1 summarises the methodology adopted in this research to develop the recommendations for a MPS policy.

As can be seen in the flowchart, the process started with a literature review of the state-of-the-art research, available test methodologies and international best practice related to motorcycle-to-barrier incidents.

Consecutively, a STATS19 data search was carried out to identify all recorded motorcycle-to-barrier incidents on the National Highways network between 2014 and 2018. Google Street View images were used to develop a better understanding of the incident locations and identify the barrier type present and additional data, such as horizontal curve radius and crossfall, was collated from HAPMS. GIS software (QGIS) was also used to identify incident clusters. The resulting database and the incident clusters were then analysed in detail to understand the nature and characteristics of motorcycle-to-barrier incidents on the SRN.

The findings from this analysis were combined with the findings from the literature review to develop recommendations for aiding National Highways in developing their MPS related policy.

A more detailed explanation of the incident data analysis methodology is presented in Section 6.1.

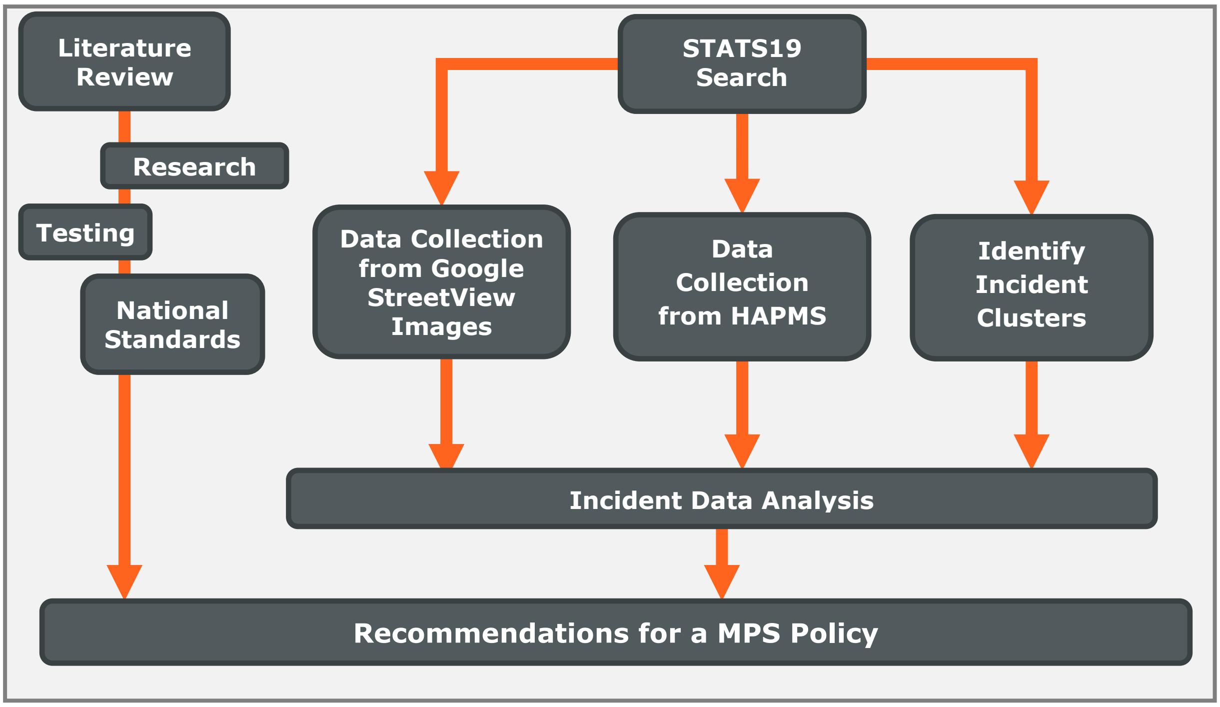

Figure 1: Methodology

3 Literature review on barrier incidents involving motorcyclists

3.1 Introduction

It is important to understand the problem of motorcyclists and barriers in general, before going into the specific details required for data analysis. This gives a fuller view of the context within which the data exists. For this reason, a thorough literature review was carried out and the results are presented in this section.

The section starts by exploring the nature of motorcycle-to-barrier incidents (Section 3.2.1). The most common types of motorcycle incidents are analysed from a barrier incident perspective. The aim is to establish an understanding of how these incidents happen.

Then the most common types of locations where motorcycle-to-barrier impacts are observed are analysed in Section 3.2.2. The aim is to understand where these incidents happen.

This is followed by an examination of the types of interaction between the motorcyclist and the barrier during incidents in Section 3.2.3. The aim is to understand the modes of interaction in more detail.

Then the causes of injury resulting from these interactions are analysed in Section 3.2.4, which is followed by a detailed look into the most common types of injuries resulting from these incidents in Section 3.2.5.

A review of the available literature on the effect of barrier type on injury severity is presented in Section 3.2.6, with the aim of understanding whether certain types of barriers pose a greater risk for motorcyclists than others.

A summary of current MPS use in the UK is presented in Section 3.3.

Then a review of the national statistics from around the world, concerning motorcyclist to barrier incidents in general is presented in Section 3.4, to develop an understanding of the scale of the issue from a global perspective. Examples of safety measures from different countries, which aim to reduce the risk of injury in motorcycle-to-barrier incidents are presented, to help to understand the international approach taken.

3.2 Understanding the nature of motorcycle-to-barrier Incidents

3.2.1 Most common types of motorcycle incidents

The 2004 DfT Road Safety Research Report No.54, “In-Depth Study of Motorcycle Accidents” (DfT, 2004) gives a good insight into the most common type of motorcycle incidents observed in England. A sample of 1,790 motorcycle accidents from 1997 to 2002 were analysed as a part of the DfT research. The most common types of incidents observed are explained in the following sections.

3.2.1.1 Right of Way Violations (ROWVs)

The DfT report showed that ROWVs were the most common type of motorcycle incident observed. Of the total 1,790 cases, 681 (38%) involved ROWVs.

The ROWVs are multiple vehicle incidents in which, usually, the driver of another vehicle fails to see the motorcyclist and pulls in front of the rider. In fact, the study showed that less than 20% of the ROWVs involve a motorcyclist who was judged to be either fully or partially to blame for the incident. The majority of ROWVs were observed to occur at T-junctions, followed by roundabouts and crossroads. Most of these incidents occurred within the urban environment.

Due to the nature of these incidents, from a National Highways perspective, this type of incident is likely to be observed in traffic conflict zones, such as merges, diverges and weaving areas, which are usually located within the vicinity of grade separated junctions. An impact or near-miss with another vehicle has the potential to direct a motorcycle into a barrier.

This type of incident could also occur on link roads, away from the junctions, where another motorist fails to see the rider and pulls in front of the rider during high-speed travel.

Due to their nature, these incidents are likely to involve a primary impact with another vehicle, prior to the impact with the barrier. For this reason, injuries may happen before the rider even reaches the barrier. Nevertheless, the installation of a motorcyclist protection system on the safety barrier system could help reduce the severity of injury to the rider during the secondary impact with the barrier.

3.2.1.2 Losing control on bends

The DfT report further states that the second most common type of motorcycle incident observed is the loss of control on bends, corners or curves. This type was observed in over 15% of all the cases. According to the report, this type of incident is almost always regarded as primarily the fault of the motorcyclist rather than other road users, and it has already been shown that such incidents are more associated with riding for pleasure than incidents of other types.

Hurt et al (Hurt, et al., 1981) found that rider error in such cases consisted of “slideout and fall due to over-braking, running wide of a curve due to excess [inappropriate] speed, or under-cornering”. These seem also to be the most frequent rider errors in bend incidents in the DfT sample.

Another cause of motorcycle incidents on bends can be the existence of debris, such as gravel, dirt, oil spill, etc. on the road surface. These can cause the wheels to lose their grip and the motorcycle to skid and overturn.

Losing control on bend incidents (which then result in a dismounted motorcyclist sliding across the road surface) is the type of incident for which the majority of the MPS available on the market are designed.

3.2.1.3 Motorcycle manoeuvrability incidents

The third most common type of motorcycle incident reported within the DfT report were specifically related to the way in which motorcyclists are able to manoeuvre their vehicles in ways that are frequently not appreciated by other motorists. Motorcycle incidents also occur when riders take the opportunity to pass slow moving or stationary traffic, which is often referred to as ‘filtering’. Less than 5% of the incidents reported within the DfT report involved a rider filtering. From a National Highways perspective, this type of incident is less likely to involve a barrier impact and more likely to involve an impact between a motorcyclist and another vehicle.

3.2.1.4 Other motorcycle incidents

The majority (over 70%) of the motorcycle incidents observed within the DfT study were covered by the scenarios outlined above. However, there were also other, less frequently observed, types of incidents.

One such type of incident is the rear-end shunt, where a motorcyclist cannot stop in time and hits the vehicle ahead of it, as shown in Figure 2.

Figure 2: Example of a rear-end shunt

This sort of incident can be observed on the approach to roundabouts. A rear-end shunt is usually a multiple vehicle scenario that does not necessarily involve a barrier impact. However, one other type of scenario, in which a motorcyclist tries to avoid a rear-end shunt, brakes suddenly, locks the front brake and loses control, is more likely to involve a barrier impact. In this scenario, the errant motorcyclist may slide on the ground after falling from the bike and may reach and hit a barrier. From a National Highways perspective, this sort of incident may be observed on sections of the network where sudden drops in traffic speed, e.g. queuing traffic, prior to off-slip roads, or at changes in posted speed limits.

3.2.2 Locations of motorcycle-to-barrier incidents

To reduce the risk of injury to motorcyclists as far as possible, all roadsides would need to be free of obstacles. However, this would be difficult to achieve, impractical and have disproportionately large time and cost implications. For this reason, it is important to understand and identify the most common types of locations where motorcycle-to-barrier incidents occur. This way a more cost-effective MPS policy can be developed. This section describes the common locations of motorcycle-to-barrier incidents identified in the literature.

Motorcycle to barrier incidents can happen in many different places; however, a review of existing published literature often identifies the most high-risk locations as curves and grade separated interchanges.

The German document, “Merkblatt zur Verbesserung der Verkehrssicherheit auf Motorradstrecken” (Leaflet for improving road safety on motorcycle routes) (FGSV, 2007) gives a good insight into the type of curves where run-off-road motorcycle incidents are more likely to occur.

The document states that certain horizontal road alignments, as shown in Figure 3, are especially susceptible to run-off-road motorcycle-to-barrier incidents. The first case (A) is a combination of several consecutive curves with different radii. This is a physically challenging combination for the riders and it is usually against rider expectations. It is easier to make an error and miss the correct line during the successive direction changes.

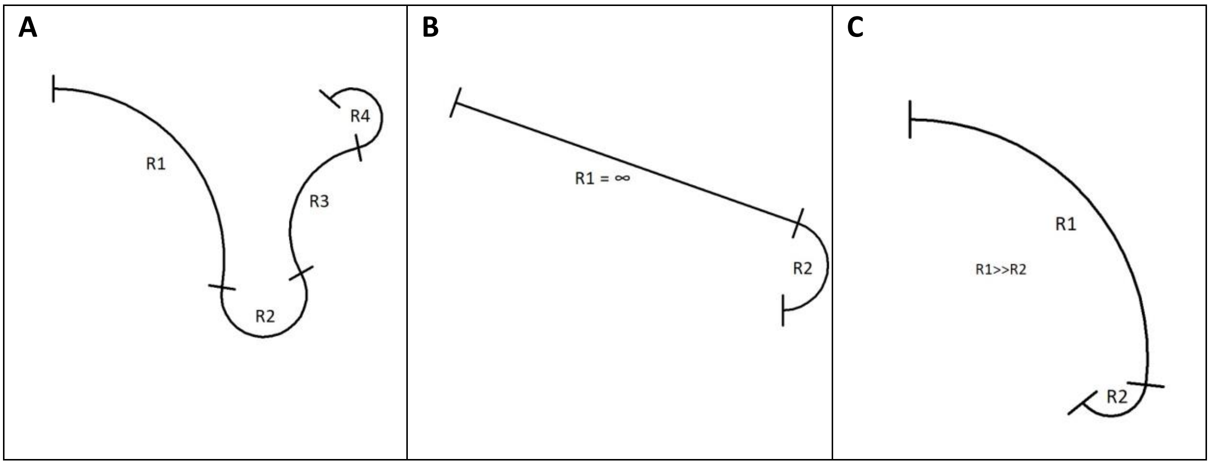

Figure 3: High risk horizontal road alignment combinations

The second case (B) is a long straight followed by a sharp bend. The long straight gives enough distance for reaching higher speeds, while judging the brake point before the sharp curve can be difficult for riders. This combination can also be against rider expectations.

The third case (C) is a combination of two consecutive curves in the same direction with decreasing radiuses. It is very hard to judge and keep the correct cornering line in this combination as the correct line changes suddenly in the middle of the corner. This design is also against rider expectations.

The FGSV document states the other common features of curves, where run off road motorcycle incidents occur, as poor visibility, reverse superelevation and low-grip surfaces.

Grezbieta at al. (2010) analysed motorcycle impacts into roadside barriers in Australia and New Zealand for 2001 to 2006. They showed that 80.8% of fatal motorcycle-to-barrier incident sites involved a bend in the horizontal alignment of the road. The number of incidents for left- and right-hand bends were almost equally distributed.

A comprehensive study was carried out in Spain to determine the variables to be taken into account for the decision of MPS installation (García, et al., 2007). The study divided the most common motorcycle-to-barrier incident locations into four scenarios, by horizontal curve length and minimum horizontal curve radius, as shown in Table 2.

Table 2: Description of the scenarios for bend classification (García, et al., 2007)

Scenario	Curve length	Minimum Curvature radius
1	>120m	>90m
2	>120m	<90m
3	<120m	>90m
4	<120m	<90m

Different variables were recommended to be taken into account for the decision of MPS installation for each scenario, as shown in Table 3.

Table 3: Variables to be taken into account for MPS installation in each scenario (García, et al., 2007)

Scenario	Variables to be considered
1	1. Road Signs and road marking for the definition of bend layout.
	2. Position of decrease of minimum curvature radius along the bend not predictable by the rider.
	3. Isolated bend
2	1. Road Signs and road marking for the definition of bend layout.
	2. Position of decrease of minimum curvature radius along the bend not predictable by the rider.
	3. Isolated bend
3	1. Road Signs and road marking for the definition of bend layout.
	2. Location within the bend of the minimum curvature radius.
	3. Position of decrease of minimum curvature radius along the bend not predictable by the rider.
4	1. Location within the bend of the minimum curvature radius.
	2. Isolated bend.
	3. Paved shoulder.

A study of motorcycle-to-barrier incidents in France, between 1993 and 1995, showed that more than 60% of the barrier related motorcyclist fatalities occurred on curves (SETRA , 1997). The report states that the majority of the barrier related incidents occurred on tight horizontal curves on rural single carriageways; of which 30% had a radius over 400 m, 17% had a radius between 250 and 400 m, and 53% had a radius under 250 m. The study however failed to identify common incident spots on dual carriageways where the radius of curvature is often over 400 m.

A study by Rogers and White (1995) found that among the fatal motorcycle crashes classified as ‘off-path, hit object’, 78% occurred on curves. Whilst these incidents are not solely impacts with roadside barriers (i.e. they will also include impacts with other types of roadside furniture), it does indicate that there is a high proportion of impacts on bends.

Similarly, a detailed examination of 1996 Australian coroners’ records found that 79% of off-path crashes occurred on curved road sections.

Furthermore, a report by Quincy et al (1988) investigated incidents occurring on a 940 km length of highway in France over a three-year period. It concluded that there was a concentration of motorcyclist to barrier incidents on access roads and at interchanges. These are again, typically areas with tight bends.

In addition, a review by Brailly (1998) of 240 motorcyclist impacts with roadside barriers on non-urban roads in America found that the most frequent location of these incidents was on tight bends, with a radius of typically less than 250 m. These incidents occurred mainly on the outside lane, irrespective of the direction of the bend or the road category. However, incidents with barriers were far more frequent on right-hand than on left-hand bends.

In summary, all of these reports conclude that there is a high proportion of motorcyclist to barrier incidents occurring on bends and grade separated intersections. Hence, if additional protection was to be provided for motorcyclists, it may be in these locations where the greatest benefits in terms of risk reduction and cost-benefit would be attained.

3.2.3 Interaction of rider and barrier during impact

This section explores research into the interactions between motorcyclists and barriers during motorcycle-to-barrier incidents. The interaction of rider and barrier during an impact can occur in different ways. The rider may be sliding on the ground (either connected or disconnected from the bike), upright and still on the bike, or in another position during the impact, as shown in Figure 4.

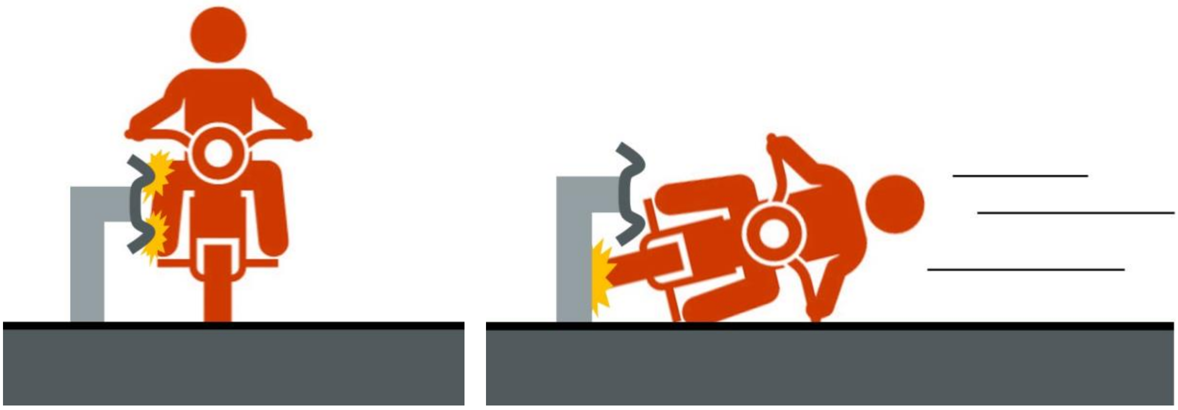

Figure 4: Examples of motorcycle-to-barrier impacts in upright and sliding positions

Current test standards for motorcyclist protection systems, as detailed in the European Technical Specification TS 1317-8: 2012, only consider the scenario of the sliding rider, as explained in more detail in Section 4.1 of this report. However, looking at the published research, it can be seen that there is typically a 50% split between upright and sliding impacts. This means that the current MPS available on the market, which are designed only to protect sliding riders, can only be useful in reducing the risk of injury in half of the impact types.

A study in New South Wales Australia (Grzebieta, et al., 2013) investigated 78 motorcycle-to-barrier impacts. It was found that in 47% of the cases the rider was still on the bike during the impact. In 44% of the incidents, the rider was sliding on the ground and in 6% the rider was ejected from the bike. The mean pre-crash speed was 100.8 km/h and the mean impact angle was 15.4˚.

Ruitz et al. (2010), studied the mechanics of motorcycle-to-barrier impacts and reported that barrier impacts occurred equally often in the upright and sliding positions. Ruitz et al. also found a mean collision angle of 13˚ and a mean impact speed of 100 km/h for fatal motorcycle-to-barrier crashes.

Peldschus et al. (2007) determined that in around three-quarters of collisions with fixed objects, the motorcyclist was in the upright position and the collisions typically occurred at shallow angles, with 13 crashes at less than 15°, two between 15° and 30°, and three between 30° and 45°.

In Germany, the DEKRA Accident Research Unit analysed 57 real-world crashes involving impacts of motorcycles and riders into roadside protection systems. The results showed that 51% of the impacts happened while the rider was in an upright position, while in 45% of the cases the motorcycle slid on its side on the road surface before it first struck the barrier. In 4% of the cases, the motorcycle impacted the barrier in an inclined position (Berg, et al., 2005)

A study conducted in France (Quincy, et al., 1988) investigated impacts between motorcyclists and roadside barriers occurring in the urban area of Paris in 1978 and 1979. The study showed that in 58% of the 38 observed incidents, the rider was sliding on the ground, while in 42% the rider was still on the bike.

In most of the barrier collisions investigated in a 2003 study by Monash University (Larsson, et al., 2003) the rider was still seated on the motorcycle at the moment of impacting the barrier. Additionally, in an examination of motorcycle crashes identified from Australian coroners' reports in 1996, only 23% involved the rider sliding before impact.

Gibson & Benetatos (2000) examined the records of fatal motorcycle crashes in New South Wales, Australia that occurred in 1998 and 1999. They concluded that motorcyclists would either impact a roadside barrier after being thrown into the air from their motorcycle (two of the eight fatalities), separate from their motorcycle and slide along the road into the barrier (one fatality) or impact the barrier whilst still on the motorcycle (three fatalities). Gibson and Benetatos also concluded that the majority of fatal roadside barrier impacts were at relatively shallow angles with respect to the barrier – five of the eight fatalities which they examined arose from impacts at an angle of 45°or less.

Duncan et al (2000), on the other hand found that the majority of motorcyclist impacts with barriers involve riders sliding across the pavement after leaving their motorcycles. He added that typical impact angles are around 12°.

Oullet (1982) also found that riders tend to impact barriers at shallow angles.

Discussions between Monash University and the Queensland Main Roads representatives, Victorian authorities and the New South Wales police (cited by Duncan et al, (2000)) suggest that typical impact angles are around 10°.

Hell & Lobb (1993) and Otte (1994) have calculated that if a rider slides into a roadside barrier at an angle of 15° with a width of 45cm, the rider has a 70% chance of directly impacting a barrier post. This probability is increased further for riders sliding or rolling sideways or impacting at shallower angles. They state that this is particularly undesirable given that impacts with posts were found to be the most likely to cause severe injuries. This probability will obviously increase as the distance between consecutive posts decreases and hence, post and rail safety fence systems with posts widely spaced could be considered to be less hazardous to motorcyclists. However, systems with posts spread too far apart could have a detrimental effect on the containment and redirection of other vehicles, such as cars, as an increase in post spacing will generally result in a greater deflection on impact.

3.2.4 Causes of injuries

This section presents results from research into the causes of injury in motorcycle-to-barrier incidents.

McDonald (2002) notes that it is now generally recognised that the actual cause of motorcyclist injury with a roadside barrier is from the supporting posts rather than the longitudinal elements. This is due to the motorcyclist generally becoming separated from their vehicle and sliding along the carriageway at the moment of impact. The hazard presented by exposed posts will be present for all post and rail systems, although there will be an increased risk from barrier systems with less distance between consecutive posts due to the increased probability of striking a post.

These findings are confirmed by the published works of Koch and Brendicke (1989) of Germany, Quincy et al (1988) of France, Duncan et al (2000) of the USA, and Sala and Astori of Sweden (1998).

An investigation of 900 motorcycle incidents in California by Ouellet (1982) also found that serious injuries were suffered by motorcyclists impacting roadside barriers due to the exposed sections of posts. However, Ouellet found that the majority of the riders struck the fence whilst still upright on the motorcycle. He reported that an impact at a shallow angle was typical, initially causing little injury due to the low speed component at right angles to the traffic flow and beam, although the edges of the beam could cause lacerations. After striking the barrier, the rider begins to separate from the bike and tumbles onto the exposed tops and lower portions of the posts, resulting in more direct, high-speed impacts.

It is the impacts with the exposed sharp edges and corners of the barrier posts concentrating the impact forces which exacerbate the potential for injury. This has been supported both by dummy tests (Quincy, et al., 1988) and real world crash data (Transport Canada, 1980). Ouellet (1982) suggests that the reasons for this are the rigidity of these objects and the velocity component perpendicular to the impacting surface being greater than in many other types of collision.

The Norwegian Public Roads Administration (NPRA)'s Handbook 231 (2004) has, in a similar way to Ouellet, identified the top of the posts as being particularly hazardous for motorcyclists if they become dismounted from their motorcycle during an impact, a view shared by Gibson and Benetatos (2000) and Duncan et al (2000). As a result, the NPRA require that posts must not extend more than 1 cm above the top of the rail for any roadside barrier installed on their roads. Posts which exceed this must be cut. In one fatal accident the NPRA report that a motorcyclist hit the top of the safety fence post and punctured a lung. It is partly for this reason that a number of wire rope systems are fitted with plastic caps on top of the posts.

The height of the barrier system and subsequent engagement with the rider has also been identified as a potentially hazardous feature (Larsson, et al., 2003), especially when a rider strikes the barrier whilst still on their motorcycle. In some cases, there may be a hazardous environment on the other side of the barrier (for example, on-coming traffic or another item of roadside furniture such as a bridge pier). This is a concern also highlighted by Peldschus (2006).

Whilst it is acknowledged that impacts between motorcyclists and roadside barriers often result in disproportionately high severity injuries, Gibson and Benetatos have concluded from their work in 2000 that impacts with trees and telegraph poles were more likely to be identified as being responsible for fatal injuries to motorcyclists than kerbs/culverts and barriers. Furthermore a Transport Canada study (1980) concluded that the most injurious types of roadside objects to motorcyclists were, in decreasing order, posts, trees, poles, barriers and culverts/kerbs. Hence, whilst the severity of a roadside barrier strike by a motorcyclist is likely to be high, it is likely in some cases to be less severe than the severity of hitting the object behind the barrier.

3.2.5 Types of injuries

This section discusses the many types of injuries which can occur during a motorcycle-to-barrier impact.

The current European MPS testing specification TS 1317-8 uses head and neck injury criteria for the assessment of MPS performance. However, the literature suggests that other injuries such as those affecting the thorax and pelvis, are also common.

Grzebieta et al. (2013) found that the thorax area had the highest occurrence of injury and maximum injury level in fatal motorcycle crashes into barriers; the head area had the second highest incidence of injury. Moreover, they found that thorax and pelvis injuries had a greater association with sliding crashes than with those in the upright posture. This suggests that the head injury criteria used in TS 1317-8 (see Section 4.1.2) may not be enough to adequately assess the performance level of tested products. For this reason, they suggest a 'thorax injury criteria' to be introduced to the test standard.

Duncan et al (2000) report that impacts with barrier posts can cause serious injuries through deceleration of the torso, fracture of the extremities to the body, or occasionally decapitation. In addition, the jagged edges of beams or wire ropes provide numerous potentially lacerating surfaces which serve to accentuate rider injury risk.

Studies have been made of the most likely areas of the body to be injured in motorcyclist to roadside barrier impacts. These are, in order, the legs, head, and thorax (Hell & Lobb, 1993). In motorcyclist collisions with fixed objects however, the chances of more than 'moderate' injuries to the head, thorax and spine are increased far more than for other regions of the body - by over half for the head, and over double for the chest and spine (Hell and Lobb, 1993; and Otte, 1994). This suggests that another factor behind the greater severity of injuries incurred by motorcyclists in roadside barrier impacts may be that they are more likely to involve impacts with vital regions of the body.

A review of the European MAIDS accident data (ACEM, 2008) concurred, stating that incidents between roadside barriers and motorcyclists are likely to cause serious injuries to lower extremity regions of the body and spinal injuries, as well as serious head injuries.

Ouellet's (1982) research agrees, suggesting that head injuries are much more likely to be severe in a head impact with a roadside barrier, than impacts with other fixed objects in the roadside.

Jessel (Jessl, 1986) has also examined the location of injuries typically sustained by motorcyclists during impacts with roadside barriers. He states that typical types of injury sustained are:

- Fractures
- Open Fractures

- Serious internal injuries and
- Amputations

The Jessel report has also examined the effect of fitting individual protection devices to the posts of roadside barriers. He found that such devices can halve the impact deceleration and the force, whilst doubling the impact time. The biomechanical tolerance of deceleration for a chest impact is 600-800m/s^2 and Jessel has shown that this could be exceeded with an unprotected post (860m/s^2) but was much lower and within tolerance if the post was protected (472m/s^2). This shows that the polystyrene protector can greatly reduce body loadings and hence, the expected level of injuries sustained by the motorcyclist.

Further work in this area has also been carried out by Dr Georg Schmidt of Heidelberg University who impacted barrier posts with cadavers (Schmidt, 1985). The tests simulated an accident where a motorcyclist would be sliding on his back, feet first, at an angle of 15° against an I-profile barrier post. This type of post was used extensively throughout mainland Europe in the 1960s, 1970s and 1980s. Tests performed at 32 or 33 km/h resulted in severe injuries without any additional protection, but minor to moderate injuries after protective padding had been applied to the barrier posts.

Further work by Schnuell from the University of Hannover, reported by Uwe Ellmers (1994) has also shown that sigma shaped (∑) posts can cause bruising only whereas I-profile posts can cause fractures or amputations under comparable conditions.

The use of sigma shaped posts instead of those with an I-profile is also supported by a report by Koch and Brendicke (1989). This approach is now being implemented extensively within mainland Europe. Within the UK, Z-profile posts are more frequently used, however no quantitative research has been undertaken to examine the likelihood of injuries from posts with this profile.

3.2.6 The effect of barrier type on injury

Motorcyclists and motorcyclists' groups often regard some type of barriers, especially wire-rope fence, to be more dangerous than the others. There are several published studies which have investigated the effect of the barrier type on the injury severity. Two main barrier types are discussed in the following sections: wire rope fence and concrete barrier.

3.2.6.1 Issues specific to Wire Rope Fence

A study into the effect of barrier type on injury severity was conducted in the USA by Daniello and Gabler (2011). In this study, 951 motorcycle-to-barrier impacts from 2003 to 2008 in North Carolina, Texas and New Jersey were analysed in detail. The study found that there was no significant difference in the percentage of KSI (killed or seriously injured) for riders involved in motorcycle collisions with W-beam (40.1% KSI) and cable barriers (40.4% KSI). However, it was found that the percentage of people fatally or seriously injured was lower in motorcycle to concrete barrier collisions.

Grezbieta at al. (2010) analysed motorcycle impacts with roadside barriers in Australia and New Zealand for 2000 to 2006. The proportion of motorcyclist fatalities resulting from each type of barrier was compared to the length of installation on the network. The study showed that W-beam comprised 71.5% of all barriers installed and resulted in 72.7% of fatalities; concrete comprised 8.6% of the barriers installed and 10.4% of the fatalities; and wire rope comprised 15.9% of the barriers installed and 7.8% of the fatalities. Therefore, assuming the probability of a fatality occurring across the network is similar; they concluded that wire rope barriers have around half the fatality rate of W-beam barriers.

In another study, Grzebieta et (2013). found that the areas of body that were injured during the 78 analysed motorcycle-to-barrier incidents in Australia and New Zealand, were similar across different barrier types (concrete, wire rope and W-beam).

Wire rope fences are often seen as a hazard by motorcyclists and motorcycling groups who often refer to them as ‘cheese-cutters’ since they feel that there is a risk of serious injury being caused during an impact with the longitudinal ropes used by the system.

However it is worthy of note that at the 2008 Annual meeting of the Transportation Research Board (TRB) International sub-committee AFB20(2) in the USA, where the topic of motorcyclist and roadside barrier impacts was discussed, presentations on incident data were presented from the UK, Italy, Spain, France and Sweden. In each case it was stressed that the ‘cheese-cutter’ effect had not been witnessed within these countries.

A report by Monash University (Larsson, et al., 2003) concurred, stating that there was no record of this occurring in Sweden despite wire rope barriers being present on 900km of Swedish roads. These findings follow a similar pattern to those of Duncan et al (2000) who have stated that there is no substantial evidence to show that wire rope barriers pose a greater risk to motorcyclists than the objects from which they are designed to shield the road user, such as trees, posts, or oncoming traffic. Duncan et al also added that there is no evidence of the ‘cheese-cutter effect”’ during injury events.

In many European countries like Sweden, road authorities are installing wire rope fence in the verge and median of both low and high-speed roads. This is due to the wire rope fence having a number of important benefits over other roadside barrier systems:

- They can have a low initial cost;
- They have a lower impact severity than some other types of roadside barrier (for car occupants, as observed during full-scale testing)
- They can cause less damage to vehicles and their occupants;
- They can be easier and safer to repair.

On National Highways roads in England, wire rope fence accounts for approximately 1.3% of all barrier installations, and a similar percentage has been reported by the Australian State authorities for their roads (ATSB, 2000).

However, some European countries, such as Belgium and the Netherlands have restricted the future use of the wire rope barrier, and in Denmark several thousand metres of existing wire rope is reported to have been removed (FEMA, 2005).

However, the Australian Transport Safety Bureau has stated that the effect of banning wire rope fence could be detrimental to overall road safety (ATSB, 2000).

This demonstrates that any decision to limit or ban the use of the wire rope fence should be considered carefully, and should consider the consequential effects on all road users, independent of their mode of travel.

A Swedish study by Pieglowski (2005) detailed the results from a questionnaire, placed on the website of the Swedish Motorcyclists' Association (SMC), examining the perception of the hazards presented by wire rope barriers. A total of 346 riders responded.

They were mostly male, outnumbering female riders by the ratio 9:1. The results from the questionnaire showed that:

- More than 97% of the respondents had not been involved in an incident with a wire rope barrier.
- More than 74% claimed to maintain speed regardless of the presence of such a barrier on the road.
- 63% of riders said they increased their distance from a wire rope barrier on becoming aware of it.
- About 69% felt less secure when riding alongside roadside barriers. On the other hand, 30% of women riders claimed to feel more secure.
- More than 75% of the respondents feared colliding with the barrier, in contrast to 18% who felt protected from head-on collisions.
- More than 55% of the respondents said that their choice of travel routes was not influenced by the presence of wire rope barrier. The remainder said that it was faster travelling by alternative routes.

Hence the results show that the presence of wire rope fence will have an effect on approximately 35% of riders, although a reduction in travelling speed, or an increase in rider awareness (caused by the use of wire rope, or any other barrier type), may have a positive effect of the overall safety of the road.

3.2.6.2 The use of concrete barrier for motorcyclist protection

There is a widely held view within rider organisations that barriers with smooth continuous longitudinal surfaces (such as concrete barriers) are likely to be much less injurious to riders (ATSB, 2000).

The FEMA report "New Standards for RRS" (2012) states that concrete barriers can especially be useful as lane dividers on motorways, in wide curves as well as straight sections, where motorcyclists are likely to impact the restraint system in an upright position and/or at an acute angle. The report further states that concrete barriers offer good redirection capabilities, thanks to their smooth, wide impact surface. In such cases, they can prove more effective in redirecting the energy and dissipating it over a larger area than metal rails in absorbing it.

This is in-line with the findings of Daniello and Gabler (2011) (mentioned in section 3.2.6.1) who stated that the percentage of riders fatally or seriously injured was lower in motorcycle to concrete barrier collisions, compared with W-beam and wire-rope collisions. It was shown that the probability of severe injury in a collision between a motorcycle and a W-beam guardrail was 1.164 times higher than of a severe injury in a motorcycle to concrete barrier collision. Furthermore, for riders wearing a helmet, it was found that the probability of a severe injury in a W-beam guardrail collision was 1.419 times greater than the probability of severe injury in concrete barrier collisions.

Another study in USA by Gabler, using 2005 Fatality Analysis Reporting System (FARS) data, found that the fatality risk in motorcycle to guardrail collisions (12.4%) is almost 1.5 times higher than the fatality risk in a motorcycle to concrete barrier collision (7.9%); as shown in Table 4.

Table 4: Fatality risk by object struck (FARS 2005) (Gabler, 2007)

Incident type	Fatality risk (fatalities per incident)
Motorcycle to post and rail steel barrier	12.4%
Motorcycle to concrete barrier	7.9%
Motorcycle to car	4.8%

The use of concrete barrier as a safer option for motorcyclists is supported by the Federation of European Motorcyclists' Associations (FEMA) who have stated that slip formed concrete barriers, are used far more frequently in Norway as a result of lobbying by the NMCU (Norwegian Motorcycle Union) and that a smooth concrete barrier is in itself 'motorcycle-friendly'. The increased safety of a concrete barrier for motorcyclists is also substantiated by Ouellet (1982) who examined these interactions in a US study.

Data from a New South Wales fatal case study (Gibson & Benetatos, 2000) and a report by Duncan et al (2000) concur that concrete barriers are safer for motorcyclists than post and rail systems when struck at shallow angles.

The same view is shared by Czajka (Czajka, 2000), who states that it is the absence of force concentrating protrusions which makes them preferable to motorcyclists over other barrier types. However, adding holes or protrusions to concrete barrier will increase the possibility of vehicles or riders becoming caught on them, thus decreasing the barrier safety performance.

In addition, the use of concrete concurs with the approach recommended by Duncan et al (2000) who state that roadside barriers should be designed with the aim of containment in mind, as long as the containment of the motorcyclist does not result in more severe injuries than would be sustained if the rider were to pass over, through or under the barrier.

The restriction on the wide-spread use of concrete barriers in Europe has been due in part to the high initial costs of the system. However in England, the use of concrete barrier is now mandatory for median barriers on roads with an AADT of over 25,000 vehicles per day, due in part to a review of the whole life costs associated with different barrier types, i.e. whilst the initial cost of the concrete barrier may be higher than for other systems, the longer life and reduced maintenance costs can make concrete barriers more economically viable over time. A study by the Australian Transport Safety Bureau (ATSB, 2000) has concurred with this, stating that concrete barriers are an economically viable option when whole life costs are considered, as lower continuing maintenance and repair costs quickly offset the higher initial concrete barrier installation costs.

The literature seems to agree that concrete is a safer option for motorcyclists, compared with steel barriers. However, with the installation of MPS, it is possible to make steel barriers more motorcycle friendly. This brings one question into mind: “Can concrete barriers be used as motorcyclist protection systems?”

To answer this question, “Association Mutua Motera”, The Spanish member of FEMA realized a full-scale crash test according to the Spanish standard UNE 135900:2005 for a “New Jersey” profile concrete barrier (Toribio, 2008). The test was carried out in the Spanish test house CIDAUT in 2007.

The results of the 60km/h, 30˚ impact are given in Table 5 below (see Section 4.1.2.3 for more detail about the criteria listed in the table). As can be seen from the results, a head injury criterion (HIC-36) of 1,585 was recorded. This value is more than 1.5 times the acceptable limit of 1,000.

Table 5: Results of the UNE135900 test of a New Jersey profile concrete barrier (Toribio, 2008)

	Measured value	Severity Level I limit	Severity Level II limit	Result
Head Injury Criterion (HIC_{36})	1584.64	650	1,000	Fail
Neck Shear Force (F_x)	1,210.95 N	1,900 N	3,100 N	Level I
Neck Tension Force (F_z)	4,717.32 N	2,700 N	3,300 N	Fail
Neck Compression Force (F_z)	6,340.03 N	3,200 N	4,000 N	Fail
Neck Bending Moment (M_{OCx})	129.13 Nm	134 Nm	134 Nm	Level I
Neck Flexion Moment (M_{OCy})	14.22 Nm	190 Nm	190 Nm	Level II
Neck Extension Moment (M_{OCy})	47.99 Nm	42 Nm	57 Nm	Level II

This shows that concrete barrier, although safer than a steel barrier system with no MPS installed, poses a greater level of risk than using a motorcyclist protection system, for sliding configuration impacts.

Furthermore, as was previously discussed in Section 3.2.3, approximately only half of the motorcycle-to-barrier impacts occur in a sliding configuration. For upright impacts, during which interaction with the top of the barrier is likely, concrete is advantageous, as the majority of the MPS on the market does not provide protection for the top of the barrier, while concrete has a smooth top surface.

Key points: Understanding the nature of motorcycle to barrier incidents

- The most common type of motorcycle incident is right of way violations (38%) and the second is losing control on bends (15%). Most MPS on the market are designed for the second type of incident.
- Curves and grade-separated interchanges are often identified in literature as the most high-risk locations for motorcycle to barrier incidents. Research in multiple countries found that a large proportion of incidents occurred on bends.
- Around half of motorcycle to barrier impacts occur when the motorcycle is sliding and half when the motorcycle is upright. This means current MPS is only designed to reduce injury risk in half of the impacts which are occurring (those with sliding motorcycles).
- The cause of injury in motorcycle to barrier incidents is generally the sharp edges and corners of exposed supporting posts.
- The current MPS testing specification using head and neck injury criteria but literature suggests that injuries to the thorax and pelvis are also common.
- Research has not found evidence of the ‘cheese-cutter’ effect of wire rope fences, perceived to be a hazard by motorcyclists, or any evidence that these types of barrier are more dangerous than others.
- The literature suggests that concrete can be a safer option for motorcyclists, compared with steel barriers.

3.3 Current use of MPS in the UK

This section outlines the current and historic use of MPS in the UK, particularly on the SRN and in National Highways standards.

Due to the identification of a motorcyclist accident black spot, a trial commenced in 2004 of a proprietary motorcyclist protection device called “BikeGuard” (promoted in the UK by Highway Care).

The system is designed to cover the posts of a safety fence system, impacts with which are often thought to be the most severe type of impact (see Section 3.2.4).

The BikeGuard system has been tested to the EN1317 test requirements for cars whilst attached to a standard UK roadside barrier, and has been deemed, by National Highways, to be suitable for installation on their roads. As a result, the product is listed on National Highways’s list of accepted products under ‘Miscellaneous items’ together with Hill and Smith’s “FlexGuard” system.

The trial installation was located at the A2070 Half Cloverleaf Junction in Ashford, Kent. The BikeGuard was used to supplement the existing barrier, a combination of tensioned corrugated beam (TCB) and open box beam (OBB) safety fence.

Prior to the installation of BikeGuard, 25 casualties had occurred at the location – 3 of the casualties received fatal injuries, 8 serious and 14 slight injuries. Of those injuries sustained, 14 were attributable to motorcyclist incidents. During the trial period of the system, the speed limit was reduced from 70 to 50mph. There was circumstantial evidence that an impact has occurred with the barrier/BikeGuard system, however no personal injury occurred. During the three year study period of this paper, as shown in Section 6, there was only one serious injury motorcycle-to-barrier impact recorded on this junction.

As a result, the National Highways standard TD 19/06 (Highways England, 2006) included recommendations for the use of 'add on' MPS to post and rail type barriers at high risk sites to minimise the risk of injury to motorcycles. The standard also stated that consideration should be given to the form of VRS used at sites which were identified as being high risk for motorcyclists.

Partly as a result of these requirements, and partly due to the positive results of the initial installation at the A2070 Half Cloverleaf Junction location, use of the BikeGuard system subsequently increased. As of September 2006, 5kms had been installed on National Highways roads, with 1.3km in place on the M27 J12 near Portsmouth, in Hampshire, and on the M4 J7 near Slough, in Berkshire. Another installation (July 2007) took place on the A537 in the Peak District National Park (Highway Care, 2007) where, whilst motorcyclists represent less than 2% of the road traffic, they accounted for 75% of road users fatally or seriously injured between 2004 and 2006.

TD 19/06 has now been replaced and recommendations in the current National Highways standard CD 377 (Highways England, 2020) are not as detailed and do not specifically mention MPS. CD 377 states that:

"3.32 Where a specific risk to motorcyclists is identified, appropriate mitigation measures to reduce the risk shall be specified in the contract specific specification, using contract specific Appendix 4/1 as detailed in MCHW Series NG400 [Ref 24.N].

3.33 The risks to motorcyclists, including details of the measures adopted, shall be recorded as part of the design."

Recent work carried out by TRL for National Highways aimed to development a Lead Safety Indicator metric related to MPS. As part of this work, high risk slip roads on the SRN were identified and the proportion of these sites which had MPS installed was calculated. There were 517 high risk slip roads identified with a total length of 86km and these high-risk slip roads accounted for 3% of the total SRN slip road length. As of May 2020, 35 of the 517 high risk slip road locations had MPS installed (7.4%).

Key points: Current use of MPS in the UK

- The BikeGuard system has been trialled in the UK and approved for use by National Highways on their roads.
- The current National Highways standard (CD 377) states that 'appropriate mitigation measures to reduce risk' should be specified at high risk sites for motorcyclists.
- As of April 2020, 7.4% of high-risk slip roads on the SRN had MPS installed.

3.4 International experience

3.4.1 Severity and frequency of incidents involving motorcyclists and roadside barriers

The aim of this part of the literature review was to establish the scale of motorcycle-to-barrier incidents across the world. The following sections identify, by country, the number and severity of incidents between motorcyclists and roadside barriers reported in published text.

3.4.1.1 Australia

Research by the Australian Transport Safety Bureau (2000) has reported that motorcycle incidents appear to be comparatively rare in absolute terms, though this may be due to the low percentage of motorcycles in the vehicle fleet, in Australia estimated to be 0.5%.

This research summarised some of the known data for incidents between motorcyclists and roadside barriers:

- Incident studies consistently find that impacts involving a motorcyclist and a roadside barrier account for a small proportion (less than 5%) of rider casualties.
- A range of official accident data sources in Australia and have given serious injury rate estimates of less than 1%.
- A detailed investigation of 222 casualty crashes in the Melbourne metropolitan area (Haworth, et al., 1997) identified eight cases (3.6%) with some degree of barrier involvement.
- A study of all fatal motorcycle crashes in South Australia between 1985 and 1991 (Rogers & White, 1995) found that 2.6% involved an impact with a roadside barrier.
- An inspection of 1994 and 1996 Australian coroners' records identified nine motorcycle crashes – 2.4% of total rider fatalities – involving an impact with a roadside barrier.
- Collisions with fixed roadside objects make up nearly 40% of motorcycle fatalities in Australia and a similar proportion of car occupant casualties. However, the main roadside objects involved in fatal motorcycle incidents are trees, poles or signposts (70%).

The state of Victoria's crash statistics indicated, in a review of 2000 (Duncan, et al., 2000), that between 1991 and 1995, there were 9,059 accidents involving motorcyclists in Victoria, 84 of which involved a collision of a rider with a roadside barrier (0.9%).

3.4.1.2 Austria

In 2000, FEMA reported statistics from Austria showing that between 1990 and 1996, 5.2% of all motorcyclists' accidents occurred with a roadside barrier, accounting for 11.7% of the fatalities, a disproportionately high number (FEMA, 2000).

Furthermore, data from Östat (the Austrian Bureau for Statistics) have shown that 40% of motorcycle accidents with a roadside barrier result in severe injuries.

3.4.1.3 Canada

A review of accident statistics by Transport Canada in 1980 found that the probability of being killed as a result of impacting a roadside barrier is more than double that for other types of motorcyclist impact.

3.4.1.4 Denmark

FEMA report (in 2000) that preliminary data from Denmark has also indicated that 10% of motorcyclists who leave the road hit a roadside barrier. Of these, 20% received fatal injuries from the barrier impact whilst 60% were seriously injured.

3.4.1.5 Finland

In 50 incidents with a roadside barrier, 5 involved a motorcyclist (10%).

3.4.1.6 France

Work by Brailly (1998), studied French accidents involving motorcyclists impacting a roadside barrier. The results showed that the risk of fatality per accident is five times as great as the national average for all motorcycle accidents. The study was in two parts:

1. An analysis of national statistics recorded between 1993 and 1996;
2. A site analysis of 240 accidents that occurred on non-urban roads and involved at least one motorcyclist impacting a roadside barrier.

The study showed that a yearly average of 63 fatal, 114 serious and 118 slight cases resulted from impacts into a roadside barrier. These account for 8% of all motorcycle fatalities and 13% of fatalities on rural roads. More than 30% of the motorcyclists killed by hitting an obstacle on urban roads were caused by impacting a roadside barrier.

3.4.1.7 Germany

Koch and Brendicke, (1989) conducted regional surveys in the Federal Republic of Germany between 1986 and 1987 and found that approximately 15% of motorcycle fatalities involved an impact with a roadside barrier. The injuries were generally reported as ‘severe’.

Uwe Ellmers (1998) at the VTI conference of 1998 presented the findings of a further study, reporting that the probability of receiving fatal injuries rises from 2.2% to 10.9% when the roadside is fitted with a roadside barrier.

Dohman (1987) also gives details of case studies where motorcyclist injuries resulting from an impact with a barrier have been examined, showing that:

- Research in Tuebingen during 1984 shows that 16% of all motorcycle fatalities were linked to an impact with a roadside barrier.
- Westfalen-Lippe 1980 to 1982: One in 6 motorcycle to roadside barrier collisions resulted in a serious or fatal injury.

The report also investigated more general statistics regarding the German Highways and stated that of the 50 riders who struck a roadside barrier, 3 were killed, 31 were seriously injured and 16 were slightly injured.

A further paper by Ellmers (2002) discussed three approaches for providing additional protection to motorcyclists:

- One involved a long-term program to replace sharp-edged “I” section posts (commonly used in Germany) with less hazardous “∑” (sigma) posts.
- Another considered the application of a second beam to the lower part of the barrier. However, this was not viewed by BASt as a practical option because of the associated cost and difficulties with curved installations. There were also uncertainties about how this modification would affect the overall performance of the barrier system when struck by other types of vehicle, e.g. cars.
- The most effective protection method was thought to be a plastic foam protector which could be fitted to each post. The main purpose of this device was to shield riders from the sharp edges presented by the posts rather than to absorb the energy of the impact - tests suggested that they would offer the greatest reduction in injury risk at low impact speeds (up to 20 km/h).

3.4.1.8 Norway

The Norwegian Public Roads Administration report on Motorcyclist Safety (2004), states that annually about 45 motorcyclists are injured in reported barrier collisions in Norway. The report showed that of the 45 casualties, 10 were injured due to hitting the pavement, 6-7 injured after being thrown over guardrail, 5-6 injured when hitting the rail, 5-6 injured when hitting the rail post and 2-3 injured while skidding under rail. The study revealed that severity was highest when hitting the rail.

3.4.1.9 Sweden

A review of incidents on Swedish roads, compiled by Monash University (Duncan, et al., 2000) has stated that ‘motorcyclists are around 30 times more likely to be involved in a serious or fatal crash.’

However, a further report by Monash University in 2003 (Larsson, et al., 2003) continues by stating that “in a further Swedish study of all motorcyclists killed between 1997 and 1998, 13% of the cases involved an impact with a” roadside barrier.

3.4.1.10 USA

In 2005, motorcycle crashes were found to be the leading source of fatalities in guardrail crashes in USA (Gabler, 2007). In 2005 for the first time, motorcycle riders suffered more fatalities (224) than the passengers of cars (171) or any other single vehicle type involved in a guardrail collision. In terms of fatalities per registered vehicle, motorcycle riders were dramatically overrepresented in number of fatalities resulting from guardrail impacts. Motorcycles composed only 2% of the vehicle fleet, but accounted for 42% of all fatalities resulting from guardrail collisions. From 2000 to 2005, approximately one in eight motorcyclists who struck a guardrail were fatally injured – a fatality risk over 80 times higher than for car occupants involved in a collision with a guardrail.

3.4.2 International solutions to the motorcycle-to-barrier problem

The subsequent sections outline the methods being undertaken by a number of countries to address the issue of motorcyclist impacts with safety fences, and in some cases, the specific measures taken with regard to wire rope fencing.

There are many different approaches adopted by different European countries to address the safety issue with barriers and motorcyclists. An overview of some of the successful national approaches was compiled and published by FEMA in 2012 in the report "New Standards for Road Restraint Systems for Motorcyclists". Some of the information presented here is taken directly from that report. The rest is sourced from various publications.

3.4.2.1 Australia

The Government of Victoria continue to install wire rope barriers as they state that such systems are considered to be a very effective type of barrier for the vast majority of road users in Australia (ARRB correspondence, 2008).

3.4.2.2 France

As a result of the 1997 SETRA report (SETRA , 1997), the French government published new regulations to cover the installation of MPS, including their location and type.

The French national directive says that for new roads, MPS should be installed on the external side of highways and roads with separated carriageways when the radius of the bend is equal to or less than 400m. On the other roads, the MPS should be installed in the external side of bends with a radius equal to or less than 250m. The installation is also necessary in the external side of all bends for grade separated junctions. (FEMA, 2012)

The LIER protocol (see Section 4.1) for the testing and evaluation of MPS performance was also created as a consequence of this directive.

3.4.2.3 Germany

The German approach for the identification of motorcyclist black spots and MPS implementation is presented in the document: "Leaflet to Improve Road Safety on Motorcycle Roads" (FGSV, 2007). This comprehensive document reflects the German approach which aims to solve the problem by improving the whole road infrastructure and possibly avoiding the motorcycle accidents in the first place. Some of the recommended improvements are:

- replacing guardrails with earth walls;
- using flexible bollards for delineation instead of direction signs;
- installing MPS;
- clearing roadsides on curves to improve sight distance;
- using double continuous lines to reduce the risk of running off in curves.

The document also gives the following characteristics of a “motorcycle road” where a motorcycle accident black spot is most likely to be:

- low traffic volume;
- low proportion of heavy goods traffic;
- sufficient number of curves;
- no urban areas;
- no differences in elevation along the road.

3.4.2.4 Netherlands

The Ministry of Transport in the Netherlands has adopted MPS installation guidelines after pressure from local motorcyclists’ association. A simple decision tree is used to define the locations of installation according to the level of priority. This simple decision tree, which can be found in the FEMA report, takes the following road properties into account for defining the level of priority in MPS installation:

- curve radius;
- availability of clear space for evasive manoeuvres;
- visibility;
- irregularity in road design;
- effect of the road layout on rider expectancies.

3.4.2.5 Norway

The Norwegian “Vision Zero”, which has the aim that no person to be killed or seriously injured in traffic, has been the core of road safety in Norway since the mid-1990s. The approach to reach this goal includes infrastructure improvements in the shape of forgiving roadsides. As a part of this, motorcyclist safety is integrated in the infrastructure design guidelines with the handbook 245: “Motorcycle Safety, a Motorcycle Guide for Highway Engineers”. These guidelines are used for road safety audits to check elements such as:

- pavement condition;
- position and necessity of guardrails;
- lightning and position of signage;
- sight distance;
- clearing of roadside objects.

In 2006, after years of lobbying by the Norwegian Motorcycle Union (NMCU), the Norwegian Minister of Transport announced a ban on the future installation of wire rope barriers in Norway (NMCU, 2006).

3.4.2.6 Portugal

In Portugal, the issue of motorcyclists and barriers is regulated by the law 33/2004. The Law requires that “The crash barrier protections shall be placed on the black spots of roads or shoulders whose location, characteristics, grade, or existing fixed and rigid obstacles less than two meters away from the limits of the carriage way, are likely to generate greater damages than those occurred in an impact against the said crash barriers, namely bridge abutments, piles, walls, poles and large trees.”. Portugal also adopted Spanish MPS testing specification UNE135900:2008 as a standard.

According to Portuguese regulations a MPS must be placed:

- in curves with radius under a minimum value;
- in curves with no super-elevation or super-elevation under a minimum value;
- in small radius curves with a high downward gradient (>4%);
- in consecutive circular curves in the same direction with decreasing radius;
- in cloverleaf interchanges and other smaller radius slip roads;
- at entry points at intersections and interchanges;
- in zones prone to skidding and icing.

In addition to MPS installation, safety barriers in rural areas must be replaced wherever possible by obstacle free shoulders.

3.4.2.7 Spain

Spain is known to be one of those European countries where motorcycling is very popular. Following public pressure, including calls for the installation of MPS by Spanish motorsport celebrities, the public authorities announced important investments for the installation of protective systems around the country (FEMA, 2012).

According to Spanish regulations, the installation of MPS on existing barriers is recommended at the outside shoulders in curves on dual carriageways with a radius lower than 400 meters, and on deceleration lanes on exit slip roads. MPS installation is also recommended for single carriageway roads with a shoulder width of over 1.5m when the radius is lower than 250m, and on any other highway that has a speed reduction at a curve higher than 30km/h. (FEMA, 2012)

Spain also adopted their MPS testing specification UNE135900:2008 as a standard and therefore MPS products in the Spanish market are required to be tested.

3.4.2.8 Sweden

The National Road Administration in Sweden is concentrating exclusively on the installation of wire rope barriers. On the 1st January 2005 there were 950km of Swedish roads incorporating wire rope barrier and every year another 150-200km are installed. The National Swedish Road Administration says that there are another 1,000km that can be rebuilt with the wire rope barrier (FEMA, 2005).

3.4.2.9 Switzerland

The use of additional motorcyclist protection devices in Switzerland is the responsibility of the Local Authorities. Individual foam post protectors and/or additional protective rails are sometimes used on routes with a high density of motorcyclist traffic.

Key points: International experience

- The review of statistics from across the world showed that the number of motorcycle to barrier incidents is generally small but these incidents are likely to be high severity.
- This has led to a targeted approach by most countries and the development of criteria to identify sites where MPS would be most beneficial, considering elements such as:
    - Small curve radius
    - Consecutive circular curves
    - Availability of clear space for evasive manoeuvres
    - Visibility
    - Irregularity in road design
    - Effect of road layout of rider expectations
    - Entry points at intersections and interchanges
    - Zones prone to skidding and icing

4 Motorcyclist Protection Systems and their testing

4.1 Testing standard explained

Within Europe the current full-scale impact test requirements for vehicle restraint systems (VRS) are specified within the European standard, EN 1317. More specifically, the test requirements for roadside barriers and parapets are contained within EN 1317-1&2.

In the absence of a European standard for testing barriers for motorcyclists, several test houses developed their own in-house methodologies. These were later used as a basis to prepare the draft for a Technical Specification (TS), which was subsequently published in 2012. This technical specification is now added as a new part (Part 8) of EN 1317. The document was published as a Technical Specification to allow test houses to gain experience in using the standard prior to its conversion to a full European Norm.

4.1.1 Background to TS 1317-8

The lack of a standardized testing method for the evaluation of MPS performance has been a problem for more than a decade. In 1998, the French test house LIER developed their own in-house testing procedure to address this issue. The main idea behind the LIER protocol was to accelerate an Anthropomorphic Test Device (ATD) (commonly known as a 'dummy') on a sledge, with a horizontal orientation, towards a barrier system to model the common scenario of an errant rider sliding on the ground, having fallen from a motorcycle. A similar procedure was later adopted by the Spanish test house CIDAUT, which in 2008 became the Spanish national testing standard UNE-135900 (Evaluation of system behaviour for the protection of motorcyclist in safety barriers and posts).

In June 2008, members of CEN voted for the addition of a new section to EN 1317, relating to the testing of MPS. For this purpose, European Technical Committee (TC) 226 worked on harmonising the in-house testing methods that were available at that time. The LIER and Spanish protocols were selected as the basis and these were modified to form 1317 Part 8 draft.

Because it is a technical specification, TS 1317-8 is not obligatory for any country unless it is mandated by a National Regulation. Therefore, National Road Authorities can still install motorcyclist protection systems that they believe to be safe without the requirement of testing them according to TS 1317-8.

Both the LIER and CIDAUT procedures were similar in their fundamental approach; however there are a number of distinct differences between the two approaches. TS 1317-8 generally combines these two approaches as shown in Table 6.

Table 6: Comparison of LIER, CIDAUT & TS 1317-8 test procedures

Test set up	LIER	CIDAUT		TS 1317-8	
ATD	Hybrid II fitted with the head and neck of a Hybrid III, 80kg	Hybrid III		Modified Hybrid III	
Impact Speed	60km/h ± 5%	60km/h		Test 1: 60km/h ± 1% Test 2: 70km/h ± 1%	
Impact Angle	30˚ ± 0.5˚	30˚		30˚ ± 2˚	
Dummy Orientation	On back, head forwards Test 1: at 30˚ to barrier Test 2: parallel to barrier	On back, head forwards All at 30˚ to barrier		On back, head forwards All at 30˚ to barrier	
Point of Impact	Test 1: Head aimed at post Test 2: Shoulder aimed at post	Test 1: Head aimed at post Test 2: Head offset from post Test 3: Head at centre-point between two posts		Test 1: Head aimed at post Test 2: Head offset from post Test 3: Head at centre-point between two posts	
Acceptance Criteria/Limits		Severity Level I	Severity Level II	Severity Level I	Severity Level II
Head Injury Criterion (HIC_{36})	≤ 10000	650	1000	650	1000
Neck Shear Force (F_x)	≤ 3300 N	-	-	≤ 1900 N	≤ 3100 N
Neck Tension Force (F_z)	≤ 3300 N	-	-	≤ 2700 N	≤ 3300 N
Neck Compression Force (F_z)	≤ 4000 N	-	-	≤ 3200 N	≤ 4000 N
Neck Bending Moment (M_{OCx})	-	134 Nm	134 Nm	134 Nm	134 Nm
Neck Extension Moment (M_{OCy})	-	42 Nm	57 Nm	42 Nm	57 Nm
Neck Flexion Moment (MOCy)	-	190 Nm	190 Nm	190 Nm	190 Nm

4.1.2 Testing and evaluation requirements of TS 1317-8

4.1.2.1 Scope of TS 1317-8

TS 1317-8 specifies requirements for the impact performance of systems designed for the reduction of impact severity for motorcyclists impacting barriers whilst sliding along the ground, having fallen from their vehicle. Other incident scenarios, such as riders impacting the barrier while still on their motorcycles or while they are rolling along the ground are not yet considered in TS 1317-8. The systems concerned by TS 1317-8 are those fitted to barriers, or barriers that have inherent rider protection or risk reduction capability.

4.1.2.2 Test methods

The full-scale impact tests in TS 1317-8 consist of launching a Hybrid III ATD with a modified shoulder at a given speed against a barrier with an MPS installed. At the moment of impact, the ATD is sliding with its back and legs stably in contact with ground. The ATD is equipped with a helmet and dressed in motorcyclist safety clothes in accordance with the requirements specified in the technical specification.

During the test, accelerations, forces and moments acting on the head and neck are measured with instrumentation inside the ATD. High and normal speed cameras are used to capture test footage that describe the behaviour of the MPS, barrier and ATD.

TS 1317-8 divides MPS into two categories: continuous motorcyclist protection systems (CMPS) and discontinuous motorcyclist protection systems (DMPS). A CMPS is a MPS placed continuously along a barrier, such as a secondary rail. A DMPS is a MPS placed locally around potentially aggressive elements of a barrier such as posts.

There are three launch configurations defined in TS 1317-8:

Post-centric impact: This launch configuration is generally intended to represent the configuration resulting in the most severe impact-related injuries. The approach path of the ATD is a line parallel to the ground, passing through the centre of the post section and forming a 30˚ angle with respect to the centreline of the un-deformed test item.

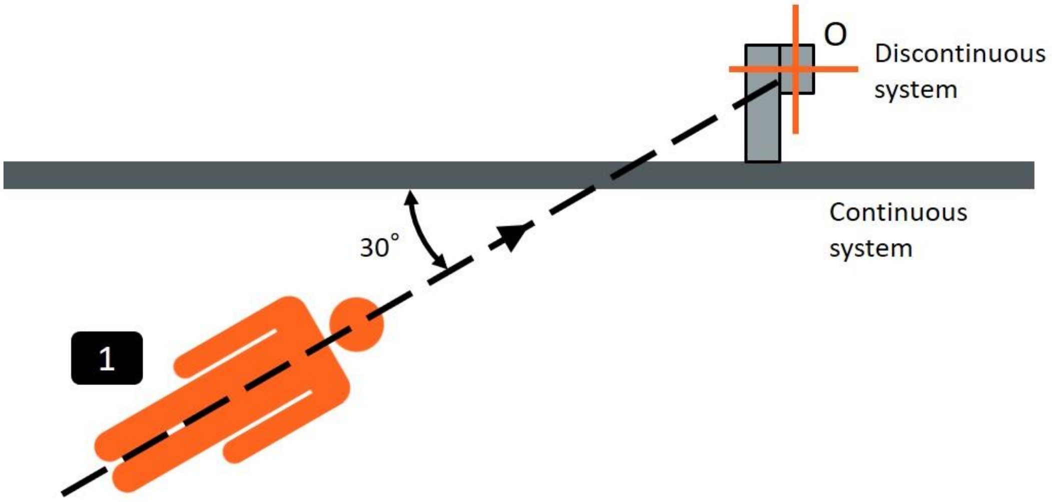

Figure 5: ATD trajectory for post-centric impact

Post offset impact: The purpose of this configuration is to impact the edge of a DMPS which may be potentially aggressive and/or to achieve maximal deceleration of the ATD. The approach path of the ATD is defined by a line parallel to the ground and parallel to a line at 30˚to the centreline of the un-deformed test item, passing through the point O. Approach path shall be 20 cm upstream of the 30˚ line passing through point O. This configuration is only applicable when test item is a DMPS.

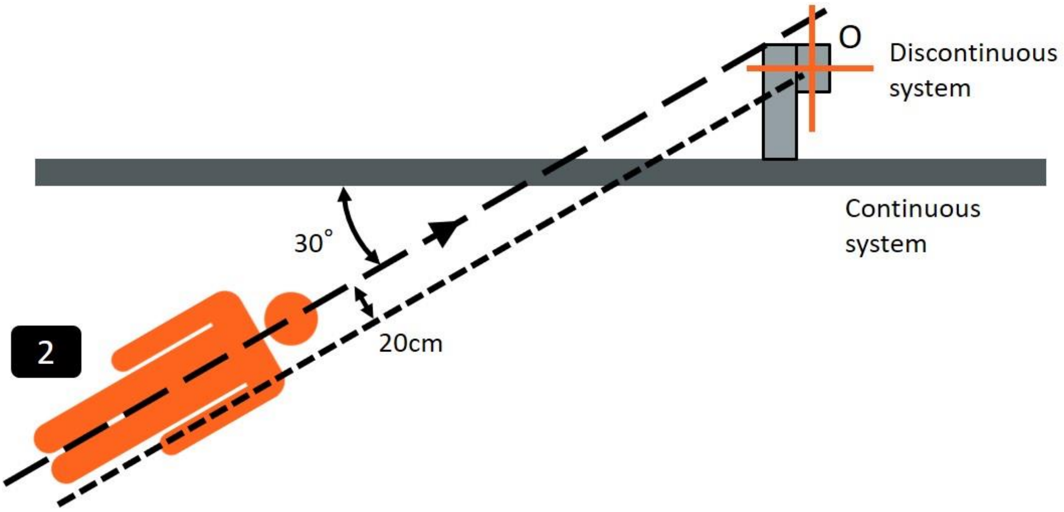

Figure 6: ATD trajectory for post-offset impact

Mid-span Impact: This test is only applicable to CMPS and is primarily intended to test the robustness of the test item where it is most flexible and to evaluate the potential for the trapping of limbs in the area where this is most likely to occur. The approach path of the ATD is defined by a line, parallel to the ground, passing through point I and forming a 30˚angle with respect to the centreline of the un-deformed test item.

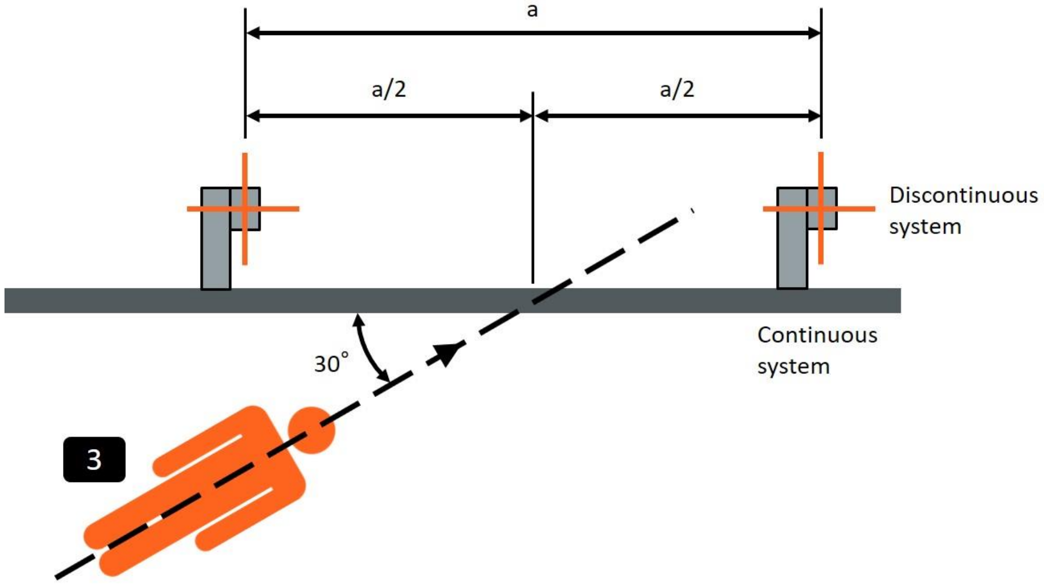

Figure 7: ATD trajectory for mid-span impact

4.1.2.3 Performance classes

The performance of an MPS is determined by two classes: the speed class and the severity level. Table 7 shows all the test types defined in TS 1317-8 with corresponding speeds, MPS types and launch configurations.

Table 7: TS 1317-8 tests

Test	MPS type	Launch configuration	Speed (km/h)
TM.1.60	CMPS and DMPS	Post-Centred	60
TM.2.60	DMPS	Post offset	60
TM.3.60	CMPS	Mid-span	60
TM.1.70	CMPS and DMPS	Post-Centred	70
TM.2.70	DMPS	Post offset	70
TM.3.70	CMPS	Mid-span	70

Speed Classes: The speed class of the MPS is determined by the impact speed of the tests performed. Speed classes in TS 1317-8 are described in Table 8.

Table 8: TS 1317-8 speed classes

For DMPS		
Class	Tests required	
D60	TM.1.60	TM.2.60
D70	TM.1.70	TM.2.70
For CMPS		
Class	Tests required	
C60	TM.1.60	TM.3.60
C70	TM.1.70	TM.3.70

Severity Levels: The severity level of the MPS is determined by biomechanical indices, which are either measured via ATD instrumentation or calculated by using these measurements. Head Injury Criterion (HIC36) is the index representing the head injury risk and it is calculated by using the accelerations acting on the head of the ATD, which are recorded during the test. Neck injury risk is represented by forces and moments acting on the neck of the ATD, which are listed in Table 9.

For each impact test, two severity levels are defined (level I and level II). A severity level is achieved only when the values of all the biomechanical indices obtained from test data are equal to or less than the corresponding maximum limits shown in Table 9.

A product will have a classification of speed and severity level.

Table 9: TS 1317-8 severity levels

Acceptance Criteria/Limits		
	Severity Level I	Severity Level II
Head Injury Criterion (HIC_{36})	650	1000
Neck Shear Force (F_x)	≤ 1900 N	≤ 3100 N
Neck Tension Force (F_z)	≤ 2700 N	≤ 3300 N
Neck Compression Force (F_z)	≤ 3200 N	≤ 4000 N
Neck Bending Moment (M_{OCx})	134Nm	134Nm
Neck Extension Moment (M_{OCy})	42Nm	57Nm
Neck Flexion Moment (M_{OCy})	190Nm	190Nm

4.1.3 Issues related to TS 1317-8 and the testing of MPS

TS 1317-8 currently addresses only the scenario where a rider impacts a safety barrier while sliding along the ground, having fallen from a motorcycle. However, as shown in the literature review (See Section 3.2.3), this is neither the only mode of interaction between motorcyclists and roadside barriers, nor the most common. In fact, the review of literature has shown that, on average, only half of the motorcycle-to-barrier collisions occur in the sliding position. This shows that TS 1317-8 addresses only one part of the problem. This is one of the main reasons why the current TS 1317-8 is criticised as being only a step forward, rather than being a complete solution to motorcycle-to-barrier safety.

The next step in MPS testing is the development of testing methodologies that consider other modes of interaction between motorcyclists and roadside barriers. Unfortunately, the amount of research on this area is only very limited at the moment. In order to develop new testing methodologies, a better understanding of motorcyclist barrier interaction must be developed. For this purpose, in-depth studies of motorcyclist and barrier accidents are needed.

Another issue related to the testing of MPS in accordance with TS 1317-8 is the financial risk for the test house. A modified and instrumented Hybrid-III dummy is an expensive piece of equipment. Due to the nature of TS 1317-8, this expensive piece of equipment has to undergo direct impact with the systems being tested, which may result in damage to the dummy. This adds considerable financial risk to the test house undertaking the test. Perhaps it is for this reason that many test houses are reluctant to offer TS 1317-8 as a part of their services today.

But perhaps the biggest issue related to the testing of MPS today is related to the possible change in impact performance of an already tested barrier system when a MPS is installed to it. A MPS should not only be tested to TS 1317-8, but the host barrier, to which the MPS will be installed, should also be re-tested with the MPS fitted, in accordance with EN1317-1&2. This should be done to demonstrate that the additional system does not change the performance level of the barrier. This, however, creates a supplementary problem, in that it is not clear whose responsibility it is to test the combinations of different barrier and MPS systems.

For example, if the highways authority want to install MPS “A” under the barrier system “B” is it manufacturer A’s responsibility to re-test their product with MPS, or is it manufacturer B’s responsibility, or neither? Considering the numerous combinations of barrier and MPS system available on the market today, the financial implications for testing every combination would be significant.

Another issue is the lack of in-depth studies that evaluate the on-site performance and effectiveness of many kilometres of tested MPS applied across Europe today. It is not possible to evaluate current testing methods completely, without studying the real-life performance of the approved systems.

4.2 Systems available on the market

There are many different MPS available on the market today. The majority of these MPS are from countries such as Spain, Germany, France and Italy, where motorcycle use is more widespread. In fact, Spain seems to be the country leading MPS development.

Nearly all of the MPS available on the market today are only designed to protect impacting riders that are sliding on the ground having fallen from their motorcycles. There are nearly no designs to protect riders from other types of barrier impacts. This is an expected situation, since there is currently no testing standard for the other types of impact.

Many of the MPS have been tested to the MPS testing requirements of either the UNE 135900-1&2, LIER, or TS 1317-8 protocols, and/or to the passenger vehicle testing requirements of EN1317-1&2. However, only a small number of these systems have been tested according to both an MPS testing standard and EN1317-1&2.

Adding a MPS to an existing barrier can have some adverse effects during an impact with a car. This concern was supported by tests carried out in BAst, Germany. The testing indicated that there would be an increased probability of a car climbing up the barrier due to the addition of the lower secondary rail, although the results of the testing were still deemed to meet the requirements of EN1317-1&2. It should be noted that different MPS-barrier combinations can result in different characteristics. Therefore, it is important to test the complete systems both to a MPS testing method and to EN1317-1&2 before installation, as specified within TS 1317-8.

The section below describes the two main types of MPS.

4.2.1 MPS types

Current MPS designs available on the market can be categorized into two main categories: secondary rails and post protection systems.

4.2.1.1 Secondary rails

This is the most common MPS type currently being manufactured and promoted within Europe. In this type of MPS (shown in Figure 8), a secondary rail is fitted underneath the main longitudinal of the barrier system. This type of system provides continuous protection from posts for errant motorcyclists impacting the barrier while sliding along the ground, having fallen from their motorcycles. However, these systems do not provide any protection for riders impacting the barriers while they are still on their motorcycles.

Figure 8: BikeGuard from Highway Care Ltd.

The main advantage of these systems is that they can be fitted easily under the existing barrier installations, without the need of replacing them. However, as it was previously mentioned, addition of a secondary rail can have adverse effects on the performance of a barrier during an impact with a car. Another disadvantage of these systems is that they can make snow clearing operations harder.

4.2.1.2 Post protection systems

This type of system focuses only on the most aggressive element of a barrier system, the post. These are discontinuous systems where each post is covered individually by the MPS.

These systems are usually easier and quicker to install and cheaper than other MPS. They can also be used in tight corners, where other MPS types may not be.

Like secondary rails, these systems only provide protection for errant riders sliding along the ground having fallen from their motorcycle.

Key points: MPS and their testing

- The testing specification for MPS is TS 1317-8, developed by combining existing French and Spanish protocols. It is not obligatory unless mandated by a National Regulation.
- TS 1317-8 only tests impacts where the motorcyclist is sliding along the ground. However, around half of incidents involve a motorcyclist hitting a barrier whilst upright.
- An issue related to testing of MPS is the need to re-test host barriers once MPS have been fitted but it is not clear whose responsibility this is.
- Current MPS designs can be sorted into two main categories.
  - **Secondary rails** which are fitted underneath the main longitudinal of the barrier system
  - **Post protection systems** where each post is covered individually by the MPS

5 Understanding the scale of motorcycle-to-barrier incidents on the National Highways network

There is clear evidence from the review of literature which shows that motorcycle-to-barrier impacts are generally high severity events. However, it is important to understand the scale, frequency, and historic trends of this type of incident. This will enable possible investment in safety measures to be evaluated and compared with competing investment options targeting safety problems.

This section begins by exploring the wider context of the problem by considering casualty statistics for the whole SRN and how motorcyclist casualty numbers compare with other road user groups. The popularity of the motorcycle is then considered through analysis of licensing data and finally the scale of motorcycle-to-barrier incidents on the SRN is established.

5.1 SRN overview

The aim of this section is to give an overview of casualty numbers on the SRN, in order to set the wider context for the motorcycle-to-barrier collision analysis. Casualty numbers and casualty rate trends for the SRN are presented, calculated using STATS19 data and traffic data from tables published by the DfT (DfT, 2020)[1].

Figure 9 shows SRN casualty figures by severity between 2005 and 2018. The total SRN traffic is also shown by the yellow lines. The casualty numbers and the traffic have all been indexed to the 2005 figure so that the trend can be more easily identified.

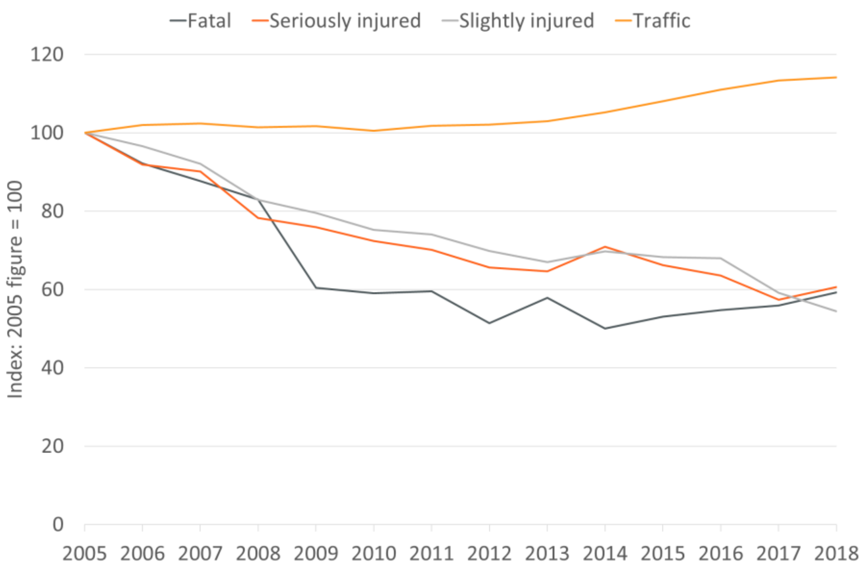

Figure 9: Traffic and reported casualties by severity, indexed to 2005 figure, SRN 2005-18

[1] All charts showing data from 2005 to 2018 use serious and slight casualty numbers which have been adjusted to account for the changes in severity reporting by police which began around 2015.

As shown in Figure 9, the general number of reported casualties from incidents of all severities has decreased since 2005, despite the increase in traffic. However, for the purpose of this research, it is important to understand the trends for motorcyclist incidents in particular.

Figure 10 shows the number of motorcyclist casualties on the SRN by severity.

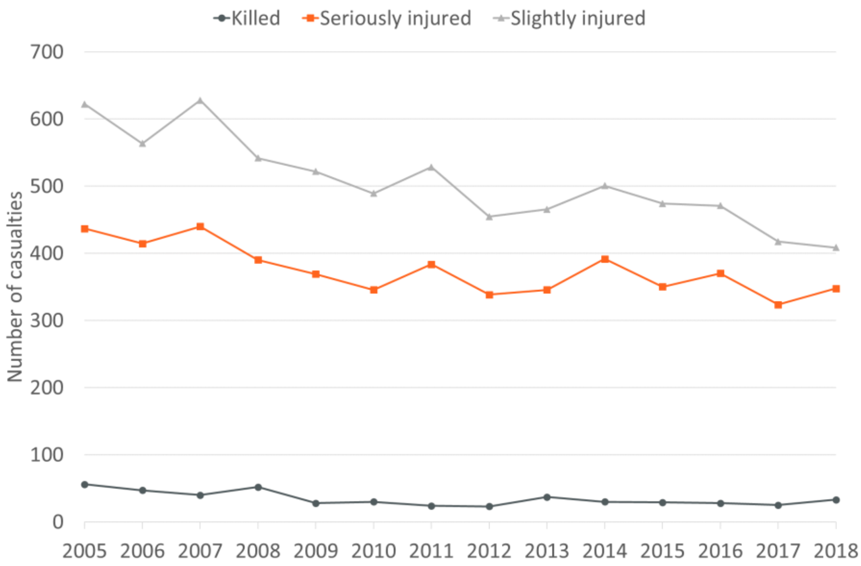

Figure 10: Motorcyclist casualties in STATS19, SRN 2005-18

Looking at Figure 10, it can be seen that the number of motorcyclist casualties decreased slightly between 2005 and 2018. The number of slight casualties decreased by 34%, the number of seriously injured by 20% and fatalities by 41%. These changes are in line with the decreases seen for all casualties in Figure 9, suggesting that the trend in motorcyclist casualties has been similar across recent years as the trend for all casualties.

However, it is important to consider the levels of motorcycle traffic over recent years when interpreting casualty trends. Therefore, Figure 11 shows the trends in casualty rates (all severities) for motorcycles and non-motorcycles on the SRN between 2005 and 2018. The casualty rates have been indexed to the 2005 figure to allow the trends to be compared more easily.

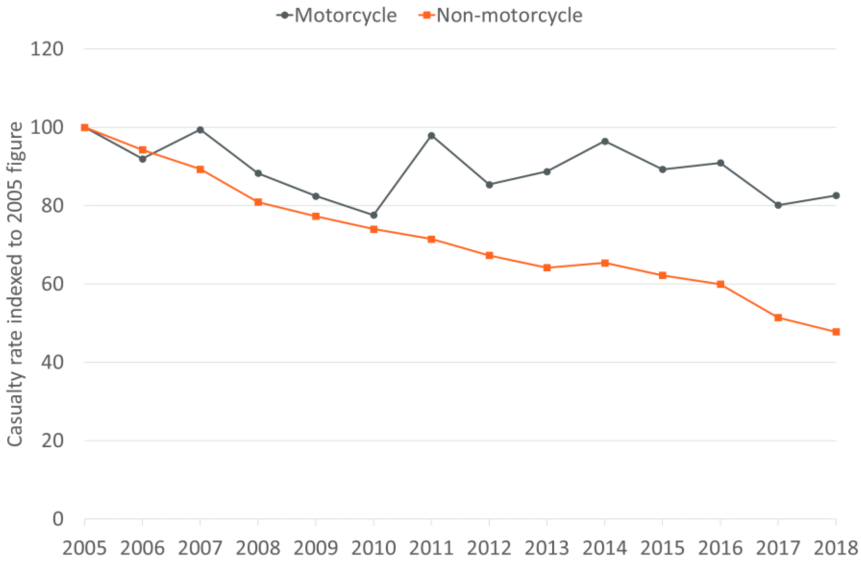

Figure 11: Total casualty rates (casualties per billion vehicle kilometres) for motorcyclist and non-motorcyclists, indexed to the 2005 figure, SRN 2005-18

Figure 11 shows that the casualty rates for motorcyclists and non-motorcyclists both showed similar decreasing trends between 2005 and 2010. However, after 2010 the non-motorcyclist casualty rate trend continued decreasing but the motorcyclist casualty rate increased and then flattened. This means that, across the whole period, the non-motorcyclist casualty rate decreased by 52% whereas the motorcyclist casualty rate only decreased by 17%.

What cannot be seen from Figure 11, but is important to note, is that the motorcyclist casualty rate is much higher than the casualty rate for non-motorcyclists and this is true across the whole period from 2005-2018. On average across the period, the motorcyclist casualty rate was 12 times higher than the casualty rate for non-motorcyclists.

To further understand how casualties are split across different road user groups, data from 2014-2018 was examined in more detail. Figure 12 shows the proportion from each road user group of killed, seriously injured and slightly injured casualties.

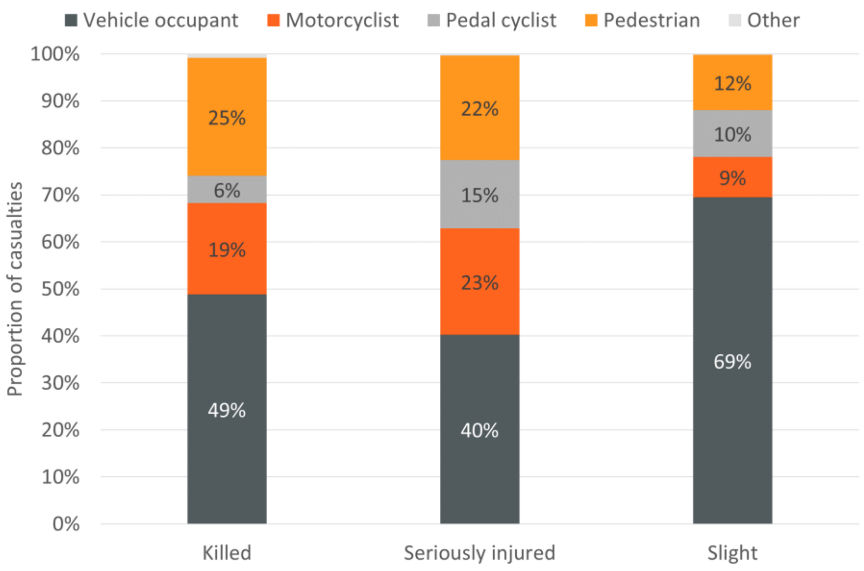

Figure 12: Proportion of casualties by road user type and severity, SRN 2014-18

Figure 12 shows that vehicle occupants account for the largest proportion of slightly injured casualties (69%). However, the vulnerable road user groups, and especially motorcyclists and pedal cyclists account for larger proportions of the killed and seriously injured casualties.

However, there are vast differences in the amount of traffic in each of these road user groups, and it is important to account for this when looking at the data. Figure 13 shows motorcycle and vehicle occupant casualty rates for the same period, split by severity.[2]

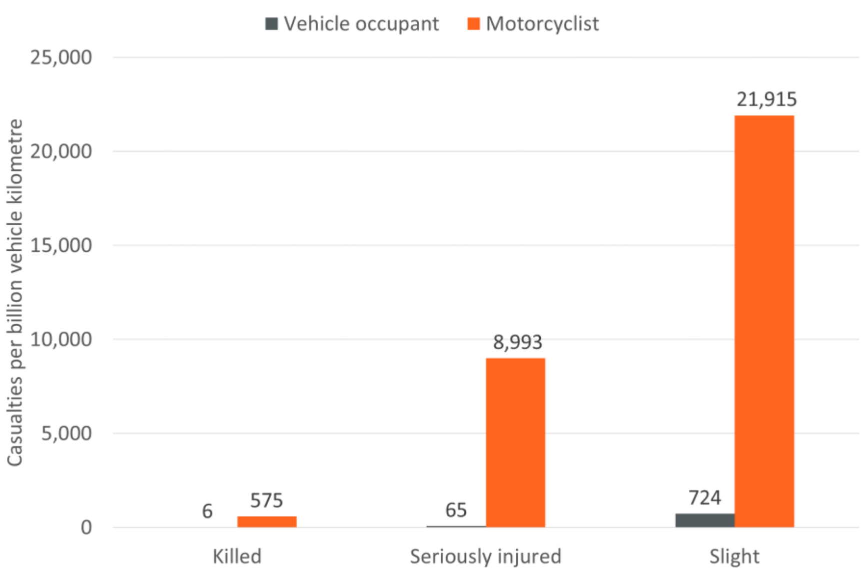

Figure 13: Casualties per billion vehicle kilometres travelled for motorcyclists and non-motorcyclists by severity, SRN 2014-18

[2] Traffic data for pedal cyclists and pedestrians on the SRN was not available.

When adjusted to take into account the relative distance travelled, as shown in Figure 13, motorcyclists clearly have a much higher casualty rate than vehicle occupants for all severities.

In other words, motorcyclists are at much higher risk of injury or fatality than vehicle occupants. In fact, across the period 2014-18, there were 98 times more motorcycle fatalities per billion vehicle kilometres than vehicle occupant fatalities and 137 times more seriously injured motorcyclist casualties than seriously injured vehicle occupant casualties per billion vehicle kilometres travelled.

Key points: Overview of SRN casualty statistics

- Overall, total casualty numbers on the SRN have been decreasing since 2005, despite an increase in traffic.
- From 2010 onwards, the non-motorcyclist casualty trend was decreasing but the motorcyclist casualty trend increased and then flattened.
- Vehicle occupants accounted for the largest proportion of slight casualties (2014-18) but VRU groups (including motorcyclists) accounted for the larger proportion of fatal and serious casualties.
- Motorcyclists had a much higher casualty rate than vehicle occupants for all severities in the period 2014-2018
- Motorcyclists are at much higher risk of injury or fatality than vehicle occupants so preventing motorcyclist casualties is important.

5.2 Popularity of the motorcycle

It is known that for leisure, environmental and financial reasons, motorcycling has become ever more popular during the last two decades. Information published by DfT on the number of licensed motorcycles in Great Britain (DfT, 2020) has been analysed to investigate this further.

Figure 14 shows the number of licensed motorcycles in Great Britain each year from 1994 to 2018.

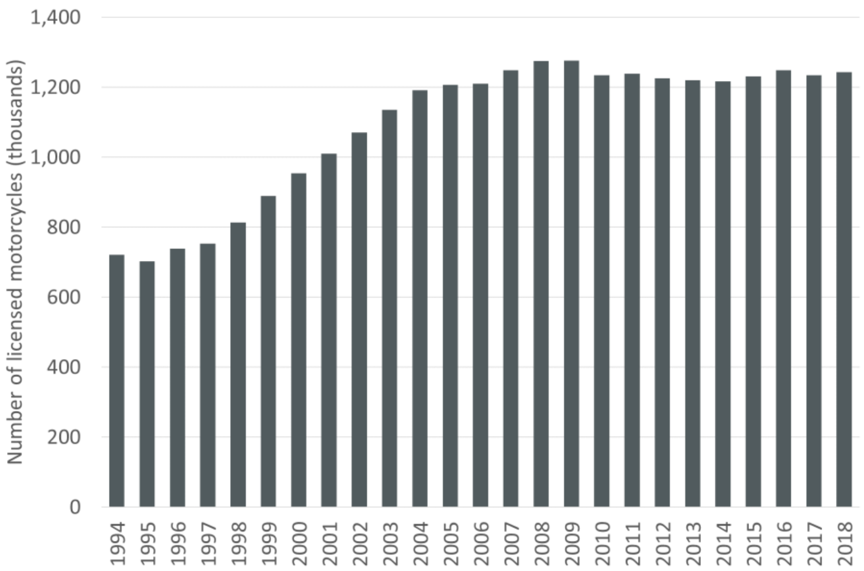

Figure 14: Number of licensed motorcycles in Great Britain, 1994-2018[3]

As shown in Figure 14, the number of licensed motorcycles in Great Britain kept increasing from the late 1990s to 2009. From 2009 onwards, the number of licensed motorcycles in Great Britain appears to have stabilised.

Interestingly, not only has the total number of licensed motorcycles increased, but also the proportion of bikes with larger engines. As shown in Figure 15, motorcycles with an engine size of over 500cc became more and more popular up to 2009 when their popularity started to decrease but the number of motorcycles with an engine size of greater than 1000cc has increased steadily between 1995 and 2018. In 1995, 28% of licensed motorcycles had an engine size over 500cc but by 2018 this had almost doubled to 55%. Motorcycles with larger engines are more powerful and therefore can demand more experience from the rider to establish safe control. In contrast, the popularity of bikes with an engine size less than 50cc has decreased.

[3] Motorcycles includes mopeds and scooters

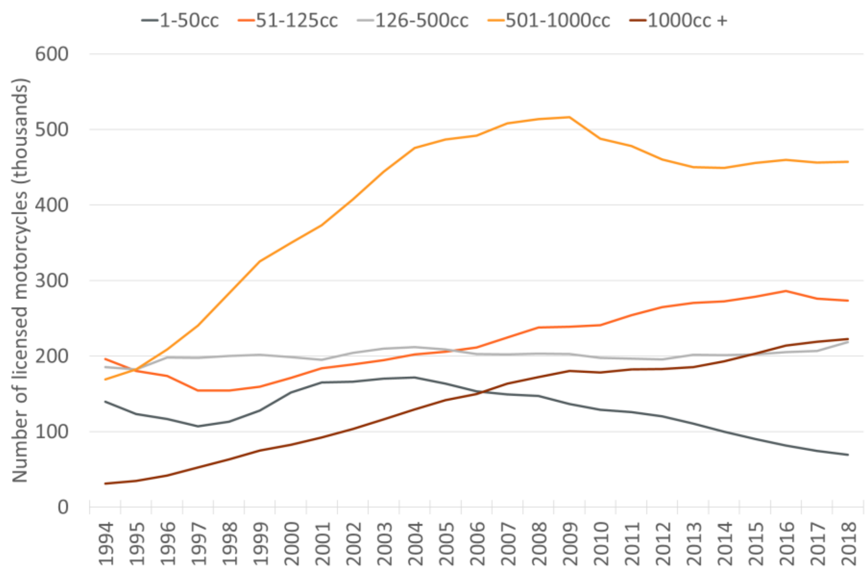

Figure 15: Number of licensed motorcycles in Great Britain by engine size, 1995-2018

5.3 The scale of motorcycle-to-barrier incident casualties 2014-2018

Having looked at the general trends in motorcycle incidents, it is important to now examine and understand the scale of motorcycle-to-barrier incidents in particular. For this purpose, STATS19 records for the period 2014-2018 are analysed in more detail.

5.3.1 Overview

The aim of the analysis presented in this section is to identify the overall scale of motorcycle-to-barrier incidents and what proportion of total SRN casualties are accounted for by this type of incident.

Figure 16 shows the scale of all reported casualties (fatal, slight and serious) resulting from motorcycle-to-barrier impacts, compared with the rest of the road traffic casualties recorded on the National Highways network between 2014 and 2018.

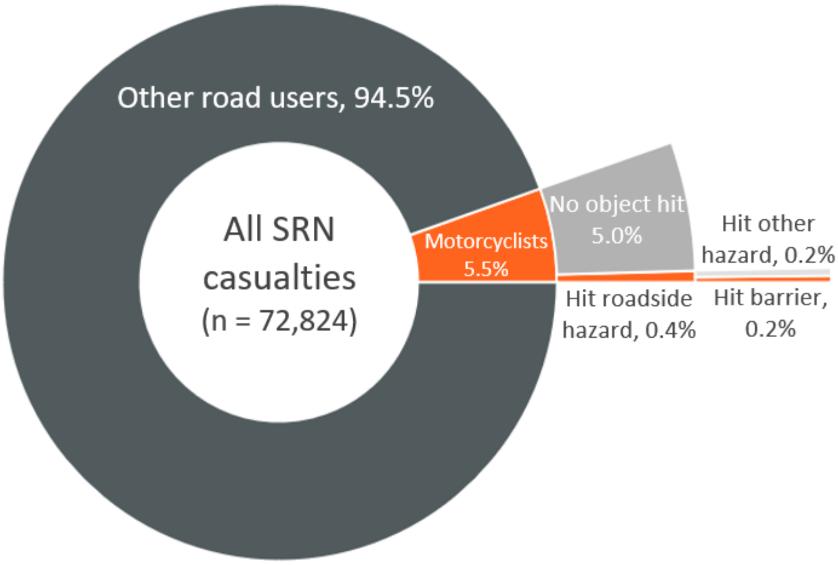

Figure 16: Breakdown of SRN casualties showing scale of motorcyclist casualties from collisions with barriers, 2014-18

Across the 2014-18 period, motorcyclists only accounted for 5.5% of all reported casualties on the network (4,199 casualties). Of all the recorded motorcycle casualties, 327 resulted from incidents where at least one roadside hazard was hit. Of all motorcycle to roadside hazard casualties, only 184 resulted from hitting a barrier, an average of 37 per year. In other words, motorcycle-to-barrier incident casualties accounted for only 0.2% of all casualties recorded on the National Highways network between 2014 and 2018.

Figure 17 is similar to Figure 16, but this time only Killed or Seriously Injured (KSI) casualties are shown.

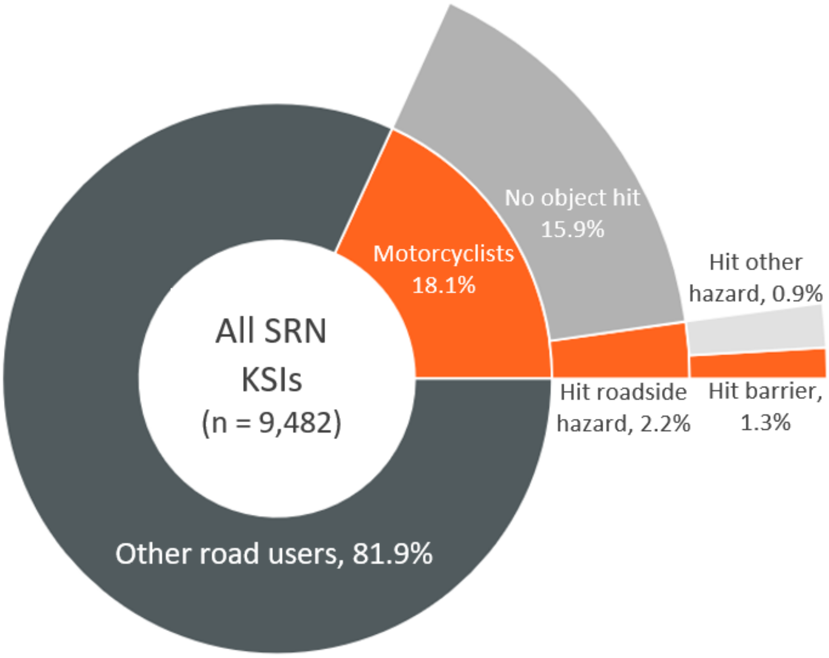

Figure 17: Breakdown of SRN KSIs showing scale of motorcyclist KSIs from collisions with barriers, 2014-18

Motorcyclists, with 1,719 reported KSI casualties, accounted for 18.1% of all reported KSI casualties on the National Highways network between 2014 and 2018. Compared with the figure for casualties of all severities, this percentage is more than doubled. This is a good indicator for the higher severity nature of motorcycle incidents in general.

Of all the recorded motorcyclist KSI casualties, 208 (2.2%) were from incidents where at least one roadside hazard was hit. These 208 casualties account for 2.2% of all SRN KSI casualties. Only 123 motorcyclist KSI casualties were from incidents where a motorcycle hit a barrier (1.3% of all KSI casualties on the SRN).

These figures show that the number of casualties from motorcycle-to-barrier incidents is relatively small when compared with the total number of casualties on the SRN. However, the small numbers should not mean that attempts to prevent these casualties are not made, especially when MPS exist which could do so.

5.3.2 Commonly impacted roadside objects

When a motorcyclist leaves the carriageway during a collision, they may not necessarily hit a barrier. This section explores the roadside objects commonly hit by motorcycles and how they vary in the severity of the resulting injury.

For casualties where the motorcyclist left the carriageway and collided with a roadside object, Figure 18 shows the number of casualties by the type of object the motorcycle hit first.

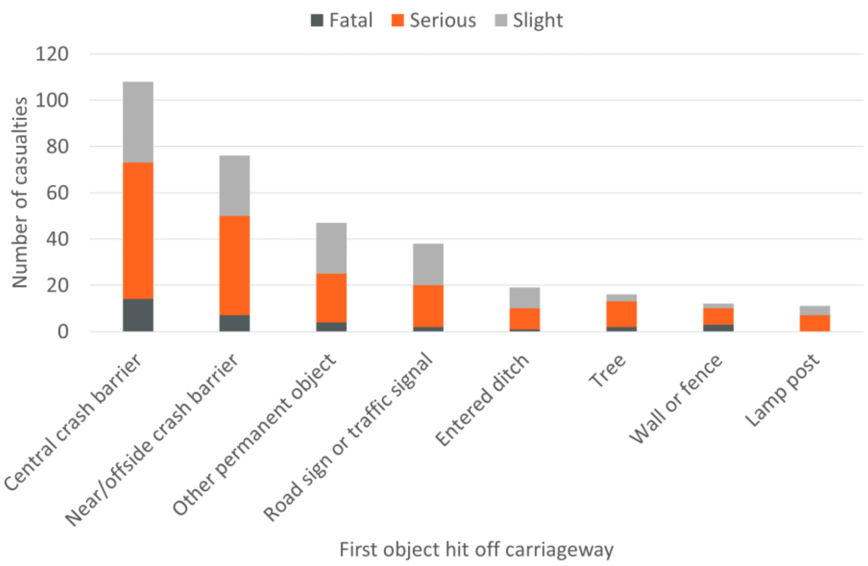

Figure 18: Number of motorcyclist casualties by first object hit off carriageway and severity, SRN 2014-18

As can be seen from the figure, central barriers and nearside/offside barriers were the object types which accounted for the highest and second highest number of motorcyclist casualties. "Other permanent object" which can include many different types of objects was third, followed by "Road sign or traffic signal".

Figure 19 adjusts the previous figure by the percentage of fatal, serious and slight injury casualties resulting from impact with each type of hazard. This way the consequences of hitting each type of roadside hazard can be evaluated, regardless of the total number of incidents.

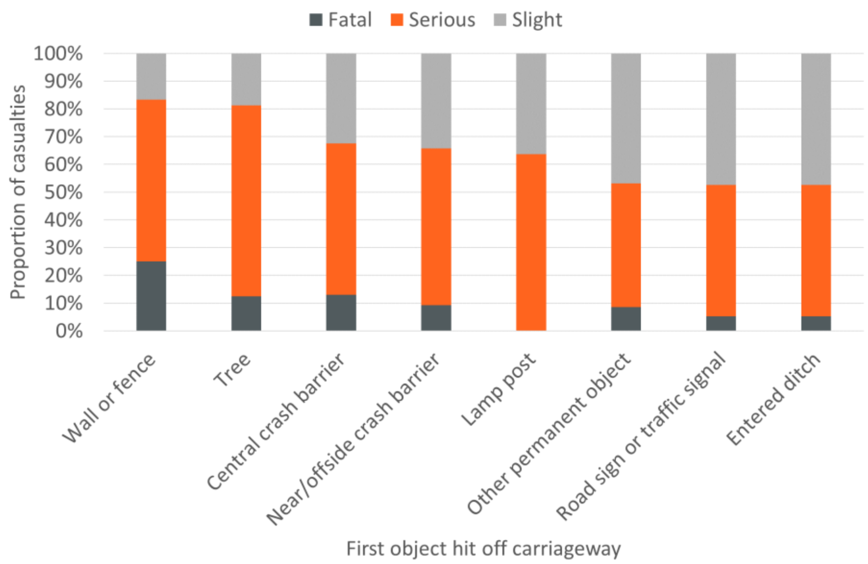

Figure 19: Proportion of motorcyclist casualties by first object hit off carriageway and severity, SRN 2014-18

As shown in the figure, hitting a wall or fence caused the highest ratio of serious or fatal injuries for motorcyclists, with 83% of this sort of impact resulting in either a serious injury or fatality (10 out of 12 casualties). This was closely followed by trees (81% KSI) and then central and nearside or offside crash barriers (68% and 66% KSI respectively).

The results in this section show that, whilst impacts with barriers may not result in as many fatal and seriously injured casualties as some other roadside hazards, they are the most commonly hit. This is to be expected because barriers are often installed to prevent impacts with the more dangerous hazards behind. The fact that barrier impacts account for the highest proportion of motorcyclist casualties from impacts with roadside objects gives a good reason for making these barriers as safe as possible.

5.3.3 Severity of motorcycle-to-barrier incidents

The information presented in Section 5.3.1 showed that motorcycle-to-barrier impacts are low in numbers, compared to other types of incidents, and other types of motorcycle incidents. However, as shown in the literature review, these incidents usually result in high severity outcomes.

To get an understanding of the effect of barrier impact to motorcyclists, single vehicle motorcycle-to-barrier collisions were analysed in more detail. The reason for investigating single vehicle collisions only is to assess the outcomes of collisions where barrier impact was the only major injurious event.

Figure 20 shows the number of single vehicle barrier accidents on the SRN between 2014 and 2018, for motorcycles and non-motorcycles. Note that, unlike the previous figures, this time the number of collisions instead of the number of casualties is shown, split by the most severe injury outcome in that collision.

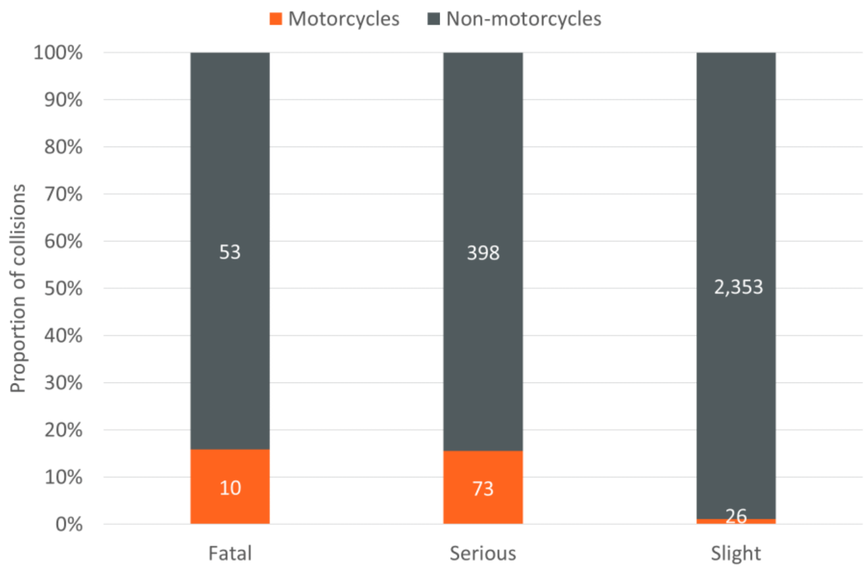

Figure 20: Proportion of single vehicle barrier collisions by vehicle type and most severe outcome, SRN 2014-18

As shown in the figure there were 10 fatal, 73 serious and 26 slight injury single vehicle motorcycle-to-barrier incidents. In the same period, there were 53 fatal, 398 serious injury and 2,353 slight injury single vehicle non-motorcycle-to-barrier incidents recorded. Figure 20 also shows that the proportions of fatal and serious single vehicle barrier incidents which involved motorcyclists were both substantially higher than the proportion of slight single vehicle barrier incidents involving these vehicles.

At first glance, motorcycles, with only 109 (4%) of the 2,913 single vehicle barrier incidents, may not look like a big problem compared to non-motorcycles. However, it is important to account for exposure so Figure 21 shows the number of collisions per billion vehicle kilometres travelled for motorcycles and non-motorcycles, split by severity.

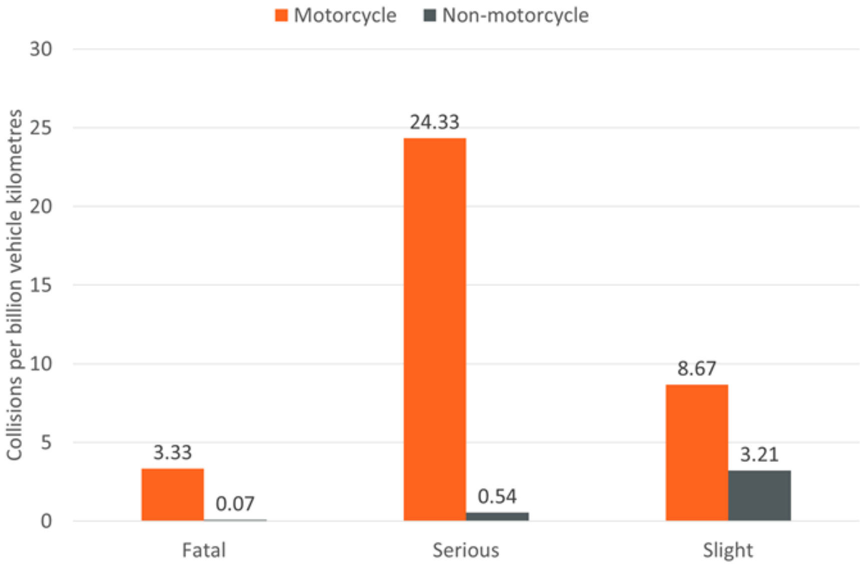

Figure 21: Single vehicle barrier incidents per billion vehicle kilometres for motorcycles and non-motorcycles, SRN 2014-18

As can be seen in Figure 21, adjusting the numbers with distance travelled per year reveals that motorcycles are heavily over-represented. More specifically, motorcycles (with 2.33 fatal collisions per billion vehicle kilometres) are roughly 33 times more likely to become involved in a fatal single vehicle barrier incident than non-motorcycles (with 0.07 fatal collisions per billion vehicle kilometres).

The differences in barrier incident severity for motorcycles and non-motorcycles is explored further in Figure 22, which shows the proportion of motorcycle and non-motorcycle single vehicle barrier collisions by severity.

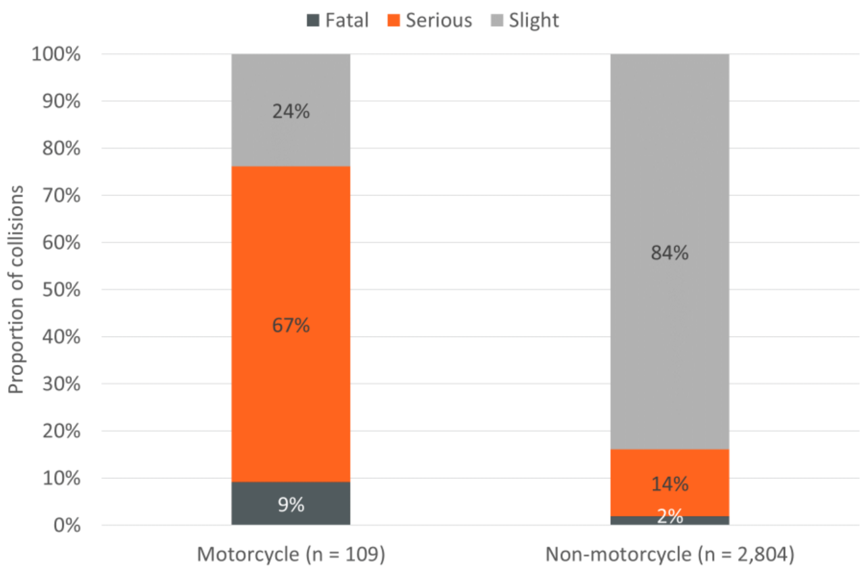

Figure 22: Proportion of motorcycle and non-motorcycle single vehicle barrier collisions by severity, SRN 2014-18

The results in Figure 22 show that only 16% of recorded non-motorcycle-to-barrier impacts resulting in fatal or serious injury, while for motorcycles 76% of the recorded barrier impacts resulted in either a fatality or serious injury.

This suggests that barriers are working better for non-motorcycles than they do for motorcycles. This is to be expected, as many barrier systems have been designed and tested for cars, not for motorcyclists.

Key points: The scale of motorcycle to barrier incident casualties 2014-18

- Motorcyclist casualties are often high severity; motorcyclist accounted for 18% of KSI SRN casualties but only 6% of total casualties.
- Motorcycle to barrier incident casualties accounted for only 0.2% of total SRN casualties but 1.3% of KSI casualties.
- Crash barriers are the most commonly hit roadside objects by motorcycles which leave the carriageway, giving a good reason for making these barriers as safe as possible.
- Motorcycles are roughly 33 times more likely to become involved in a fatal single vehicle barrier incident than non-motorcycles
- Only 16% of non-motorcycle to barrier impacts resulted in fatal or seriously injury but this figure is 76% for motorcycle to barrier impacts. This suggests that barriers are working better for non-motorcycles than they do for motorcycles.

6 Analysis of motorcycle-to-barrier incidents on the National Highways network

It is important to understand the motorcycle-to-barrier incidents in more detail, so that the common characteristics of these incidents can be identified, such as common incident locations, most harmful barrier types, and common factors in the incidents. This will help National Highways to develop a more robust and targeted MPS policy. For this purpose, a detailed analysis was performed, based mainly on STATS19 data. The methodology and the results of this analysis are presented in this section.

6.1 Methodology

Figure 23 presents the methodology adopted for the data analysis and the following sections describe the different steps in more detail.

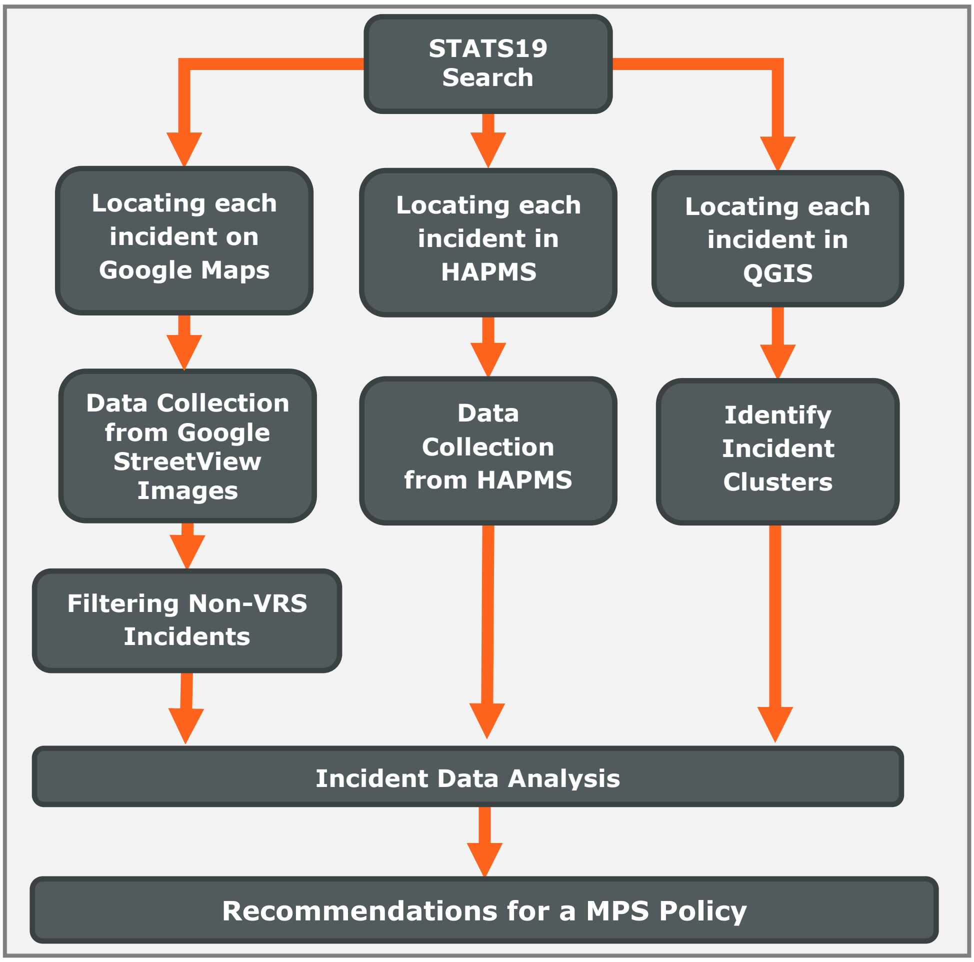

Figure 23: Methodology for data analysis

6.1.1 STATS19 Search

6.1.1.1 Background to STATS19

The STATS19 database is a database of reported injury collisions on public roads in Great Britain, owned by the Department for Transport. The database covers road traffic collisions which resulted in injury, occurred on the public highway, involved at least one road vehicle, and became known to the police within 30 days. Excluded from STATS19 are confirmed suicides, deaths from natural causes and injuries to pedestrians with no vehicle involvement (e.g. a fall on the pavement). There are also no damage-only collisions recorded in STATS19 and collisions resulting in only slightly injured casualties are known to be under-reported in the database.

Information recorded in STATS19 is collected by the police and includes data such as the time, location and severity of collisions, the type of vehicle(s) involved and the vehicle movement at the time of the accident, and information about the drivers and casualties involved. Casualties recorded in the database are classed as either 'killed', 'seriously injured' or 'slightly injured' and the severity of a collision is defined as the severity of the most severely injured casualty in that collision.

The data collected by the police is supplied to DfT who publish an annual dataset each year. An enhanced dataset containing more detailed vehicle data and sensitive variables such as breath test information and contributory factor data is supplied to TRL by DfT. The latest year of data available to TRL at the time of writing this report was 2018.

More information about the STATS19 database can be found on the gov.uk website[4].

6.1.1.2 Identifying motorcycle-to-barrier incidents

The process started with a STATS19 data search for motorcycle-to-barrier incidents which occurred on the National Highways network between 2014 and 2018. A motorcycle-to-barrier incident was defined as an incident where at least one motorcycle hit a barrier. This included both single and multiple vehicle incidents.

The following filters were applied to the STATS19 data:

- Location: National Highways network (using the Trunk Marker field)
- Study Period: 01/01/2014 to 31/12/2018 inclusive;
- Vehicle Category equals:
  - Motorcycle 50cc and under
  - Motorcycle over 50cc and up to 125cc
  - Motorcycle over 125cc and up to 500cc
  - Motorcycle over 500cc

[4] https://www.gov.uk/government/collections/road-accidents-and-safety-statistics

  - Motorcycle - unknown cc
  - Electric motorcycle
- Motorcycle has struck a barrier in either the verge or the median; First object hit off carriageway equals:
  - Central crash barrier
  - Nearside or offside crash barrier

The output of the search was a dataset which contained the information shown in Table 10, for 178 incidents.

Table 10: Fields obtained from STATS19 search

Collisions:	Vehicles:	Casualties:
PF	PF	PF
Year	Year	Year
Accident severity	Vehicle ref	Vehicle ref
Number of vehicles	Vehicle type	Casualty ref
Number of casualties	vehicle manoeuvre	Casualty class
Date	skidding and overturning	Casualty sex
Weekday (1 = Sunday)	junction location	Casualty age
Time	hit object in carriageway	Casualty injury
Longitude	vehicle leaving carriageway	
Latitude	hit object off carriageway	
1st road class	vehicle movement from	
1st road number	vehicle movement to	
Road type	journey purpose	
Speed limit	Driver sex	
Junction detail	Driver age	
Weather conditions		
Road surface condition		
Light conditions		
Special conditions at site		

6.1.2 Data collection from Google Street View

6.1.2.1 Locating incidents

After the initial STATS19 search, each incident was located on Google Maps using the GPS coordinates provided within STATS19.

To help the analysis, the incidents were colour-coded according to the most severe outcome. A red place mark was used for fatal incidents, yellow for serious injury incidents and green for slight injury incidents, as shown in Figure 24.

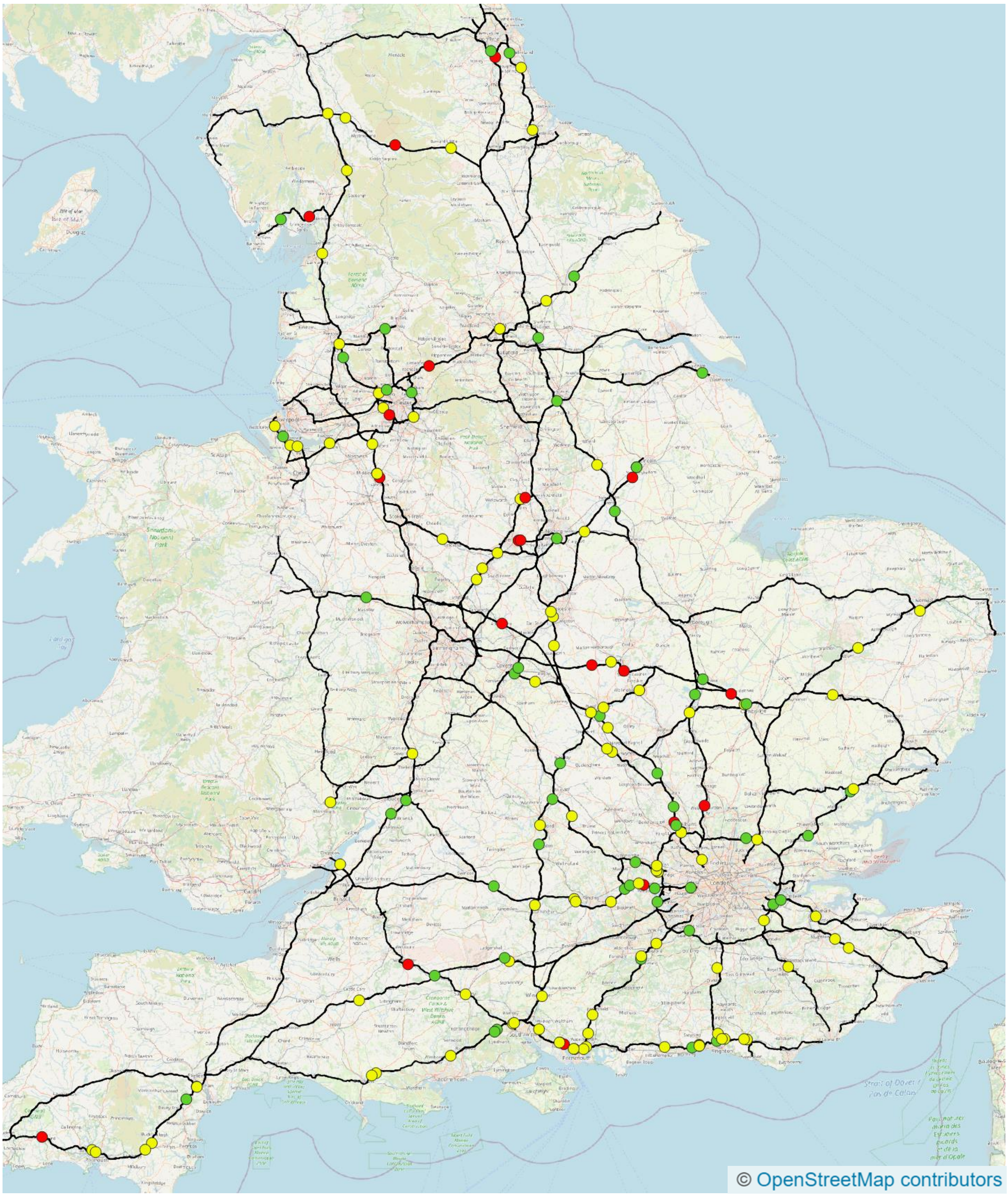

Figure 24: Motorcycle to barrier incident distribution on the SRN (2014-2018) (OpenStreetMap)[5]

Also, several fields from STATS19, such as road number, direction of travel, and object hit off carriageway were written into the description for each place mark. These descriptions were

[5] All base maps in this document courtesy of OpenStreetMap. Please see http://www.openstreetmap.org/copyright for copyright information.

later used alongside satellite and Google Street View images to develop a better understanding of each incident.

6.1.2.2 Collecting information

Once the location and the direction of travel for each incident had been identified, Google Street View images were examined to identify the type of barrier involved in the incident. For each site, where available, Street View photos from before and after the date of the incident were reviewed to identify any potential changes in barrier type. The barrier type information was added to the dataset to be used in further analysis.

This process also identified that some of the roadside objects recorded as “crash barrier” in STATS19 were not actually vehicle restraint systems, but other roadside objects that were miscoded by the police officer completing the form. These investigations led to four of the 178 incidents initially identified in the STATS19 search being removed from the final dataset.

In addition to identifying barrier type, more detail about the location of the incident was also collected during the review of Street View images. STATS19 records whether or not any incident took place at a junction and high level junction detail information. However, more detailed information about the characteristics of the incident location was required so Street View images were used to:

- identify whether incidents happened on bends or straight sections,
- identify whether bends were left- or right-hand bends,
- identify merges, diverges and weaving sections,
- distinguish between the main line and slip road sections of grade-separated junctions,
- establish whether it was likely that MPS was installed at the time of the incident[6].

6.1.3 Collating information from HAPMS

As part of the National Highways TRACS contract, curvature is one of the parameters that is continually uploaded into the National Highways Pavement Management System (HAPMS). Using the sections identified from each incident location, the matching curvature values could be extracted from the HAPMS database. The frequency of the data was every 10m and had chainage and OSGB XY GPS values attached. The data was plotted onto GIS software with the 10m curvature values styled to differentiate various levels of curvature.

6.1.4 Identifying incident clusters

Once the final dataset had been collated, the data was loaded into GIS software (QGIS) and cluster analysis was done. The cluster analysis involved creating 500m buffers around each

[6] It was not possible to know for certain if MPS was installed at the time of the incident because the Street View images may not have been taken close to the incident date. The closest available images to the incident date have been used.

point. A process was then run to identity how many other points were within each buffer zone. With each buffer having an attached number of points inside, a style could be applied differentiating buffers with 1, 2, 3 or 4 and more points. Clusters could then be identified and viewed by zooming to the ones with the greater number of points inside.

6.2 Data analysis results

This section presents the results of detailed analysis of the dataset of motorcycle-to-barrier incidents identified on the SRN. An overview of the dataset is presented in Section 6.2.1 and then the detailed analysis is split into three sections which investigate human factors (Section 6.2.2), vehicle factors (Section 6.2.3) and road environment factors (Section 0). These categories have been chosen because they are the categories often used when analysing what factors contributed to a collision and because they are three of the Safe System pillars.

The casualties examined here are only the motorcycle riders and their passengers. For multiple vehicle incidents involving non-motorcycle vehicles, only the casualties from the motorcycle are considered within the scope of this research.

6.2.1 Overview

The analysed database, after filtering, consisted of 174 motorcycle-to-barrier incidents. A total of 180 motorcyclist casualties resulted from the 174 incidents. Table 11 presents a summary of the incidents and resulting casualties by severity.

Table 11: Summary of motorcycle-to-barrier incident severity, SRN 2014-18

	Number of Incidents	Proportion of incidents	Number of Casualties	Proportion of casualties
Fatal	20	11%	20	11%
Serious	99	57%	101	56%
Slight/not injured	55	32%	59	33%
Total	**174**	**100%**	**180**	**100%**

The majority of motorcycle-to-barrier incidents (68%) involved a motorcyclist who was killed or seriously injured (KSI) and there were a total of 121 KSI casualties resulting from the 174 motorcycle-to-barrier incidents. There was one incident where no motorcyclists were injured.

Figure 25 shows a breakdown of these incidents by the severity of the most severely injured motorcyclist and the number of the vehicles involved. The number of vehicles is considered as a key parameter for this research, as this identifies different impact scenarios and influencing factors. Single vehicle collisions accounted for 62% of motorcycle-to-barrier incidents (108 collisions) whereas collisions involving multiple vehicles accounted for 38% (66 collisions).

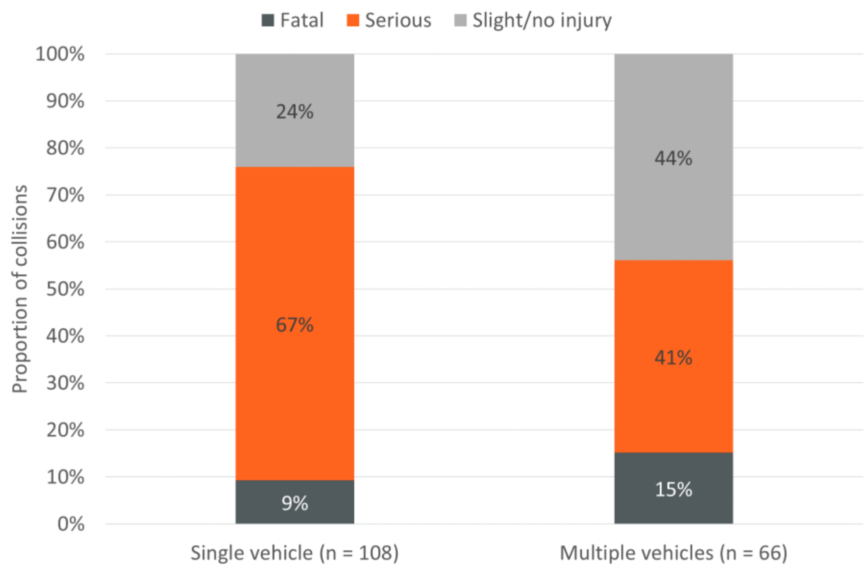

Figure 25: Proportion of motorcycle-to-barrier incidents, by the number of vehicles involved and severity of most severely injured motorcyclist, SRN 2014-18

The graph above shows that, whilst there is lower percentage of killed or seriously injured motorcyclists in multiple vehicle incidents, the percentage of fatalities alone is greater than for single vehicle incidents. This may be due to the different nature of each type of incident.

Key points: Overview of motorcycle to barrier incidents on the SRN

- There were 174 motorcycle to barrier incidents on the SRN between 2014 and 2018, resulting in 180 motorcyclist casualties.
- Of the 180 motorcyclist casualties, 11% were killed, 56% were seriously injured and 33% were slightly injured.
- Single vehicle collisions accounted for 62% of motorcycle to barrier incidents and multiple vehicle incidents accounted for 38%.

6.2.2 Human factors

By studying the human factors, it may be possible to detect the characteristics of the people who are more likely to get involved in a motorcycle-to-barrier incident. This is especially important when preparing a rider awareness or training policy, since it may be possible to target the most relevant group of people.

6.2.2.1 Age of rider

Figure 26 shows the age distribution of the motorcycle riders who became involved in recorded barrier incidents.

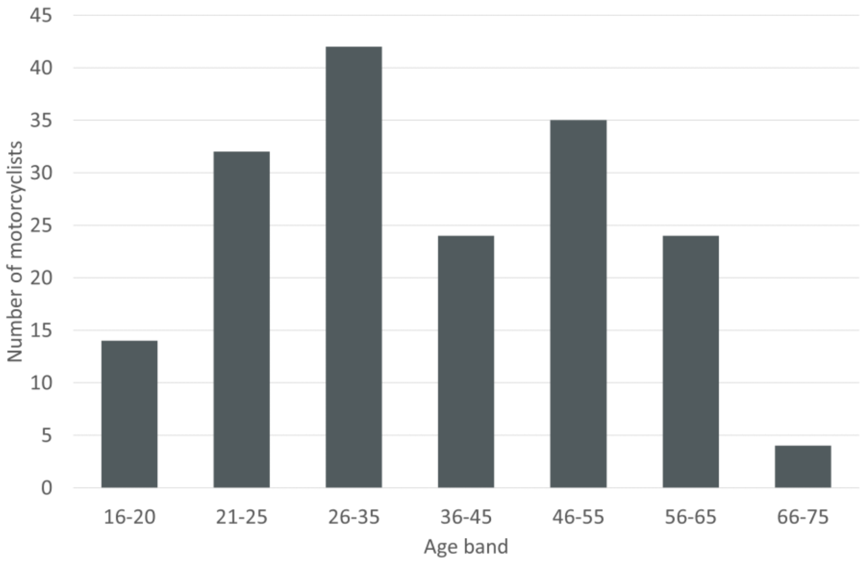

Figure 26: Number of motorcyclists involved in motorcycle-to-barrier incidents by age band, SRN 2014-18

The figure shows that the highest number of motorcycle-to-barrier incidents were recorded for the 26-35 age group, followed by the 46-55 and 21-25 age groups. It is interesting to note that there are fewer motorcyclists involved in barrier incidents from the 36-45 age group than for the age groups on either side. However, it is difficult to comment accurately without having the exposure data for each age group.

The larger number of incidents involving 46-55 year old motorcyclist compared with 36-45 year olds could be partly explained by “Born again” bikers. These are a known problematic group with a tendency to become involved in incidents. They are usually middle-aged men who return to motorcycling with powerful motorcycles, after a long break, possibly with rusty riding skills. These riders may also be more likely to be able to afford more expensive and more powerful bikes. However, with increased age, their reactions may not be as sharp to meet the demands of these more powerful bikes.

Figure 27 explores Figure 26 in more detail as the data is divided into single and multiple vehicle incidents. The aim of this separation is to compare the age distributions of riders involved in different incident scenarios.

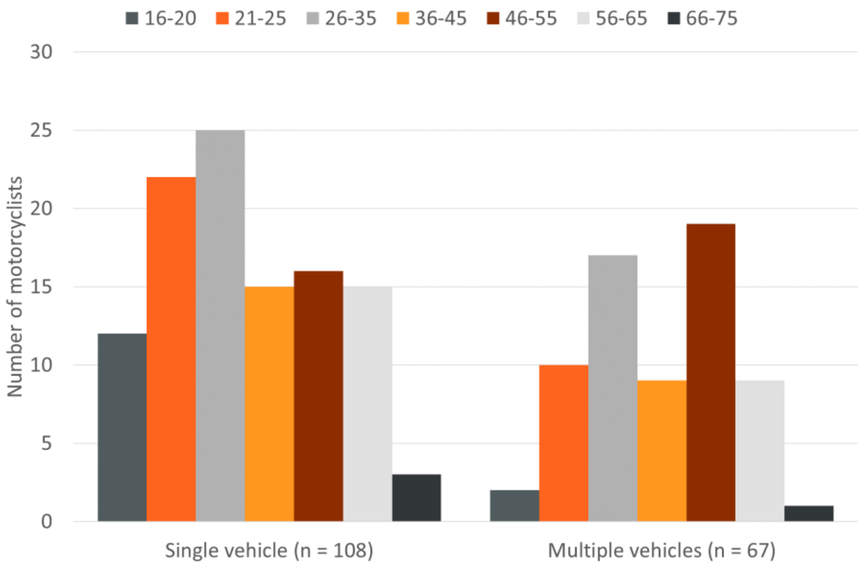

Figure 27: Number of motorcyclists involved in motorcycle-to-barrier incidents by age band of rider and number of vehicles in collision, SRN 2014-18

The rider age distribution seen for multiple vehicle incidents is similar to that seen for all incidents in Figure 26, with the largest numbers of incidents seen in the 26-35 and 46-55 year old age groups. However, the age distribution for riders involved in single vehicle incidents differs and the same peak in the 46-55 year old age group is not seen.

One of the differences between single and multiple vehicle incidents is the level of responsibility by the rider on the outcome. In single vehicle incidents, the rider is usually the only person who is responsible (not including road and environment factors); however, in multiple vehicle incidents the fault may be the other vehicle's driver/rider (for example, conspicuity-related types of incidents). The larger proportion of riders in multiple vehicle incidents who are in the 46-55 year old age group may be partly due to the reaction time of these riders, and hence their inability to identify and react to the actions or mistakes of other drivers in such incidents.

Another difference between single and multiple vehicle incidents is in the 16-20 age band; 11% of riders in single vehicle incidents were in this age group compared with only 3% in multiple vehicle incidents. This may indicate that inexperience and/or inappropriate speed may be one of the causation factors associated with the much greater number of single vehicle incidents. Riders within this age band may also be likely to take greater levels of risk with their riding.

However, it should be noted that the total number of both single and multiple vehicle incidents are small and therefore conclusions drawn from this chart should be treated with caution.

Figure 28 shows the severity of the incident outcome for each age group (note that the number of motorcyclists in the 66-75 age group is very small and so the proportions for this category should be interpreted with caution).

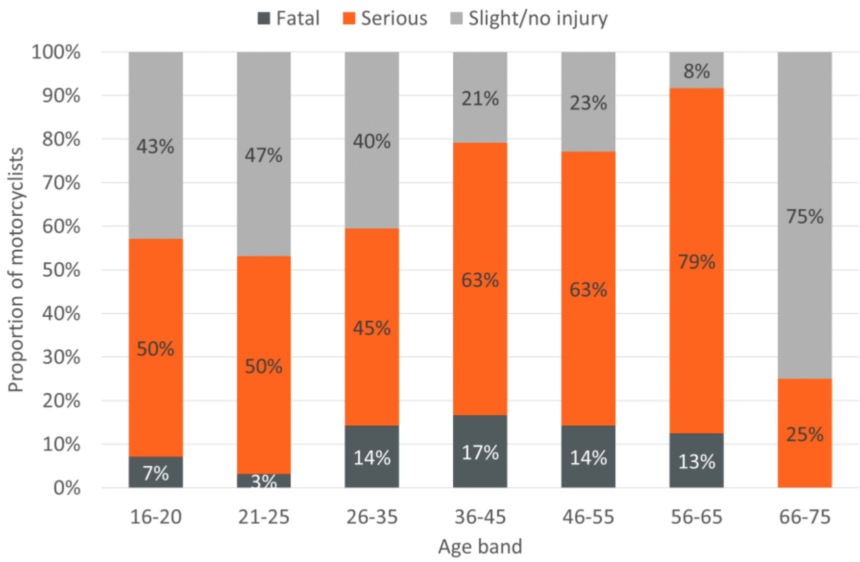

Figure 28: Proportion of motorcyclists in each age band by severity of most severely injured motorcyclist in collision, SRN 2014-18[7]

The percentage of riders suffering fatal or serious injury is larger for older age groups (between 36 and 65) than younger age groups. One of the reasons for this may be that older riders can be more susceptible to sustaining injury in the event of an incident.

6.2.2.2 Gender of rider

Figure 29 shows the number of motorcycle-to-barrier incidents by gender of the rider and the severity of the outcome.

[7] Percentages may not sum to 100% due to rounding

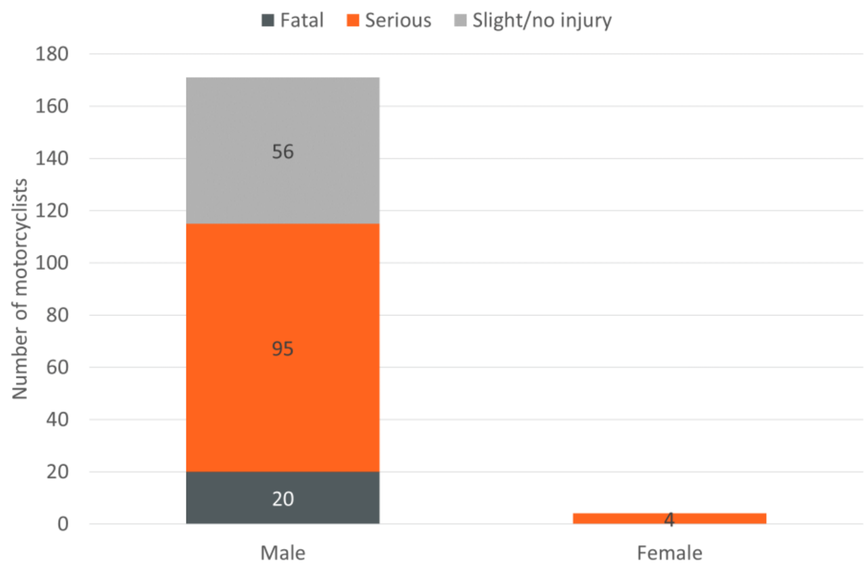

Figure 29: Number of motorcyclists in motorcycle-to-barrier incidents by gender of rider and severity of most severely injured motorcyclist, SRN 2014-18

As shown in the figure, the rider was male in 171 (98%) of the incidents, and female in only four (2%) of the incidents. This suggests that motorcycle-to-barrier incidents are predominantly a male issue. This is to be expected because it is generally known that motorcycles are more popular amongst males and therefore the number of male motorcyclists on the roads is likely to be higher than the number of female motorcyclists. However, data on the number of motorcycle licences by gender could not be gathered for this project and therefore it is not possible to include exposure in this analysis.

6.2.2.3 Date and time of incident

The time of the incidents can say a lot about the nature of the riders that are involved in these incidents. Although there is a designated "journey purpose" data field in STATS19, this section is either left empty or recorded as "Other/not known" for the majority of the cases.

In order to try and gain more insight into journey purpose, the number of motorcycle-to-barrier incidents have been analysed by the day of the week on which the incident happened. The results are shown in Figure 30.

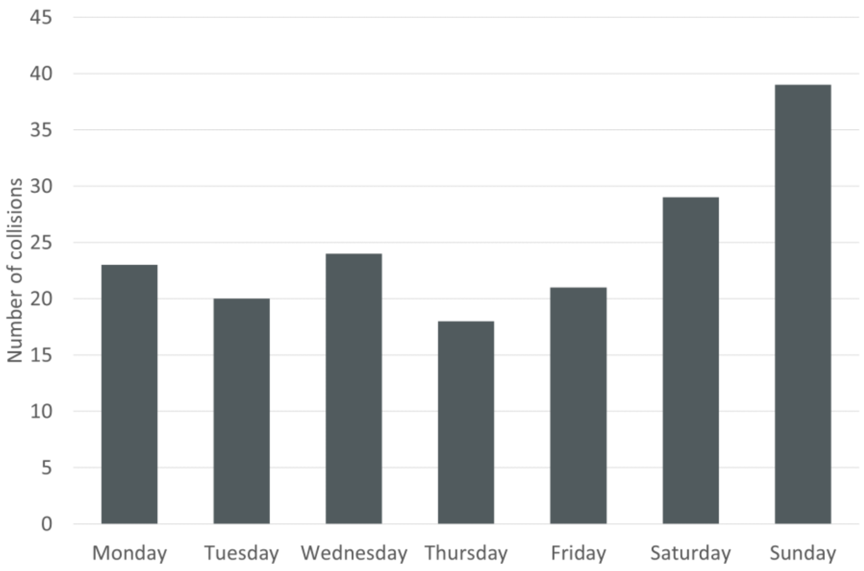

Figure 30: Number of motorcycle-to-barrier incidents by the day of the week, SRN 2014-18

Looking at Figure 30, it can be seen that the number of incidents rises towards the weekend and reach a peak on Sunday. This trend suggests that a good portion of these incidents happen during recreational/leisure rides, since less incidents happen on weekdays and more happen on weekends.

Figure 31 divides the same data by single and multiple vehicle incidents. This divide reveals a very interesting difference in trends.

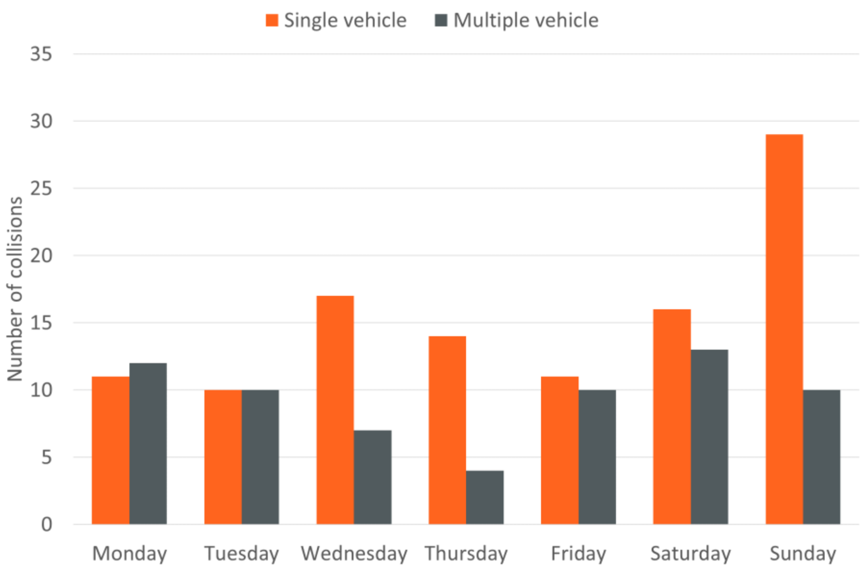

Figure 31: Number of motorcycle-to-barrier incidents by the day of the week and number of vehicles in the collision, SRN 2014-18

Multiple vehicle incidents seem to be less affected by the day of the week and the number of collisions stays at similar levels throughout the week. This may be partly due to the fact that multiple vehicle accidents can happen regardless of the motorcycle rider's intentions as it can happen due to the fault of other road users.

On the other hand, the day of the week seems to have a clear effect on the number of single vehicle motorcycle-to-barrier incidents. The numbers rise on weekends when recreational open riding is more likely to happen during which motorcycle riders may be more likely to push their limits.

Figure 32 shows the number of motorcycle-to-barrier incidents by month. The figure indicates that the number of incidents is greater during periods of warmer, fine and dry weather (the recreational motorcycling season).

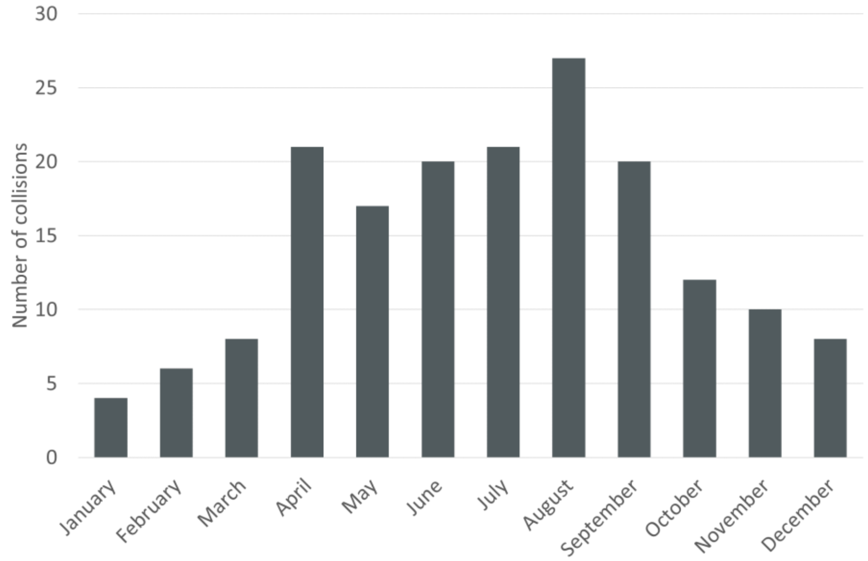

Figure 32: Number of motorcycle-to-barriers incidents by month, SRN 2014-18

Figure 33 divides the same data into single and multiple vehicle incidents.

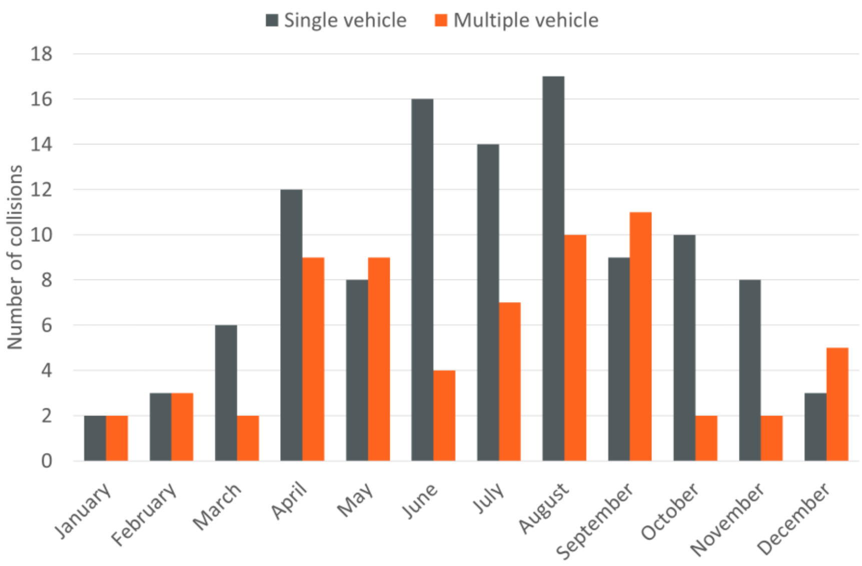

Figure 33: Number of motorcycle-to-barrier incidents by month and number of vehicles involved, SRN 2014-18

seasonal trend observed in Figure 32 is still noticeable in the number of single vehicle incidents. This may indicate that many of the single vehicle incidents are associated with recreational riding, with riders more likely to push the boundaries of their bikes. However, the number of multiple vehicle incidents appears to be unaffected by the month of the year.

Key points: Human factors

- The highest number of motorcycle to barrier incidents were recorded for the 26-35 year old rider age group, followed by the 46-55 year old group. The large number of riders in the 46-55 year old age group could be explained by people returning to motorcycling with powerful motorcycles, after a long break and possibly with rusty riding skills and slower reaction times.
- The vast majority of casualties from motorcycle to barrier incidents are men but this is likely to be because there are more male motorcyclists on the road.
- The number of incidents rises towards the weekend and reaches a peak on Sunday. This trend is seen particularly for single vehicle incidents, suggesting that these incidents happen during recreational riding when riders are more likely to push their limits.
- There are more motorcycle to barrier incidents in the warmer months which is expected as this is the recreational motorcycling season.

6.2.3 Vehicle factors

This section explores factors related to the vehicles which are involved in the incident. Unfortunately, information available in STATS19 about the vehicles involved in an incident is limited.

Figure 34 shows the number of motorcycles involved in motorcycle-to-barrier incidents by vehicle category.

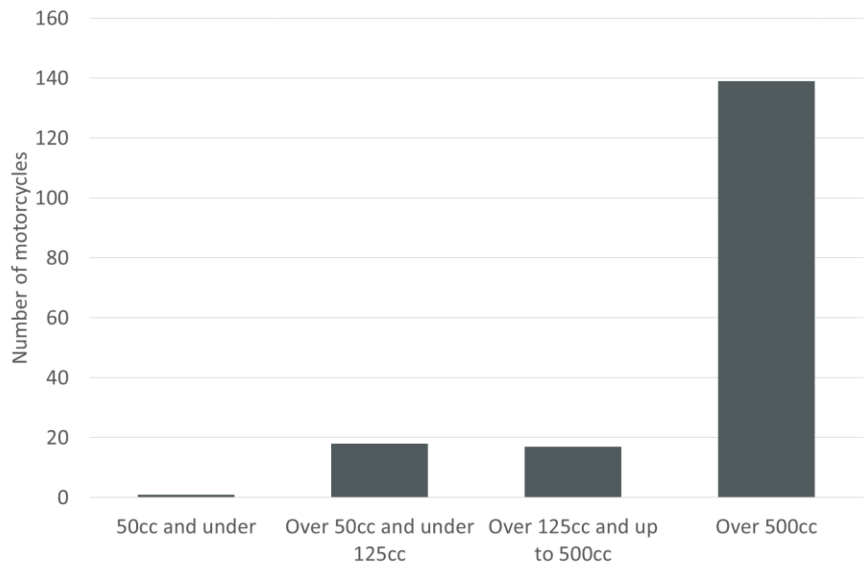

Figure 34: Number of motorcycles in motorcycle-to-barrier incidents by type, SRN 2014-18

As can be seen from the figure, 139 (79%) of the 175 motorcycles involved in motorcycle-to-barrier incidents had an engine size over 500cc. However, it is worth noting that analysis of motorcycle licensing data presented in Section 5.2 showed that the 501-1000cc category of motorcycle accounted for the by far the largest number of licensed motorcycles between 2014 and 2018. Therefore, it is likely that the motorcycles over 500cc are involved in a higher number of incidents than other motorcycles because there are more of them on the road.

For 159 of the 175 motorcycles involved in motorcycle-to-barrier incidents, the actual engine capacity of the motorcycle involved in the incident was also recorded within the STATS19 data collection process. The distribution of these is presented in Figure 35.

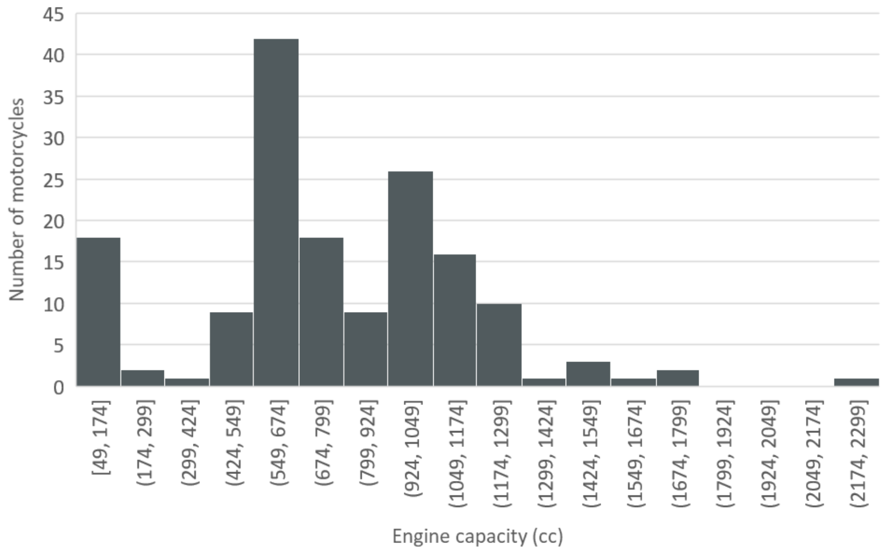

Figure 35: Engine size distribution for motorcycles involved in barrier incidents, SRN 2014-18

The mean engine size for motorcycles involved in barrier incidents was 774cc. It can also be seen that the most motorcycles involved in incidents had an engine capacity between around 500cc and 1000cc.

Figure 36 presents the number of motorcycles involved in motorcycle-to-barrier incidents by the age band of the rider and the motorcycle engine size.

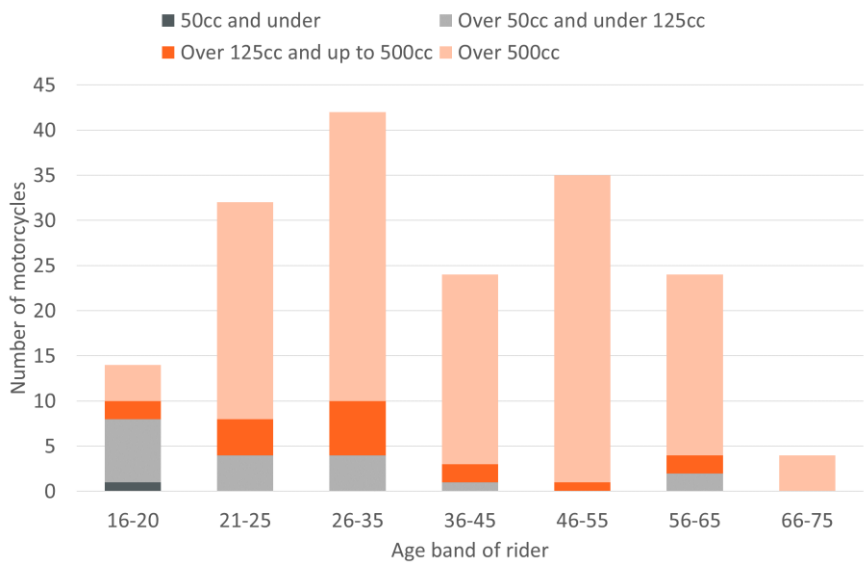

Figure 36: Number of motorcyclists in motorcycle-to-barrier incidents by type and age band of rider, SRN 2014-18

Examination of Figure 36 suggests that older riders are more likely to be involved in incidents whilst riding more powerful motorcycles. This is to be expected because more powerful motorcycles are likely to be more expensive and therefore less likely to be ridden by younger people who may not be able to afford them.

Key points: Vehicle factors

- The majority of incidents involved a motorcycle with an engine size above 500cc. However, this is to be expected as these motorcycles account for a large proportion of the licensed motorcycles on the road.
- Older riders involved in incidents were more likely to be riding more powerful motorcycles.

6.2.4 Road environment factors

Road environment factors are perhaps the most relevant group of factors for this research, since they are directly related to the National Highways network. These factors are also often easier to influence whereas human and vehicle factors can be more difficult. For example, it is often easier to improve the physical conditions, such as surface friction in an incident black spot, than educate all the riders who are using the road. The aim of studying these road environment factors is to detect common physical properties of motorcycle-to-barrier incident locations. These can then be used to decide on the higher priority types of sites for remedial action to reduce the risk of a motorcycle-to-barrier incident.

6.2.4.1 Road class

Figure 37 shows the number of motorcycle-to-barrier incidents by road class and severity.

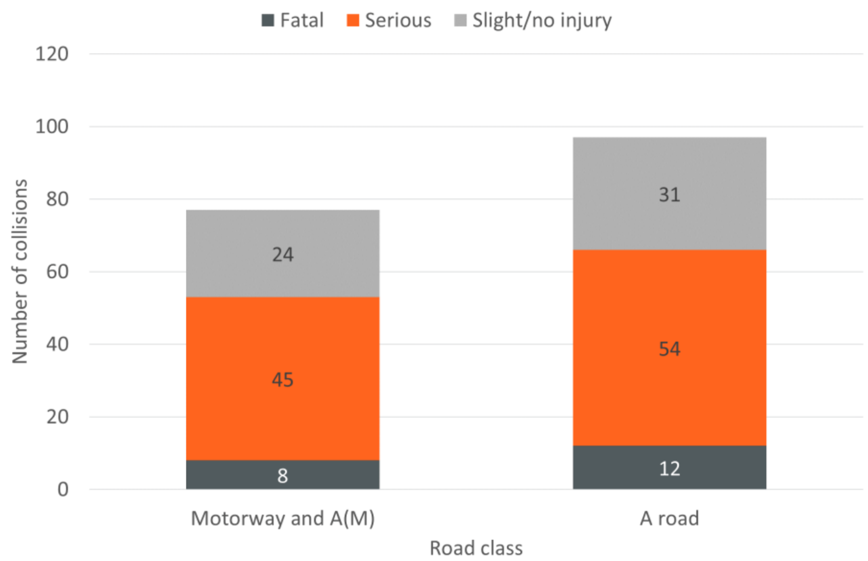

Figure 37: Number of motorcycle-to-barrier incidents by road class and severity of most severely injured motorcyclist, SRN 2014-18

As shown in Figure 37, of the 174 motorcycle-to-barrier incidents occurring on the SRN between 2014 and 2018, 97 (56%) happened on A roads and 77 (44%) on motorways and A(M) roads (there were only seven incidents on A(M) roads).

The severity distribution for each road class is very similar, with both road classes having the same proportion of KSI incidents (68%). Motorways and A(M) roads have a very slightly smaller proportion of fatal incidents than A roads (10% and 12% respectively).

6.2.4.2 Speed limit

Figure 38 shows the number of motorcycle-to-barrier incidents by the speed limit of the road where they occurred.

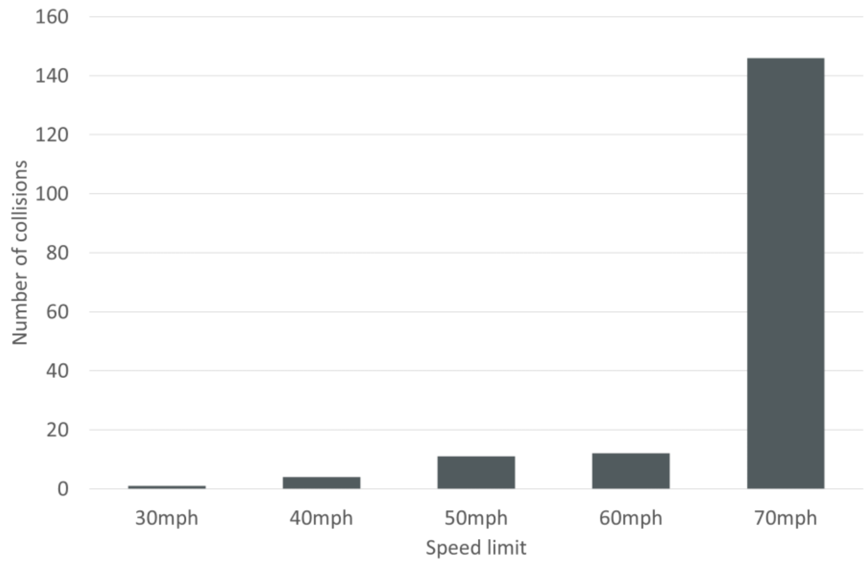

Figure 38: Number of motorcycle-to-barrier incidents by speed limit, SRN 2014-18

Examination of the speed limit in Figure 38 shows that the majority of motorcycle-to-barrier incidents (84%) occurred on network sections with a speed limit of 70mph. The high-speed nature of these incidents may render a possible MPS installation less effective, as the systems available on the market today are tested to a maximum impact speed of 43.5mph (70km/h).

6.2.4.3 Road type

Figure 39 shows the road type recorded within STATS19 for the 174 motorcycle-to-barrier incidents. Of the 174 incidents, 142 (82%) occurred on dual carriageways, 28 (16%) on slip roads and 4 (2%) on roundabouts.

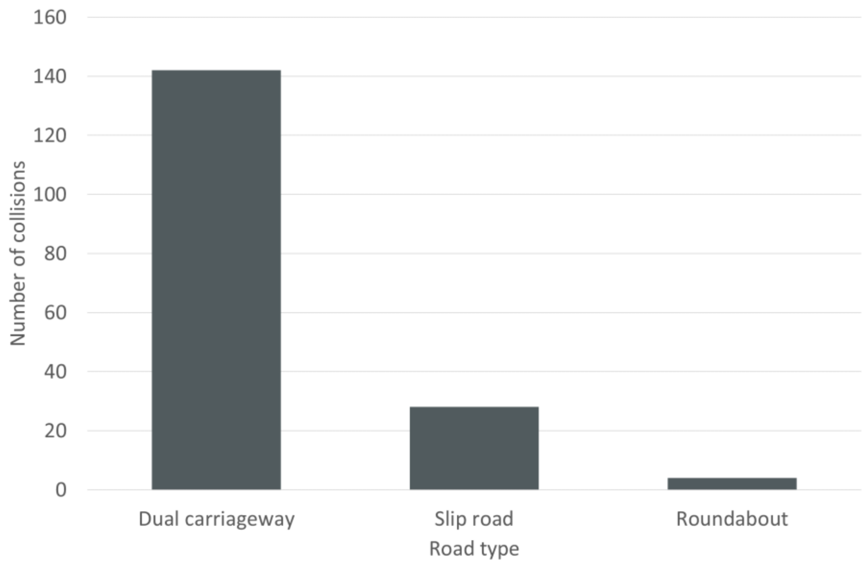

Figure 39: Number of motorcycle-to-barrier incidents by STATS19 road type classification, SRN 2014-18

However, investigation of all these incident locations using Google Street View images revealed that some of the incident locations which are coded as dual carriageway actually happened on loops, slip and connector roads that are located at the end of, or before, a dual carriageway. Furthermore, some of these dual carriageways are two-way slip roads, which are designed as recommended within TD22/06 “Layout of Grade Separated Junctions” section 5.27. The authors believe this type of classification makes it difficult to identify the most frequent motorcycle-to-barrier incident location types. For this reason, a new type of classification was introduced for the purposes of this study.

In order to develop the new classification, each incident location was examined using satellite and Google Street View images in conjunction with the STATS19 data. Each location was then classified into the following categories and sub-categories.

- **Link roads:** uninterrupted main road sections located between junctions.
  - **Bends**
  - **Straight sections**
  - **Laybys**
- **At-grade junctions:** junctions such as roundabouts, where all traffic is located on the same level.
- **Grade-separated junctions:** junctions, such as partial cloverleaf or interchange, where traffic flows of main roads are located on different levels and are connected through connector/slip roads and loops.
  - **Slip roads:** the connector roads within a grade-separated junction, including loops.
  - **Diverge areas:** a section of mainline carriageway where traffic leaving the mainline towards a slip road diverges from the mainline traffic.
  - **Merge areas:** a section of mainline carriageway where traffic joining from a slip road merges with the mainline traffic.
  - **Weaving areas:** a section of carriageway between a successive merge and diverge, where vehicles leaving the mainline at the diverge have to cross the paths of vehicles that have joined the mainline at the merge.
  - **Mainline section of a grade-separated junction:** the section of main road, stretching through the grade-separated junction area, from the beginning of the diverge zone to the end of the merge zone.

A diagram of a grade-separated junction showing the different parts used in the classification above is shown in Figure 40.

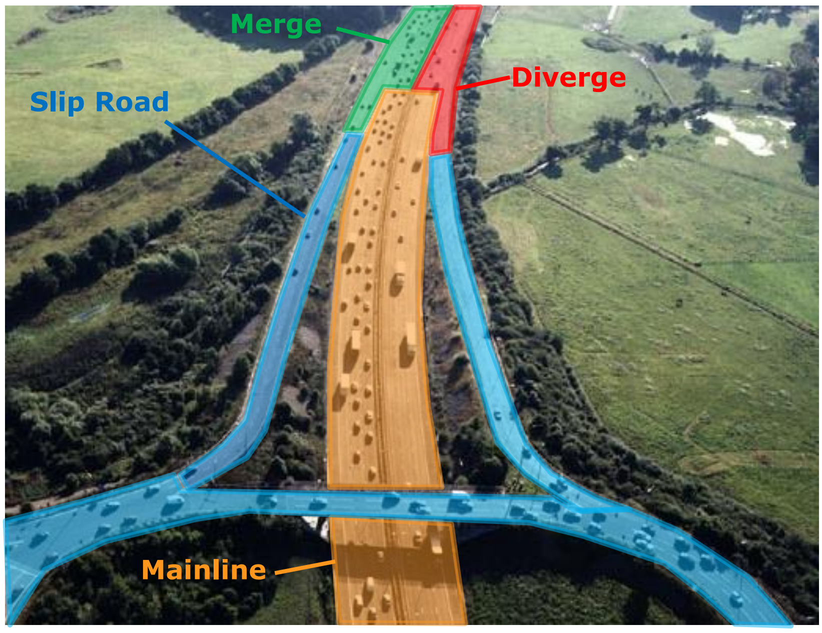

Figure 40: Slip and main road sections on a grade-separated junction

The distribution of motorcycle-to-barrier incidents, classified using the definitions above, is presented in Figure 41.

As can be seen from the figure, the majority of the motorcycle-to-barrier incidents on the SRN occurred at junctions (65%).

When looking at the link roads in detail, it was observed that 38 of the 61 incidents occurred on straight road sections with a horizontal curve radius of more than 1000m. This is the most difficult group of incidents to target with a motorcyclist risk reduction policy, as it is very difficult to prioritise one location over the other in these long stretching featureless roads, unless an incident cluster can be identified. The other 23 link road incidents occurred on bends with a horizontal curve radius less than 1000m. These are easier to target with a risk reduction policy, however, the overall number of incidents at these locations is low.

Looking at the incidents occurring at junctions shows that the majority of incidents occurred on grade-separated junctions (89 out of 113 junction incidents). Within the grade-separated junctions, almost half of the incidents occurred on slip roads (41 out of 89 grade-separated junction incidents). This is a substantial number which accounts for 24% of the 174 motorcycle-to-barrier incidents. Considering the number of incidents and the ease of locating them, slip road locations should be considered as priority locations for risk reduction measures.

Of the remaining grade-separated junction incidents, 40 occurred at merge or diverge points or in weaving areas. These are prime locations for right of way incidents. These are also locations where sudden drops and increases in traffic speed and volume occur due to vehicles leaving and joining the carriageway. These changes in traffic and speed can cause an inexperienced motorcyclist to lose control due to sudden breaking or sudden acceleration. Therefore, risk reduction measures could also be beneficial at these locations.

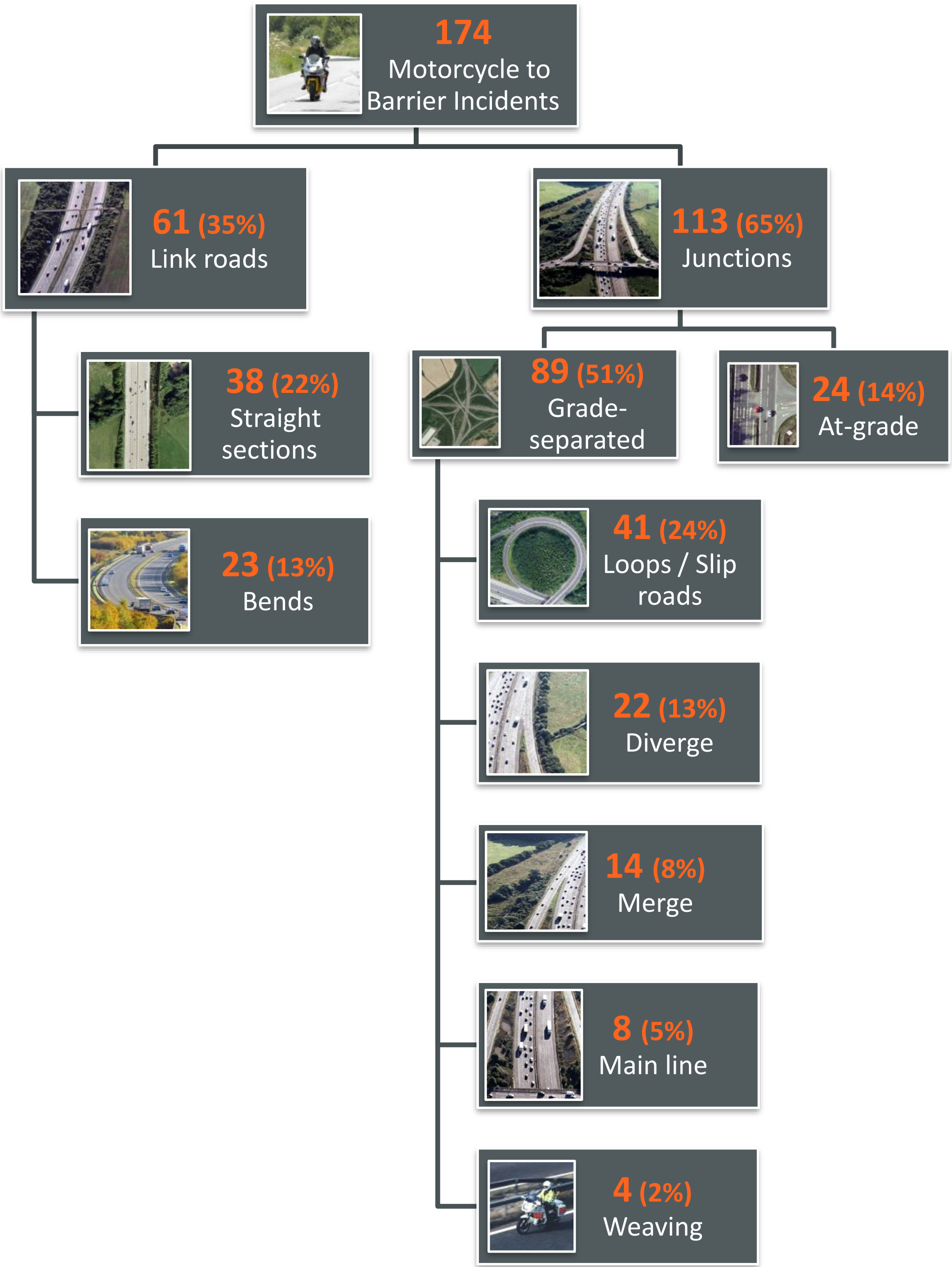

Figure 41: Distribution of motorcycle-to-barrier incidents on the National Highways network

6.2.4.4 Curve radius

Horizontal curve radius is known to be an important factor in motorcycle-to-barrier incidents, as demonstrated within the literature review. However, curve radius is not recorded in the

STATS19 database. For this reason, horizontal curve radius for each incident location was extracted from the HAPMS database, as explained in the methodology section (Section 6.1.3). Figure 42 presents the number of incidents for each horizontal curve radius band by severity.

Figure 42: Number of motorcycle-to-barrier incidents by horizontal curve radius and severity of most severely injured motorcyclist, SRN 2014-18

As can be seen from the figure, the majority of the incidents are grouped within the extremities of the horizontal curve radius spectrum. This indicates the presence of two different types of incident:

- The first group is on the sharp bend areas of 0-100m horizontal curve radius. These are the expected, loss of control on sharp bend incidents.
- The larger group is at the other end of the spectrum, with horizontal curve radius over 1000m. These are incidents that occur on effectively straight sections of road.

Looking at the severity levels for the two groups, it can be seen that the majority of the fatalities occurred on the straight sections, while there are only two fatalities recorded within the 0-100m radius range. This shows that although there are a large number of incidents on tight radius bends, they are not so often fatal and hence a policy of implementing a risk reduction policy on tight bends may only reduce the number of serious or slight injuries and not necessarily the number of fatalities. Most fatalities are occurring on straight sections of road where, unless there is a historical cluster, the location will be very difficult to predict and hence, for a policy to be written.

Figure 43 divides the same data into single and multiple vehicle accidents. Once again there is a visible pattern.

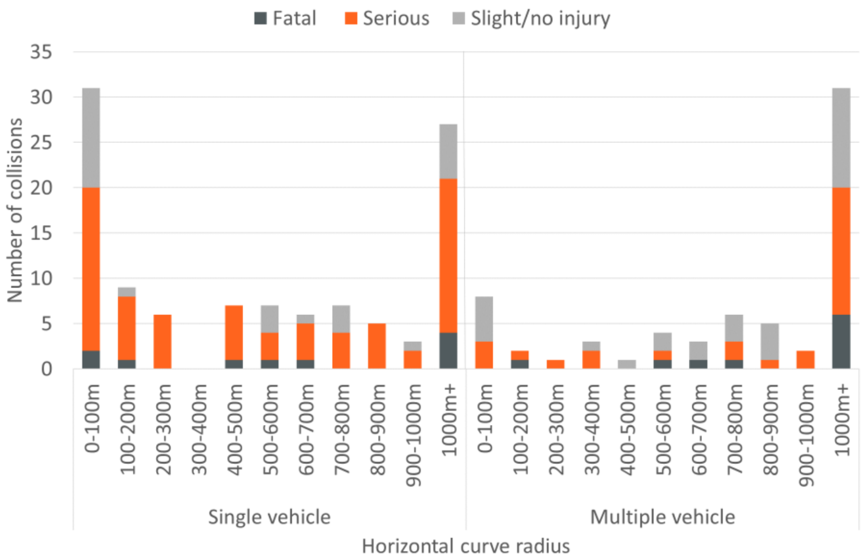

Figure 43: Number of motorcycle-to-barrier incidents by number of vehicles invovled, horizontal curve radius and severity of most severely injured motorcyclist, SRN 2014-18

It appears that tight bend incidents predominantly involve a single vehicle, where there was no other responsible person other than the rider (excluding environment and vehicle factors). It may be argued that an MPS or similar risk reduction method would be more likely to be useful in these circumstances, where there is no primary impact with another vehicle and speed is likely to be less than on a straight section of road.

Incidents on straight sections of road (radius>1000m) are distributed more equally between single and multiple vehicle incidents. However, within these straight section incidents, the percentage of incidents resulting in a fatal or serious injury is higher for single vehicle incidents than they are for multiple vehicle incidents. The high severity and lack of other vehicle involvement in these straight section single vehicle incidents suggests that inappropriate speed may have been a contributory factor. As mentioned before, MPS available on the market today are tested to a maximum impact speed of 43.5mph (70km/h), which may make them less effective in this type of high-speed impacts.

Figure 44 combines the horizontal curve radius and junction position.

As can be seen from the figure, tight curves where a motorcycle-to-barrier incident occurred were mostly slip roads of grade-separated junctions (27 incidents), although there were also 10 such incidents at at-grade junctions.

Straight (curve radius>1000m) sections of grade-separated junctions with merges, diverges and weaving areas also had a substantial number of motorcycle-to-barrier impacts. The largest group was the motorcycle-to-barrier incidents which occurred on straight sections outside junctions. These long stretching straight roads are difficult to prioritise for MPS application due to the long lengths which need to be installed to cover the whole section of road and the associated costs.

It is interesting to note that there are almost as many motorcycle-to-barrier incidents on slip roads with tight curves (27 incidents) as there are on straight link road sections (29 incidents).

If treating the long straight lengths is difficult for the reasons discussed above, an alternative could be to install MPS on smaller section of tightly curved slip roads which could have a similarly sized effect on casualty numbers.

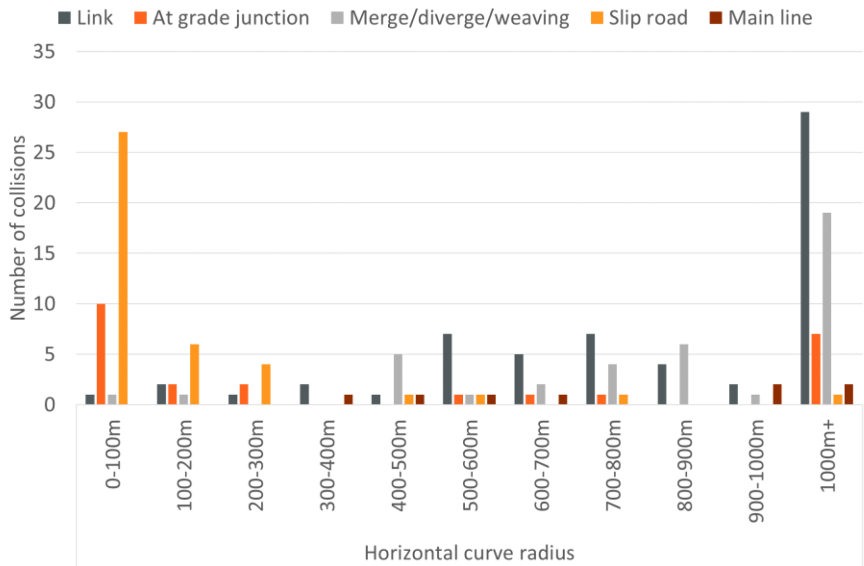

Figure 44: Number of motorcycle-to-barrier incidents by horizontal curve radius and incident location, SRN 2014-18

6.2.4.5 Bend direction

Figure 45 shows the number of motorcycle-to-barrier incidents by the direction of the bend where the incident took place, for single and multiple vehicle incidents.

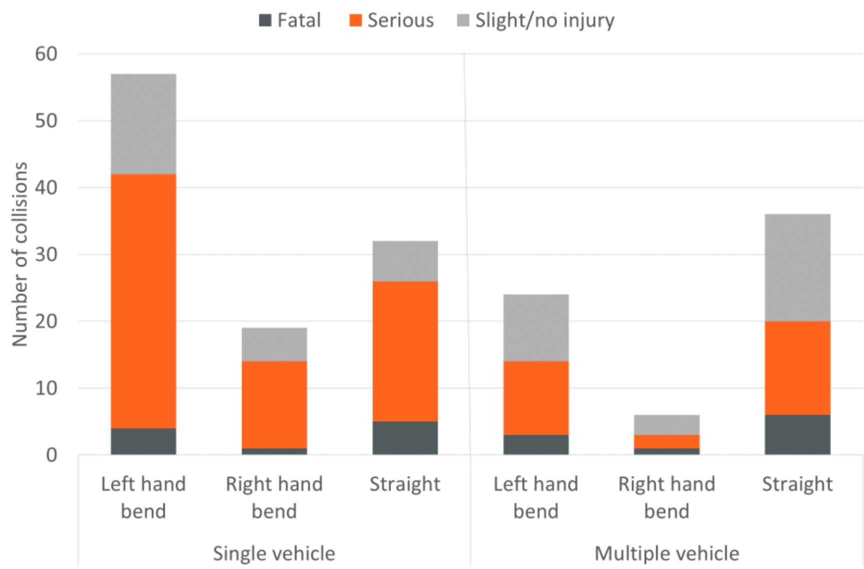

Figure 45: Number of motorcycle-to-barrier incidents by number of vehicles involved, direction of bend and severity of most severely injured motorcyclist, SRN 2014-18

The figure shows that the majority of single vehicle incidents occurred on bends, with left-hand bends having substantially more incidents than right-hand ones. One of the reasons for this may be the existence of hard shoulder on leftmost side of the road. This gives more clear space to motorcyclists who run out of the road on right-hand bends, to get back into control and return to the road. On the contrary, errant motorists usually have less space on the right-hand side of the road to get back in control of their vehicle and hence an impact with a barrier becomes more likely. In addition, the UK drives on the left and therefore most loops and slip roads within grade-separated junctions, which have been shown to have high incident numbers (see Figure 41), are left-hand bends.

Just over half of multiple vehicle incidents occurred on straight sections of road. Due to their nature, multiple vehicle incidents on high-speed roads are difficult to predict; the case is even more challenging for featureless straight sections of roads.

Figure 46 shows the number of single vehicle incidents recorded on bends only (106 incidents), by bend direction and location of the struck barrier.

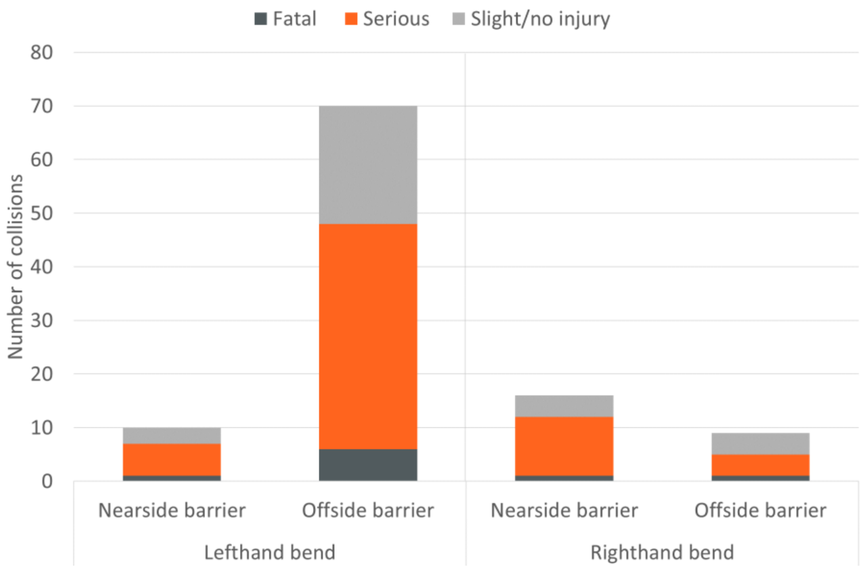

Figure 46: Number of motorcycle-to-barrier incidents on bends by direction of bend, location of struck barrier and severity of most severely injured motorcyclist, SRN 2014-18[8]

As shown in the figure, motorcyclists generally strike the offside barriers on left-hand bends, and nearside barriers on right-hand bends. This is mainly due to the underlying nature of motorcycle riders running wide on bends. In a similar way to the results from Figure 45, the reason for more offside barriers being struck than the nearside ones could partly be explained by the existence of extra recovery space on the nearside due to the existence of the hard shoulder.

[8] There was one incident where the information recorded in STATS19 was not sufficient to determine if the struck barrier was on the offside or nearside. This incident has been excluded from the chart.

6.2.4.6 Barrier type

The type of barrier struck in the incident is another useful parameter which is not recorded within STATS19. This information was collected by looking at Google Street View images at the incident locations. However, this method has some shortcomings. The exact location of the incident, where the Street View image was checked, may not be correct. However, it is rare to have two different types of barriers in a small area, which makes this less of a problem. The other shortcoming is the difference between the date of the incident and the date on which the Street View image was captured. It is possible that the type of barrier may have been changed between these dates. This problem is minimised with the new version of Street View, which provides images from different dates. Therefore, it is assumed that the possible error introduced shouldn't be high enough to affect the general trend. Nevertheless, the information on barrier type should be evaluated with these shortcomings taken into account.

Figure 47 shows the number of motorcycle-to-barrier incidents by barrier type and incident severity.

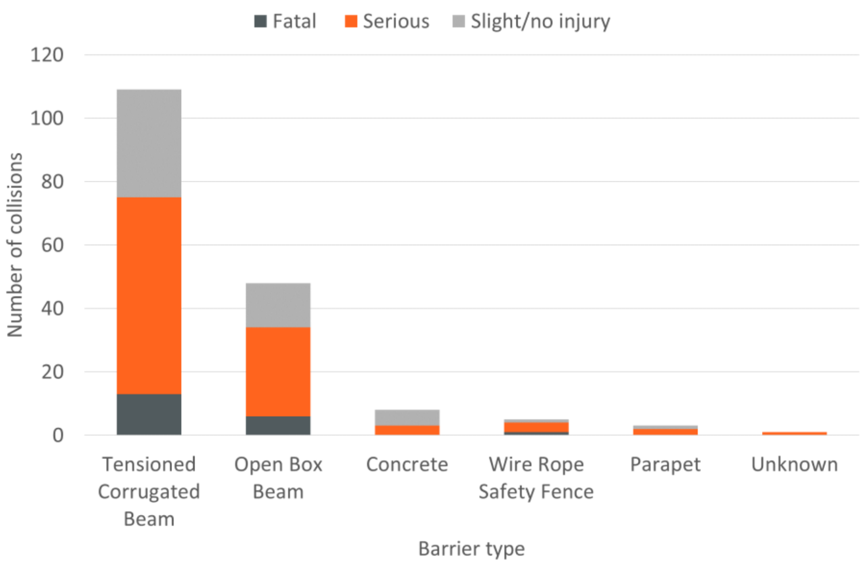

Figure 47: Number of motorcycle-to-barrier incidents by barrier type and severity of most severely injured motorcyclist, SRN 2014-18

As can be seen from the figure, the majority of motorcycle-to-barrier incidents involved a Tensioned Corrugated Beam (TCB) barrier (63%). This was followed by Open Box Beam (OBB) with 28% and concrete with 5%. There were only five wire rope fence impacts recorded on the National Highways network between 2014 and 2018; of which one was a fatality but one which did not result in any injury to the motorcyclist.

In order to develop a better understanding of the effect of barrier type on the severity of the outcome, the proportion of incidents involving each barrier type is split by severity in Figure 48. Note that the number of incidents involving Wire Rope Safety Fence, concrete barrier and parapets are small and therefore robust conclusions about the severity outcomes cannot be drawn.

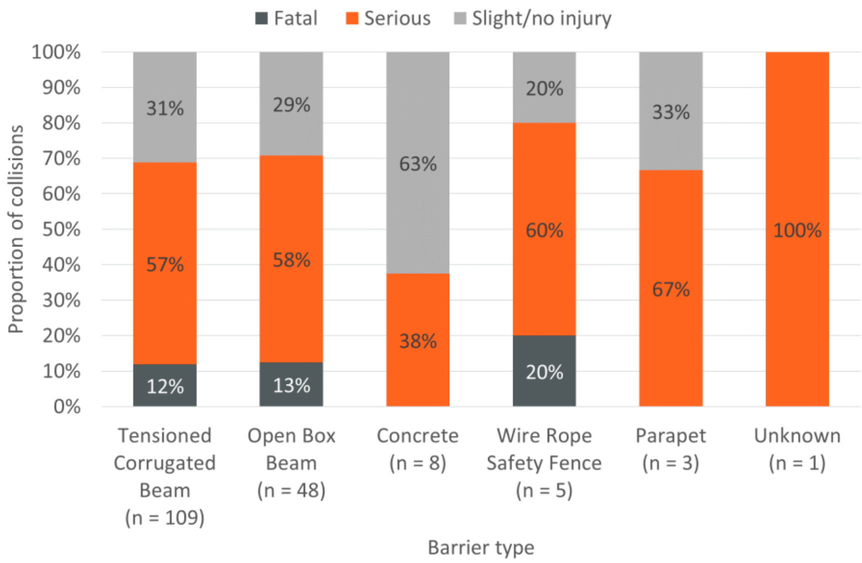

Figure 48: Percentage of motorcycle-to-barrier incidents by barrier type and severity of most severely injured motorcyclist

The figure shows the proportion of incidents where a motorcyclist was killed or seriously injured is similar for TCB and OBB. This is perhaps expected, since the main cause of injury on steel barrier systems is known to be the posts, which are the same in profile for these two types of barriers.

It is, however, not easy to comment about the performance of the other types of barrier as the number of recorded incidents are too small to reveal any substantial relationship. It should also be noted that, while TCB and OBB are used on all types of roads, concrete barriers are only installed on high speed roads with large traffic volumes (road with an Average Annual Daily Traffic equal to or greater than 25,000 vehicles per day). This means that concrete barriers are likely to suffer higher energy impacts and therefore may result in more severe injuries. However, the quantity of data is insufficient to allow further analysis to assess the effects of differences in speeds and road types.

6.2.4.7 Skidding and overturning

Figure 49 shows the number of motorcycle-to-barrier incidents by whether the motorcycle skidded or overturned. This gives a good indication of the way the motorcyclist interacted with the barrier.

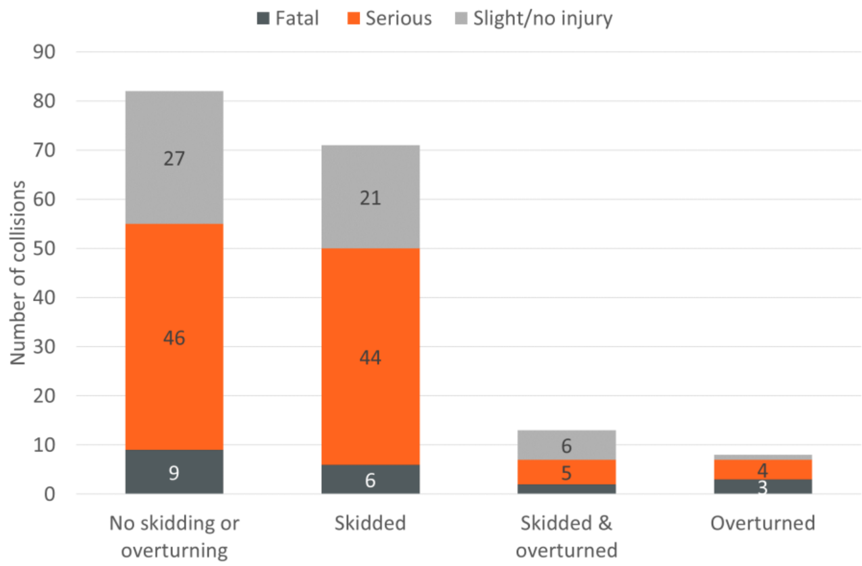

Figure 49: Number of motorcycle-to-barrier incidents by whether the rider skidded or overturned and the severity of the most severely injured motorcyclist, SRN 2014-18

As shown in the figure, 41% of the riders skidded before hitting the barrier. This ratio is similar to the findings of other research, presented in the literature review section. This shows that installation of additional rails to shield the posts may not be a good enough solution to address the other modes of motorcyclist to barrier interaction. As explained in Section 4, MPS currently on the market are only tested with a sliding dummy configuration and there is no assessment of the level of protection for riders hitting barriers on an upright position.

6.2.4.8 Environmental conditions

This section explores the environmental factors such as weather, lighting and road surface conditions, which can contribute towards an incident occurring.

Looking at the previous figures, one may expect weather and surface condition to be an important factor in skidding for single vehicle, tight bend radius incidents. Figure 50 shows the number of motorcycle-to-barrier incidents by horizontal curve radius and road surface condition.

Figure 50 shows that a vast majority of the tight curve incidents happened on dry roads. This adds further evidence to the theory that these incidents happen because riders are pushing the limits of their motorcycle or using excessive speed.

In fact, almost all (90%) of the recorded motorcycle-to-barrier incidents on the National Highways network between 2014 and 2018 occurred in fine weather without any high winds.

The vast majority of motorcycle-to-barrier incidents happened in daylight (156 out of 174 incidents, 81%). However, of the 33 incidents which happened in darkness, 19 (58%) happened where there was no street lighting.

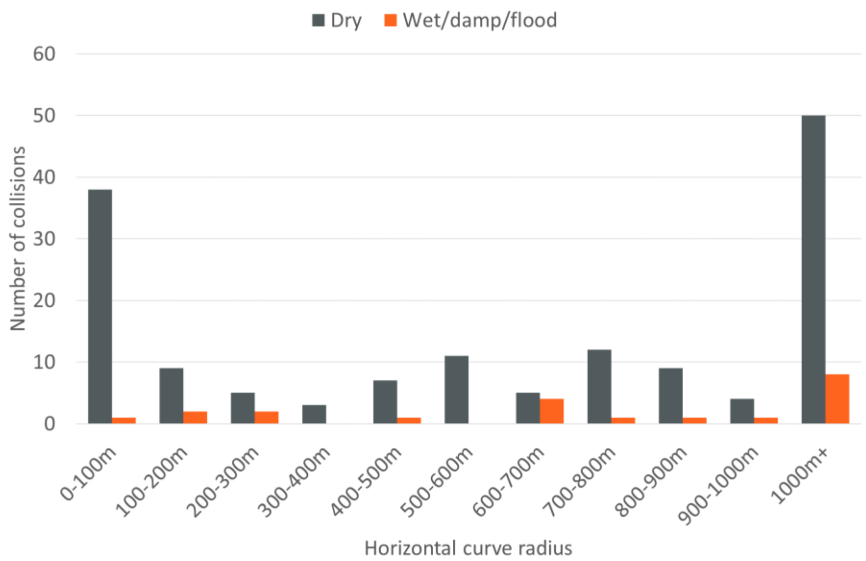

Figure 50: Number of motorcycle-to-barrier incidents by horizontal curve radius and road surface condition, SRN 2014-18

Key points: Road factors

- The vast majority of motorcycle to barrier incidents happened on roads with a speed limit of 70mph. MPS are tested to a maximum impact speed of 43.5mph which is much lower.
- 65% of the incidents were at junctions and most of these occurred within grade-separated junctions.
- Almost a quarter of all motorcycle to barrier incidents occurred on slip roads. These locations should be considered as priority locations for risk reduction measures.
- 40 incidents happened at merge or diverge points or in weaving areas, which are prime locations for right of way violation incidents, and risk reduction measures could also be beneficial at these locations.
- Most of the incidents are grouped within the extremities of the horizontal curve radius spectrum, either on occurring on tight bends or straight roads.
- There are almost as many motorcycle to barrier incidents on slip roads with tight curves as there are on straight link road sections. Therefore, localised installation of MPS on slip roads could prevent a similar number of casualties to longer lengths installed on straight sections of road.
- There are more incidents on left hand than right-hand bends and motorcyclists generally strike the offside barriers on left hand bends, and nearside barriers on right-hand bends.
- The majority of motorcycle to barrier incidents involved a TCB barrier (63%), followed by OBB with 28%.
- There were only five wire rope fence incidents, one was a fatality but one did not result in any motorcyclist injury.
- 41% of motorcyclists skidded before hitting the barrier. This supports the findings from the literature review which suggest that only half of the impacts occurring are those which MPS is designed for.
- There is no substantial evidence to suggest that weather, lighting or road surface conditions have an effect on the likelihood of motorcycle to barrier incidents.

6.3 Incident cluster analysis

Cluster analysis was undertaken to identify places with high numbers of motorcycle-to-barrier incidents. A cluster is defined as an area in which at least two motorcycle-to-barrier incidents happened within a certain radius.

Figure 51 shows the locations of the 11 clusters identified. A red circle indicates that the incidents in the cluster were within 500m of each other and a blue circle indicates that they were within 1000m of each other.

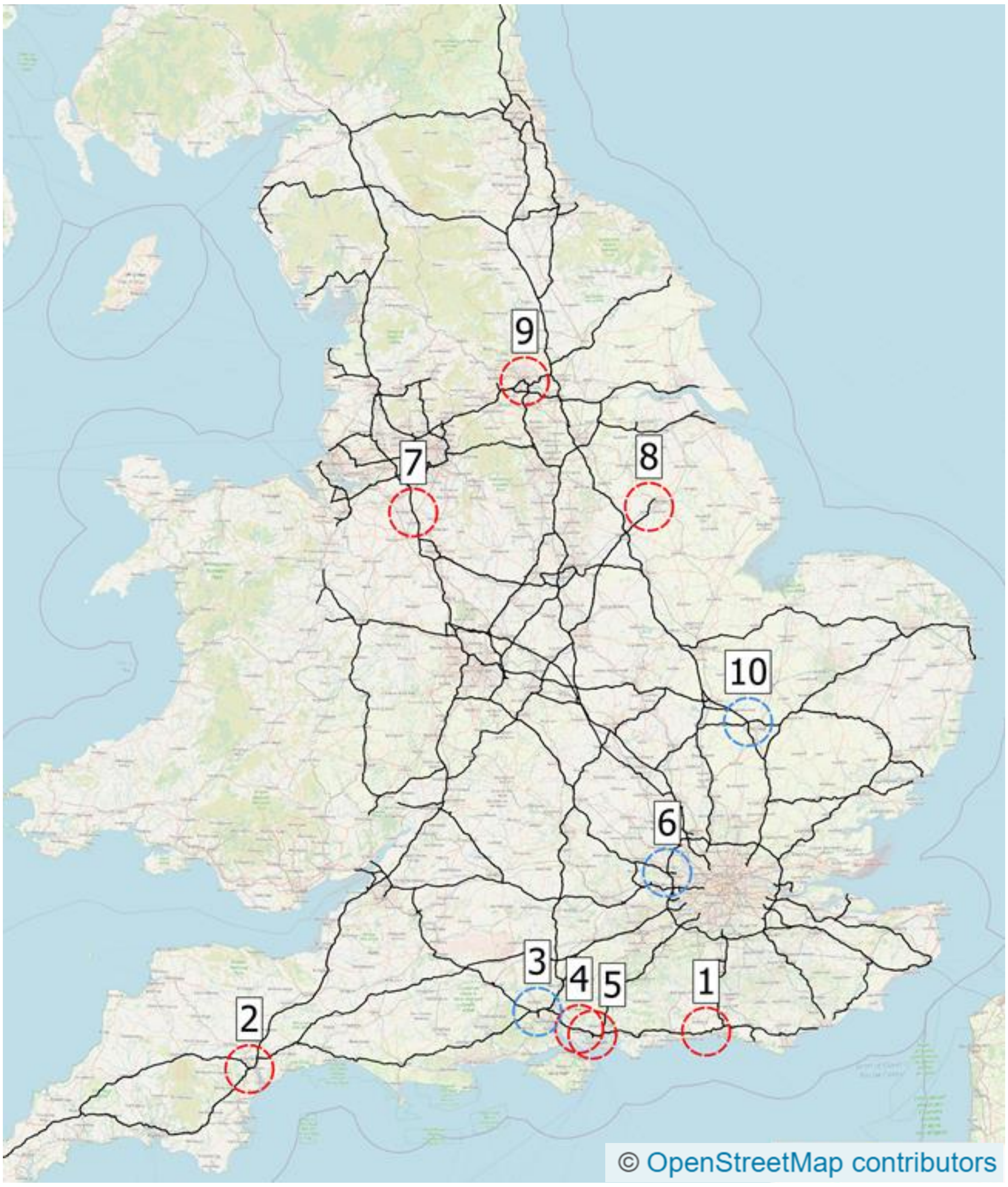

Figure 51: Motorcycle to barrier incident clusters on the SRN (OpenStreetMap)

The clusters are spread across the network and all of them are at junctions, apart from one (Cluster 7). There are 28 motorcycle-to-barrier incidents within the 12 clusters in total; these account for 16% of the 178 motorcycle-to-barrier incidents on the SRN between 2014 and 2018. This shows that addressing only incident clusters is not enough to solve the problem, but it may highlight common factors which can be used to determine where there is a higher risk of incidents occurring in the future.

The next sections describe each of the 12 clusters in more detail. For each cluster, a map showing the location of the cluster and the incidents is presented. Incidents are colour-coded by severity; fatal incidents are red, serious incidents are yellow and slight incidents are green.

6.3.1 *Cluster 1: Junction between A27 and A283*

Cluster 1 was located on the grade-separated junction between the A283 and the A27 Shoreham Bypass. There were six incidents recorded on this junction; all were single vehicle incidents resulting in seriously injured casualties. Two of the incidents occurred on the northern loop while four occurred on the southern loop, as shown in Figure 52.

In both incidents on the northern loop, the motorcyclists were riding motorcycles over 500cc and travelling on the southbound carriageway, going ahead round a left-hand bend. Both incidents occurred in daylight and dry conditions. One motorcyclist (Incident B) was recorded as having skidded and hit the central barrier. The other (Incident A) did not have any skidding recorded. In both cases, the motorcyclists hit Open Box Beam (OBB) barriers.

Of the incidents on the southern loop, three happened on the northbound carriageway and one (Incident F) on the southbound carriageway. Again, all the motorcyclists involved had manoeuvre in STATS19 recorded as "Going ahead" round a left-hand or right-hand bend. In all the incidents on the northbound carriageway (Incidents C, D and E), the motorcyclist skidded before hitting OBB barrier but no skidding is recorded for the motorcyclist in Incident F. Review of Google Street View showed MPS was likely to have been present at the locations of Incidents D and E at the time of the incident.

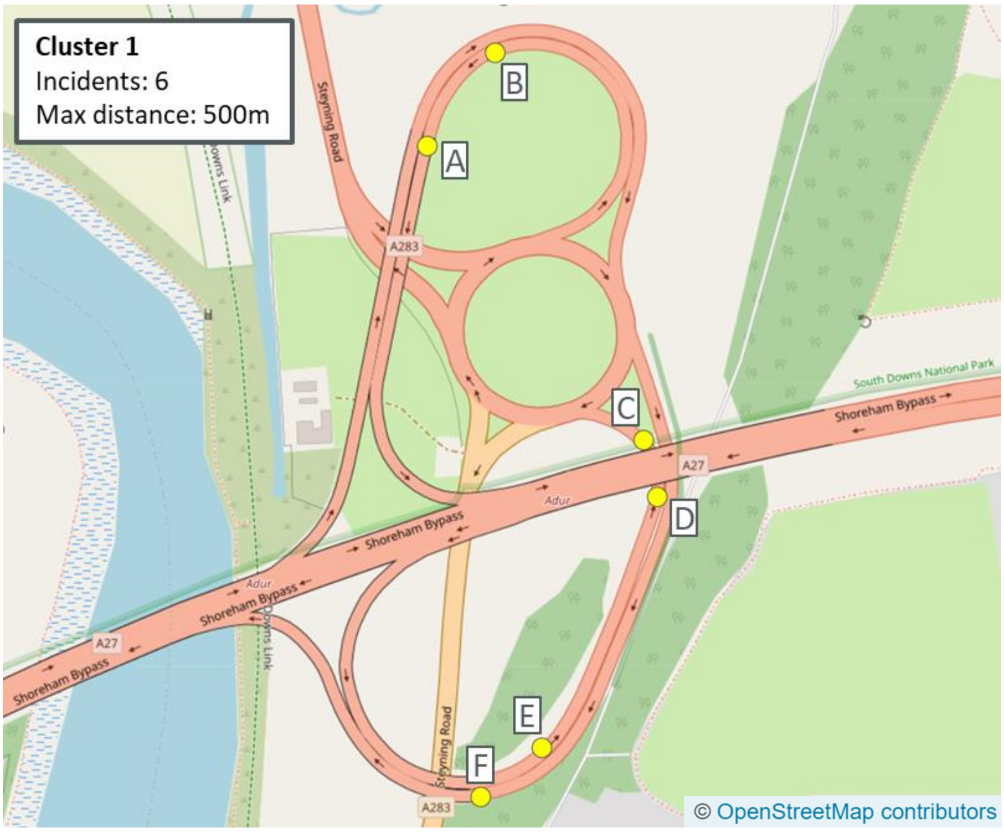

Figure 52: Cluster 1, A27/A283 Junction (OpenStreetMap)

6.3.2 Cluster 2: M5 Junction 31 Pearce's Hill Interchange

Cluster 2 was located on the Pearce's Hill Interchange at junction 31 of the M5. There were two incidents, both located on the same loop of the junction. Both were single vehicle incidents involving powerful motorcycles (both close to 1000cc).

Incident A involved a 929cc motorcycle going ahead round a left-hand bend. The motorcycle left the carriageway onto the central reserve, hit the central crash barrier which was OBB, and rebounded. No skidding was recorded, and the motorcyclist received slight injuries.

Incident B involved a 1084cc motorcycle, also going ahead round a left-hand bend. The motorcycle is recorded as having skidded and overturned, hitting the OBB central crash barrier and rebounding. This incident resulted in serious injuries.

There was no MPS present at either incident location in this cluster.

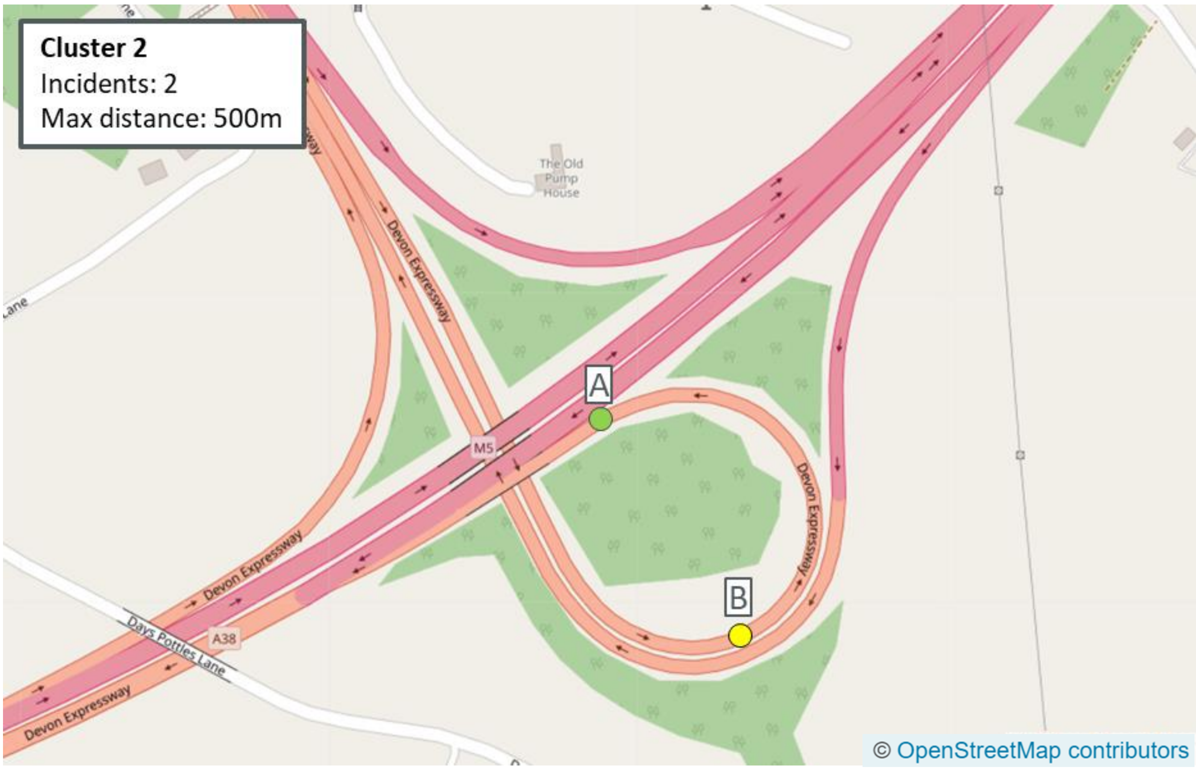

Figure 53: Cluster 2, M5 Junction 31 Pearce's Hill Interchange (OpenStreetMap)

6.3.3 Cluster 3: M27 Junction 3 Nursling Interchange

Cluster 3 was located at Junction 3 of the M27, at the Nursling Interchange, and comprises two serious incidents. One was a single vehicle incident and the other involved two vehicles.

Incident A occurred on the main eastbound carriageway of the M27, at the diverge of the junction 3 slip road. This incident involved two vehicles, one of which was a 1188cc motorcycle going ahead which skidded left the carriageway onto the central reserve. The front of the motorcycle hit the Tensioned Corrugated Beam (TCB) central barrier.

Incident B was a single vehicle incident which occurred on the southbound M271 approaching the Nursling Interchange junction with the M27. The motorcyclist involved was riding a 1050cc motorcycle and was going ahead on the main carriageway. STATS19 records that the motorcycle skidded, and the back of the motorcycle impacted the TCB central barrier before it rebounded.

There was no MPS present at either incident location in this cluster.

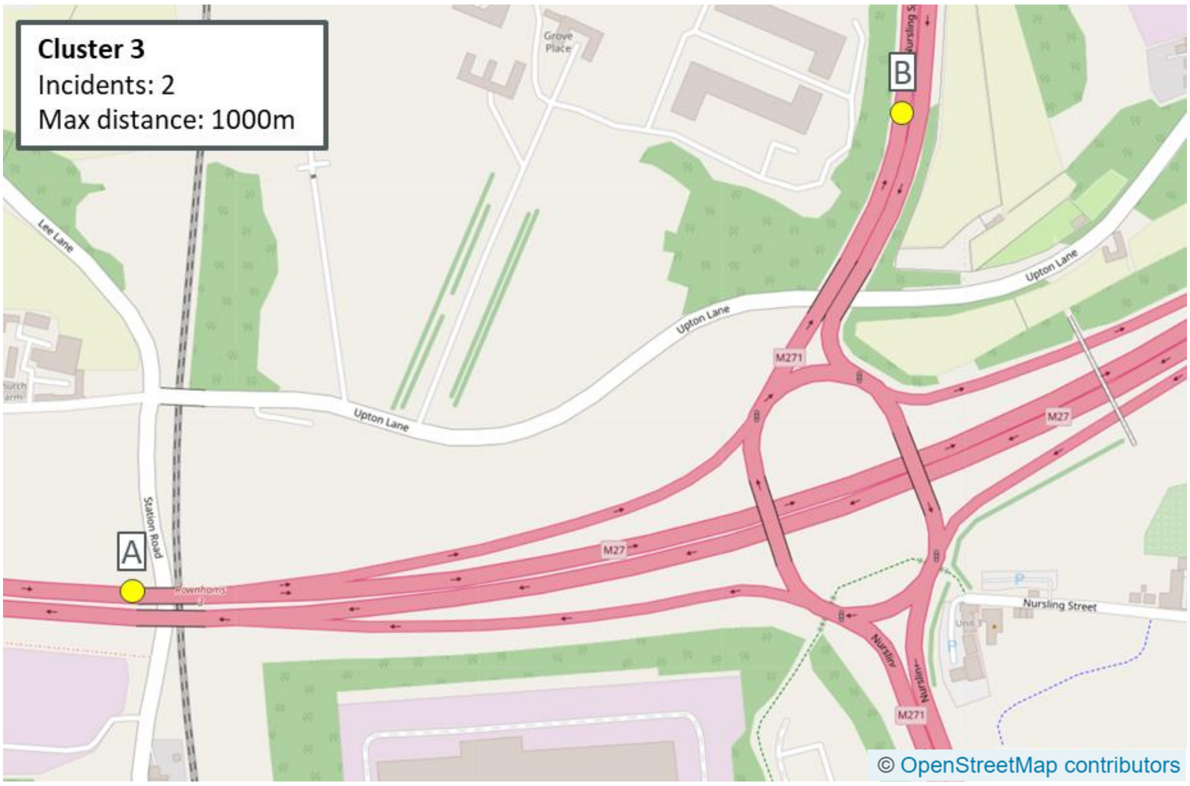

Figure 54: Cluster 3, M27 Junction 3 Nursling Interchange (OpenStreetMap)

6.3.4 Cluster 4: M27 Junction 10 North Hill Interchange

Cluster 4 was at the North Hill Interchange at junction 10 of the M27. The cluster includes two single vehicle incidents, on different parts of the grade-separated junction. Both incidents resulted in seriously injured casualties.

Incident A involved a 689cc motorcycle going ahead round a left-hand bend on the southern loop of the junction. The motorcycle skidded, left the carriageway to the offside, and hit the offside barrier which was TCB.

Incident B also involved a motorcycle which skidded whilst going ahead round a left-hand bend. The 1157cc motorcycle left the carriageway and hit the TCB offside barrier. This incident occurred on the slip road between the A32 and the eastbound carriageway of the M27.

There was no MPS present at either incident location in this cluster.

Figure 55: Cluster 4, M27 Junction 10 North Hill Interchange (OpenStreetMap)

6.3.5 Cluster 5: M27 Junction 12, Hilsea Interchange

Cluster 5 was located at junction 12 of the M27, the Hilsea Interchange. The two incidents in this cluster occurred on different parts of this complicated junction.

Incident A occurred on the loop joining the southbound M275 with the westbound M27. This was a single vehicle incident involving a 626cc motorcycle going ahead around a left-hand bend. The front of the motorcycle hit the OBB barrier and the motorcyclist was seriously injured. A Google Street View review showed that it is likely that a MPS was present at this incident location at the time of the incident.

The other incident (Incident B) happened at a merge point where a slip road from the northbound M275 joins the main carriageway of the westbound M27. This incident involved two vehicles, one of which was a 996cc motorcycle. The motorcycle skidded and left the carriageway onto the central reserve where it hit an OBB barrier and the motorcyclist sustained slight injuries. There was no MPS present at this incident location.

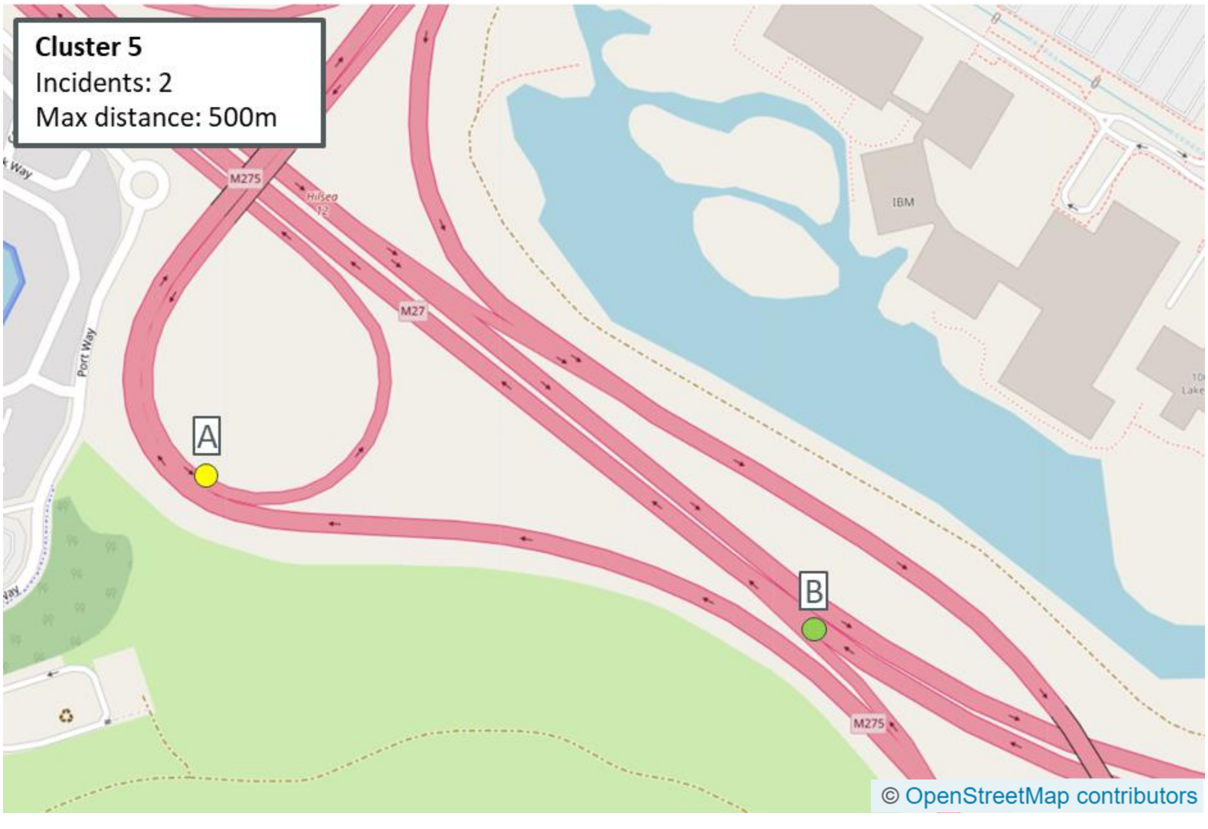

Figure 56: Cluster 5, M27 Junction 12, Hilsea Interchange (OpenStreetMap)

6.3.6 Cluster 6: M25 Junction 16, Denham Interchange

Cluster 6 was located on junction 16 of the M25, where the M40 meets the M25 at the Denham Interchange. There were three serious single vehicle incidents in this cluster, all on different slip roads within this large grade-separated junction. Two of the incidents were very close together but the third was further away.

Incident A was on the slip road which links the westbound M40 with the clockwise M25. A 675cc motorcycle was travelling round a right-hand bend and skidded. The motorcycle left the carriageway on the nearside and hit the TCB nearside barrier.

Incident B occurred on the loop joining the clockwise M25 to the eastbound M40 and involved a 599cc motorcycle. The motorcycle was going ahead round a left-hand bend and hit a TCB crash barrier. No skidding or overturning was recorded.

The third incident (Incident C) happened on the other side of the junction to the other two incidents, on the slip road linking the eastbound M40 with the anti-clockwise M25. A motorcycle with engine size over 500cc was going ahead round a right-hand bend when it skidded and left the carriageway on the nearside. It hit an OBB barrier before rebounding.

There was no MPS present at any of the incident locations in this cluster.

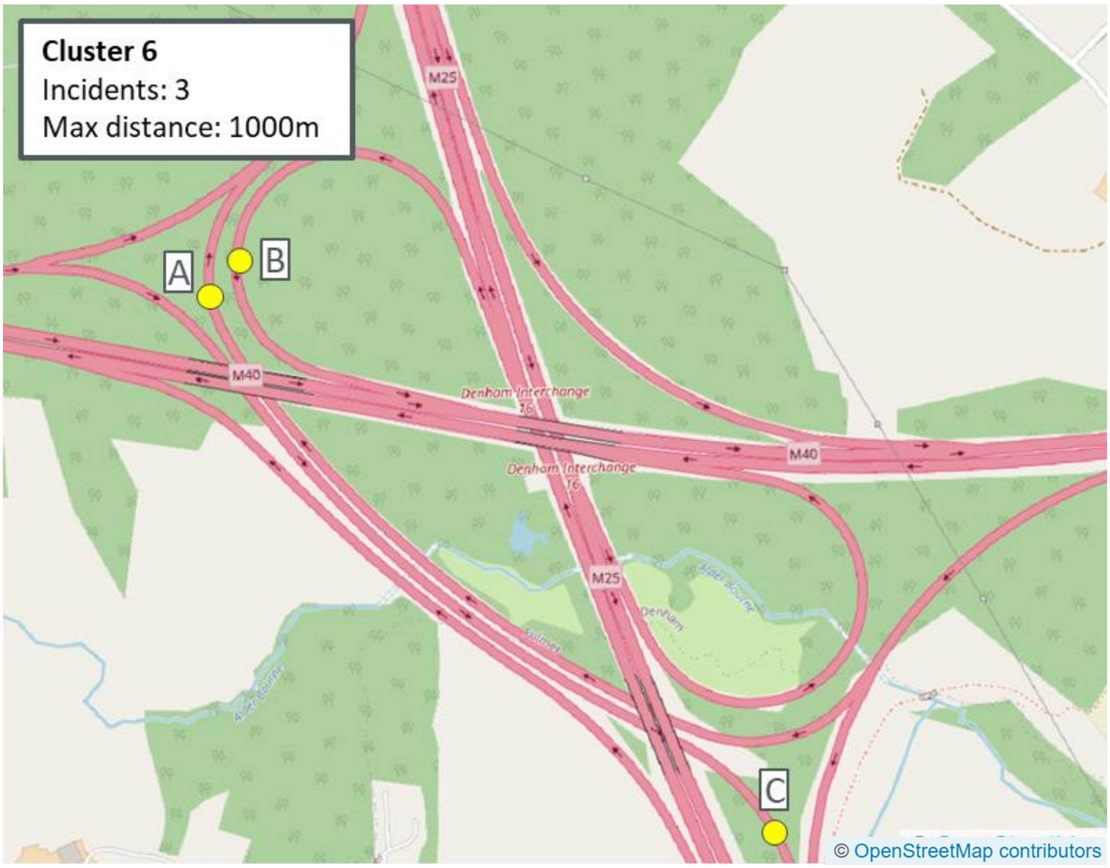

Figure 57: Cluster 6, M25 Junction 16, Denham Interchange (OpenStreetMap)

6.3.7 Cluster 7: M6 south of Junction 18

Cluster 7 was located on the southbound carriageway of the M6 between junctions 18 and 17, just after the Broad Lane overbridge. This is the only cluster which is on the main carriageway and not at or near a junction.

Incident A was a two-vehicle incident involving a 1450cc motorcycle. The motorcycle was going ahead along the carriageway and then left the carriageway on the nearside and hit a TCB barrier. No skidding or overturning was recorded. The motorcyclist sustained fatal injuries.

Incident B involved a single 2294cc motorcycle going ahead along the road. The motorcycle hit road works in the carriageway and then left the road on the nearside. The motorcycle then hit the barrier and rebounded. The motorcyclist in this incident was seriously injured.

There was no MPS present at either incident location in this cluster.

Figure 58: Cluster 7, M6 South of Junction 18 (OpenStreetMap)

6.3.8 Cluster 8: A46/B1190 junction

Cluster 8 is located on an at-grade roundabout junction between the A46 and the B1190. There were two incidents in this cluster, and both resulted in slight injuries for the motorcyclist.

Incident A was a two-vehicle incident involving a motorcycle with an engine size of over 500cc. The motorcycle was going ahead round a right-hand bend as it left the roundabout. No skidding is recorded, but the motorcycle left the carriageway on the nearside and hit the TCB barrier.

Incident B was a single vehicle incident which involved a 599cc motorcycle which was entering the roundabout and turning left. The motorcycle left the carriageway on the offside, hit the TCB central crash barrier and crossed the central reserve. STATS19 records that the motorcycle skidded and overturned during this incident.

There was no MPS present at either incident location in this cluster.

Figure 59: Cluster 8, A46/B1190 Junction (OpenStreetMap)

6.3.9 Cluster 9: M621 Junction 4

Cluster 9 was located at junction 4 of the M621. The cluster comprises two single vehicle incidents close together on the same section of the junction, the slip road linking the northbound M621 and the northbound A61.

Incident A involved a 535cc going ahead round a left-hand bend. The motorcycle hit a bollard or refuge in the carriageway, left the carriageway to the offside and then hit an OBB barrier before rebounding. The motorcyclist sustained serious injuries.

Incident B was similar to Incident A. It involved a motorcycle going ahead round a left-hand bend which then left the carriageway on the offside before hitting an OBB barrier and rebounding. However, in Incident B there was no object hit in the carriageway and the motorcycle was less powerful (124cc). Also, the motorcyclist in Incident B was only slightly injured.

There was no MPS present at either incident location in this cluster.

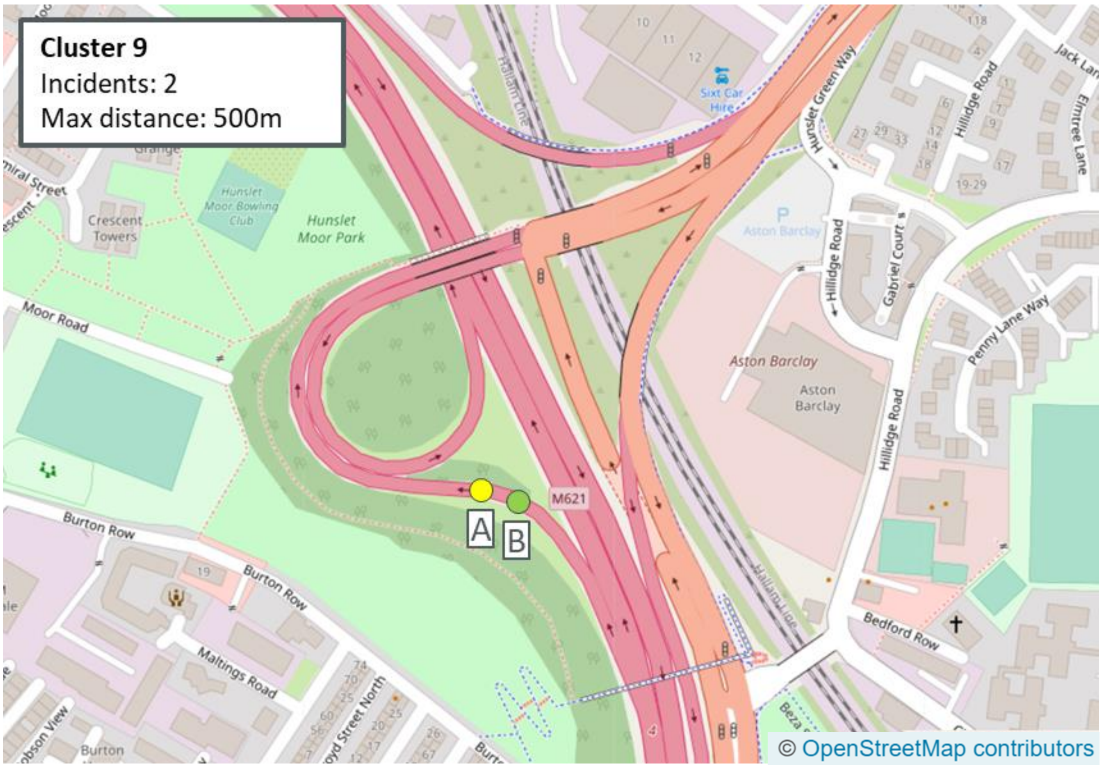

Figure 60: Cluster 9, M621 Junction 4 (OpenStreetMap)

6.3.10 Cluster 10: M11 Junction 14, Girton Interchange

Cluster 10 was located on the Girton Interchange at junction 14 of the M11. There were two incidents in this cluster on different parts of the junction, and both involved two vehicles.

Incident A occurred on the loop which links the northbound M11 with the eastbound A428 and involved a 599cc motorcycle. The motorcycle was going ahead round a left-hand bend when it skidded and left the carriageway on the offside, impacting an OBB barrier. The motorcyclist was seriously injured.

Incident B took place at the merge where the slip road from the southbound A14 joins the main carriageway of the A428. The 599cc motorcycle was overtaking another vehicle and left the carriageway onto the central reserve. The back of the motorcycle hit the TCB central barrier and the motorcyclist sustained slight injuries.

There was no MPS present at either incident location in this cluster.

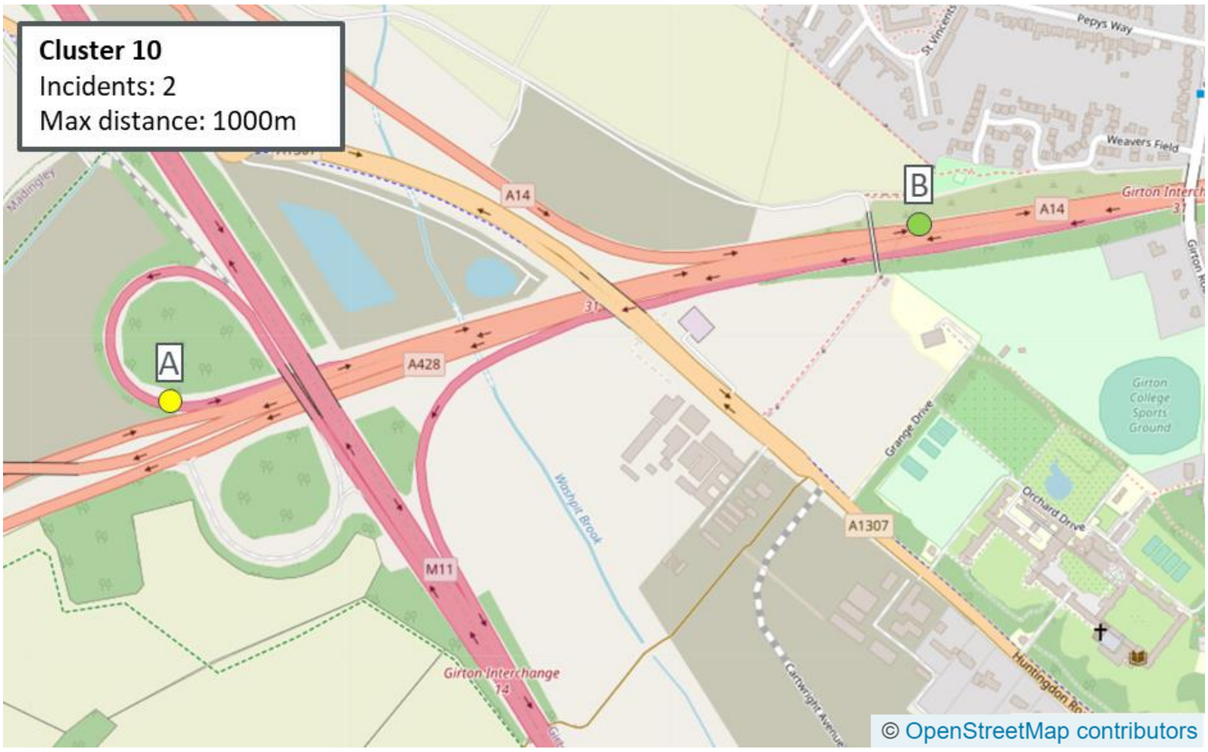

Figure 61: Cluster 10, M11 Junction 14, Girton Interchange (OpenStreetMap)

Key points: Incident clusters

- All but one of the ten clusters identified were at junctions, and eight were at or near grade-separated junctions.
- The most common location for incident clusters was tightly curving loops or slip roads within grade-separated junctions, seven out of 10 clusters included at least one incident in this type of location.
- The largest cluster contained six incidents, all on curved parts of a complicated grade-separated junction on the A27.
- Only two of the cluster sites are likely to have had MPS installed at the time of at least one of the incidents (based on Google Street View images).

7 Conclusions

This section summarises the findings from the literature review and the incident data analysis and the conclusions which can be drawn from this research.

7.1 Conclusions drawn from the literature review

The aim of the literature review was to understand the nature of motorcycle-to-barrier incidents in detail, establish the level of their current usage on the SRN and gather information about how different countries are dealing with the issue of motorcycles hitting barriers.

Research showed that most common type of motorcycle incident in Great Britain is right of way violations and the second is losing control on bends. Most MPS on the market are designed for the second type of incident, which accounts for only 15% of motorcycle incidents.

In addition, current MPS are designed to reduce injury when a motorcyclist is sliding along the ground. However, multiple pieces of research have shown that these types of incidents account for only half of motorcycle-to-barrier impacts and the SRN incident data analysis in this report also supports that finding. This means that the frequent types of incidents and outcomes (for example, whether or not motorcyclists in incidents at a location frequently come off their vehicles) should ideally be considered when prioritising sites for MPS installation. However, there will not often be sufficient data to do this.

Curves and grade-separated junctions are identified in the literature as high risk locations for motorcycle-to-barrier incidents and research showed that this was the case in multiple countries. This suggests that these installing MPS at these locations could be beneficial.

Research has shown that the cause of injury to motorcyclists in impacts with barriers is the sharp edges of exposed supporting posts. Some of these can be prevented with the use of MPS but current MPS does not offer protection to motorcyclists who impact the top of posts. The most common types of injury are to the head, thorax and pelvis but the current MPS testing specification only uses head and neck criteria.

Interestingly, the literature reviewed in this report found no evidence of inherent danger of wire rope fence, perceived by many motorcyclists to have a ‘cheese-cutter’ effect. Wire rope fence was not found to be more dangerous than other barrier types or the other roadside objects it is used to protect road users from. When comparing barrier types, concrete barrier has been shown to be a safer option for motorcyclists than steel barriers and the top of a concrete barrier does not present the same risks as the top of a steel one because there are no posts.

MPS are not widely used in the UK. The BikeGuard system was trialled in 2004 and approved for use by National Highways. However, only 7.4% of high risk slip roads on the SRN had MPS installed as of April 2020. The current National Highways standard (CD 377) states that ‘appropriate mitigation measures to reduce risk’ should be specified at high risk sites for motorcyclists.

Research and statistics from 14 countries were reviewed to gain further insight into how other countries are addressing the problem of motorcycle-to-barrier incidents. The review showed that the number of motorcycle-to-barrier incidents in generally small but these incidents are often high severity. This has led to a targeted approach by most countries and Portugal and the Netherlands have developed criteria to prioritise sites for MPS installation. These criteria include consideration of elements such as

- Small curve radius,
- Consecutive circular curves,
- Availability of clear space for evasive manoeuvres,
- Visibility,
- Irregularity in road design,
- Effect of road layout of rider expectations,
- Entry points at intersections and interchanges,
- Zones prone to skidding and icing.

7.2 Conclusions drawn from review of incident data

The aim of the incident data analysis was to understand the scale of motorcycle-to-barrier incidents on the SRN and the common characteristics of these incidents.

Analysis of all casualties on the SRN showed that motorcyclists are at much higher risk of injury or fatality than vehicle occupants. Motorcyclists account for 18% of KSI casualties on the SRN but only 1.3% of SRN KSI casualties are from motorcyclist to barrier incidents. This shows that the number of casualties from motorcyclist to barrier incidents on the SRN is small compared with the total casualties.

However, small numbers should not mean that attempts to prevent these casualties are not made, especially when MPS exist which could do so. The most commonly hit object for a motorcyclist leaving the carriageway is a crash barrier but the data shows that these barriers do not work as well for motorcycles as they do for non-motorcycles; 16% of non-motorcycle-to-barrier impacts resulted in KSI casualties compared with 76% for motorcycles. This highlights the need to make barriers safer for motorcyclists.

Detailed analysis of motorcycle-to-barrier incidents on the SRN was undertaken to identify common characteristics of these incidents. There were 174 motorcycle-to-barrier incidents on the SRN between 2014 and 2018, resulting in 180 motorcyclist casualties, 67% of whom were killed or seriously injured. The majority of these incidents (62%) were single vehicle incidents.

Analysis of casualty demographics and incident date and time information showed that single vehicle motorcycle-to-barrier incidents in particular are common during recreational riding, as shown by the higher incident numbers during the summer months and weekends. Motorcyclists riding recreationally are more likely to push the limits of their motorcycles and drive at inappropriate speeds which can lead to 'losing control on bends' incidents, as mentioned in the literature review. MPS are designed to reduce injury risk in these types of incidents.

Of the 174 incidents analysed, 65% were at junctions and most of those occurred within grade-separated junctions. When these incidents were examined in more detail, it was found that almost half were on slip roads, meaning that slip road incidents accounted to almost a quarter of all SRN motorcycle-to-barrier incidents. These locations should therefore be considered as priority locations for risk reduction measures. The remaining incidents within grade-separated junctions took place at merge or diverge points or in weaving areas, which are prime locations for right of way violation incidents and risk reduction measures could also be beneficial here.

More motorcycle-to-barrier incidents occur on left-hand bends than right-hand bends. Also, as the UK drives on the left, loops and slip roads in grade-separated junctions (which have been shown to have high incident numbers as mentioned above) are more likely to be left-hand bends. This suggests that prioritising installing MPS on left-hand bends, particularly on loops or slip roads, could be beneficial.

Analysis of the horizontal curve radius at the incident locations showed that most of the incidents were grouped towards the extremities of the curve radius spectrum, either occurring on tight bends or straight sections of road. However, installing MPS on long, straight sections of road can be costly and it is also difficult to identify exactly where along a featureless stretch of road MPS would be most beneficial.

It is therefore worth noting that there were almost as many motorcycle-to-barrier incidents on slip roads with a curve radius less than 100m (27 incidents) as there were on straight link road sections (29 incidents). These numbers are small, but they do indicate that installing smaller lengths of MPS on more localised slip road sections could provide similar benefits to installing longer lengths on a straight road.

The results from the incident cluster analysis further support this finding. Eight out of the ten clusters identified were at grade-separated junctions and seven out of these eight included at least one incident on a tightly curving loop or slip road.

8 Recommendations

It is recommended that the following policy be adopted in order to assess and reduce the risk of motorcyclist to barrier incidents, should it be considered that there is a sufficiently high risk of incidents occurring to warrant the publication of a risk reduction policy. Recommendations have also been made for prioritising locations to assess, based on common characteristics of motorcycle-to-barrier incident locations.

8.1 Recommended policy

- Investigate the methods that would decrease the probability of a motorcyclist leaving the carriageway (e.g. improving road surface, improved signage or better visibility).
- Where possible, remove any existing hazard(s).
- Where possible, move any existing hazard(s) further from the carriageway.
- Where possible, make the hazard(s) passively safe for an impact by a motorcyclist (as there is no published testing standard to ascertain the passive safety performance of roadside hazards through an impact by motorcyclist, engineering judgement should be used to make this assessment).
- With consideration of the safety for all road users, remove any unnecessary lengths of barrier.
- If the hazard cannot be removed, relocated or made passively safe for motorcyclists, then installation of an MPS, compliant with TS 1317-8, should be considered.
- If the installation of an MPS cannot be justified (for example due to a cost benefit analysis), then a review of the proximity of any remaining hazards to the front face of the barrier should be carried out to ascertain whether the working width of the system could be increased by the removal of posts from the barrier system. The removal of the posts would decrease the probability of an impact by a motorcyclist, and thus reduce the risk of injury.

8.2 Recommendations for locations to prioritise

Those sites identified as having a history of motorcyclist to barrier impacts (for example those clusters identified within this report) should be prioritised for assessing the risk posed to motorcyclists, using the methodology above. However, the review of the STATS19 data has shown that these locations are few in their number.

Therefore, it is recommended that locations with the following characteristics be prioritised when assessing locations for motorcycle risk. These are road characteristics which are common at locations where motorcycle-to-barrier incidents occur.

- In the vicinity of grade-separated junctions:
    - Slip roads and loops, especially where there are curves with a radius of less the 100m or a left-hand bend.
    - Downstream of merge points

  - Upstream of diverge points
  - Weaving areas.
- On link roads:
  - Left-hand bends
  - Sections with a curve radius of less than 100m
  - Straight sections (curve radius of 1000m or more)

In addition to the road common incident location characteristics above, it is recommended that enhanced prioritisation should also be given to grade-separated junctions and link roads where one or more of the following also exists:

- Routes regularly travelled by motorcyclists/where the percentage of motorcyclist traffic is high
- Locations where the barrier system is located close to the edge of the carriageway
- Reverse and/or insufficient super-elevation
- Locations of frequently queuing traffic
- Locations of queue discharge
- Consecutive curves in the same direction, with decreasing radius
- Sharp horizontal curves located at the end of long straights, without a sufficient transition spiral
- Locations with poor sight distance
- Locations likely to experience icing and skidding
- Locations where other hazards to motorcyclists exist

8.3 Additional considerations

A reasonable number of motorcyclist to barrier incidents occur on straight sections of dual carriageway roads (with a horizontal curve radius greater than 1000m). Unless there is a history of incidents on a small stretch, there may not be justification for the installation of MPS at all such sites. However, the review of literature carried out within this work has suggested that concrete barriers can offer less of a risk of injury to motorcyclist than steel barrier systems without an MPS installed, especially in narrow angle impacts. Hence, the current National Highways policy for the installation of concrete barriers in the median of motorways with an AADT of over 25,000 vehicles per day, may go some way to reducing the risk of injury to motorcyclists in such median barrier incidents in the future.

9 References

ACEM, 2008. *A Safety Plan for Action,* s.l.: The Motorcycle Industry in Europe (acem).

Astori, S. & Sala, G. M., 1998. *New Concepts and Materials for Passive Safety of Motorcyclists.* Gothenburg, s.n.

ATSB, 2000. *Review of Wire Rope Safety Barriers. Working Party Report,* s.l.: Australian Transport Safety Bureau.

ATSB, 2000. *Review of Wire Rope Safety Barriers. Australian Transport Safety Bureau Working Party Report,* Canberra: Australian Transport Safety Bureau.

Berg, F. A. et al., 2005. *Motorcycle Impacts into Roadside Barriers—Real-world Accident Studies, Crash.* Washington D.C., s.n.

Brailly, 1998. *Etude des accidents de motocyclistes avec choc contre glissières de sécurité,* s.l.: s.n.

CEN, 2012. *CEN/TS 1317-8, Road Restraint Systems - Part 8: Motorcycle Road Restraint Systems Which Reduce the Impact Severity of Motorcyclist Collisions with Safety Barriers.* Brussels: CEN, European Committee for Standardization.

Czajka, M., 2000. *Designing Roads for Motorcycle Safety,,* s.l.: Unpublished report.

Daniello, A. & Gabler, H. C., 2011. Effect of Barrier Type on Injury Severity in Motorcycle-to-Barrier Collisions in North Carolina, Texas, and New Jersey. *Transportation Research Record: Journal of the Transportation Research Board,* p. pp. 144–151.

DfT, 2004. *In-depth Study of Motorcycle Accidents,* Notthingam: Department for Transport.

DfT, 2020. *TRA4211: Motor vehicle traffic by vehicle type on roads managed by Highways England.* [Online]
Available at: https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra#traffic-based-on-a-static-road-management-status-tra42
[Accessed October 2020].

DfT, 2020. *VEH0305: Licensed motorcycles, scooters and mopeds by engine capacity: Great Britain and United Kingdom.* [Online]
Available at: https://www.gov.uk/government/statistical-data-sets/veh03
[Accessed October 2020].

Dohman, M., 1987. *Passive Sicherheit von Schutzplanken,* s.l.: s.n.

Duncan, C., Corben, B., Truedsson, N. & Tingvall, C., 2000. *Motorcycle and Safety Barrier Crash-Testing: Feasibility Study,* s.l.: Monash University Accident Research Centre.

Ellmers, U., 1994. *Improving safety for motorcyclists through sheathing of the guardrail posts,* Düsseldorf : VDI.

Ellmers, U., 1998. *Guardrail post-protection for improving the safety of motorcycle riders.* s.l., s.n.

Ellmers, U. & Kloechkner, R., 2002. *Motorcycle Collisions with Road Restraint Systems.* s.l., s.n.

Erginbas, C. & Williams, G., 2013. *Development of policy for the provision of 'motorcycle friendly' adjuncts to road restraint systems,* s.l.: Unpublished.

Erginbas, C. & Williams, G., 2014. *Motorcyclists and Barriers on the Highways Agency Road Network,* s.l.: s.n.

FEMA, 2000. *Final report of the Motorcyclists and Crash Barriers Project, v2.00 ,* s.l.: Federation of European Motorcyclists' Associations.

FEMA, 2005. *The Road to Success – Improving Motorcyclists' Safety by Improving Crash Barriers,* s.l.: Federation of European Motorcyclists' Associations.

FEMA, 2012. *New Standards for Road Restraint Systems for Motorcyclists,* s.l.: FEMA.

FGSV, 2007. *Merkblatt zur Verbesserung der Verkehrssicherheit auf Motorradstrecken (Leaflet for improving road traffic safety on motorcycle routes),* Köln: FGSV.

Gabler, H. C., 2007. *The risk of fatality in motorcycle crashes with roadside barriers,* United States: Virginia Tech.

García, J. et al., 2007. *Improving Motorcyclists' Safety in Spain by Enhanced Crash Test Procedures and Implementation Guidelines,* s.l.: Fundación CIDAUT, Junta de Castilla y León and Universidad de Valladolid.

Gibson, T. & Benetatos, E., 2000. *Motorcycles and Crash Barriers,* New South Wales: NSW Motorcycle Council.

Grzebieta, R., Bambach, M. & McIntosh, A., 2013. Motorcyclist Impacts into Roadside Barriers, Is the European Crash Test Standard Comprehensive Enough?. *Transportation Research Record: Journal of the Transportation Research Board,* pp. No. 2377, pp. 84–91.

Grzebieta, R. et al., 2010. *Fatal Motorcycle-Into-Road-Safety-Barrier Crashes,* s.l.: The University of Adelaide Centre for Automative Safety Research.

Haworth, N., Smith, R., Brumen, I. & Pronk, N., 1997. *Case control Study of Motorcycle Crashes. Report CR174,* s.l.: Federal Office of Road Safety,.

Hell, W. & Lobb, G., 1993. *Typical Injury Patterns of Motorcyclists in Different Crash Types - Effectiveness and Improvements of Countermeasures.* San Antonia, Texas, s.n.

Highways England, 2006. *TD19/06 Design Manual for Roads and Bridges, Volume2 Highway Structures: Design, Section 2 Special Structures, Part 8.* s.l.:Highways England, Transport Scotland, Welsh Assembly Government, The Department for Regional Development Norther Ireland.

Highways England, 2020. *CD 377 Requirements for road restraint systems.* s.l.:Highways England, Transport Scotland, Welsh Assembly Government, The Department for Regional Development Northern Ireland.

Hurt, H., Ouellet, J. & Thom, D., 1981. *Motorcycle Accident Cause Factors and Identification of Countermeasures, Volume 1: Technical Report,* Los Angeles, California: Traffic Safety Center, University of Southern California,.

Jessl, P., 1986. *Anprallversuche an Leitplanken mit Dummies,* Bochum: s.n.

Koch, H. &. B. R., 1989. *Motorcycle accidents with guardrails..* Gotenburg, Sweden, VTI National Swedish Road and Traffic Research Institute, pp. 39-51.

Larsson, M., Candappa, N. & Corben, B., 2003. *Flexible Barrier Systems Along High-Speed Roads: A Lifesaving Opportunity.,* s.l.: Monash University Accident Research Centre.

Mcdonald, M., 2002. *Motorcyclists and Roadside Safety Hardware.* Pacific Grove, California, s.n.

Norwegian Public Roads Administration, 2004. *MC Safety Design and Operation of Roads and Traffic Systems,* Norway: Directorate of Public Roads.

Otte, D., 1994. *Biomechanics of Impacts to the Legs of Motorcyclists and Constructional Demands for Leg Protectors on the Motorcycle.* Lyon, France, s.n.

Oullet, J., 1982. *Environmental hazards in motorcycle accidents.* DesPlaines, Ottawa Association for the Advancement of Automotive Medicine.

Peldschus, S., 2006. *Report on accident scenarios for motorcycle-motorcyclist-infrastructure interaction. State-of-the-art. Future research guidelines APROSYS Deliverable AP-SP41-0003,* Munich: s.n.

Peldschus, S. et al., 2007. *Technical Basis for the Development of a Test Standard for Impacts of Powered Two-wheelers on Roadside Barriers.* Lyon, France, s.n.

Pieglowski, T., 2005. *The Influence of Wire Rope Barriers on Motorcyclists,* s.l.: Luleå University of Technology, Sweden.

Quincy, R., Vulin, D. & Mounier, B., 1988. Motorcycle Impacts with Guardrails. *Transportation Research Circular 341, TRB, National Research Council*, p. pp. 23–35.

Rogers, J. & White, M., 1995. *Factors contributing to Fatal Motorcycle Crashes in South Australia ,* s.l.: South Australian Department for Transport .

Ruiz, D. G. et al., 2010. Overview on the Development of a Test Standard for the Evaluation of Motorcyclists’ Impacts on Road Infrastructure Elements. *International Journal of Crashworthiness,* p. pp. 1–17.

Schmidt, G., 1985. *Essais biomécaniques concernant la protection passive contre les accidents d'utilisateurs des deux roues motorisés lors du choc contre les supports de glissières de sécurité,* Germany: Heidelberg University.

SETRA , 1997. *Les glissières métalliques dans l'accidentologie des motocyclistes,* s.l.: SETRA (Service d'Etudes technique des Routes et Autoroutes).

Toribio, J. C., 2008. Barreras rígidas de hormigón Comportamiento ante el impacto de motoristas (Rigid Concrete Barriers, Behaviour on the Impact of Motorcyclists). *Asociacion Mutua Motera* , pp. 62-65.

Transport Canada, 1980. *Motorcycle Accident Study, Report Number TP2673 and CR800,* s.l.: Transport Canada.

Motorcyclists and Barriers on the National Highways Road Network

The aim of this report is to use findings from a review of literature and detailed incident data analysis to make recommendations to National Highways to help them develop a risk reduction policy specifically for motorcyclist to barrier incidents.

The literature review found that there is clear evidence that motorcycle-to-barrier impacts are infrequent, but high severity incidents. Additionally, it was found that current Motorcyclist Protection Systems (MPS), designed to reduce risk of injury to a motorcyclist when impacting a safety barrier, are only likely to reduce injury risk in around half of cases because they are only designed for impacts where a motorcyclist is sliding along the ground.

There were 174 motorcycle-to-barrier incidents on the SRN between 2014 and 2018 which were analysed in detail to investigate the common characteristics of these types of incidents The analysis showed that the number of motorcycle-to-barrier incidents was small (accounting for only 0.2% of all SRN casualties). However, the need to make barriers safer for motorcyclists was highlighted by the fact that 76% of motorcycle-to-barrier impacts resulted in killed or seriously injured (KSI) casualties between 2014 and 2018 compared with 16% for non-motorcycle-to-barrier impacts.

It was also found that there were a similar number of motorcycle-to-barrier incidents on slip roads with a curve radius less than 100 m as there were on straight link road sections. This indicates that installing smaller lengths of MPS on curved slip road sections could provide similar benefits to installing longer lengths on a straight road, which is known to be more difficult and costly.

Other titles from this subject area

PPR2043 Road to Zero Harm: Technical Report. Glaze S et al. 2024

PPR2003 RAIDS Phase 3 Year 1 Annual Report. Hunt R et al. 2022

TRL
Crowthorne House, Nine Mile Ride,
Wokingham, Berkshire, RG40 3GA,
United Kingdom
T: +44 (0) 1344 773131
F: +44 (0) 1344 770356
E: enquiries@trl.co.uk
W: www.trl.co.uk

ISSN 2514-9652

DOI 10.58446/qnbe1555

https://doi.org/10.58446/qnbe1555

PPR2051