

Synthesis title: Motorways

Observatory main category: Roads

Other relevant syntheses to be consulted:

- Training (Drivers)
- Young drivers (Drivers)
- Older drivers (Drivers)
- Speed (Drivers)
- Signing and Marking (Roads)
- Road Works (Roads)
- Cameras (Compliance and the Law)
- Speed (Compliance and the Law)
- Fatigue (Drivers)

Keywords:

- Motorways, Speed, Driver fatigue, Driver experience, Lighting, Tunnels, Smart Motorways, All Lane Running, ALR, Managed Motorways, Hard Shoulder Running, HSR.

Key facts

- In 2016, there were 896 Killed and Seriously Injured (KSI) casualties on motorways (RRCGB, DfT, 2017), which compared to:
 - 11,801 on A-roads;
 - 3,588 on B-roads; and,
 - 9,638 on 'Other' roads
- In Great Britain, motorways carry about 21% of all traffic but they only account for 5% of fatalities and 5% of injured casualties (RRCGB, DfT, 2017)
- In countries where data on speed measurements in free-flowing traffic are available, up to 30% of drivers exceed speed limits on motorways.
- In a study analysing crash data collected from UK motorways, 'A' roads and 'B' roads, Flatley and colleagues found that between 3 and 30% of crashes could be attributed to driver sleepiness between 1995 and 2004, the 30% figure relating to the M40 in Warwickshire (Flatley, Reyner, & Horne, 2004).
 - This is comparable to earlier reports which stated that driver fatigue can account for anywhere between 4% and 20% of all collisions, though this was not directly related to motorways (RoSPA, 2001; Jackson, Hilditch, Holmes, Reed, Merat & Smith, 2011)

According to the latest report (RRCGB, DfT, 2017), casualties of killed and serious severities increased on motorways in 2016 compared with the 2011-2015 average:

- The number of fatalities decreased by 7%;
- The number of serious injuries increased by 15%; and,
- The number of slight injuries decreased by 6%
- There was also a 2.6% increase in traffic between 2014 and 2015.

Summary

This document has been compiled to highlight and summarise the safety aspects of motorways as a sub-category of roads, primarily in Great Britain.

Motorway travel is relatively safe: motorways carry about 21% of all traffic, but only account for 5% of fatalities and 5% of injured casualties (RRCGB, DfT, 2017); however, there are a number of key sub-topics relating to motorway safety which are currently subject to global debate.

The purpose of this document is to provide the reader with an overview of these sub-topics and provide material for further reading. Therefore, this synthesis has been summarised broadly into the following areas:

- Speed on Motorways;
- Driver fatigue/sleepiness on Motorways;
- Inexperienced drivers on Motorways;
- Motorway Lighting;
- Motorway Tunnels; and,
- Smart Motorways

Excessive speed (i.e. speed in excess of the speed limit) on motorways is a major issue in many countries. While the reasons drivers engage in speeding are varied and can relate to personal biases and environmental cues, the result is the same. That is, higher travel speeds increase the frequency and severity of collisions (e.g. Elvik, Christensen, Amundsen, 2004). In Germany, many of the motorways do not have speed limits or only have temporary speed limits imposed at peak running times. This is a major source of debate as, whilst German motorways are regarded as some of the most safely engineered roads, the country ranks only eighth lowest in terms of deaths per billion vehicle kilometres on motorways in Europe (European Transport Safety Council, 2008b). Decreasing traffic speed on motorways is likely to significantly reduce the rate of road traffic collisions (RTCs).

Motorways are notorious for providing a monotonous driving environment due to their form (e.g. few junctions, unidirectional flow, and minimal conflict) and the constantly flowing nature of the traffic on these roads (RoSPA, 2001). This means that fatigue or sleepiness in drivers on motorways may be more prevalent when compared to other road types. Drivers of Large Goods Vehicles (LGVs) may be more at risk from these effects than drivers of other vehicles due to the large distances involved whilst in transit, though little research has been identified to address this issue. Some research has shown that driving in the early hours of the morning and during the middle of the afternoon are the worst times for fatigue-related road traffic incidents (RTIs) (e.g. Horne & Reyner, 1995). This may be due to the lack of traffic on the roads at the time combined with the natural circadian rhythms of the human body.

Lighting on motorways is an issue that is currently under debate. Switching off lighting on motorways during the late night hours can save up to 20% on usage costs. Motorway lighting may or may not reduce the potential for night-time RTCs – some evidence shows that switching off street lights does not significantly affect collision rate – but it can be of assistance to the emergency services when attending an RTC.

The number of RTCs in motorway tunnels which result in KSI casualties is shown to be disproportionately high compared with the remainder of the motorway network in The Netherlands. However, it was shown that by introducing sectional control or average speed cameras in a motorway tunnel in Austria reduced RTIs by 33% over a two year period (International Transport Forum, 2008).

Smart Motorways have been developed in order to increase the capacity of a motorway without the need to construct extra lanes. This provides a cost-effective solution to motorways that suffer from congestion at peak times. The impact of Smart Motorways on road safety is not yet clear. Such schemes installed on the M42 in the UK and on motorways in The Netherlands suggested a decrease in the number of RTCs and fatalities. However, this work was early on in the development of this technology and further evidence relating to the safety implications of Smart Motorways is needed. More data on the behaviour of drivers using Smart Motorways will allow researchers to understand the safety benefits and likely effects on road users.

Methodology

This synthesis consists of research identified as relating to the topic of Motorways within the category of Roads, focussing on general safety and RTI prevention.

This synthesis was originally compiled during August – September 2012, and then reviewed and updated in January 2016. In December 2017, statistics from Reported Road Casualties Great Britain were updated to [Reported Road Casualties Great Britain 2016](#).

A detailed description of the methodology used to produce this review is provided in the Methodology section of the Observatory website at <http://www.roadsafetyobservatory.com/Introduction/Methods>.

The steps taken to produce this synthesis are outlined below:

- **Identification of relevant research** – searches were carried out on pre-defined research (and data) repositories. As part of the initial search some additional information sources were also consulted, which included <http://www.ingentaconnect.com>. Search terms used to identify relevant papers included but were not limited to:
 - ‘Managed motorways’;
 - ‘Hard shoulder running’;
 - ‘Motorway lighting’;
 - ‘Motorway tunnels’;
 - ‘Motorway driver fatigue’;
 - ‘Motorway driver tiredness’;
 - ‘Speed on motorways’;
 - ‘Exceeding speed limits’; and,
 - ‘Motorways new drivers’.

In the original review, a total of 108 pieces of relevant research were identified.

- **Initial review of research** – primarily involved sorting the research items based on key criteria, to ensure the most relevant and effective items went forward for inclusion in this synthesis. Key criteria included:
 - Relevance – whether the research makes a valuable contribution to this synthesis, for example robust findings from research into excessive speed on motorways.
 - Provenance – whether the research is relevant to drivers, road safety policies or road safety professionals in the UK. If the research did not originate in the UK the author and expert reviewer have applied a sense check to ensure that findings are potentially relevant and transferable to the UK.
 - Age – priority given to the most up to date titles in the event of overlap or contradiction.

- Effectiveness – whether the research credibly proves (or disproves) the effectiveness of, for example, managed motorways or the effects of lighting switch-off late at night.

Following initial review 32 pieces of research were taken forward to form the basis for this synthesis. The updated search yielded a further 21 papers to be included in the synthesis.

- **Detailed review of research** – key facts, figures and findings were extracted from the identified research to highlight pertinent issues and interventions.
- **Compilation of synthesis** – the output of the detailed review was analysed for commonality and a synthesis written in the agreed format. Note that the entire process from identifying research to compiling the synthesis was conducted in a time-bound manner.
- **Review** – the draft synthesis was subjected to extensive review by a subject matter expert, proof reader and an independent Evidence Review Panel.

Please note that:

- Research conducted in the United Kingdom was used where possible in the compilation of this document; however, where there was found to be insufficient material in a particular field, research from worldwide sources was used in order to provide as comprehensive coverage as possible.
- All referenced URLs were correct at the time the initial research was conducted.

Key statistics

Overall, there are two key features of risk relating to motorways which are discussed in the following synthesis:

- Features relating to the driver (such as speeding, driving experience, and fatigue), and;
- Features relating to the driving environment (including lighting and tunnels).

Technological advances in motorway design can help reduce the risks to road workers. However, the likely impact on road users of using such technologies must also be considered. As such, Smart Motorways are discussed within the context of driver safety.

Although vehicle design can also play an important role in improving driver safety, whether on or off the motorway environment, no research directly linking vehicle safety features and/or technology with improved motorway safety was identified, so this element has not been included in this synthesis.

General statistics about motorways

The following section is included to provide an overview of the general safety with respect to motorways. More specific topics are covered in the sections that follow.

- Compared to other road types, motorways are the safest roads in Great Britain. Data from 2014 showed that motorways carry about 21% of all traffic but they only account for 5.4% of fatalities and 4.7% of injured casualties (DfT, 2015).
- A report by the European Commission reported that around 8% of all fatalities between 2010 and 2014 resulted from crashes on the EU TEN-T network (a network consisting mainly of motorways) (European Commission, 2015).
- This is a similar picture for Great Britain where, according to the latest Reported Road Casualties Great Britain (RRCGB) report (DfT, 2015), motorways carry around 21% of all traffic, but account for only 5.4% of fatalities and 4.7% of injured casualties.
- In 2014, there were 814 Killed or Seriously Injured (KSI) casualties on motorways (DfT, 2015), which compared to:
 - 11,518 on A-roads;
 - 3,417 on B-roads; and,
 - 8,833 on 'Other' roads
- KSI casualties on GB motorways in 2014 were 29% lower compared to the 2005-2009 average.

Speed

According to RRCGB, on average, 46% of vehicles were exceeding the 70mph speed limit at any given time (in free-flow conditions) on motorways in 2014 (DfT, 2015). This is not only an issue in the UK and other European countries have found similar results:

- In countries where data on speed measurements in free-flowing traffic are available, up to 30% of drivers exceed speed limits on motorways (ETSC, 2011).
- The combined percentage of car drivers that reported violating the speed limit 'often', 'very often' or 'always' in European countries on motorways was 28% (ETSC, 2011).
- A survey with UK motorists showed that as many as 70% of drivers reported "regularly" or "occasionally" breaking the 70mph motorway limit (RAC, 2015).
 - This compares with 44% who admitted exceeding the 20 and 30mph limits on non-motorway roads. This suggests the prevalence of speeding may be greater on motorways compared with non-motorways.
- Some evidence has suggested that the increase in risk associated with increasing one's speed by 50% is comparable to that exhibited after alcohol consumption.
 - Driving with 0.5g/l Blood Alcohol Concentration (BAC) increases the risk of a fatal RTC by a factor of 5, the same as driving about 50 per cent faster. Drivers have been shown to be aware of the increased risk of being involved in a fatal collision after drinking but largely underestimate the increased risk of being involved in a fatal collision when speeding (ETSC, 2011).

Fatigue

Despite being some of the safest roads to drive on, motorways also have a tendency to be the most monotonous for the driver; research concerning the topic of driving fatigue has shown that monotonous, unstimulating stretches of road (such as motorways) are riskier for fatigued drivers. These effects are quantifiable, and road casualty data from GB showed that, in 2014, 2,046 (2%) of all accidents reported had fatigue recorded as a contributory factor. Of these, 339 occurred on motorways (DfT, 2015), representing 7% of all recorded accidents on motorways. The following research also supports that fatigue can have a significant effect on RTCs.

- Driver fatigue is a major cause of RTCs, accounting for up to 20% of traffic collisions and up to a quarter of fatal and serious RTCs on roads in Great Britain (RoSPA, 2011).
- Sleep-related vehicle RTIs comprise between 16-23% of RTIs, the higher proportion being relevant for motorways (Horne & Reyner, 1995).
- One survey of car drivers suggested that tiredness is a contributory factor in 7% of all RTIs. However, on motorways, this proportion rises to 15% (Maycock, 1995).

Lighting

Lighting can reduce the likelihood of crashes of all severities on motorways. A study by Frith and Jactett (2015) prepared for the New Zealand Transport Agency found that lit (versus unlit) motorways reduced crashes by:

- 33% for all crashes
- 42% for injury crashes
- 67% for serious and fatal crashes

The sample used in this analysis was substantial; over 8,000 crashes were included.

Tunnels

According to work by Caliendo and De Guglielmo (2012), severe collision rates (which included injury and fatal crashes) in tunnels were found to be between 9.13 - 20.45 crashes per 100 million vehicle-kilometres, compared to 8.62 - 10.14 crashes per 100 million vehicle-kilometres on the associated motorway.

- However, this result was not found for all 195 unidirectional tunnels studied, and as such the authors suggest that driver factors as well as the physical characteristics of the tunnel were likely to play an important role.

Smart Motorways

Formerly known as Managed motorways/Hard shoulder running, “Smart Motorway” is the term for schemes which use technology to enhance capacity on motorways and, hence, reduce congestion.

- The implementation of such schemes resulted as a response to the forecasted increase in traffic by 44% between 2010 and 2035 and an increasing need to reduce the costs of congestion (Highways England, 2014).

Research findings

Summaries of key findings from several research reports are given below. Further details of the studies reviewed, including methodology, findings, and links to the reports are given in the References section.

The driver

Speed

When considering all types of roads, motorways are comparatively safer (European Commission, 2015; DfT, 2015). However, there are a number of key issues that increase the risk of being involved in a collision while driving on a motorway; given the relatively high speeds on motorways, the risks relating to speed are particularly pertinent.

Driving at a speed that is inappropriate for the conditions has been shown to increase the risk of involvement in an RTC and increase the severity of the RTC (Aarts & van Schagen, 2006; Richter, Berman, Friendman & Ben-David, 2006; Elvik et al., 2004). Work by Elvik and colleagues (2004) estimated that *“a 10% reduction in the mean speed of traffic would result in a 37.8 [%] reduction of the number of fatalities”*.

There are various elements of the environment, the vehicle and the individual which influence drivers' speed choices and these are not always conscious. For example, excessive speed on motorways may be due to drivers' perception that the motorway environment is less dangerous. Evidence for this has been widely identified, for example, a recent qualitative study by Watters and Beck discussed various road safety topics with a group of 25 undergraduate students. Their results showed that most students felt that speeding was very common and it was not seen as being particularly dangerous (Watters & Beck, 2015). This perception could have an adverse effect on the number of severe or fatal RTCs that occur, as shown by the following data from the International Transport Forum (2009):

- Road users perceive motorways as 'safe'; therefore they tend to drive at speed inappropriate for the situation with the result that a 'minor' RTC often has serious consequences. In addition, the comfort of modern vehicles, the carriageways and roads in general diminish a driver's perception of the actual speed at which he or she is travelling.
- Although there are fewer RTCs (per vehicle-kilometre) on motorways compared to other road types, they can be more severe, clearly owing to the higher speeds on motorways.

The study by Watters and Beck (2015) also found that participants believed that following the travelling speed of traffic was more important than abiding by the speed limit. In addition, the authors identified that, of all the risky behaviours discussed, speeding was viewed as the most justifiable particularly when one is late or in a hurry. The 'optimism bias' (also known as 'false consensus') is discussed quite frequently within this context as it refers to the inflated perception that other drivers engage in non-compliant behaviour more often than they actually do (Haglund & Aberg, 2000). A study engaged over 500 drivers in Turkey and Sweden and collected data relating to self and other drivers on a Driver Behaviour Questionnaire, containing 28 items on driving violations and errors (Warner & Aberg, 2014). Participants responded to items on a Likert Scale ranging from 1 ("never") to 6 ("nearly all the time"). The authors found that the item "disregard the speed limit on a motorway" had the highest mean response for self (average of 3.77 on a 6-point scale) and for other drivers (4.29).

There is also some evidence that the optimism bias could be more pronounced at higher speeds. A study by Haglund & Aberg (2000) found that a significantly higher number of drivers in their 'high speed' group (i.e. drivers whose observed speed limit was found to be 100km/h or higher), 58%, estimated that other drivers exceeded the speed limit. Note that the motorway speed limit in Sweden is 110km/h. These findings support previous research showing that speeding may not be perceived as negatively as other road violations, particularly in relation to higher speed limits (Wallén, Warner & Aberg, 2014).

In the UK, an increase of speed limits from 70 to 80mph on motorways was considered a few years ago. However, according to researchers, such as Sexton and Johnson (2010), the potential positive value of increasing the motorway speed limit to 80mph, due to a reduction in journey times, could be off-set by an increase in casualties. In addition, the debate surrounding the increase of speed limits in itself may have undermined the legitimacy of the current 70mph speed limit in the UK. Results from a recent study of over 2,000 motorists carried out in the UK found that people who are more likely to speed are also more likely to believe speed limits on motorways are set too low (Fernández-Medina, Helman, Posner, Durrell & Rillie, in press).

Despite this evidence, some believe that removing motorway speed limits entirely (as has been done on many German motorways) is the way forward, but the statistics suggest this would be detrimental to safety:

- 52% of the length of German motorways does not currently have a speed limit, whilst 15 per cent has a temporary speed limit (i.e. a speed limit at some times of day). In terms of deaths per billion vehicle kilometres driven on motorways, in 2006 Germany ranked only eighth lowest out of the European countries for which there were data (Great Britain was fourth lowest by comparison) (ETSC, 2008b).

For more information on speed please refer to the Speed Syntheses (in the Driver and Rider categories).

Driving experience

Some research has linked driving experience and the likelihood of being involved in an RTC on different road types:

- As drivers become more experienced, the proportion of their RTCs that occur in towns or on city roads decreases, and the proportion of their RTCs that occur on fast dual-carriageways and motorways increases (Wells, Tong, Sexton, Grayson & Jones, 2008). Note that nothing in this study enables an assessment of why this pattern occurs. It is possible that the effect is just due to exposure (as people gain experience, they may become more likely to travel greater distances on motorways). Alternatively, it is possible that the rate at which people become safer with increasing experience varies by road type.

Studies have also shown that novice drivers have a poorer understanding of 'risk' and how to react in certain situations which can be particularly dangerous in high speed environments such as on the motorway.

- It has been shown that less experienced drivers' reaction times to hazardous scenarios were longer than those with more experience of driving. This suggests that experience is important in the development of some perceptual skills (Crundall, Underwood & Chapman, 1999).

Improved driver training and/or other education are/is likely to help reduce the risk for inexperienced drivers; however, the largest risk reduction for an individual driver is likely to result from increased driving experience.

Fatigue

Several research papers highlight that fatigue-related RTIs are more prevalent at certain times of the day, which may be correlated with natural circadian rhythms. It has also been suggested that these times coincide with monotonous driving conditions, such as on motorways when there are low volumes of traffic.

- 'Early hours' RTIs occurred most often on motorways, perhaps because low traffic densities and monotonous driving could be contributing to boredom and associated fatigue at these times (Clarke, Ward, Bartle & Truman, 2005).
- The early hours of the morning and the middle of the afternoon are the peak times for fatigue RTIs, and long journeys on monotonous roads, particularly motorways, are the most likely to result in a driver falling asleep (RoSPA, 2011).
- Sleep-related vehicle RTIs are largely dependent on the time of day and account for a considerable proportion of vehicle RTIs, especially those on motorways and other monotonous roads (Horne & Reyner, 1995).

Additionally, it has been shown that monotony caused by travelling at fixed speeds (particularly slower speeds) can have a negative effect on drivers' alertness (RoSPA, 2011). This is further supported by research conducted by Valencia University who found that driver brain activity increased where speed varied. In addition, reaction time appears to be longer for subjects travelling at slower fixed speeds than for those travelling at faster fixed speeds (Törnros, 1994).

- Driver Electroencephalography (EEG) – the study of electrical activity in the brain – showed that activity tended to be significantly higher when speed was modified periodically than when it remained constant (Tejero & Chóliz, 2002).

There is also some evidence that fatigue-related fatal collisions are more likely to occur on the hard shoulder.

- In a study using UK STATS19 data, Michalaki and colleagues found that driver fatigue was the second most common contributory factor for hard shoulder collisions (these include collisions occurring while entering, leaving or parking on the hard shoulder), with fatigue being a contributory factor in 23% of all fatal accidents occurring on the hard shoulder compared with 12% of fatal accidents on the main carriageway (Michalaki, Quddus, Pifield & Huetson, 2015). There are a number of possible explanations for this. For example, it may be partly attributable to drivers who are fatigued being more likely to be making use of the hard shoulder and therefore more exposed to collisions in this particular environment. An alternative explanation is that people who fall asleep at the wheel become more likely to leave the carriageway. A further possibility is that other collision types that are common on the main carriageway are less likely to occur on the hard shoulder, thus indirectly increasing the proportion of collisions on the hard shoulder which are fatigue-related.

It is considered that fatigue is an issue which is exacerbated at certain times of the day and by a general lack of stimulation created by monotonous driving conditions. A better understanding about the likely crash scenarios which present the highest risk to fatigued drivers could help researchers find ways to reduce the likelihood of fatal collisions under these conditions.

For more information about driver fatigue, please refer to the Fatigue synthesis.

The driving environment

Lighting

There have been debates over whether or not to switch off motorway lights during periods of the night when traffic flow is lowest. Whilst this would save energy, the provision of lighting can have an impact on the ability of emergency services to operate effectively at the scene of an RTC.

- As reported in Howard (2012), it is the general opinion of the Institution of Lighting Professionals (ILP) that road lighting on all road types:
 - Reduces night time collisions;
 - Reduces night time crime and,
 - Helps emergency services;

Research by Wanvik (2008) identified the following:

- Although road lighting is perceived to increase road safety generally, in the Netherlands between 1987 and 2006, 536 collisions were due to collision with lighting posts.
- The safety benefits of road lighting appear to be negligible during conditions of fog.
- As new vehicle and road technology is implemented in the future, the need for and benefit of road lighting will probably be reduced.
- Motorway lights in the future will be of the adaptive type, in that the lights usage will adapt to the situation automatically. This will lead to significant energy savings.
- A technology that may reduce energy consumption on low traffic motorways is that of LED guide lights– low-power, ground-level up-lighting. However, the effect on RTCs needs to be evaluated.

Tunnels

Tunnels are relatively uncommon features on road networks around the world. Although drivers may be more cautious when driving through tunnels, it is possible that the characteristics of the tunnel may change the likelihood and/or severity of collisions.

Calvi et al. undertook a study with 20 drivers (ages 22-46 years) in a driving simulator. They found that drivers tended to drive more slowly and the frequency of trajectory corrections was smaller when driving through a tunnel. The authors concluded that this is likely to be due to the relatively unfamiliar environment of the tunnel causing drivers to pay more attention (Calvi, De Blasiis & Guattari, 2012).

In contrast, other studies have found that severe accident rates may be higher in tunnels, when compared with the associated motorway. This may be related to the geometric and traffic characteristics of tunnels (Caliendo & De Guglielmo, 2012).

Smart Motorways

Congestion on the Strategic Road Network (SRN) is estimated to cost around £2 billion a year (Highways England, 2014). With the SRN carrying approximately 33% of all traffic in the UK, including 66% of all freight traffic (DfT, 2015b), it is critical to implement measures for reducing congestion.

'Managed Motorways' were first introduced as a response to increasing traffic congestion. The design primarily involved the use of a Dynamic Hard Shoulder (DHS), which enabled the hard shoulder to be opened to vehicles during periods of high traffic flows (thus improving capacity) and closed at other times. This was seen as a more cost effective and environmentally friendly solution compared with traditional motorway widening (Highways England, 2014). However, whilst hard-shoulder running could provide an increased capacity, the effects on access for emergency services was severely impacted (Barker, 2010).

More recently there has been a shift towards 'Smart Motorways' across GB. A Smart Motorway uses technology to manage traffic, improve journey time reliability, improve traffic flow and reduce congestion. This is achieved through the use of Variable Message Speed Limits (VMSLs) and conversion of the hard shoulder as an extra lane (Highways England, 2014). The key difference between these two systems is the introduction of the 'all lane running' in smart motorways which involves sections of the motorway having the hard shoulder permanently converted into a running lane. This represents an advance from the previously employed DHS as it theoretically removes any confusion over whether or not the hard shoulder is open. However, some sections of Smart Motorways still make use of DHS, which may inadvertently exacerbate confusion.

One of the main features of Smart Motorway systems is that speed can be controlled to improve traffic flow in changing conditions. Enforcement of these speeds is achieved through digital enforcement cameras placed throughout the network. There is evidence to support the use of speed cameras as a countermeasure for speeding behaviour (Smith, Lawton, Beard, Durrell, Scoons, & Lloyd, 2015; Fernández-Medina & Posner, *in press*). In contrast, there is some evidence to suggest drivers may slow down on the approach to an enforcement measure but then speed up again downstream of the enforcement measure (De Pauw, Daniels, Brijs, Hermans & Wets, 2014). However, the impact of this speed profile on safety is not clear.

One of the key factors necessary in order for VMSLs to be effective on Smart Motorways is the perceived credibility of the speed limits by road users. There is recent evidence to show that people who are more likely to speed are also more likely to believe speed limits on motorways are set too low (Fernández-Medina *et al.*, *in press*). If VMSLs are not perceived to be credible, this could lead to increased non-compliance by motorists travelling on these sections of the SRN.

There is further evidence suggesting that credibility is an important concept in relation to how drivers respond to technology, including on-road messages (e.g. Zhong, Zhou, Ma & Jia, 2012). For example, Zhong and colleagues collected data on route choice behaviour, socio-economic and travel characteristics of over 300 drivers. The data were used to assess the likely predictors of VMS compliance through a regression analysis. Their results showed that the degree of trust in VMS was a significant factor in relation to compliance (Zhong et al., 2012). This is problematic in a scenario where signs and signals are the primary cue for drivers to modify their behaviour, such as when using Smart Motorways, as these could have a detrimental impact on driver behaviour (e.g. driving too fast for conditions as they do not believe in the credibility of the message that is being presented to them).

How effective are current measures in reducing collisions?

The following statements present statistics that highlight the contribution that various motorway interventions have had on improving road safety.

Lighting

- Typical reductions in 'road usage costs' resulting mainly from RTC savings from lighting are given as 20% for Motorways (Crabb, Beaumont & Webster, 2009).
- The estimated effect of motorway lighting in preventing night-time RTCs in The Netherlands (during dry conditions) is 49%. The effect was reduced during wet or snowy conditions, and may not be comparable in other countries like Britain and Sweden (Wanvik, 2008).

Tunnels

- New technologies such as section control (also known as average speed cameras) are being implemented in a number of countries, with early evaluations showing positive impacts on speed and crashes. In Austria, average speed cameras used over a section of motorway with a tunnel were associated with injury crash reductions of 33% over two years, with a cost-benefit of 1:5.3 (International Transport Forum, 2008).

Smart Motorways

- Rush-hour lanes (similar to dynamic hard shoulders in the UK) are in operation in The Netherlands. Serious accidents decreased by 40% over the period 2004-2006 compared to 2001-2003, while the overall reduction on the whole motorway network was 30% (ETSC, 2008a).

Gaps in research

- It was found that published research into motorway tunnels in the UK was particularly sparse. This may be due to there being fewer motorway tunnels in the UK compared with some European countries where RTCs in tunnels are more prevalent.
- To date, there is only a limited amount of evaluation regarding the effectiveness of Smart motorways but research carried out by Highways England (2016) provides an initial overview of their effect on collision frequency. Based on the evaluation of two all lane running sections on the M25, Smart motorways appear to have reduced average journey times by between 2% and 9%. While reductions in the collision rates per unit distance were not significant, they were accompanied by increases in traffic volumes. In addition, monitoring of 'Red X' compliance found that, on average, 7% of vehicles were non-compliant. As Smart motorways become more prevalent, it is likely that the amount of research material in this area will increase.
- More research is required on the midnight 'switch off' with respect to motorway lighting.

References

Title: Driving speed and the risk of road crashes: A review
Author / organisation: Aarts, L. and van Schagen, I.
Date: 2006
Format: Pdf
Link: http://www.sciencedirect.com/science/article/pii/S0001457505001247
Free / priced: Priced
Objectives: To review and discuss available literature in relation to crash risk and speed.
Methodology: A non-systematic review of literature was undertaken and findings are discussed.
Key Findings: <ul style="list-style-type: none">• Research to date supports the finding that crash rate increases as a function of speed, but this relationship is not always straight forward.• These findings are reported in self-report studies and case-control studies.• The studies reviewed found no evidence that vehicles which travel at speeds slower than surrounding traffic had an increased crash rate.• Large speed variance was found to be related to an increased crash risk.
Themes: crash risk, speed-crash relationship
Comments: Although the review was not systematic, it provides an overview of research in this area.

Title: Incident Policy for Managed Motorways
Author / organisation: Barker, E. (HCG/HRG)
Date: 2010
Format: Pdf
Link: http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Incident_Management_Final_Report_Issue_V1_2.pdf
Free / priced: Free
Objectives: Investigation in to the effects of Managed Motorway operations relating to access of the first responder to an RTI; the assigned RTI type / classification which determines the response grade of the Traffic Officers and maintenance contractors, and the ability of the Traffic Officer Service (TOS) to manage one or more RTIs at the same time as managing multiple Managed Motorway sections.
Methodology: The task was delivered in two phases, commencing with a scoping report to determine the outline risks to these areas and identify appropriate methodologies to further analyse these risks. The second phase of this task involved establishing the nature of these risks and how these may alter between Managed Motorway (MM) schemes when in operation.
Key Findings: <ul style="list-style-type: none"> • Traffic officer response times are generally lower on Dynamic Hard Shoulder Running sections and a greater proportion of RTIs are detected.
Themes: Hard Shoulder, Managed Motorway
Comments: Limited to the M42-ATM section between April 2008 and march 2009.

Title: Accident Rates in Road Tunnels and Social Cost Evaluation
Author / organisation: Caliendo, C, and De Guglielmo, M.L.
Date: 2012
Format: Pdf
Link: http://www.sciencedirect.com/science/article/pii/S1877042812043327
Free / priced: Priced
Objectives: The aim of the study was to estimate accident rates and the associated cost of accidents in Italian motorway tunnels.
Methodology: A short literature review alongside data collection and analysis was undertaken. <ul style="list-style-type: none"> • Data relating to collisions in tunnels and associated motorways was evaluated between 2006 and 2009. • The dataset included 195 unidirectional tunnels. • Crash data and traffic flow data were collected during the study period.
Key Findings: <ul style="list-style-type: none"> • The data analysis showed that severe accident rates were higher in tunnels than on other stretches of motorways which contained the tunnel (comparison group), with between 9.13 and 20.45 crashes per 100 million vehicle km. <ul style="list-style-type: none"> ○ However, this was only found for approximately two-thirds of the tunnels included in the study. • Driver behaviour, visibility and tunnel design were found to play a role in the increased accident rates.
Themes: Tunnels, collisions, Italian motorways
Comments: The study provides recent data on motorway crashes relating to tunnels.

Title: An Empirical Study of the Effects of Road Tunnel on Driving Performance
Author / organisation: Calvi, A., De Blasiis, M.R., and Guattari, C.
Date: 2012
Format: Pdf
Link: http://www.sciencedirect.com/science/article/pii/S1877042812044217
Free / priced: Priced
Objectives: To gain a better understanding of tunnel driving.
Methodology: The researchers employed a driving simulator
Key Findings: <ul style="list-style-type: none"> • Drivers tend to drive differently in tunnels. • Drivers in the study tended to incur in less trajectory corrections (i.e. less lateral accelerations) and drive more slowly in the tunnel. • They also tended to show a significantly higher average lateral position with respect to the centre lane when compared to the same road section without a tunnel. <ul style="list-style-type: none"> ○ This is likely to do with drivers moving away from the right tunnel wall (i.e. deviating to the left); this is a potentially dangerous behaviour if drivers travel too closely to the other lane.
Themes: driving through tunnels, safer driving behaviour

Title: An In-depth Study of Work related Road Traffic Accidents
Author / organisation: Clarke, D., Ward, P., Bartle, C., Truman, W. (University of Nottingham) Date: 2005 Format: Pdf Link: http://www.dft.gov.uk/pgr/roadsafety/research/rsrr/theme5/anindepthstudyofworkrelated.pdf Free / priced: Free
Objectives: Road traffic RTIs whilst at work are the single largest cause of occupational fatality in the United Kingdom. Work-related road RTIs do not comprise a homogeneous group, but take many forms, encompassing the use of varying types of vehicle used for diverse purposes and including special sub-groups such as those working in, on, or near the highway.
Methodology: A sample of 2111 RTI cases was considered, including 1009 in detail, from Midland police forces, involving drivers/workers of all ages and covering the years 1996–2004 inclusive. Each case was summarised on a database including the main objective features (such as time and place) and a summary narrative, a sketch plan and a list of explanatory factors. The summary narrative, in particular, included judgements by the researchers that emphasised the sequence of events leading up to the RTI.
Key Findings: <ul style="list-style-type: none"> • Large Goods Vehicles (LGVs) were found to be over-represented in RTIs that occur on rural A class roads and motorways. The top three error/violation types for rural A roads were rear-end shunts (including avoidance RTIs) (36 per cent); ROWVs (21 per cent); and loss of control on bends/other (20 per cent). Insecure loads also appeared in 8 per cent of these RTIs. • 'Early hours' RTIs occurred most often on motorways, perhaps because low traffic densities and monotonous driving could be contributing to boredom and associated fatigue at these times.
Themes: Fatigue, RTIs
Comments: Good academic research paper involving quantitative analysis.

Title: Review of the class and quality of street lighting
Author / organisation: Crabb, G., Beaumont, R., Webster, D. (TRL)
Date: 01/2009
Format: Pdf
Link: https://www.theilp.org.uk/documents/css-sl1-class-and-quality-of-street-lighting/css-sl1-class-and-quality-of-street-lighting.pdf
Free / priced: Free
Objectives: The project was intended to provide Local Authorities with current and relevant information on which to base decisions on the lighting levels to specify for the next six road hierarchy categories defined in 'Well Maintained Highways'.
Methodology: Desk study; Consultation exercise with a number of local authorities to assess how the standards are applied in practice and where improvements might be made; A study of the range and cost of currently available lighting equipment, together with estimates of energy and whole-life costs of a range of systems.
Key Findings:
<ul style="list-style-type: none"> • Typical reductions in 'road usage costs' resulting mainly from RTI savings from lighting are given as 20 per cent for Motorways and semi-motorways.
Themes: Lighting
Comments: Relevant information for local authorities.

Title: Driving experience and the functional field of view
Author / organisation: Crundall, D., Underwood, G. and Chapman, P. (University of Nottingham)
Date: 1999
Format: Pdf
Link: http://www.psychology.nottingham.ac.uk/staff/dec/references/Perception1999.pdf
Free / priced: Free
Objectives: To establish whether experienced drivers have wider fields of peripheral vision than less experienced drivers.
Methodology: Participants were made to view video clips taken from a moving drivers' perspective, including hazardous scenarios, whilst responding to peripheral light targets.
Key Findings:
<ul style="list-style-type: none"> • Peripheral vision is important in lane maintenance: the task of keeping a car between two peripheral markers, such as lane markings. • The results demonstrated a strong degradation of the Functional Field of View (FFoV) during hazardous sections of driving video clips. • It was proven that less experienced drivers reaction times to hazardous scenarios were longer than those with more experience of driving. • This suggests that a perceptual measurable skill develops with drivers who have more driving experience.
Themes: Inexperienced drivers
Comments: Not motorway specific but could be applied to motorway driving scenarios including lane changing. Good academic paper.

Title: Behavioural effects of fixed speed cameras on motorways: overall improved speed compliance or kangaroo jumps?
Author / organisation: De Pauw, E., Daniels, S., Brijs, T., Hermans, E., and Wets, G. Date: 2014 Format: Pdf Link: http://europepmc.org/abstract/med/25217731 Free / priced: Priced
Objectives: To evaluate the effects of fixed speed cameras on motorways.
Methodology: The researchers undertook a before and after comparison of travelling speeds in two locations with speed cameras in Belgium. The outcomes analysed included: <ul style="list-style-type: none"> • Average speed • Odds of drivers exceeding the speed limit • Odds of drivers exceeding the speed limit by more than 10%
Key Findings: <ul style="list-style-type: none"> • Speeds were found to decrease where cameras were located. • The presence of speed cameras also decreased drivers' odds of exceeding the speed limit.
Themes: speed cameras, interventions for speeding

Title: Reported Road Casualties Great Britain: 2014
Author / organisation: Department for Transport Date: 2015 Format: Pdf https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463797/rrcgb-2014.pdf Free / priced: Free
Objectives: To present statistics on personal injury RTIs in 2014 on public roads (including footways) in Great Britain, which became known to the police.
Methodology: Full casualty statistics in Great Britain for 2014.
Key Findings: In 2014: <ul style="list-style-type: none"> • Motorways carried around 20 per cent of GB motor traffic, but accounted for just 5% of road deaths (96 deaths) and 3% of serious injuries (718 serious casualties) which means they are the safest road type. • Mile-per-mile, the risk of death on motorways was around 5 times lower than the equivalent figure for rural roads and 3 times lower than for urban roads. • Car occupants comprise by far the biggest casualty group on motorways: in 2013 they accounted for almost 70% of motorway KSIs, with motorcyclists the next largest group (12%) and goods vehicle occupants (vans and HGVs) comprising a further 10%. • In 2014, deaths on motorways fell from 100 in 2013, to 96 in 2014, but seriously injured casualties increased from 660 to 718. • Motorway traffic levels rose by 1.6%.
Themes: RTIs
Comments: Up to date annual statistics – highly relevant material

Title: Strategic Road Network Statistics
Author / organisation: DfT
Date: 2015b
Format: Pdf
Link: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/448276/strategic-road-network-statistics.pdf
Free / priced: Free
Objectives: To summarise up to date statistical results relating to the SRN.
Methodology: Statistical analysis of UK crash and exposure data.
Key Findings: <ul style="list-style-type: none"> • Although the SRN is only 2% of the road network in the UK, it carries 33% of all traffic and 66% of all HGV traffic. • 99% of vehicles were found to use the SRN at least once a year. • The age group using the SRN most frequently is the 25- 44 years group.
Themes: SRN traffic
Comments:

Title: Speed and road accidents: An evaluation of the Power Model
Author / organisation: Elvik, R., Christensen, P. and Amundsen, A.
Date: 2004
Format: Pdf
Link: http://www.trg.dk/elvik/740-2004.pdf
Free / priced: Free
Objectives: The objective of this work was to evaluate the relationship between speed and road safety.
Methodology: The authors undertook a systematic literature search and meta-analysis. In order to be included, research had to fulfil the following criteria: <ul style="list-style-type: none"> • Report the relative change in speed • Report the relative change in the number of accidents or victims A total of 98 studies were included in the analysis.
Key Findings: <ul style="list-style-type: none"> • The results of the analysis indicated that there was a strong statistical association between speed and road safety. • It was estimated that a 10% reduction in the mean speed of traffic would result in a 37.8 reduction in fatalities.
Themes: speed and road safety
Comments: This study employs a robust methodology and as such the work has been cited widely in relation to this topic.

Title: Road Safety in the European Union
Author / organisation: European Commission
Date: 03/2015
Format: Pdf
Link: http://ec.europa.eu/transport/road_safety/pdf/vademecum_2015.pdf
Free / priced: Free
Objectives: To provide key statistics and information about the overall road safety situation in the EU.
Methodology: Review and analysis of EU-based collision statistics.
Key Findings: <ul style="list-style-type: none"> • Generally the EU has seen reductions in the number of road fatalities since 2010, though these are not decreasing at the expected rate to achieve the target set for 2020. • Certain countries, including the UK, Sweden and the Netherlands have the lowest reported road fatality rates; while countries such as Latvia, Romania and Bulgaria have the highest rates. • The EU TEN-T network (which consists mostly of motorways) is believed to be comparatively safe with only around 8% of fatalities occurring on these roads.
Themes: statistics, EU, fatality rates
Comments: This presents relevant and recent fatality data for the EU (including the UK).

Title: Road safety: EU reports lowest ever number of road deaths and takes first step towards an injuries strategy
Author / organisation: European Commission
Date: 03/ 2013
Format: Pdf
Link: http://europa.eu/rapid/press-release_IP-13-236_en.htm
Free / priced: Free
Objectives: EU press release.
Methodology: A press release was developed as a response to findings from EC data analysis. The press release provides figures for EU fatalities per million inhabitants, by country.
Key Findings: <ul style="list-style-type: none"> • The document provides an update on the state of affairs in relation to the EU Road Safety Action Program 2011-2020. The aim of the program is to halve the number of road deaths in Europe by 2020. • Around 250,000 people are seriously injured on European roads. • In 2012, Malta, the UK and Sweden were the countries with the lowest number of fatalities per million inhabitants. • Germany (where many motorways remain without speed limits) came in at number 8 with 44 million fatalities per million inhabitants. This compared to 26-31 fatalities for Malta, the UK and Sweden.
Themes: fatalities, EU member states, EU road safety action programme 2011-2020
Comments: For more detailed information, the interested reader should refer to the EC website.

Title: Driving for Work: Managing Speed
Author / organisation: European Transport Safety Council Date: 2011 Format: Pdf Link: http://etsc.eu/documents/PRAISE%20Thematic%20Report%208%20Driving%20for%20Work%20Managing%20Speed.pdf
Free / priced: Free
Objectives: To mobilise knowledge needed to create work-related road safety leadership.
Methodology: The first part looks at the impact that speeding can have and presents levels of compliance with speed limits for different road user types. The second part focuses on management issues covering topics from journey planning to payment schemes with advice on how such practices can help to manage speeding in the work context. The third part of the Thematic Report looks at what employers can do from risk assessment of potential speeders and identification of training - including also eco driving synergies - to the promotion of safer and more economic driving. It also looks at what can be done to rehabilitate speeding offenders. The final part looks specifically at different speed management technologies which can also be a useful additional tool in managing speed.
Key Findings: <ul style="list-style-type: none"> • In countries where data on speed measurements in free-flowing traffic are available, up to 30 per cent of drivers exceed speed limits on motorways. • The percentage of car drivers that reported violating the speed limit 'often', 'very often' and 'always' in European countries on motorways was 28 per cent. • Drivers are usually aware of the increased risk of being involved in a fatal collision after drinking but largely underestimate the increased risk of being involved in a fatal collision when speeding. Driving with 0.5g/l Blood Alcohol Concentration (BAC) increases the risk of a fatal crash by a factor of 5, the same as driving about 50 per cent faster. The increased risk of driving at 180km/h on a 120km/h motorway is therefore similar to the risk of driving with a 0.5g/l BAC. • Applying the 'Power Model' to current numbers of deaths indicates that if every driver slowed down by only 1 km/h, more than 100 road deaths per year could be prevented on motorways.
Themes: RTIs, Speed
Comments: Report focussed on work-related road safety in Europe, but still relevant to this document.

Title: Reducing deaths on motorways
Author / organisation: European Transport Safety Council Date: 2008a Format: Pdf Link: http://www.etsc.eu/documents/PIN%20Flash%208.pdf Free / priced: Free
Objectives: Introducing the new Road Safety Performance Index.
Methodology: Comparing the Road Safety Performance Index between countries in the European Union.
Key Findings: <ul style="list-style-type: none"> • Motorways are the safest roads by design. Yet in 2006 at least 3270 people were killed on the motorway network in the European Union, representing about 8 per cent of the total number of road deaths. • Although motorways account for only 1 per cent of the length of all paved roads, more than one quarter of all kilometres are driven on this part of the road network. • The proportion of the traffic driven on motorways has been increasing over the past decade. • Since the introduction of the ATM scheme, no one was killed on the M42 and RTI rates decreased by 25 per cent. • 30 rush-hour lanes are also in operation in the Netherlands. Serious RTIs decreased by 40 per cent over the period 2004-2006 compared to 2001-2003, while the overall reduction on the whole motorway network was 30 per cent. • Every day in Europe some motorway sections are blocked for many hours due to RTIs involving HGVs.
Themes: Speed, Hard Shoulder Running
Comments: Interesting comparison of M42 with managed motorways outside of the UK.

Title: German Autobahn: The Speed Limit Debate
Author / organisation: European Transport Safety Council Date: 2008b Format: Pdf http://www.etsc.eu/documents/copy_of_Speed%20Fact%20Sheet%201.pdf Free / priced: Free
Objectives: To examine the debate over the potential introduction of a national speed limit on the German Autobahn.
Methodology: SPEED Fact Sheet.
Key Findings: <ul style="list-style-type: none"> • 52 per cent of the German motorways do not currently have a speed limit. • 15 per cent have a temporary speed limit. • German motorways are amongst the most safely engineered roads in Europe. However, in terms of deaths per billion vehicle-kilometres driven on motorways, Germany ranks eight in 2006 out of the European countries for which there is data (Great Britain were twelfth by comparison). • There is clear evidence from sections on which a limit was introduced that the number of road deaths and injuries decreased.
Themes: Speed
Comments: Good comparison of European countries speed issues but lacking in quantitative analysis.

Title: Understanding and influencing driver compliance: final report
Author / organisation: Fernández-Medina, K.M., Helman, S., Posner, R., Durrell, L. and Rillie, I. Date: <i>in press (not yet published)</i> Format: TBC Link: TBC Free / priced: Free
Objectives: To understand the reasons for non-compliant behaviour among drivers in the UK, and to explore the countermeasures currently used as well as their effectiveness in reducing non-compliant behaviour on the road.
Methodology: Two systematic literature reviews, an online questionnaire with over 2,000 motorists, and two qualitative analyses were undertaken.
Key Findings: <ul style="list-style-type: none"> • Speed is the most frequently studied topic in relation to non-compliance. • The reasons why drivers engage in non-compliant behaviour are varied, and the data analysis showed that demographic variables (such as age and gender) and not always sufficient to predict likelihood to engage in such behaviours. • Messages need to be tailored to individual behaviours and authorities should take caution to ensure existing biases are not reinforced by messaging campaigns.
Themes: non-compliance, speeding behaviour
Comments: This report is currently under review and should be published sometime in 2016 by Highways England and TRL.

Title: Understanding and influencing driver compliance: literature review
Author / organisation: Fernández-Medina, K.M. and Posner, R. Date: <i>in press</i> Format: TBC Link: TBC Free / priced: Free
Objectives: To systematically review available literature on the following topics: <ul style="list-style-type: none"> • The reasons for non-compliance among road users • Current interventions to improve non-compliant behaviour
Methodology: Two systematic literature reviews were undertaken.
Key Findings: <ul style="list-style-type: none"> • The reasons for non-compliance are varied and complex and are not always related to volition. <ul style="list-style-type: none"> ○ The Theory of Planned Behaviour and perceptual biases are discussed within this context. • In terms of interventions, speed cameras were found to be the most effective although engineering measures (relating to road design and layout) have also shown promise.
Themes: non-compliant behaviour, speeding, interventions
Comments: This report is currently under review and should be published sometime in 2016 by Highways England and TRL.

Title: The relationship between road lighting and night-time crashes in areas with speed limits between 80 and 100km/h
Author / organisation: Firth and Jackett Date: 09/ 2015 Format: Pdf Link: https://www.nzta.govt.nz/assets/resources/research/reports/573/573-the-relationship-between-road-lighting-and-night-time-crashes.pdf Free / priced: Free
Objectives: To investigate the effects of road lighting on crash experience.
Methodology: A three-year comparison of crash data was made before and after lighting was installed in a section of road in Auckland, NZ. The impact was assessed using generalised linear modelling.
Key Findings: <ul style="list-style-type: none"> • Motorways crashes reduced by: <ul style="list-style-type: none"> ○ 33% for all crashes ○ 42% for injury crashes ○ 67% for serious and fatal crashes
Themes: Motorways crashes, lit versus unlit conditions
Comments:

Title: Sleep-related crashes on sections of different road types in the UK (1995-2001)

Author / organisation: Flatley, D., Reyner, L.A. & Horne, J.A.

Date: 10/2004

Format: Pdf

Link: [http://dclg.ptfs-europe.com/AWData/Library1/Departmental%20Publications/Department%20for%20Transport/2004/Sleep%20related%20crashes%20on%20sections%20of%20different%20road%20types%20in%20the%20UK%20\(1995-2001\).pdf](http://dclg.ptfs-europe.com/AWData/Library1/Departmental%20Publications/Department%20for%20Transport/2004/Sleep%20related%20crashes%20on%20sections%20of%20different%20road%20types%20in%20the%20UK%20(1995-2001).pdf)

Free / priced: Free

Objectives: Review of audits in order to establish the number of crashes resulting in injury and death that are sleep related.

Methodology: Review of audits that include detailed analyses of all crashes occurring on sections of roads of differing types in order to establish the number of crashes resulting in injury and death that are sleep related. Audits were focused on lit and unlit motorways (as sleep related crashes tend to occur under monotonous driving conditions) that differed in density and number of lanes, and included urban and rural motorways. Audits were also carried out on monotonous A trunk and non-trunk roads with dual and single carriageways, lit and unlit and 'B' single carriageway.

Key Findings:

- 17% of road traffic crashes resulting in injury or death were sleep related
- Proportions varied between 3% and 30% depending on road type
- Sleep related crashes are more evident during the early hours of the morning
- While increasing traffic density leads to increasing road traffic crashes and sleep related crashes per mile per year, both for 24 hours and during the early hours of the morning, the proportion of crashes that are sleep related increases as traffic volume increases on non-motorways, but with increasing traffic volume the proportion of crashes occurring on motorways that are sleep related decreases
- Artificial lighting during hours of darkness reduces road traffic crashes on motorways with high traffic density
- 85% of drivers causing sleep related crashes were men
- 38% of drivers causing sleep related crashes were 30 or under

Themes: Motorways crashes, sleep related crashes, driver fatigue

Comments:

Title: Managed Motorways – All Lanes Running All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment
Author / organisation: Gorell, R. (Highways Agency) Date: 05/2012 Format: Pdf Link: http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/MMFD-ATA-035_-_Issue_1_0_08-05-12.pdf Free / priced: Free
Objectives: This study focussed on the safety implications of Managed Motorways.
Methodology: <ul style="list-style-type: none"> • Analysis of RTI and casualty data on both dual 3-lane motorways and multi-lane all-purpose trunk roads. • Detailed analysis of more significant safety hazards. • Hazard assessment undertaken with respect to the Managed Motorway – All Lanes Running concept.
Key Findings: <ul style="list-style-type: none"> • Analysis of RTI and casualty data collected from all the Dual 3-lane Motorways and multi-lane All-Purpose Trunk Roads (APTR) in England indicates that 3-lane APTRs have a rate of Killed and Seriously Injured (KSI) RTIs that is approximately 9 per cent higher than that encountered on the Dual 3-lane motorway network. • If all Dual 3-lane motorways in England were converted to Dual 4-lane motorways without a hard shoulder, and without further mitigation, cost of KSI would rise by between an estimated £24m and £54m per year. • Over the typical design life of 30 years this would accumulate to a cost of £720m to £1,620m (without discounting). • If the design life is 60 years this would accumulate to a cost of £1,440m to £3,240m (without discounting).
Themes: Managed Motorways, Hard Shoulder
Comments: Covers ALR for both APTR and motorways.

Title: Speed choice in relation to speed limit and influences from other drivers
Author / organisation: Haglund, M. and Aberg, L. Date: 2000 Format: Pdf Link: http://www.sciencedirect.com/science/article/pii/S1369847800000140 Free / priced: Priced
Objectives: To gain a better understanding of drivers' attitudes toward speeding and the influences from other road users on speed choice.
Methodology: The researchers collected vehicle speeds and questionnaire data from a sample of 533 Swedish drivers.
Key Findings: <ul style="list-style-type: none"> • A good relationship was found between self-reported speeds and recorded travelling speeds. • Most of the drivers in the study exceeded the 90km/h speed limit. • Attitudes were found to be important in relation to speed choices. • Other road users, as opposed to friends and family, were found to have an impact on drivers' speed choices. • Three variables relating to a) percentage of drivers speeding (i.e. "What is the proportion of drivers exceeding the speed limit by more than 10 km/h?"), b) attitudes toward speeding, and c) comparisons with other drivers, accounted for 44% of the variance in intention to speed.
Themes: Social influences on speeding behaviour
Comments:

Title: SM-ALR monitoring: M25 Twelve month evaluation reports
Author / organisation: Highways England Date: 2016 Format: Pdf Link: http://www.roadsafetyknowledgecentre.org.uk/knowledge/1524.html Free / priced: Free
Objectives: Evaluate the effectiveness of smart motorways
Methodology: Evaluation of the effect of smart motorways on journey time, flows, safety and hazards on two all lane running sections of the M25. Data was compared using a before and after analysis..
Key Findings: <ul style="list-style-type: none"> • For the J23 to J27 section of the motorway journey time was reduced by 5% in the clockwise and 9% anticlockwise • For the J5 to J6 average journey times were reduced by 3% in the clockwise direction and 2% anti-clockwise. • Backdrop of increased traffic flow between before and after period: 10% between J23 and J27 and 13% (clockwise) and 3% (anticlockwise) between J6 and J7 • Small but not statistically significant reduction in collision rate • An average of 7% of vehicles were non-compliant with the 'Red X' signs • Only 42% of all users are aware of the Smart motorways scheme.
Themes: Smart motorways, journey time, safety, hazards, flow

Title: Smart Motorways fact sheet 01
Author / organisation: Highways Agency (now Highways England)
Date: 2014
Format: Pdf
Link: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/363993/Smart_motorways - Fact Sheets.pdf
Free / priced: Free
Objectives: To provide customers with information about Smart Motorways.
Methodology: Information only
Key Findings: The document describes the purpose and elements relating to Smart Motorways, including hazards, changes from DHS, and 'what to do' sections.
Themes: Smart Motorways
Comments: This is an information only publication.

Title: Sleep related vehicle accidents
Author / organisation: Horne, J. and Reyner, L. (British Medical Journal)
Date: 1995
Format: Pdf
Link: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2548939/pdf/bmj00582-0029.pdf
Free / priced: Free
Objectives: To assess the incidence, time of day, and driver morbidity associated with vehicle RTIs where the most likely cause was the driver falling asleep at the wheel.
Methodology: Two surveys were undertaken, in southwest England and the midlands, by using police databases or on the spot interviews.
Key Findings: <ul style="list-style-type: none"> • Sleep related vehicle RTIs are largely dependent on the time of day and account for a considerable proportion of vehicle RTIs, especially those on motorways and other monotonous roads. • Sleep related vehicle RTIs comprise about 16-23 per cent of RTIs, the higher proportion being relevant for motorways.
Themes: Fatigue
Comments: Older research material but still relevant to the synthesis.

Title: The switch off debate
Author / organisation: Howard, A. (Institution of Lighting Professionals) Date: 2012 Format: Pdf Link: https://www.theilp.org.uk/documents/lightscene-switch-off/lightscene-2012-professional-lighting-seminar-allan-howard.pdf Free / priced: Free
Objectives: To determine whether road lights should be switched off for all/part of the night.
Methodology: N/A – PowerPoint presentation.
Key Findings: <ul style="list-style-type: none"> • Cost of UK road traffic RTIs on Motorways equates to £1,789,030 for each fatality, £219,460 for each serious injury and £25,680 for each slight injury category. • It is the view of the Institution of Lighting Professionals (ILP) that road lighting: <ul style="list-style-type: none"> ○ Reduces night time collisions; ○ Reduces night time crime and the perception of crime; and, ○ Helps emergency services;
Themes: Lighting
Comments: Conference PowerPoint presentation – difficult to determine significance of figures.

Title: Fatigue and road safety: a critical analysis of recent evidence
Author / organisation: Jackson, P., Hilditch, C., Holmes, A., Reed, N., Merat, N., & Smith, L. Date: 02/ 2011 Format: Pdf Link: https://www.researchgate.net/profile/Alison_Holmes/publication/242153402_Fatigue_and_road_safety_a_critical_analysis_of_recent_evidence/links/0046352e653163a8b3000000.pdf Free / priced: Free
Objectives: To evaluate the scale of the driver fatigue problem in the United Kingdom.
Methodology: A systematic review of literature was undertaken and reported.
Key Findings: <ul style="list-style-type: none"> • Fatigue affects neurocognitive performance; these effects are exacerbated by the circadian rhythm and task duration. • Driver fatigue is estimated to contribute to 4-20% of all collisions. • Young, male drivers are most commonly involved in fatigue-related collisions • Drivers may continue to drive even when they are aware of their tiredness; this is likely to be due to a combination of past experiences, social norms and journey goals.
Themes: fatigued driving, crash risk

Title: Driver sleepiness as a factor in car and HGV accidents
Author / organisation: Maycock, G. (TRL) Date: 1995 Format: Pdf Link: https://trl.co.uk/reports/TRL169 Free / priced: Free
Objectives: To explore the relationship between RTIs and daytime sleepiness.
Methodology: Driver survey.
Key findings: <ul style="list-style-type: none"> • In one survey, car drivers suggest that, tiredness is a contributory factor in 7 per cent of all RTIs. On motorways, this proportion rises to 15 per cent and in the early hours of the morning the proportion is even higher.
Themes: Fatigue
Comments: Good UK-based research confirming findings of other papers in the field of driving fatigue.

Title: Exploring the factors affecting motorway accident severity in England using the generalised ordered logistic regression model
Author / organisation: Michalaki, P., Quddus, M.A., Pifield, D. and Huetsen, A. Date: 2015 Format: Pdf Link: http://www.sciencedirect.com/science/article/pii/S0022437515000833 Free / priced: Priced
Objectives: The objective of the work was to analyse and compare the factors affecting the severity of hard shoulder (HS) and main carriageway (MC) collisions on the motorway.
Methodology: STATS19 data is evaluated and analysed using a regression model. The analysis is used to identify those factors affecting the severity of collisions occurring on either the HS or MC on motorways in the UK.
Key Findings: <ul style="list-style-type: none"> • Factors such as peak-hour traffic, visibility and number of vehicles were found to affect accident severity regardless of location. • The most important variable in the MC model was speed limit, which tended to increase the severity of the collision. • Driver fatigue was an important factor for both types of collisions. Though it was the second most important factor in HS collisions.
Themes: motorway collisions, driver fatigue
Comments:

Title: Recommendations/Conclusions on Speed Moderation
Author / organisation: Organisation for Economic Co-operation and Development /International Transport Forum Date: 2009 Format: Pdf Link: http://www.internationaltransportforum.org/Pub/pdf/09CDsr/PDF_EN/16_RecommSpeed_EN.pdf
Free / priced: Free
Objectives: Minutes of the Council of Ministers meeting in Budapest on 29 – 30 th May 1996 (published 2009).
Methodology: N/A.
Key Findings: <ul style="list-style-type: none"> • Since motorways are particularly intended for transit traffic and avoid built-up areas, exclude local services and slow traffic, they are by and large safer than other roads. • Although RTIs are fewer, they are more severe, clearly owing to the higher speeds on motorways. • Because users perceive motorways as ‘safe’, they tend to drop their guard or drive too fast with the result that a ‘minor’ RTI (puncture, traffic jam, fog) often has serious consequences. In addition, the comfort of modern vehicles, the carriageways and roads in general diminish the driver’s perception of the actual speed at which he is travelling. • All European countries except for Germany have adopted a national speed limit on motorways: Policing and the use of speed checks are needed to ensure compliance with speed limits. • Infrastructure design, together with proactive traffic flow management, must, and will have, a greater role to play in motorway safety.
Themes: Speed
Comments: Minutes of a meeting – therefore may contain bias.

Title: TOWARDS ZERO Ambitious Road Safety Targets and the Safe System Approach
Author / organisation: Organisation for Economic Co-operation and Development /International Transport Forum Date: 2008 Format: Pdf Link: http://www.internationaltransportforum.org/Pub/pdf/08TowardsZeroE.pdf Free / priced: Free
Objectives: To highlight the institutional management changes required in many countries to implement effective interventions through a strong focus on results, and builds the economic case for road safety investment.
Methodology: The working group carried out a survey to collect information and data on road safety performance, recent road safety strategies, the costs of road crashes and expenditures on road safety.
Key Findings: <ul style="list-style-type: none"> • New technologies such as section control or average speed cameras are being implemented in a number of countries, with early evaluations showing positive impacts on speed and crashes. In Austria, cameras used over a section of motorway with a tunnel were associated with injury crash reductions of 33 per cent over two years, with a cost-benefit of 1:5.3. • Average fatal crash rates per vehicle kilometre can be up to 6 times higher on 2-lane rural roads than on motorways.
Themes: Tunnels, RTIs
Comments: Research conducted mostly outside of UK, therefore may be of limited use.

Title: RAC Report on Motoring 2015, The speed of change
Author / organisation: RAC Date: 09/ 2015 Format: Pdf Link: http://www.rac.co.uk/pdfs/report-on-motoring/rac-rom-2015 Free / priced: Free
Objectives: The purpose of this yearly report is to gain a better understanding of British motorists' on-road behaviours, travel patterns, and perceptions about the road network and other road-related issues.
Methodology: Survey data was collected online from 1,555 British drivers who held a current driving licence and drove at least once a month.
Key Findings: <ul style="list-style-type: none"> • Drivers reported a number of key concerns, including: <ul style="list-style-type: none"> ○ The poor condition of local roads ○ Driver distraction ○ The cost and convenience of parking • More people admitted to breaking the speed limit in 2015 than 2014, with 7 in 10 drivers reported they “regularly” or “occasionally” break the speed limit.
Themes: British motorists, speeding behaviour

Title: An evaluation of options for road safety beyond 2010
Author / organisation: Sexton, B. and Johnson, B. (TRL)
Date: 2010
Format: Pdf
Link: https://trl.co.uk/reports/PPR397
Free / priced: Free
Objectives: To describe the methods that have been used to estimate the casualty reductions that might be expected to arise from a number of potential road safety intervention options raised for consideration as part of the work by the Department for Transport in preparation of a road safety strategy post 2010.
Methodology: The options are presented in four groups defined by the level of detail of the estimation: options taken to full cost benefit analysis; options taken to partial cost benefit analysis; options with quantitative casualty benefit estimates and options with qualitative casualty benefit estimates. The report describes in detail the analytical methods used to estimate the costs and benefits associated with the list of potential options.
Key Findings: <ul style="list-style-type: none"> • The positive net present value effect of increasing the motorway speed limit to 80mph, due to a reduction in journey times, is off-set by an increase in casualties.
Themes: Speed
Comments: UK-based research, therefore of high significance.

Title: The effectiveness of roads policing strategies
Author / organisation: Smith, L., Lawton, B., Beard, G., Durrell, L., Scoons, J., and Lloyd, L.
Date: 2015 Format: Pdf
Link: http://trid.trb.org/view.aspx?id=1342534
Free / priced: Priced
Objectives: To evaluate the effectiveness of enforcement in Hampshire and the Thames Valley.
Methodology: The project team undertook four distinct tasks: <ul style="list-style-type: none"> • A literature review • An analysis of driver offence data • An analysis of collision data • A series of compliance surveys
Key Findings: <ul style="list-style-type: none"> • Data suggested that special focus should be given to offenders who are male and under the age of 30. • Speed was found to be a particular problem during evenings and weekend; the combination of engineering solutions and fixed speed cameras could help alleviate the issue. • Seat belt wearing rates are generally high. • Mobile phone use has increased in recent years with males being more likely to use a mobile phone while driving.
Themes: speeding; drink-driving; mobile phone use; age and gender comparisons

Title: Driving on the Motorway: The Effect of Alternating Speed on Driver's activation level and mental effort
Author / organisation: Tejero, P. and Chóliz, M. (Universidad de Valencia) Date: 2002 Format: Pdf Link: http://www.ingentaconnect.com/search/article?option1=ka&value1=motorway+speed&sortDescending=true&sortField=default&pageSize=10&index=5
Free / priced: Priced
Objectives: To provide empirical evidence regarding the effects of alternating speed on the level of driver activation on a motorway route in real traffic.
Methodology: Monitoring drivers of various ages travelling at constant and varying speeds via an Electroencephalogram (EEG) and heart rate monitor.
Key Findings: <ul style="list-style-type: none"> • Driver Electroencephalography (EEG) – electrical activity in the brain – tended to be significantly higher when speed was modified periodically than when it remained constant. • No significant difference was found relating to cardiovascular measurements during the same experiment.
Themes: Tiredness/Fatigue
Comments: Non-UK research (Spain), but applicable to drivers worldwide.

Title: Driver fatigue and road accidents
Author / organisation: The Royal Society for the Prevention of Accidents (RoSPA) Date: 2011 Format: Pdf Link: http://www.rosipa.com/rospaweb/docs/advice-services/road-safety/drivers/driver-fatigue-2011.pdf Free / priced: Free
Objectives: To review published research and data concerning: a) the scale of the sleep related RTI problem; b) the causes of driver fatigue; and, c) potential measures to reduce RTIs caused by sleepy drivers.
Methodology: The literature research was conducted through RoSPA's Information Centre, a Transport 2000 CD-ROM and the internet. The main UK research considered in this report is the various studies into sleep related road RTIs by Professor Horne at the Sleep Research Centre at Loughborough University, and TRL research. International studies, particularly from the USA, Australia, New Zealand and Canada, have also been considered.
Key Findings: <ul style="list-style-type: none"> • Driver fatigue is a major cause of RTIs, accounting for up to 20 per cent of serious RTIs on motorways and monotonous roads in Great Britain. • Journeys involving long periods of driving on monotonous roads, such as motorways, are more likely to result in a driver falling asleep at the wheel. • The early hours of the morning and the middle of the afternoon are the peak times for fatigue RTIs, and long journeys on monotonous roads, particularly motorways, are the most likely to result in a driver falling asleep.
Themes: Fatigue
Comments: Good review document with quantifiable findings.

Title: Effect of Driving Speed on Reaction Time During Motorway Driving
Author / organisation: Törnros, J. (Swedish Road and Transport Institute)
Date: 1994
Format: Pdf
Link: http://dx.doi.org/10.1016/0001-4575(94)00084-Y
Free / priced: Priced
Objectives: To establish if there is a change in reaction time when travelling a long distance at a fixed speed on a motorway.
Methodology: Measurement of reaction time in 24 subjects travelling at various speeds on a Swedish motorway for 200km.
Key Findings: <ul style="list-style-type: none"> • Reaction time appeared slower for subjects travelling at slower fixed speeds, than for those travelling faster.
Themes: Tiredness/Fatigue
Comments: Non-UK research (Sweden), but still applicable to UK-based motorway driving.

Title: Drivers' tendency to commit different aberrant driving behaviours in comparison with their perception of how often other drivers commit the same behaviours
Author / organisation: Wallén Warner, H. and Aberg, L.
Date: 2014
Format: Pdf
Link: http://www.sciencedirect.com/science/article/pii/S1369847814001156
Free / priced: Priced
Objectives: To examine the relationship between drivers self-reported on-road behaviours and the perception of other drivers' behaviours.
Methodology: Over 500 participants from Turkey and Sweden completed a questionnaire, including the Driving Behaviour Questionnaire (DBQ).
Key Findings: <ul style="list-style-type: none"> • Most participants reported engaging in the 28 driving behaviours (as measured by the DBQ) less often than other drivers. • The differences between perceptions of own versus other drivers' likelihood of engaging in the behaviours was smaller for errors/ lapses than for aggressive and ordinary violations. <ul style="list-style-type: none"> ○ That is, drivers were more likely to think other drivers' commit violations more frequently than them.
Themes: optimism bias
Comments: The study provides data for a commonly known road safety principle in a sample of Turkish and Swedish drivers.

Title: Effects of Road Lighting on Motorways
Author / organisation: Wanvik, P. (Norwegian Public Roads Administration) Date: 2008 Format: Pdf Link: http://dx.doi.org/10.1080/15389580902826866 Free / priced: Priced
Objectives: The study has three objectives. To investigate how the effect of road lighting on motorway RTIs varies with different weather and road surface conditions. The second is to evaluate the future benefit of road lighting as a safety measure on motorways. The third is to evaluate the need for further research in the field of motorway lighting.
Methodology: This article presents a cross-sectional study of the effects of road lighting on motorways mainly in the Netherlands. The main source of data is a Dutch database of RTIs covering the period 1987 – 2006, but British and Swedish data are also used.
Key Findings: <ul style="list-style-type: none"> • The estimated effect of motorway lighting in preventing darkness RTIs in the Netherlands during dry conditions is 49 per cent. This effect was much lower in British and Swedish data and also during wet or snowy conditions. • Collisions with lighting poles constitute a large number of RTIs on lit motorways and reduces the safety effect of road lighting. • Road lighting seems to be ineffective during fog. • It is essential that vehicles running off the road are taken care of in a safe way before they hit a light pole or other vehicle or object. • In the long term, the benefit of road lighting will probably be reduced along with the implementation of new vehicle and road technology. • Future motorway lighting will be of the adaptive type for the purpose of energy savings. • LED guide lights may be an alternative to road lighting on low traffic motorways in order to reduce energy consumption. However, the effect on RTIs needs to be evaluated.
Themes: Lighting
Comments: Partial-UK research (Netherlands and Sweden data also used). Report produced in Norway.

Title: A qualitative study of college students' perceptions of risky driving and social influences

Author / organisation: Watters, S.E. and Beck, K.H.

Date: 2015

Format: Pdf

Link: <http://www.tandfonline.com/doi/pdf/10.1080/15389588.2015.1045063>

Free / priced: Priced

Objectives: The purpose of the study was to assess the risk perceptions of young drivers regarding dangerous driving behaviours.

Methodology: Qualitative research was undertaken; the sample included:

- n = 25 undergraduate students between the ages of 18 and 22 years
- 4 focus groups (5-8 students per group)

Key themes and topics of discussion were identified through a detailed coding procedure.

Key Findings:

- The key topics identified related to driving behaviours, rationalisations, influence attempts, passengers and the law.
- Distracted driving and drink driving were the most discussed behaviours in focus groups. Some findings showed that participants felt that certain behaviours, such as texting at red lights or when stopped, were acceptable.
- Speeding was also discussed, but participants felt that speeding may not be equally as dangerous on different types of roads or in different situations. Driving slowly was believed to be more dangerous than speeding.
- Although for many behaviours there was a belief that in some cases, it may be acceptable to undertake risky behaviours, speeding in particular was viewed as being justifiable.
- Not all respondents believed that it would be right to intervene if a friend/ family member was undertaking unsafe behaviours while driving.

Themes: qualitative research, speed as justifiable behaviour, common behaviours

Comments: Qualitative work with a small sample, however, the themes identified are in line with findings from previous research.

Title: Cohort II: A Study of Learner and New Drivers: Main Report
Author / organisation: Wells, P., Tong, S., Sexton, B., Grayson, G., and Jones, E. (TRL)
Date: 2008
Format: Pdf
Link: http://www.strictly-driving.co.uk/cohort2.pdf
Free / priced: Free
Objectives: 'Cohort II' was a major six-year study, funded by the Department for Transport, providing an up-to-date picture of how 'cohorts' of learner drivers in Great Britain undertake driver training and testing, and of their subsequent experiences as new drivers.
Methodology: Questionnaire results from a random sample of 8000 practical test candidates on learning to drive and experiences of newly qualified drivers.
Key Findings: <ul style="list-style-type: none"> As drivers become more experienced, the proportion of RTIs in towns or on city roads decreases, and the proportion of RTIs on fast dual-carriageways and on motorways increases correspondingly.
Themes: New Drivers
Comments: Minimal content on motorways for new drivers.

Title: Effects of different factors on drivers' guidance compliance behaviors under road condition information shown on VMS
Author / organisation: Zhong, S., Zhou, L., Ma, S. and Jia, N.
Date: 2012
Format: Pdf
Link: http://www.sciencedirect.com/science/article/pii/S0965856412001115
Free / priced: Priced
Objectives: To explore the factors which relate to driver compliance with Variable Message Signs (VMS).
Methodology: Route choice behaviour (i.e. compliance with VMS) was assessed using a questionnaire with a sample of 328 participants.
Key Findings: <ul style="list-style-type: none"> A number of demographic and exposure variables were important determinants of route choice, mainly age, driving experience and annual mileage. The degree of trust in VMS (defined as low, medium and high) was also an important determinant of guidance compliance with VMS.
Themes: VMS trust; driver route choice
Comments: Note that the compliance variable in this study related to route choice, therefore, the relationship to compliance in other domains (such as speeding) are not assessed.