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1 Executive Summary

- My analysis showed, using a before and after comparison, that there was a statistically significant reduction in both the casualty rate and average number of casualties per year for All Lane Running (ALR) motorways compared to traditional motorways.

- For both Controlled Motorway (CM) and Dynamic Hard Shoulder (DHS) there was a slight reduction in the casualty rate and the average number of casualties, however these did not pass the significance threshold.

- A counterfactual scenario looks at what could have happened to the number of casualties on the motorway were the smart motorway not implemented. Counterfactual analysis showed that in half the schemes appraised the counterfactual predicted a higher number of casualties than what was observed, suggesting smart motorways improved the safety on those sections of roads. However, further analysis is needed to determine whether these changes are statistically significant and can be attributed to the implementation of the smart motorway.

2 Introduction

2.1 My name is Claire Murray, I am a Transport Planning consultant with 6 years of highway appraisal experience and I am employed by a global consulting company. Between 2018 and 2020 I undertook a part-time Masters in Transport Planning at the University of Leeds. My dissertation was entitled 'Smart Motorways: Disentangling Fact from Fiction' and aimed to determine whether the public are right to perceive smart motorways as more dangerous than their traditional counterparts.

2.2 Of the five views the parliamentary inquiry is most interested in, I am going to focus on the safety of smart motorways and the adequacy of the safety measures in place.

3 Safety of Smart Motorways

3.1 There are three types of smart motorway's currently in use in the United Kingdom. These are CM, DHS and ALR. The characteristics of these are shown in Table 3-1 below.

Table 3-1 Smart Motorway Summary Table, Source Adapted from Department for Transport & Highways England, 2020

Smart Motorway Type	First Opened	Overhead Gantries?	Variable Speed Limits?	Hard Shoulder?
Controlled Motorway	M25 J10-15 1995	Yes	Yes	Yes – Full Time
Dynamic Hard Shoulder	M42 J3a-7 2006	Yes	Yes	Yes – Part-Time with ERA's 500-800m apart
All Lane Running	M25 J23-27 2014	Yes	Yes	No – ERA's spaced max 2.5km apart

Note: ERA stands for Emergency Refuge Area

3.2 The analysis undertaken during the dissertation used smart motorway locations which had sufficient data on both the Highways England WebTRIS database of traffic flows and the STATS19 personal injury road accident reporting form.

3.3 Three types of statistical analyses were undertaken to understand the safety of smart motorway types compared to their traditional counterparts: the average number of casualties per year, casualty rates and the counterfactual scenario.

Average Number of Casualties per Year

3.4 The average number of casualties per year used the casualty data from STATS19. This meant that the results were not weighted by the amount of traffic that travels along each carriageway but this is useful for gauging the general context. Only schemes which had both before and after casualties were included in this analysis.

3.5 Below in Figure 3-1 is a graph detailing the average number of fatal and serious casualties before and after opening the smart motorway by motorway type. It shows that across all the smart motorway types the average number of fatal casualties reduces after implementation compared to before. The same pattern is seen with ALR and DHS with the number of serious casualties reducing, however after implementation of a CM the number of serious casualties increases.

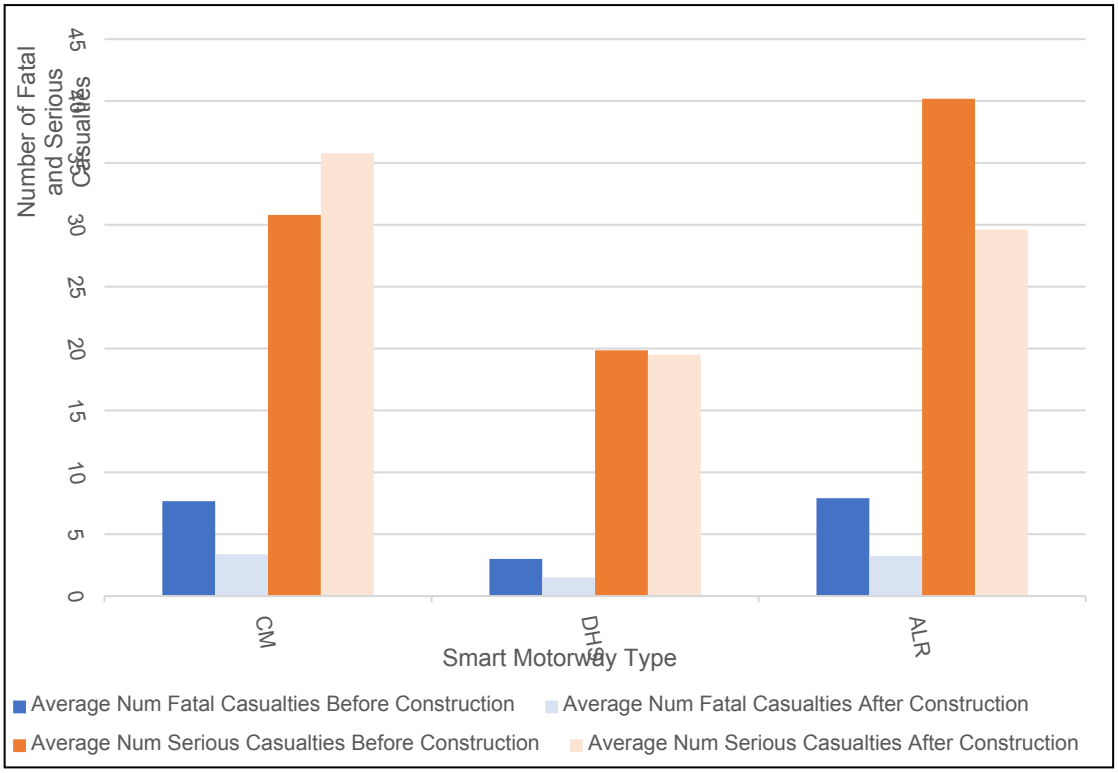

Figure 3-1 Comparison by Motorway Type of the Average Number of Fatal and Serious Casualties per Year Before and After Implementation of a Smart Motorway, Source Own Work

3.6 Figure 3-1 shows the fatal and serious casualties for each smart motorway type. All motorway types have seen a reduction in the number of fatal collisions post implementation of the smart motorway of between 59% for ALR and 50% for DHS with CM in the middle at 56%. With regards to the serious casualties in the same figure, CM has increased casualties by 16% whereas ALR and DHS reduced casualties by 26% and 2% respectively.

3.7 Results of a Wilcoxon Signed Rank Test showed that for both of these severities of casualties only the ALR had a difference that could be classed as significant at the 95% confidence level for both fatal and serious casualties. This means that in this case there is evidence to suggest the reduction in fatal and serious casualties on ALR schemes could be as a result of the implementation of the smart motorway.

3.8 Using the same method used to calculate the fatal and serious casualties above, Figure 3-2 was created to show the number of slight casualties and all casualties regardless of severity before and after implementation of a smart motorway by type. It shows that the number of slight casualties and in turn the number of all types of casualties reduced after implementation of the smart motorway for all types.

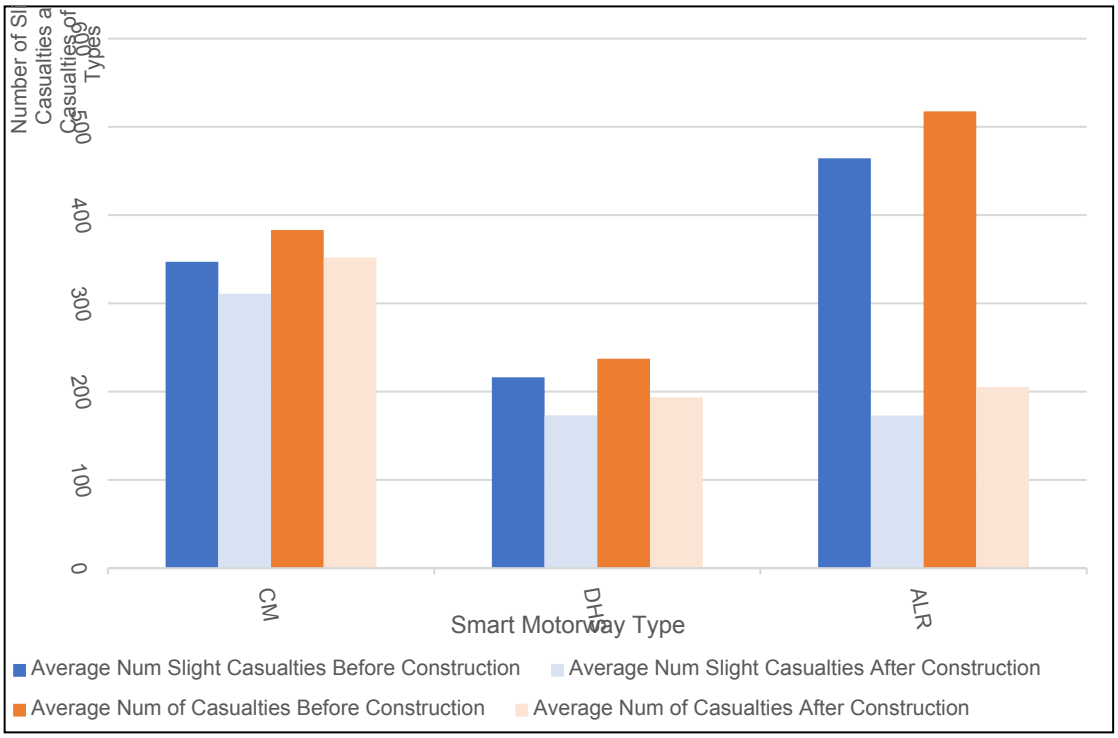

Figure 3-2 Comparison by Motorway Type of the Average Number of Slight Casualties and Casualties of All Severities per Year Before and After Implementation of a Smart Motorway, Source Own Work

3.9 The number of slight casualties and then all casualties before and after the implementation of the smart motorway is shown in Figure 3-2. Once again, the biggest reduction was seen in ALR with 63% less slight casualties compared to before opening of the smart motorway. DHS and CM resulted in a reduction of 20% and 10% respectively.

3.10 When this is aggregated to include all types of casualties the smallest reduction is CM motorways with 8%, although this is not surprising as a CM is most similar to a conventional motorway. DHS is second with an overall reduction of 18%, followed by ALR with 60%. The reduction seen on ALR despite an increase in the volume of traffic hints that the addition of technology has made these links safer, despite the increased risk of stopping in a live lane.

3.11 Statistical analysis on the results shown in Figure 3-2 was undertaken and it was found that for the slight casualties only DHS and ALR motorways had results which suggest a statistically significant reduction in casualties of this type.

3.12 When all the casualty types are aggregated together the results of the Wilcoxon Signed Ranks test indicated that there is no evidence to suggest that there is a difference between the number of casualties pre and post implementation of a CM. For the DHS and ALR there is evidence to suggest that there is a difference in the number of casualties of all types before and after implementation of their respective smart motorways.

Casualty Rates

3.13 The advantage of casualty rates over purely using casualty data is that casualty rates consider the level of flow on a link. This means that the casualty data will be weighted by the level of flow on each link.

3.14 Figure 3-3 below shows the casualty rate per hundred million vehicle kilometres (hmvkm) for all observed casualties before and after implementation of each smart motorway type. It shows that for all types of motorways there is a reduction in the rate after implementation compared to before.

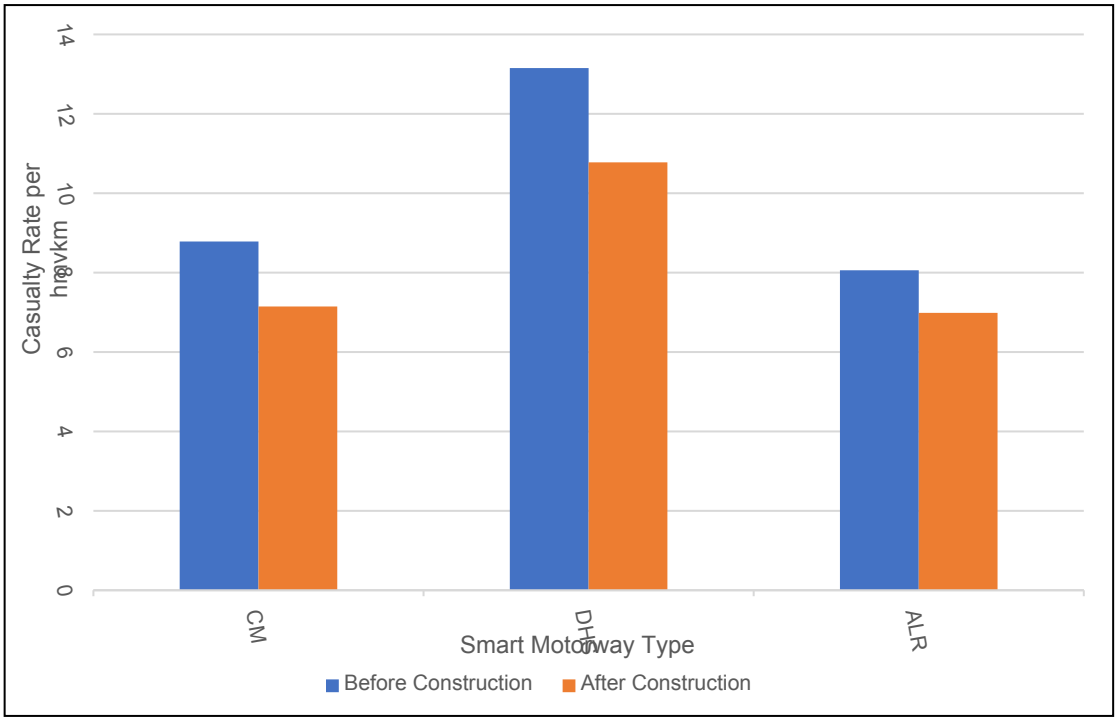

Figure 3-3 Casualty Rate per hmvkm for all observed casualties by Smart Motorway Type Pre and Post Implementation, Source Own Work

3.15 It can be seen that after the implementation of the smart motorway the casualty rate for all the motorway types decreases. Both CM and ALR have a similar pre-implementation casualty rate with a rate of 8.8 and 8.1 per hmvkm respectively. The rate for DHS is 33% bigger than CM, with a casualty rate of 13.2 per hmvkm. Post-implementation for DHS this changes to 10.8 per hmvkm (-22%), with the ALR and CM casualty rate reducing to 7.0 (-15%) and 7.1 (-23%) respectively per hmvkm.

3.16 The statistical analysis undertaken for the DHS and ALR casualty rate showed that out of the two types of motorway only ALR had a statistically significant reduction in the casualty rate after the implementation of the smart motorway compared to before. A test for the CM was not conducted due to the number of schemes contributing to the casualty rate only equalling two.

The Counterfactual Scenario

3.17 A counterfactual scenario looks at what could have happened to the number of casualties on the motorway were the smart motorway not implemented. In the *Smart Motorway Safety Evidence Stocktake and Action Plan* (henceforth known as the *Evidence Stocktake*) released by the DfT in 2020, the counterfactual scenario was defined as the effect on casualties which occurred on the rest of the motorway network (Department for Transport & Highways England, 2020).

3.18 In my dissertation, an alternate method was undertaken. Instead of using the rest of the motorway network as the comparator group the analysis in my dissertation used COBA[1] to predict a new accident rate which was then applied to flows which were factored from the Trip End Model Presentation Program (TEMPRO). This methodology better allows for the fact that smart motorway sections tend to be high-flow with consequent crash patterns.

3.19 Combining the COBA accident rate with the factored 2018 flows enabled a predicted number of casualties to be calculated. This is shown in Figure 3-4 alongside the 2010 and 2018 observed casualties. It can be seen that on certain schemes the counterfactual and the actual number of casualties are vastly different whereas on others they are much similar.

3.20 Figure 3-4 shows that on the M1 J28-31, M5 J4a-6 and the M6 J10a-11a the observed number of casualties in 2018 was lower than the predicted counterfactual. Whereas for some schemes, such as the M6 J5-8, the counterfactual predicts a much lower level of casualties compared to the 2018 observed however, the 2010 and 2018 observed casualties are very similar in magnitude. This suggests that the COBA default accident rate used to calculate the counterfactual is not a good level of fit for those schemes which have a high number of casualties but a low level of vehicle kilometres. The other schemes which fall into this category are the M25 J16-23 and M25 J23-27.

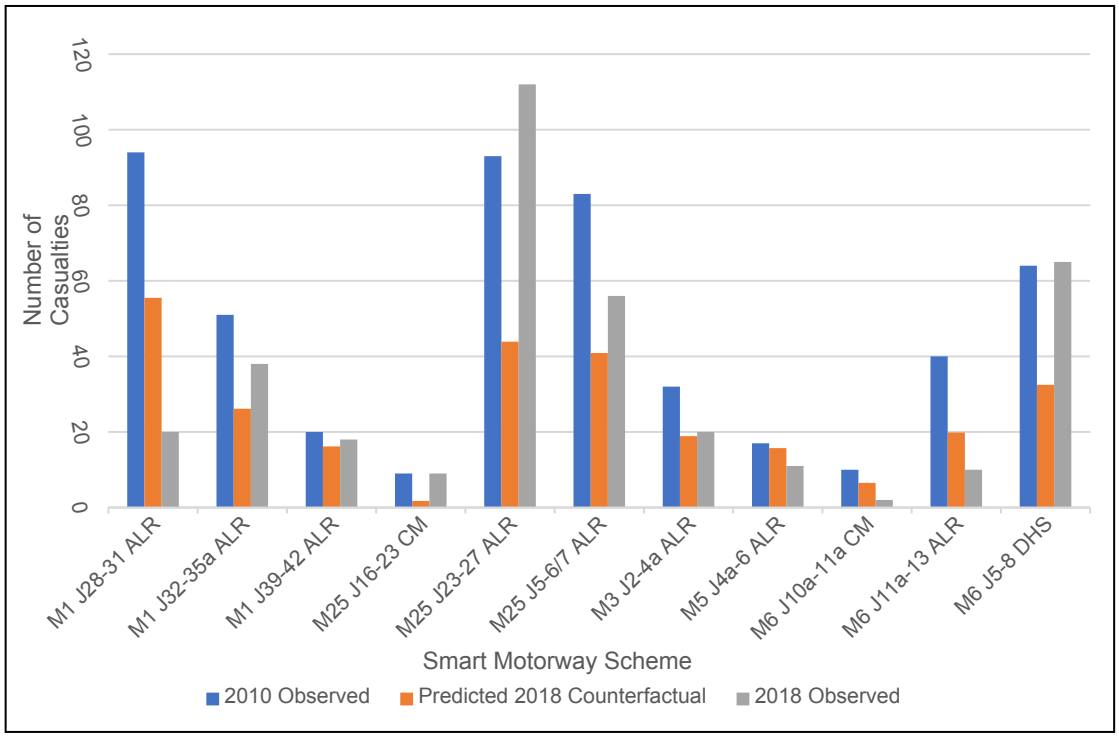

Figure 3-4 Counterfactual Predicted Number of Casualties in 2018 vs Observed Number of Casualties Pre-Implementation in 2010 and Post-Implementation in 2018, Source Own Work

3.21 Although there is no mention of the method used in the *Evidence Stocktake*, applying an estimation method to the ALR schemes and plotting alongside the data for the ALR schemes shown in Figure 3-4 produces Figure 3-5 below. Generally, it can be seen that for half the schemes both the counterfactual methods result in similar values.

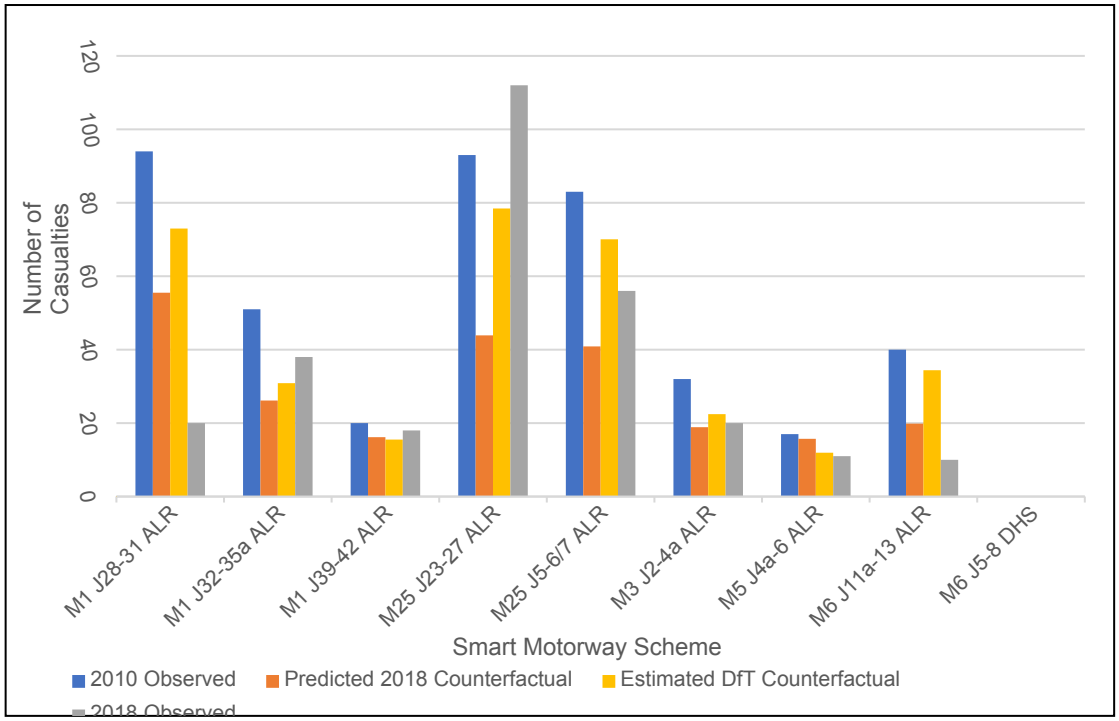

Figure 3-5 Counterfactual Predicted Number of Casualties in 2018 vs Estimated Department for Transport Counterfactual vs Observed Number of Casualties Pre-Implementation in 2010 and Post Implementation in 2018, Source Own Work and Adapted from Highways England, 2019

3.22 When the counterfactual using the COBA method is compared against an estimated Department for Transport counterfactual for ALR schemes (shown in Figure 3-5) it can be seen that in half the schemes both the counterfactuals are similar, notably the schemes that had the smallest number of casualties. In the other half there is a larger difference generally with the Department for Transport counterfactual numbers being higher than the COBA counterfactual, incidentally these are also the schemes which had a greater number of casualties.

3.23 This could mean that the COBA counterfactual is better at predicting the value when the number of casualties is small and is less accurate compared to the Department for Transport counterfactual when there are a greater number of casualties. This conclusion, however, does rely on the assumption that the Department for Transport method for calculating the counterfactual is accurate, regardless of the number casualties associated with a scheme.

3.24 The research question at the beginning of my dissertation asked whether the counterfactual scenario predicted a different number of casualties compared to the observed. What Figure 3-4 and Figure 3-5 show is that on some schemes such as both M25 schemes, the M6 J5-8 and M1 J32-35, the 2018 casualties are higher than the 2010 and both counterfactual predictions. Whereas on others such as the M1 J28-31 and M6 J11a-13 the 2018 observed casualties are lower than the counterfactual and 2010 observed.

3.25 This suggests that for some schemes, the situation was made worse with the implementation of the smart motorway, however it would be wrong to draw conclusions purely from this metric. This is because the number of casualties has not been weighted by the traffic flow along it, the amount of traffic increased for all smart motorway types analysed after the implementation of the smart motorway, and therefore this could have an impact on the casualty rate.

4 Adequacy of Safety Measures

4.1 As part of my dissertation I undertook a review and critique of the *Smart Motorway Safety Evidence Stocktake and Action Plan* which was commissioned by Grant Shapps in October 2019 and released in March 2020. The aim of the report was to analyse the data available to ensure that smart motorways and specifically ALR motorways are at least as safe as their conventional counterparts and to then recommend actions to make them safer.

4.2 Although the *Evidence Stocktake* comprehensively investigates smart motorway performance relating to the numbers of casualties and difference in risk, the report fails to investigate whether there is evidence of any delay between a vehicle stopping in a live lane and the lane being closed.

4.3 A Highways England Report into Stationary Vehicle Detection System (SVD) Monitoring (Tyler, et al., 2016), released in March 2016 investigated whether the use of SVD systems would help to mitigate the 216% higher risk of live lane breakdowns found on ALR motorways compared to a conventional motorway.

4.4 An SVD system applies radar technology to detect whether a vehicle is stationary. It then relays a notice to the control centre where an operative uses the network of CCTV cameras alongside the motorway to determine whether the notice is a genuine incident which requires attention.

4.5 Where SVD is not used it can take on average can take 17 minutes to highlight a stopped vehicle to the operator, whereas on average, 90% of events triggered by the SVD system were verified within a minute (Tyler, et al., 2016).

4.6 One of the actions highlighted in the *Evidence Stocktake* was to speed up the roll-out of SVD across the whole smart motorway network within 3 years. As shown with the evidence above this will greatly help to mitigate the higher risk of breaking down in a live lane on an ALR motorway.

4.7 However, as the evidence from the SVD system is not reported in the *Evidence Stocktake* and neither are the shortcomings of the current CCTV system the full scale of the risk and problem is not really known. The extent upon which the live lane risk is mentioned in the report is as a theory-based risk assessment then later, re-evaluated as outturn risks.

4.8 Although these assessments show that certain risks, such as tailgating and speeding are reduced by the introduction of ALR, the resulting commentary in the report does not document by how much each risk is reduced. Likewise, with the risks that have increased such as unsafe lane changing and stopping in a live lane. All that is mentioned is that overall, compared to conventional motorways, an ALR motorway has a 20% reduction in total risk.

4.9 Considering that for many schemes there was only a year of post implementation data to use, the report does well to generate results to allow for comparisons to take place. To get a more complete picture the analysis should be repeated after the Post Opening Project Evaluation (POPE) report for each scheme has been completed at 3 and 5 years after implementation. This can help to determine whether any conclusions originally drawn in this report will have changed.

4.10 It is worth noting that many of the recommendations in the *Evidence Stocktake*, such as a reduction in the spacing of ERA's and introducing enforcement of those ignoring red 'X' alongside a public awareness campaign were suggested in 2016 by the House of Commons Transport Committee. Yet, it took until 2019 for the enforcement of red 'X' violations to become law (Road Safety GB, 2019) and for this *Evidence Stocktake* to recommend the same changes be implemented and in turn timescales for completion devised.

5 Conclusion

5.1 The evidence shown here and in my dissertation, highlighted the differences between the different types of smart motorway to determine whether the different types of smart motorways are more or less dangerous than their conventional counterparts.

5.2 Overall, the various risks on an ALR motorway are less than those on a conventional motorway but there are some big increases in some types of risks. For example, the risk of stopping in a live lane has increased 216% compared to the conventional motorway (Tyler, et al., 2016). So, in that sense, a smart motorway and specifically an ALR motorway is more dangerous, however, steps to mitigate that risk have been identified in the *Evidence Stocktake.* This includes increasing the frequency of the emergency refuge areas to a maximum spacing of passing 1 every 60 seconds when travelling at 60mph and improving the visibility of both ERAs themselves and the signage displaying their locations (Department for Transport & Highways England, 2020).

5.3 The high-level statistics research presented highlights that the average number of casualties of all severities and for all types of smart motorway have decreased after implementation compared to before. The one exception is the number of serious casualties on CM which increased by 16%, but this was not a statistically significant increase.

5.4 The biggest reductions in the number of average casualties per year were on ALR motorways, where it was shown that for all types of casualties there was a statistically significant reduction in the average number of casualties post-implementation compared to before.

5.5 Where this dissertation goes further than the *Evidence Stocktake,* is that both the CM and DHS motorways have been appraised and compared alongside the ALR. This allows for a comparison between the smart motorway types, as well as the before and after scenario.

5.6 The public opinion of perceiving ALR as more dangerous is likely based upon press reports of single incidents, whereas my analysis of smart motorways across the network indicated that ALR motorways reduce the average number of casualties (per vehicle kilometre travelled).

6 References

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April 2021

Endnote

[1] COBA is an industry standard piece of software that is used to appraise the road safety costs and benefits of a highway network.