national highways

M4 junctions 19 to 20 & M5 junctions 15 to 17 dynamic hard shoulder

Five-year post-opening project evaluation

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Foreword

As Chief Customer and Strategy Officer, I want to know whether developments on our network are meeting their objectives and making a difference for our customers – the four million people that use the Strategic Road Network every day.

Evaluation is a key function in the safe running of the Strategic Road Network (SRN) and we carry out POPE[1] evaluations at set points during a major enhancement scheme's lifetime to enable us to take stock and make any necessary interventions. POPEs provide an early indication if the scheme is on track to deliver the benefits over 60 years as set out in the business case appraisal.

This report evaluates the M4 junctions 19 to 20 & M5 Junctions 15 to 17 dynamic hard shoulder (DHS) smart motorway scheme within five years of operation following its conversion from a conventional three lane motorway.

An initial study was conducted one year after the project which opened in 2014, followed by this report after five years which provides more robust data and analysis. The report includes an understanding of the safety and environmental impacts of a scheme, as well as how traffic has changed due to a scheme being in place and how the scheme supports the economy.

There are three types of smart motorway, all lane running (ALR), dynamic hard shoulder (DHS) and controlled motorway. ALR and DHS motorways create more space on some of the most congested sections of the SRN by using hard shoulder as a running lane either permanently or only at busy times. They create extra capacity with less disruption to road users and fewer environmental impacts than physically widening the road, along with reduced carbon emissions associated with construction.

Although the performance of individual scheme is important at a local level, drawing together findings at a programme level helps us to understand patterns and trends across our network.

Safety remains our number one priority and the five-year POPEs published to date (representing approximately a quarter of those in operation) demonstrate that smart motorways are delivering safety benefits in line with or above those originally forecast, with most schemes evaluated having lower collision rates than would have been expected on the conventional motorways they replaced. Where it has been possible to assess changes to the severity of such collisions, the evidence shows those collisions have been less severe.

The published five-year POPEs show that smart motorways are broadly on track to realise their envisaged environmental objectives. With further planned mitigation these will be fully met.

The five-year ALR and DHS POPEs published to date for smart motorways also show that the schemes are delivering much needed capacity with schemes accommodating up to almost a quarter (22%) more traffic than before they were converted into smart motorways. The reports indicate that many of the motorway

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[1] Post Opening Project Evaluation (POPE)

sections would have been unable to cater for today's traffic (at the busiest times) if they had not been converted into smart motorways.

According the to the reports, the schemes are currently on course to deliver benefits, but will not deliver all the originally expected benefits within the 60-year appraisal period. There has been lower traffic growth than was expected when these schemes were appraised, due to the 2008 financial crisis and lower population growth than originally forecast (this will impact all transport schemes, built around this time). This means fewer drivers are benefiting today from smart motorway schemes than original anticipated. Five-year POPEs also show that traffic on some smart motorway sections is not travelling as quickly as was forecast at the appraisal stage. Together these factors have resulted in the value for money for all schemes with five-year appraisals, over the 60-year appraisal period, currently being lower than anticipated at this stage when compared with the original appraisal. This is, however, a forecast and there is the opportunity to take further action to improve benefits.

We have therefore examined these results in detail and have identified specific actions to further improve the performance of schemes, including:

- Standardised operating procedures for DHS schemes
- Technology improvements
- Optimisation of the algorithms that set speed limits
- Investigating physical constraints off the network that impact performance

We will continue to monitor schemes in operation, enabling us to track their benefits and take further action if required to ensure these schemes deliver an improved experience for our customers.

Elliot Shaw

Chief Customer and Strategy Officer

September 2023

Table of contents

1. Executive summary

The M4 junctions 19 to 20 and M5 junctions 15 to 17 is in the Southwest of England, just north of Bristol and is the key interchange between the M4 and M5. The motorway was converted to a dynamic hard shoulder2 (DHS) smart motorway, opening for traffic in January 2014.

This scheme aimed to improve journey times, reliability and safety while providing value for money and minimising adverse environmental effects of the project.

Overall, the M4 junctions 19 to 20 and M5 junctions 15 to 17 DHS scheme is currently on course to deliver some but not all it expected benefits within the 60-year appraisal period.

The performance in the first five years indicated that the project has achieved its safety objective, following a reduction in the number and rate of personal injury collisions, compared with if the road had remained a conventional motorway. There has also been a reduction in the severity of collisions, with fewer serious and fatal collisions per year.

Journey time reliability broadly improved compared with before, while accommodating an increased number of road users meaning customers could be more certain of how long their journey would take.

Whilst the scheme is catering for 11% more traffic, traffic growth was lower than forecast compared to the original appraisal due to the 2008/09 financial crisis and lower population growth than forecast, meaning that fewer people are benefiting from the scheme than expected. Also, tolls on the Severn River Crossing were removed in December 2018 which may have influenced the traffic levels in this area3 .

Journey times tended to be longer after the conversion. This is likely to be a combination of increased traffic and deployment of the variable mandatory speed limit (VMSL) technology to smooth the flow of traffic. To safely operate the hard shoulder as a running lane, a maximum speed limit of 60mph is applied, with the ability to set lower limits. This slows down drivers to smooth the flow of traffic and achieve a higher capacity on the road. Journey times on the former motorway layout at busy times, at the most congested points, would have been even longer if the conversion had not been implemented, leading to some benefits in journey times.

Due to the observed trends in traffic growth, the anticipated impacts on air quality and noise were better than expected. Overall, the impact of the project on the majority of the environmental sub-objectives were mostly restricted to within the highway boundary as expected and were either on track to be neutral or slight adverse in line with the business case. To ensure opportunities for creating suitable habitats and connectivity are fully realised, long-term management arrangements, including grassland management plans need to be put in place and actioned. Also, the historic survey report of the locally listed Pegwell bridge should

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2 Dynamic hard shoulder (DHS) running motorways apply technology to control speeds and use electronic signs to temporarily increase capacity by utilising the hard shoulder at busy times. Emergency areas are available at regular intervals providing places to stop in an emergency.
3 Traffic analysis took place in March 2019, four months after tolls were removed on the bridges.

be made accessible to ensure the benefits of the knowledge of the historical asset contained within the report, can be shared.

Based on the evidence from the first five years, this project is not yet fully realising its anticipated value for money over the 60-year life of the project, and we are exploring what further action can be taken to improve benefits. The primary reason for the overall reduced level of benefits is lower than expected traffic growth due to the 2009 financial crisis and lower population growth together with slower journey times.

2.   Introduction

What is the project and what was it designed to achieve?

The M4 junctions 19 to 20 and M5 junctions 15 to 17 smart motorway opened in January 2014 having been in construction for three years. As well as upgrading sections of the M4 and M5 motorways, the project included improvements to Almondsbury interchange to facilitate more free-flowing traffic between the key strategic routes (Figure 1).

This project included a mix of smart motorway types to make best use of the highway estate available at the time. The dynamic hard shoulder[4] (DHS) standard was used on the M4 between junctions 19 (M32) and 20 (Almondsbury interchange) and on the M5 between junctions 16 (A38) and 17 (Cribbs Causeway). The westbound link from the M4 to M5 at Almondsbury interchange also incorporated a DHS element alongside two permanent lanes. The DHS then ends shortly after the interchange on the approach to M5 J16 and is used as a live lane all the time. On the opposite carriageway from M5 J16 to Almondsbury interchange, it mostly resembles a controlled motorway[5], with no DHS. All other links on the interchange were fitted with variable mandatory speed limit (VMSL) technology to regulate traffic flows and are thus categorised as controlled motorway standard.

There was significant congestion on these motorways prior to construction, being a key London to Southwest route. The M4 junction 19 to M5 junction 17 and converse route were much more congested than other movements on the interchange, so capacity was added in the form of a DHS to be used in peak times, whereas the interchange had technology installed to regulate speed in the form of VMSL.

The smart motorway project started construction in January 2012 and opened for traffic three years later in January 2014.

Project location

The project is located in the Southwest of England, just north of Bristol and is the key interchange between two of the country's most significant motorways; the M4 and M5. Almondsbury interchange is at the centre of this project, providing a key link to South Wales via the M4 west (Severn Bridge and Prince of Wales Bridge), the Midlands and Southwest of England via the M5, and London heading east on the M4. The project is located entirely within the country of South Gloucestershire.

Around five miles west of the project is the River Severn, where two bridges which cross into South Wales: Severn Bridge (M48) and the Second Severn Crossing (Prince of Wales Bridge, M4), which both carry traffic between England and Wales. Historically, these bridges were operated by Severn River Crossing plc to collect the tolls, until ownership was transferred to the UK government in January 2018. Control of the bridges now lies with National Highways, with tolls removed in

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[4] Dynamic hard shoulder (DHS) running motorways apply technology to control speeds and use electronic signs to temporarily increase capacity by utilising the hard shoulder at busy times. Emergency areas are available at regular intervals providing places to stop in an emergency.
[5] Controlled motorways apply technology to control speeds but retain a permanent hard shoulder.

December 2018, which may have had some impact on the five-year evaluation of this project[6].

Figure 1 - M4 junctions 19 to 20 and M5 junctions 15 to 17 project location
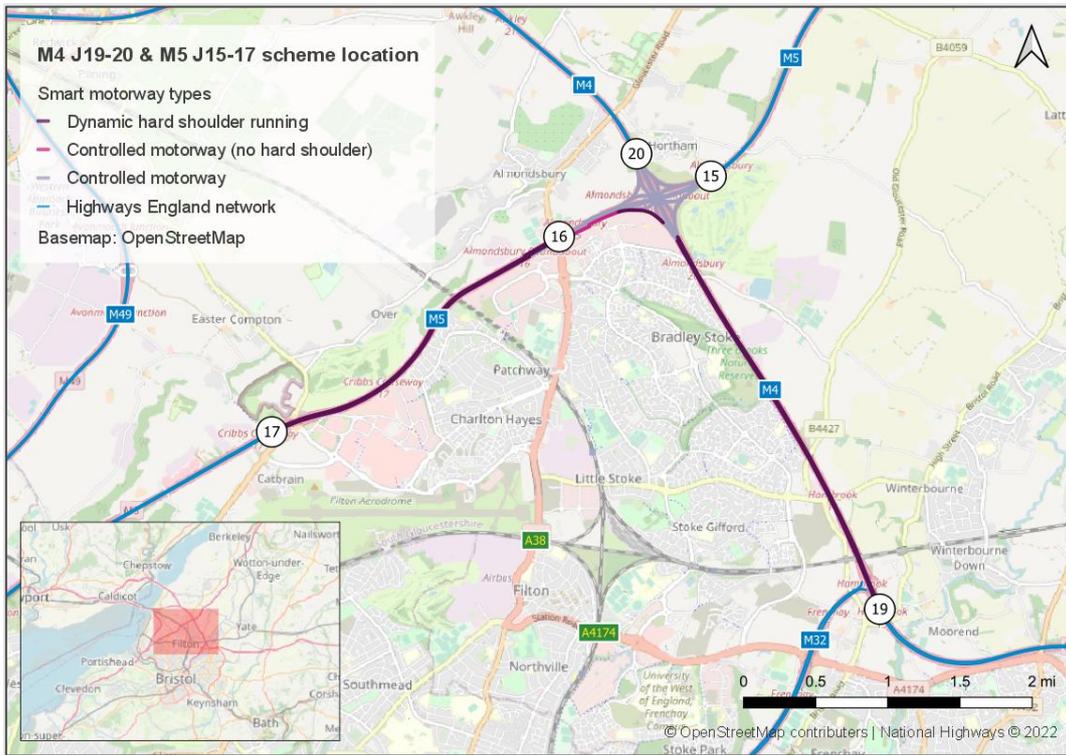
Source: National Highways and OpenStreetMap contributors

How has the project been evaluated?

Post-opening project evaluations (POPEs) are carried out for major projects to validate the accuracy of expected project impacts which were agreed as part of the business case for investment. They also seek to determine whether the expected project benefits are likely to be realised. They provide opportunities to learn and improve future project appraisals and business cases too. And are important for providing transparency and accountability for public expenditure, by assessing whether projects are on track to deliver value for money.

A POPE compares changes in key impact areas[7] by observing trends on a route before a project is constructed (baseline) and tracking these after it has opened to traffic. The outturn impacts are evaluated against the expected impacts (presented in the forecasts made during the appraisal) to review the project's performance. For more details of the evaluation methods used in this study please refer to the POPE methodology manual on our website.[8]

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[6] Traffic analysis took place in March 2019, four months after tolls were removed on the bridges.
[7] Key impact areas include safety, journey reliability and environmental impacts.
[8] https://nationalhighways.co.uk/media/exypgk11/pope-methodology-note-jan-2022.pdf

3.   Delivering against objectives

How has the project performed against objectives?

All National Highways major projects have specific objectives which are defined early in the business case when project options are being identified. These benefits are appraised to be realised over 60 years. The one-year evaluation provides early indication of progress, followed by the five-years after evaluation which gives a more detailed insight. The objectives for the M4 junctions 19 to 20 and M5 junctions 15 to 17 smart motorway included the following:

Table 1 Objectives and Evaluation summary

Objective	Five-year evaluation
Reduce the number of fatalities, casualties and incidents on the M5 J15 – J17 and M4 J19 – J20, and through the Almondsbury Interchange, per vehicle kilometre[9].	The evaluation found there has been a reduction in the number, and rate of personal injury collisions. The five year[10] evaluation concludes that the objective has been met[11].
Improve journey times and journey time reliability on the M5 between Junctions 15 and 17, on the M4 between Junctions 19 and 20 and through Almondsbury Junction.	While journey times were generally slower than before the project, reliability had improved.
Provide high or very high value for money against its whole of life costs in accordance with the Department's WebTAG guidance.	The re-forecasted value for money analysis (section 7) identified that, based on the first five years of operation, the project is not on track to deliver the forecast value for money within the 60 years forecast period, without further action to optimise benefits.
The detrimental environmental effects of the scheme shall be offset by mitigation measures where technically feasible and economic to do so.	Heritage of historic resource and biodiversity are worse than expected, the slight adverse impacts on landscape and townscape were evaluated as expected. Noise and air quality are evaluated as better than expected due to lower than forecast traffic volumes[12].

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[9] Since the objective for this project was set the appropriate measure has converted from using kilometres to miles. This objective has been assessed as the reduction of collisions per hundred million vehicle miles.

[10] Projects are appraised over a 60-year period. This conclusion is based on the findings at five years after the project opened for traffic

[11] This is also lower than the counterfactual range in absolute numbers and rates, so is considered statistically significant.

[12] Refer to section 6 for fuller details.

4.   Customer journeys

Summary

Across much of the area impacted by this project, an increase in traffic volumes was observed, in line with the average growth for National Highways motorways. This was lower than the growth forecast in the appraisal which supported the project's business case. The exception to lower than forecast growth was between junction 15 and 16 of the M5. In December 2018, tolls were removed on the Severn bridge. This change was not accounted for in the models and led to very large increases in traffic volume on the M5 heading east and the Almondsbury Interchange. This interchange connects the smart motorway with the M4 heading west – a corridor connecting to Wales via the Severn bridge.

Five years after opening, journeys took slightly longer compared to before construction. The project had an objective to improve journey times, and without further intervention, this is unlikely to be on track to be realised[13]. The limited availability of detailed journey time forecasts to compare to made it difficult to draw firm conclusions.

Smart motorways intend to improve journey time reliability, and this was an objective of this project. Reliability generally improved in both directions, meaning road users could be more certain of how long their journey would take. Average speeds also showed journeys were more consistent. Less variation in speed were seen, particularly around the Almondsbury Interchange. Average speed overall was lower five years after. Journeys took slightly longer but there was more certainty in their speed and duration.

In this project, we have implemented a dynamic hard shoulder (DHS). This adds additional capacity facilitating smoother journeys. The hard shoulder was almost always used as a running lane during the morning and evening peaks. Safe operation of a DHS requires a 60mph speed limit. Consequently, 60mph limits have been used often, particularly during peak hours but also sometimes throughout the rest of the day. During peak times, when the hard shoulder was a running lane, it was used by the lowest volume of traffic compared to other lanes. The high usage of the hard shoulder and speed restrictions has worsened journey times, but also enabled the road to handle additional traffic and make journeys more reliable.

How have traffic levels changed?

Smart motorways are built on stretches of motorway which experience high levels of congestion and/or are expected to see traffic levels increase in future years. The following sections will examine if the traffic levels changed over the evaluation period and to what extent the forecast traffic levels were realised.

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[13] In this section we are presenting before and after journey times unadjusted. For section 7 we have compared outturn journey times against a counterfactual estimate of what journey times are likely to have been without the project. This allows for the deterioration in journey times that we would have expected to have happened due to growth in background traffic levels causing additional congestion. The counterfactual calculation estimated a disbenefit of 313,000 vehicle hours in the fifth year after opening.

National and regional

To understand how the project affected traffic levels, context is required about regional and national traffic trends. Traffic volumes saw a steady increase throughout the construction period. A faster increase in traffic volumes has occurred since opening, through the second half of the decade. Despite a plateau experienced in 2017-18, growth in traffic volume returned until 2019.

Since 2011, both South Gloucestershire and the wider South West have experienced traffic growth above that of National Highways motorways. Traffic volume has increased by 12% on motorways since 2011, compared to 17% for the South West. Traffic growth in Bristol has been comparatively slower, rising just 7% since 2011.

There has been an 11% rise on the smart motorway itself, compared to pre-construction levels. Despite growth being higher than Bristol, 5 miles south, and comparable with other National Highways motorways, this is less than the background levels of growth seen in the South West region.

Figure 2 - Background changes in traffic growth
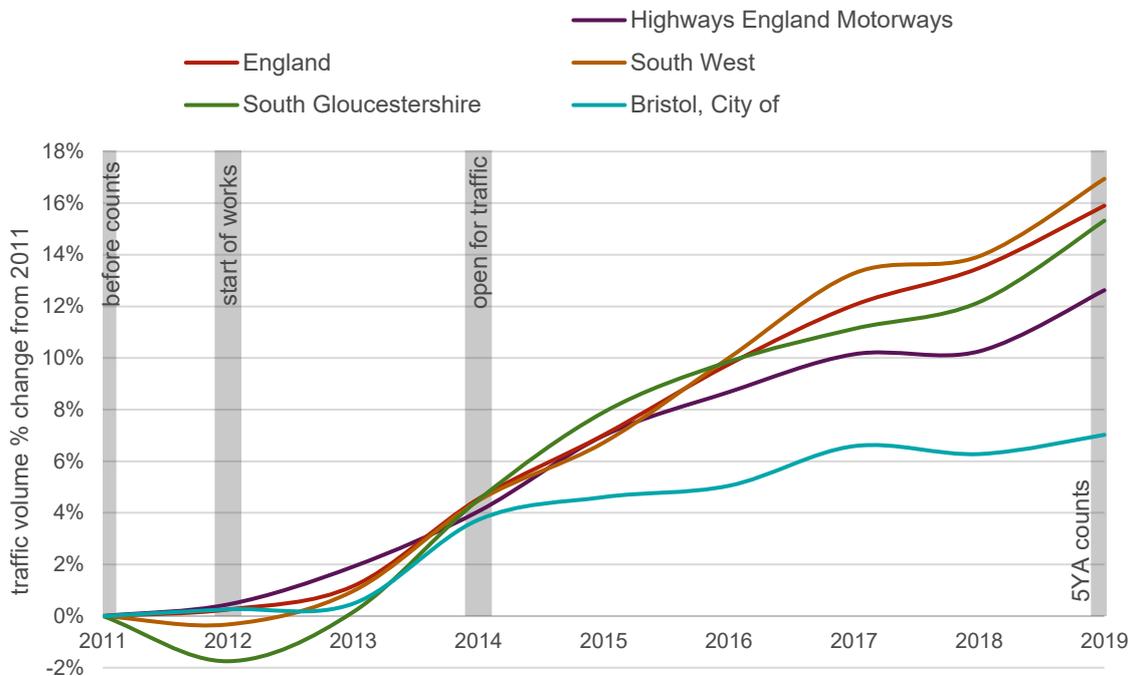
Source: Department for Transport road traffic statistics https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra

How did traffic volumes change?

Across the project extent and other connecting roads, there has been a consistent increase in average weekday traffic between March 2011 (before the project opened for traffic) and March 2018 (five-year after POPE). The mainline sections of the M4 and M5, hosting the smart motorway, have experienced an average of 11% growth 5 years after opening compared to before. This is in line with the national increase in National Highways (formerly Highways England) motorway traffic volumes, but below the regional average.

The M5 southbound has seen 16% growth exiting the Almondsbury Interchange. Other components of the smart motorway have experienced growth ranging from 7% to 11%. The M5, M4 and M32 have seen similar levels of growth.

Whilst not part of the project, the largest growth in traffic volumes since project completion occurred on the M4 J20-21 westbound. This route forms part of a corridor connecting to Wales via the Severn Bridge. The 36% increase in traffic can likely be explained by the removal of tolls on the Severn Bridge in December 2018. The impact of this change was not considered during modelling.

**Figure 3 - Average weekday traffic for M4 J19-20 & M5 J15-17 along with other SRN locations**
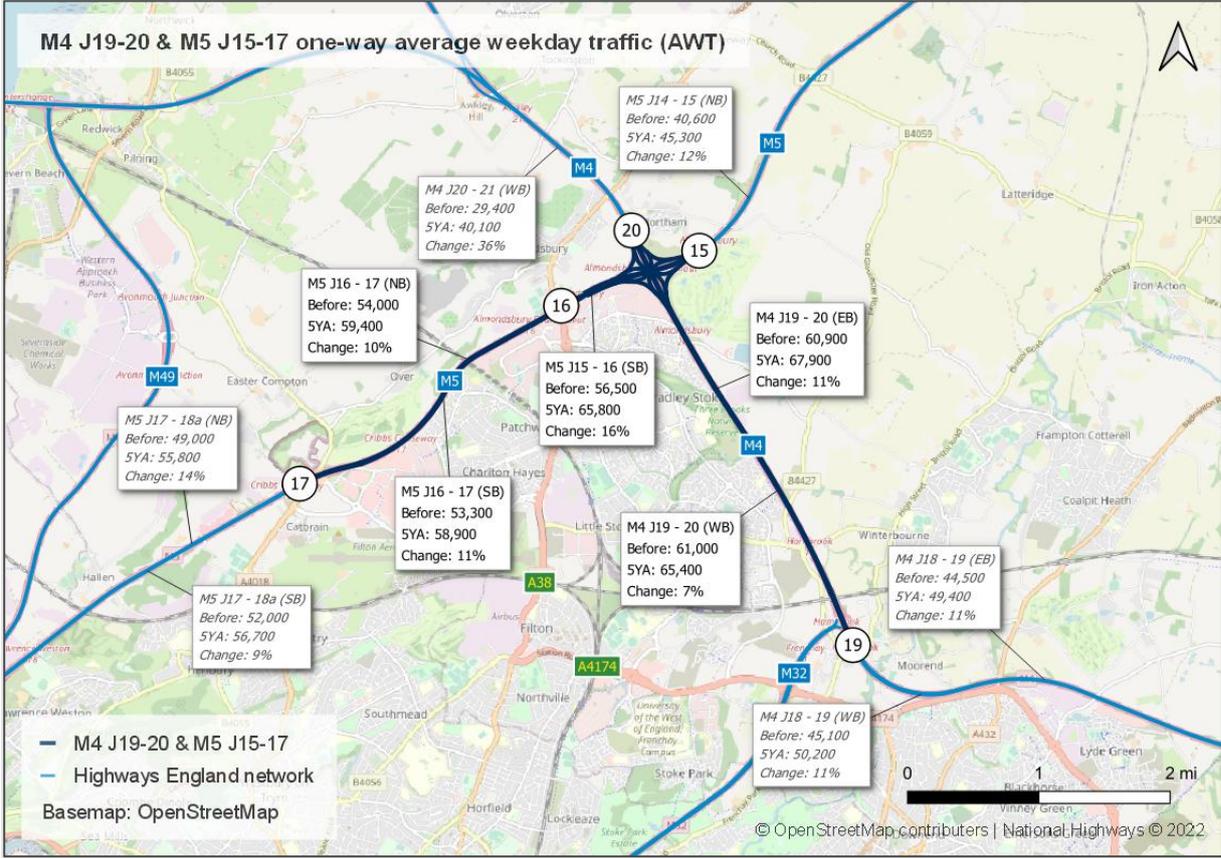
Source: National Highways traffic count data and OpenStreetMap contributors

The Almondsbury Interchange has experienced an increase in traffic volume for all directions. For most links, the increase has been below national and regional background trends.

Two directions at the interchanges have experienced large increases in traffic volume. The connections between M5 northbound to M4 westbound and opposing direction M4 eastbound to M5 southbound experienced increases of 43% and 40% respectively. This offered supplementary evidence that unanticipated higher traffic volumes approaching the Almondsbury Interchange from the north was a consequence of the removal of tolls on the Severn Bridge.

**Figure 4 - Almondsbury Interchange one-way average weekday traffic**
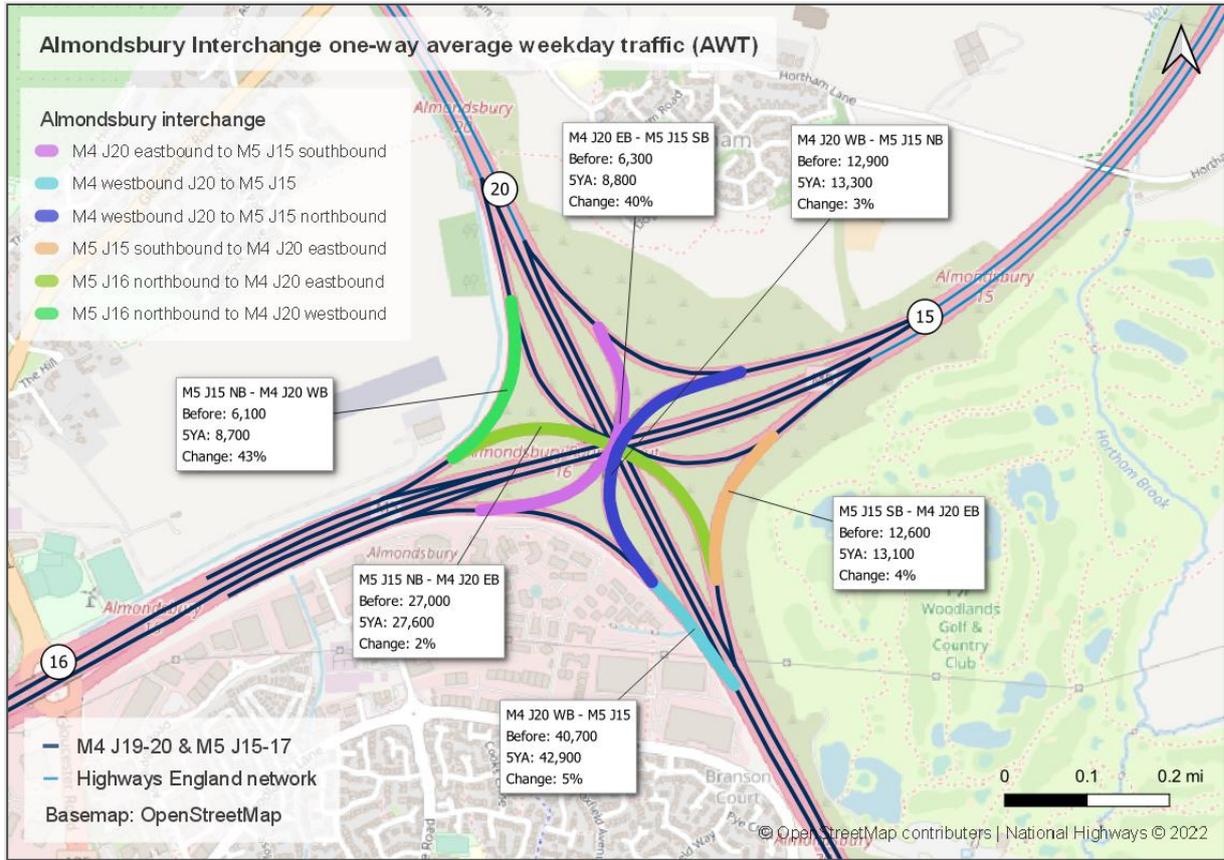
Source: National Highways traffic count data and OpenStreetMap contributors

Was traffic growth as expected within the business case?

The project's business case was informed by traffic growth forecasts for 2016 and 2031. Linear interpolation, was used to calculate the do something scenario[14] forecast for 2019. The forecast change in traffic volumes is shown in Figure 5 with the observed change in Figure 6.

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[14] DS – Do Something – the modelled scenario which included the project as part of forecasts

Figure 5 - Forecasted change in flow on M4 J19-20 & M5 J15-17
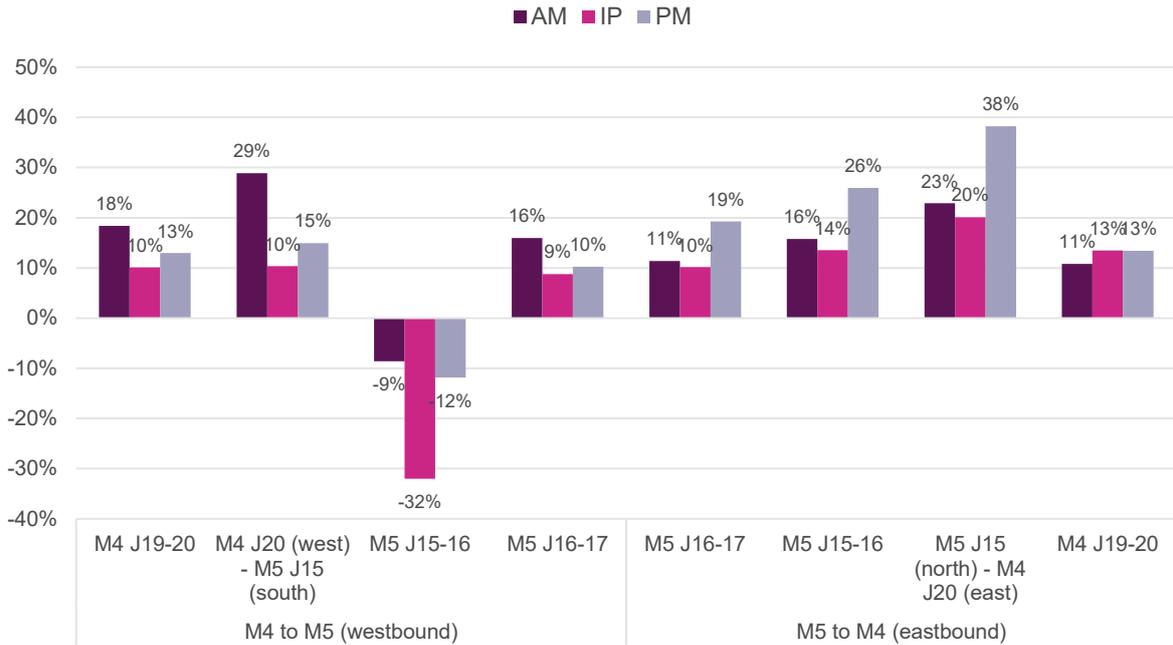
Source: Forecasts from traffic forecast report. Observed data from National Highways traffic count data. Note: Forecast change: Do minimum (2019) to do something (2019). Observed change: before smart motorway (2011) to post smart motorway (2019). 2019 forecasts were interpolated using the opening year (2016) and design year (2031).

Figure 6 - Observed change in flow on M4 J19-20 & M5 J15-17 (before versus five years after)
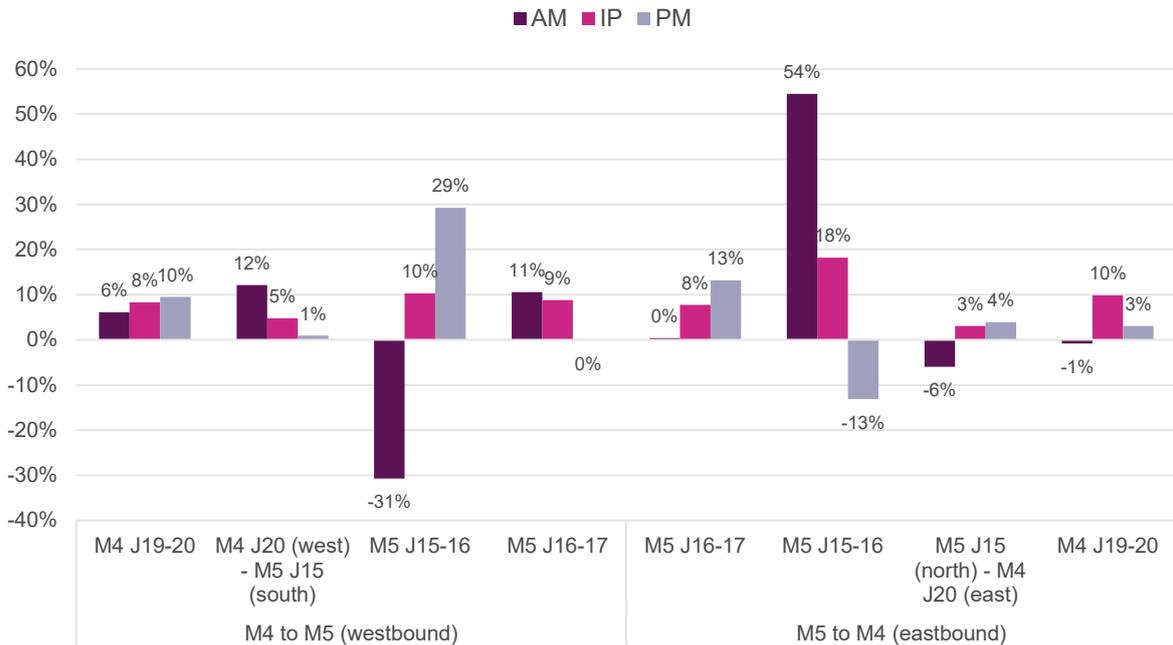
Source: Forecasts from traffic forecast report. Observed data from National Highways traffic count data. Note: Forecast change: Do minimum (2019) to do something (2019). Observed change: before smart motorway (2011) to post smart motorway (2019). 2019 forecasts were interpolated using the opening year (2016) and design year (2031).

Anticipated growth rates were typically above 10%, the majority situated around 15%, with some exceeding 20%. The only place where traffic volumes were expected to fall significantly on the M5 J15-16 (passing through Almondsbury Interchange), particularly during the inter-peak.

Compared to observed traffic growth between before and five years after, the forecasts overestimated the increase in traffic. Observed traffic volume growth was

typically below 10%, with some routes experiencing reductions in traffic volumes during certain parts of the day, despite being predicted to increase by over 10%. The anticipated reduction on the M5 J15-16 was seen in the morning peak, but increases were observed in the interpeak and PM peak.

The traffic forecasts anticipated stronger growth during AM and PM peaks with lower growth in the inter-peak. The M4 to M5 direction was expected to have higher growth in the morning peak, with higher evening peak growth anticipated for the M5 to M4 direction. There is little evidence of this pattern appearing in the observations for March 2019.

The largest increase in traffic volume was observed on the M5 J15-16 northbound, approaching the Almondsbury Interchange, particularly in the AM peak. The north-west exit of this interchange is a corridor towards the Severn Bridge. Forecasting did not account for the removal of tolls on the Severn Bridge in 2018 so has understated flows on this stretch of road.

Overall, observed two-way average weekday flows were between 13% and 29% lower than forecast (between 18,400 and 53,600 vehicles). The traffic forecasting for this project was undertaken in 2010. At this time, the full extent of the 2008 economic downturn would not have been understood nor reflected within the appraisal. It is since acknowledged that the subsequent recession stalled traffic growth between 2008 and 2011 as a consequence of impacts on fuel price and travel demand.

Relieving congestion and making journeys more reliable

Smart motorways are applied to the busiest routes to ease congestion and ensure journey times are more predictable. These routes are often where we anticipate congestion will increase and the smart motorway seeks to limit this. Analysis of journey times and speeds indicate the impact of the smart motorway on congestion. The extent to which journey times vary from the expected average journey time indicates how reliable a journey is.

This section evaluates how the project impacted journey times and the reliability of journeys.

### Did the project deliver journey time savings?

For this section, TomTom satnav data has been used to calculate average journey times for each direction and time period to facilitate comparison against the original forecasts[15].

Five years after opening, journey times have generally got slower, with the exception of M5 to M4 (eastbound) in the AM peak when journey times were on average 36 seconds faster than before construction. The greatest increase in journey times being on the M4 to M5 in the PM peak, where journey times were on average 1 minute and 24 seconds slower than before construction.. These increases in journey time are within the context of an 11% growth in traffic volume seen since we opened the smart motorway. When accounting for the observed

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[15] In this section before and after journey times are directly compared. For section 7 we compared outturn journey times against a counterfactual estimate of what journey times were likely to have been without the project. This allows for the deterioration in journey times that we would have expected to have happened due to growth in background traffic levels causing additional congestion.

traffic growth seen at five years after, if the section of road had remained as a 3-lane motorway they would have been unable to support the additional road users, without experiencing a reduction in speed[16].

Figure 7 Average journey time
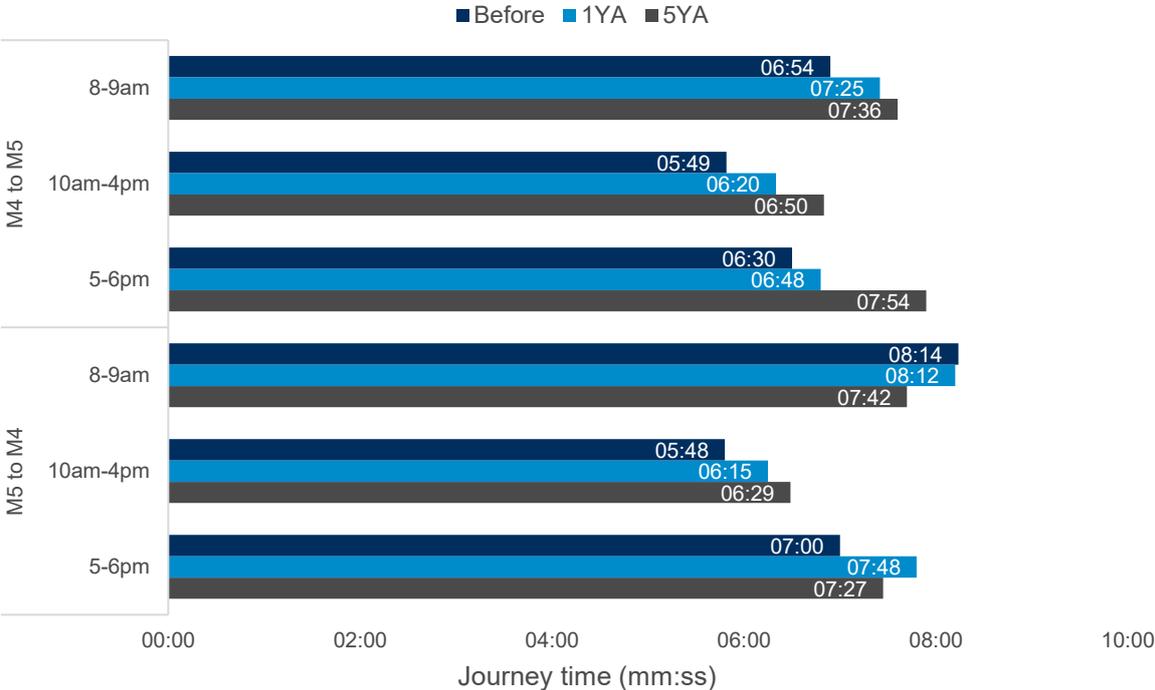
Source: TomTom satnav data March 2011, 2015 and 2019.

Were journey time savings in line with forecast?

Limited detailed forecasting information is available, so it is not possible to make direct comparisons between observed and forecast journey time changes. Specific forecasts on journey times within the project were not presented, only the overall impact on the network. In the modelled opening year (2016), there was an expectation that journeys would improve in the morning, but worsen slightly in the evening, with no change during the daytime. Larger improvements were expected in the design year (2031), with greater savings in the morning than the evening, again the daytime remains unchanged. The observed journey time impacts in this report are not considered to reflect the pattern of benefits expected across the project lifetime.

Did the project make journeys more reliable?

Congestion can make journey times unreliable. If time taken to travel the same journey each day varies, journey times are unreliable and the road user is less confident in planning how long their journey will take. If journey times vary less, the road user can be more confident in the time their journey will take and allow a smaller window of time to make that journey.

An objective of this project was to improve journey time reliability. The charts below illustrate how significant improvements in journey time reliability have been experienced for most time periods. This is indicated by the narrowing of the box

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[16] Analysis has shown that with observed increased in traffic at five years after, a 3-lane motorway would not be able to support these additional road users without experiencing a reduction in speed, in at least one peak time period.

widths. Road users have more certainty about the duration of their journey on the smart motorway, five years after opening.
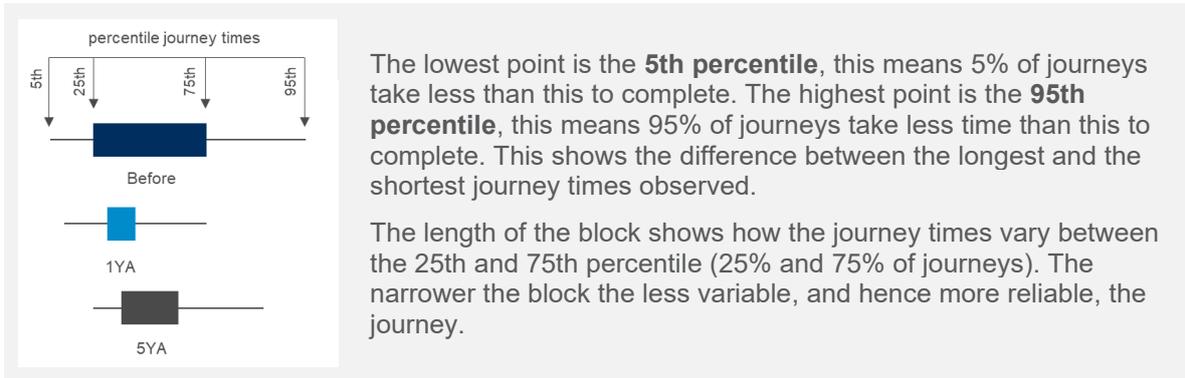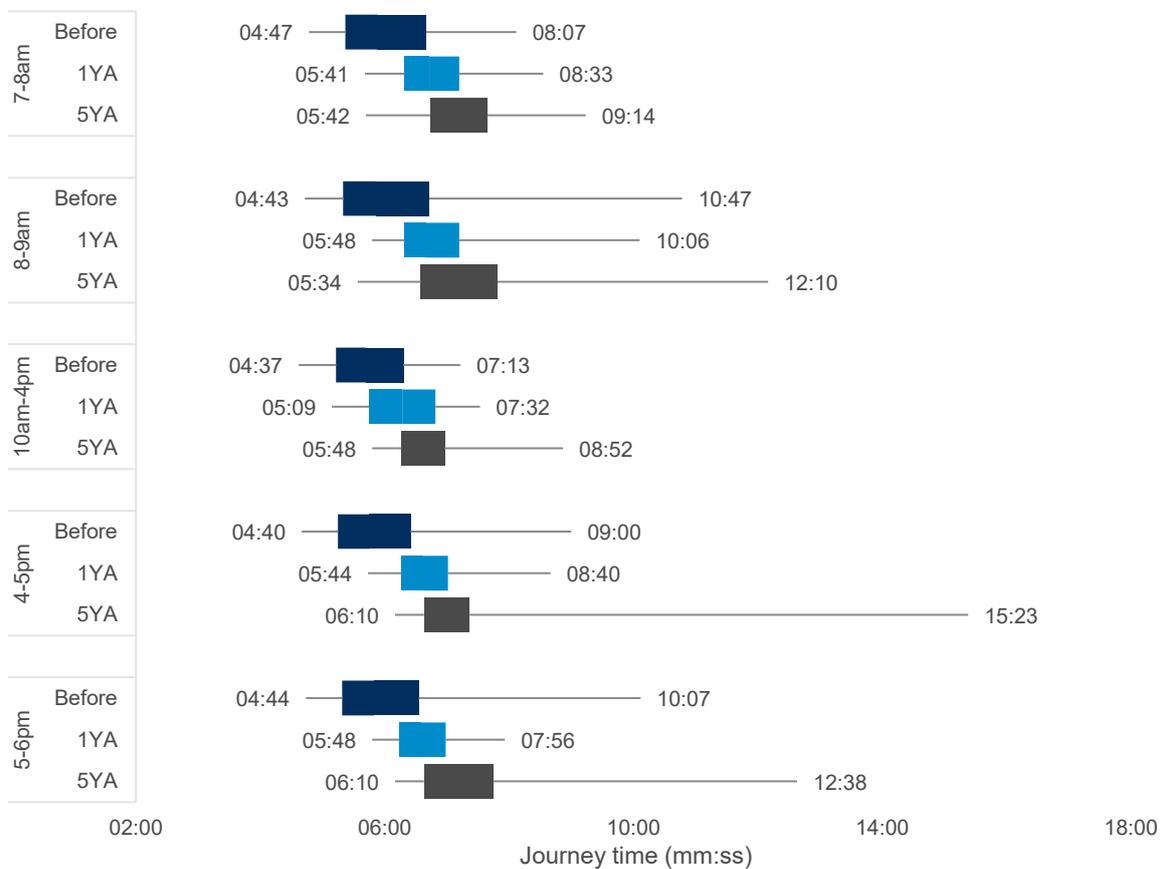
Figure 8 What does a box plot show?

The lowest point is the **5th percentile**, this means 5% of journeys take less than this to complete. The highest point is the **95th percentile**, this means 95% of journeys take less time than this to complete. This shows the difference between the longest and the shortest journey times observed.

The length of the block shows how the journey times vary between the 25th and 75th percentile (25% and 75% of journeys). The narrower the block the less variable, and hence more reliable, the journey.

Figure 9 M4 to M5 (westbound) journey time reliability

Source: TomTom satnav data March 2011, 2015 and 2019.

Figure 10 M5 to M4 (eastbound) journey time reliability
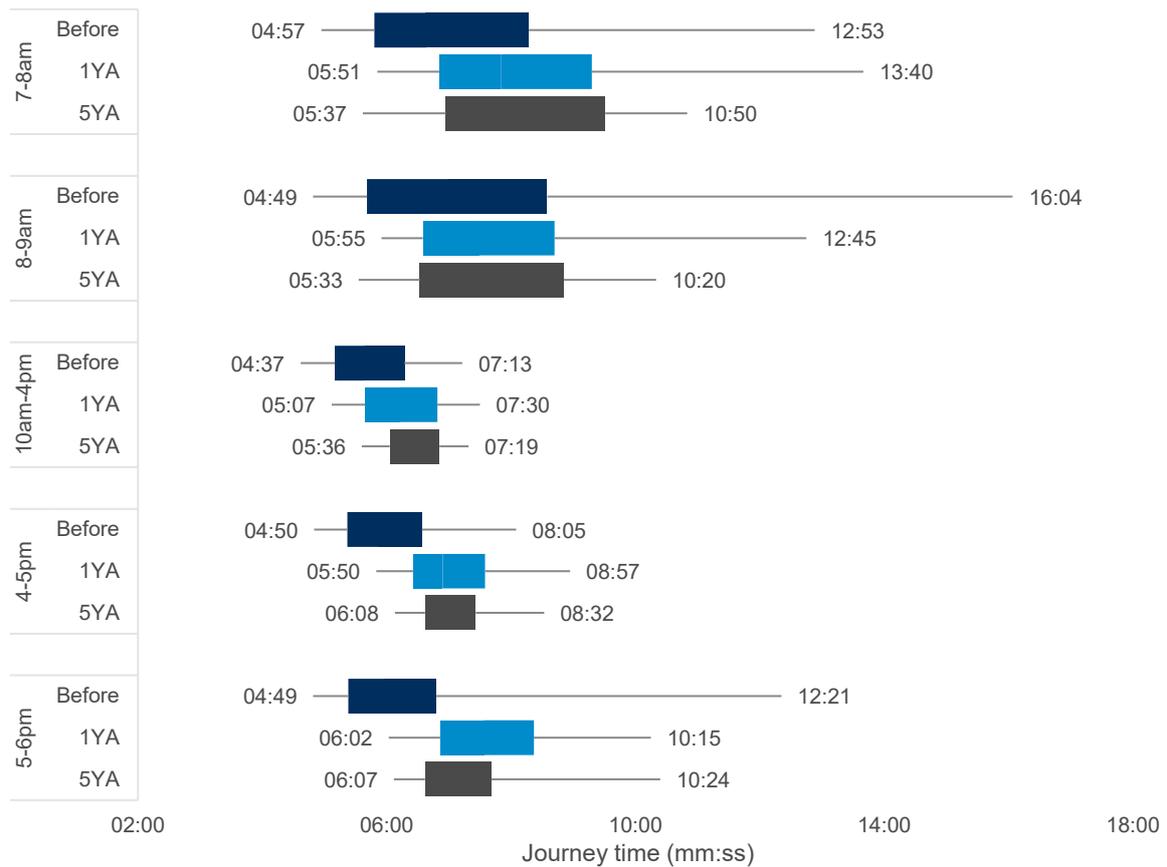
Source: TomTom satnav data March 2011, 2015 and 2019.

In the busiest time periods eastbound (M5 to M4) the longest journeys (as indicated by the 95th percentile) experienced a large improvement. Small increases were seen in other time periods. However, westbound (M4 to M5) the longest journeys have got slower, with a particularly large increase in the 4-5pm time period.

Half of all journeys made within each time period are contained within the blue and grey boxes presented in Figure 9 and Figure 10. If these boxes get shorter then journeys become less variable, meaning road users can be more confident of the time it takes to travel through the route.

In the M4 to M5 (westbound) direction, reliability improved, as shown by the boxes contracting. This has been particularly noticeable 7-8am, 10am-4pm and 4-5pm. The story is similar M5 to M4 (eastbound) – journeys have become more reliable from 8am onwards. There has been little change 7-8am. The pattern of change since one year after is mixed, with some time periods improving and others deteriorating.

The 5th percentile journey time is indicated by the value to the left of the line extending from each box plot. Just 5% of journeys are faster than this. The quickest journeys take slightly longer on average five years after opening than before. Before the implementation of this project, the shortest journeys took less than five minutes, regardless of time of travel. However, the 5th percentile sat above five minutes for all times five years after. For the PM peak in both directions, it exceeded 6 minutes.

How did the project impact speed?

TomTom satnav data has been used to understand how average speed has changed since project opening. Smart motorways aim to make journeys smoother and improve flow in already congested areas of the network. The aim is for speed to be more consistent along the route. Average speed has tended to progressively reduce one year and five years after opening. This is expected as traffic levels increase over time[17].

Figure 11 and Figure 12 show speed during the AM and PM peak. During these peak hours, Variable Mandatory Speed Limits were used to apply a 60mph speed limit by default when the dynamic hard shoulder is utilised, explaining why average speed remained below 60mph. Section 4.3.5.3 shows how the location of these average speed reductions corresponds to the parts of the road where speed restrictions were being applied most often.

Between the M4 and M5 (westbound) 5-6pm, average speed was more consistent for the first five and a half miles five years after than before (Figure 11). Before project opening, average speed dropped at the Almondsbury Interchange. Five-year after data demonstrates the interchange having less of an effect. Despite these improvements, speed is consistently lower five years after – particularly towards the M5 J17, where speed has reduced from 65mph to just above 40mph. It is worth noting that during the peak periods, there is high usage of VMSL and opening of the DHS, which automatically reduces the speed limit to a maximum of 60mph.

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[17] In this section we are presenting before and after speeds. For section 7 we have compared outturn journey times against a counterfactual estimate of what journey times are likely to have been without the project. This allows for the deterioration in journey times that we would have expected to have happened due to growth in background traffic levels causing additional congestion. The counterfactual calculation estimated a disbenefit of 313,000 vehicle hours in the fifth year after opening.

Figure 11 M4 to M5 (westbound) speed over distance 5-6pm
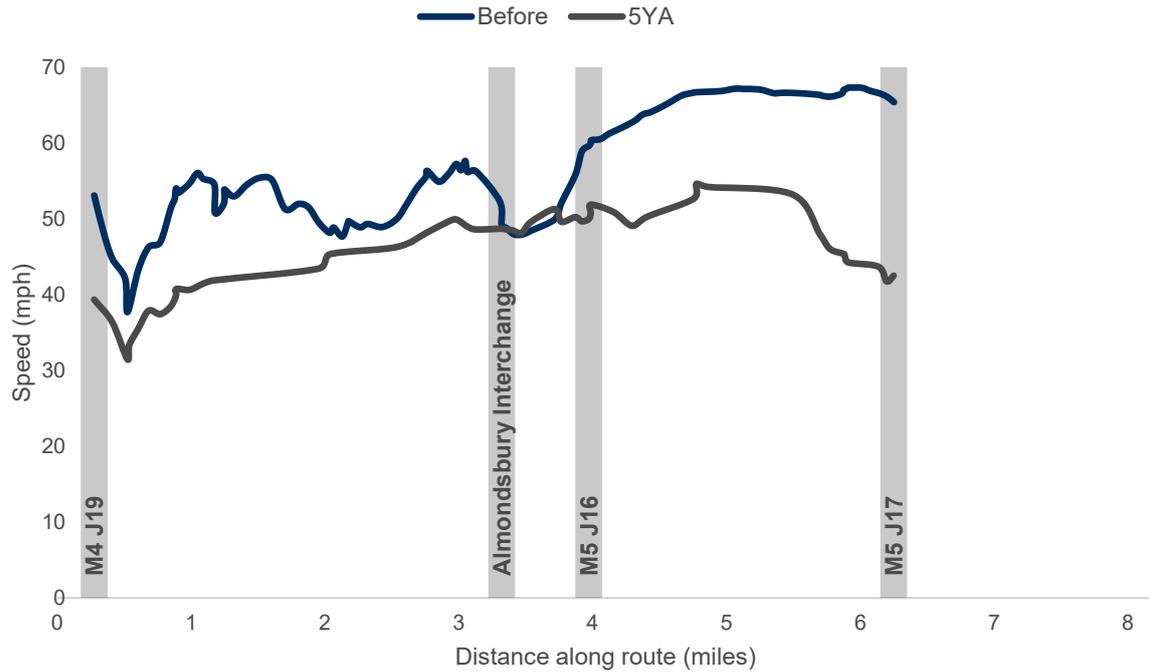
Source: TomTom satnav data March 2011, 2015 and 2019.

Figure 12 shows how for M5 to M4 (eastbound) 8-9am consistency in average speed has also improved, with less extreme peaks and troughs five years after. Overall, average speed increased slightly five years after – particularly on the approach to the Almondsbury Interchange - where the sharp reduction in speed five years after happened after the interchange, rather than just before.

Figure 12 M5 to M4 (eastbound) speed over distance 8-9am
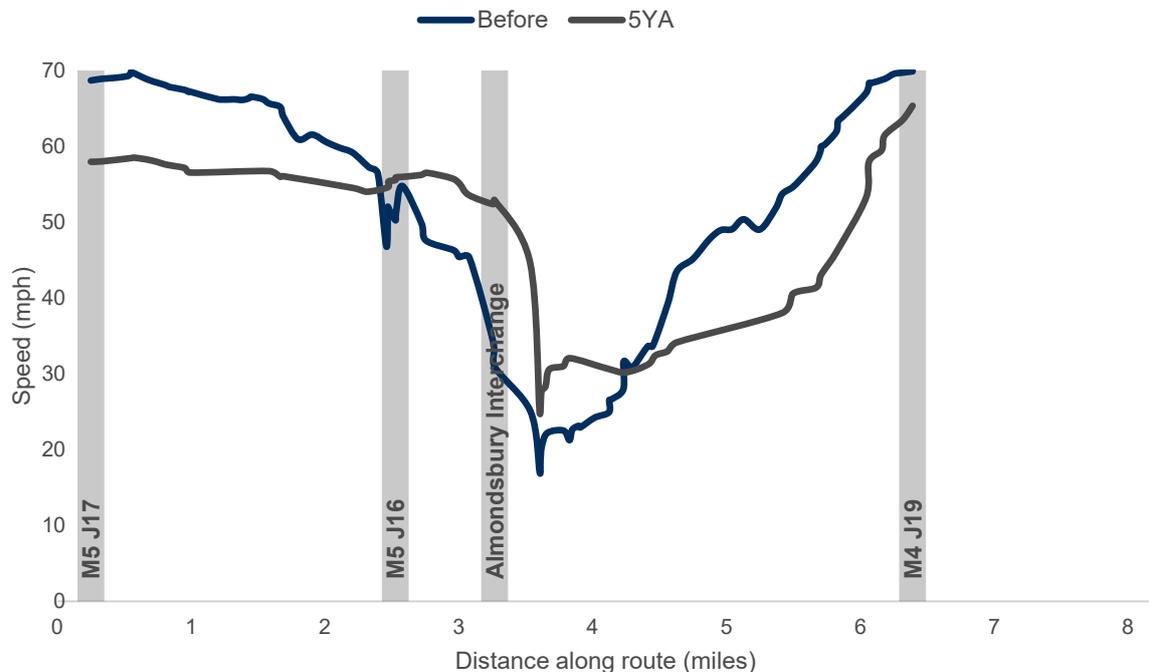
Source: TomTom satnav data March 2011, 2015 and 2019.

Further speed over distance plots are contained within Appendix A.1.

How was the smart motorway operated?

The project consists predominately of DHS motorway, where technology is applied to control speeds, and electronic signs are used to temporarily increase capacity by utilising the hard shoulder at busy times. Emergency areas are available at regular intervals, providing places to stop in an emergency.

Aside from dynamic hard shoulder, the route contains a short section of controlled motorway directly connecting to the Almondsbury Interchange. A controlled motorway applies technology to control speeds but retains a permanent hard shoulder.

How often is the hard shoulder used as a running lane?

As expected, the hard shoulder was used as a running lane most frequently during the AM and PM peaks, when traffic volumes were highest. Usage during the AM peak was 96% five years after opening in both directions.

The hard shoulder was used much less during the quieter inter-peak, between 10am and 4pm. The hard shoulder was a running lane for less than 1 and a half hours per day during this 6-hour period.

Figure 13 Hard shoulder utilisation during peak hours (average of directions) at five-years after
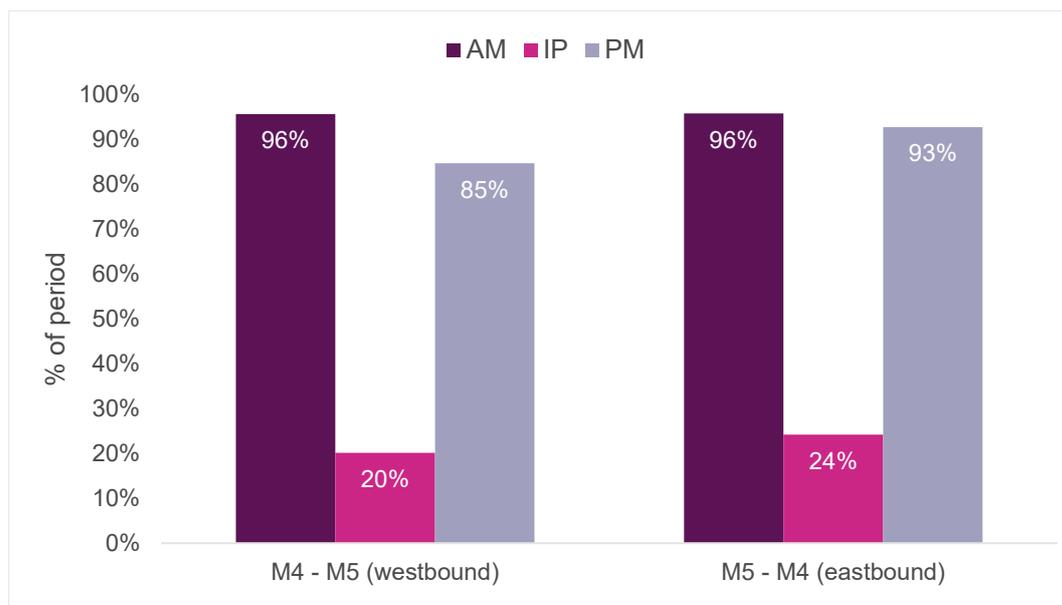
Source: National Highways MIDAS traffic data. Data aggregates dynamic hard shoulder sections

Lane utilisation of the smart motorway

This section focuses on how the lanes available were used by drivers. The project consists predominately of DHS motorway – where the hard shoulder (lane 1) can be used as a running lane to manage congestion. There are also elements of controlled motorway around the Almondsbury Interchange and on the M5 between junctions 15 and 16.

The chart below shows the lane utilisation eastbound on the M4 between junction 20 and junction 19 during the AM peak (8-9am). During this more congested time, lane usage was more evenly distributed. Despite the hard shoulder being used as a running lane 96% of the time, it was still the least used lane by drivers. Over 200 fewer vehicles per hour use this lane per hour than lane 2. This pattern is a

consequence of some drivers not utilising the hard shoulder as a running lane, despite being directed to by the variable messaging signs. The gap in usage of lane 1 compared to other lanes narrows between junctions 20 and 19 of the M4.

Figure 14 Lane utilisation between M4 J20 and J19 (eastbound) 8-9am five years after
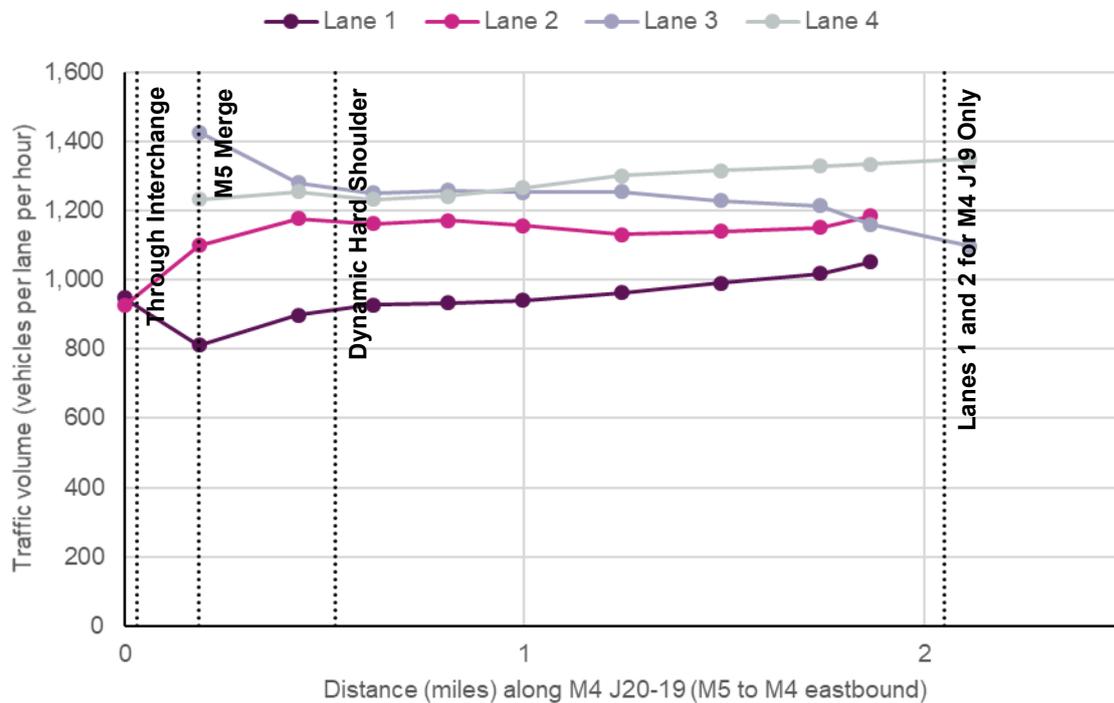
This trend was repeated in the DHS sections in the opposite direction on the M4 (westbound) and in both directions on the M5 junctions 15 to 17. Lane 1 was used most frequently by drivers on the controlled motorway section of the smart motorway connecting to the Almondsbury Interchange.

How often are speed limits set?

The smart motorway technology enables VMSLs. The charts below show how speed restrictions of 60mph or below were used over 90% of the time during the AM and PM peaks. As speed restrictions are used to smooth the flow of traffic, they were used less often during the inter-peak – typically for just an hour or two during this six-hour period.

For the M4 to M5 westbound, both the M4-M5 distributor and M5 J15-16 always had speed restrictions of 60mph or below during the AM peak five years after. 50mph restrictions were regularly in place in these locations in the AM peak.

The M5 to M4 eastbound also generally had high usage of 60mph, with the notable exception of M5 J16-15 AM peak. However, in the evening peak speed was often restricted to 50mph or less. Restrictions of 50mph and below were used more frequently during the PM peak, especially the M5 J16-15 which used 50mph speed restrictions for 81% period. Again, speed restrictions are focused on roads near the interchange. In contrast, the mainline M4 J20-19 used 50mph and below over half the time during the AM and PM peaks.

These findings fit with those shown above where journey times were shortest during the inter-peak, with journeys a few minutes longer during the AM and PM peaks. This corresponds to the times when speed restrictions are used most. Traffic volume was lowest during the inter-peak, so the demand for speed restrictions to ensure the traffic flows smoothly was less.

This data also aligns with average speed data. Average speed was lowest in the AM peak and highest in the inter-peak, matching the times when speed restrictions were used. In addition, the minimum average speed was recorded closest to the Almondsbury Interchange, where speed restrictions were most often applied. The increased usage of speed restrictions during the PM peak for M5 to M4 (eastbound) is explained by this direction having a more prominent evening peak than morning in comparison with the M4 to M5 (westbound) which had a steeper morning peak.

Speed restrictions should be used to maintain a smooth flowing network. The data suggests speed restrictions were being used predominately near the interchange and when traffic volumes were highest – this will be when the road is running closest to maximum capacity.

Figure 15 Usage of 60mph VMSL (or below) for M4 to M5 (westbound) at five years after
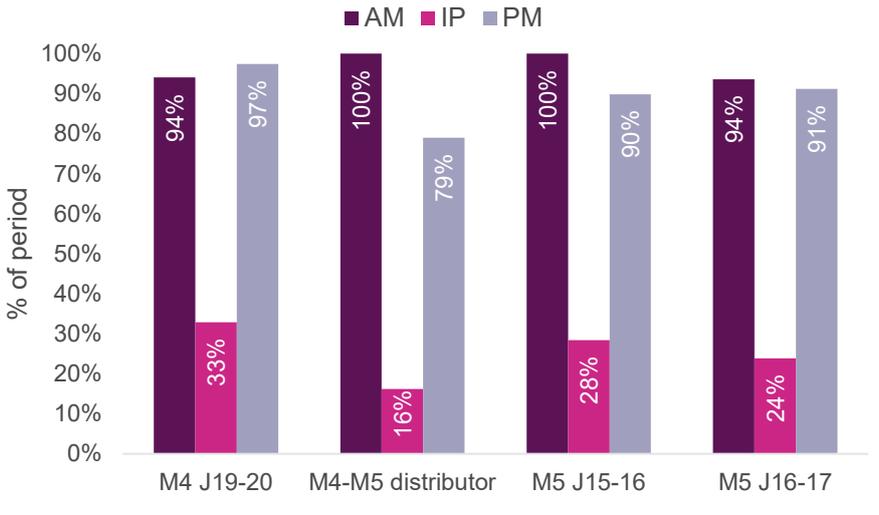
Source: National Highways MIDAS traffic data

Figure 16 Usage of 50mph VMSL (or below) for M4 to M5 (westbound) at five years after
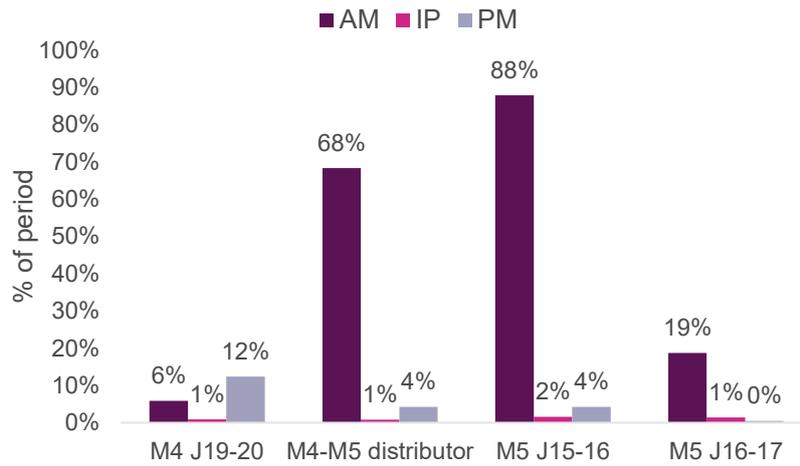
Source: National Highways MIDAS traffic data

Figure 17 Usage of 60mph VMSL (or below) for M5 to M4 (eastbound) route at five years after
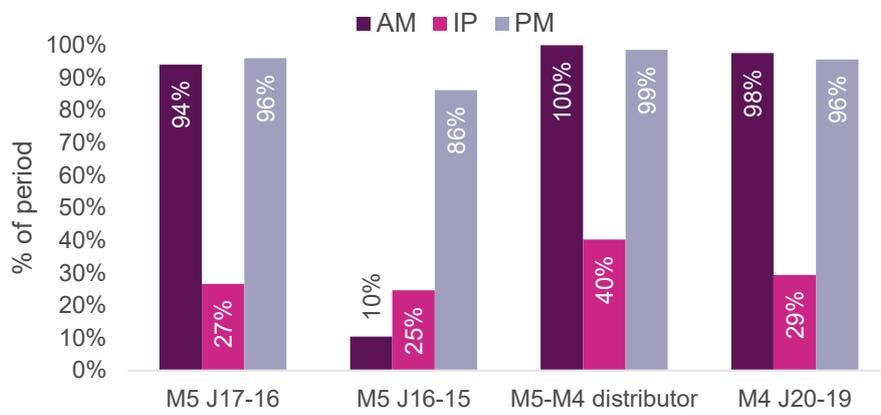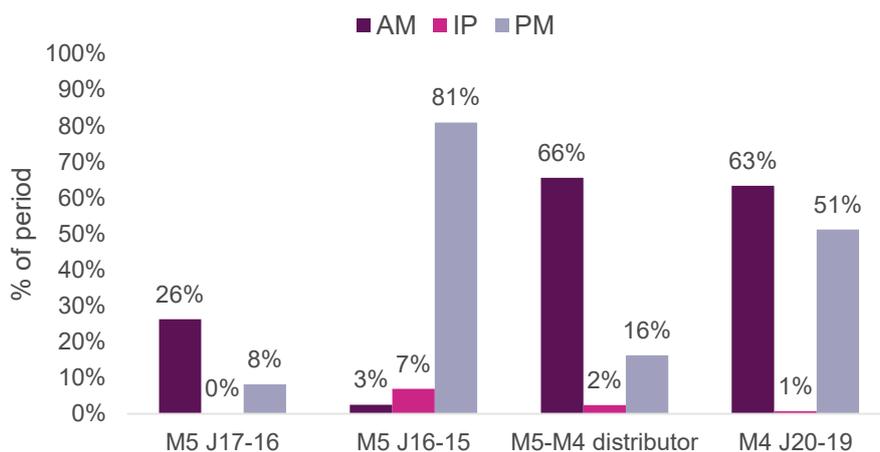

Source: National Highways MIDAS traffic data

Figure 18 Usage of 50mph VMSL (or below) for M5 to M4 (eastbound) at five years after

Source: National Highways MIDAS traffic data

5. Safety evaluation

Summary

The projects safety objective was to reduce the frequency and severity of collisions per vehicle kilometre[18]. There was a reduction in the rate and number of personal injury collisions[19] on both the project extent and the surrounding network. This is based on comparing the first five years of the project being operational with the annual average for the five years before the project improvements.

There had been an annual average reduction of 19 personal injury collisions, which is in line with the appraised business case for the project. This is based on an annual average of 19 personal injury collisions after the project was operational compared with 38 before the project. If the road had not converted to dynamic hard shoulder (DHS) running, we estimate that the number of personal injury collisions would have been between 22 and 47 (refer to Figure 22).

When accounting for the increased volume of road users over this period, the annual average rate of personal injury collisions per hmvm had also improved, with a decrease of 4 personal injury collisions per hmvm. Prior to implementation of the smart motorway, there was an annual average of 9 personal injury collisions per hmvm. This decreased to 5 per hmvm after implementation. A counterfactual[20] test was undertaken and found that the collision rate would likely have been 6 collisions per hmvm had it remained as a conventional motorway.

The severity of collisions reduced since the project was operational, with an average of 18 collisions leading to slight injuries per year after the project was operational. This is a reduction of 17 collisions as 35 were observed before the project was operational. The number of serious and fatal collisions has reduced to an average of 1 per year after the project was operational compared to an average of 3 before.

The number of FWI[21] has decreased annually. Before the project there was an annual average of 4 FWI per year. After the project became operational, this has reduced to 3 FWI per year. When accounting for the increased number of road users over this period, there had been a reduction from 0.3 to 0.1 FWI per hmvm travelled.

On the surrounding network[22] there was an average reduction of 32 personal injury collisions per year (based on an annual average of 50 personal injury collisions observed after the project had opened compared with 82 before the project). If the road had not been converted to a smart motorway, we estimate that the number of personal injury collisions would be between 64 to 103.

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[18] Since the objective for this project was set the appropriate measure has converted from using kilometres to miles. This objective has been assessed as the reduction of collisions per hundred million vehicle miles.

[19] A collision that involves at least one vehicle and results in an injury to at least one person

[20] An estimate of what would have happened if the project hadn't been implemented.

[21] The FWI weights Collisions based on their severity. A fatal collision is 1, a serious collision is 0.1 and a slight collision is 0.01. The combined measure is added up. A full number is the equivalent to a fatality.

[22] The road network is determined as part of the appraisal process to understand changes to road safety on the project extent and roads which the project may have an impact.

The evaluation found there has been a reduction in the number, and rate of personal injury collisions. The five-year evaluation concludes that the objective has been met[23].

Safety study area

The safety study area, shown in Figure 19 was defined as the project extent on the M4 between junctions 19 to 20 and M5 junctions 15-17, and a wider area including adjacent roads on the strategic road network. This area has been considered to allow us to determine the impacts on safety that the project has had on both the project extent and the wider area.

Figure 19 Safety study area
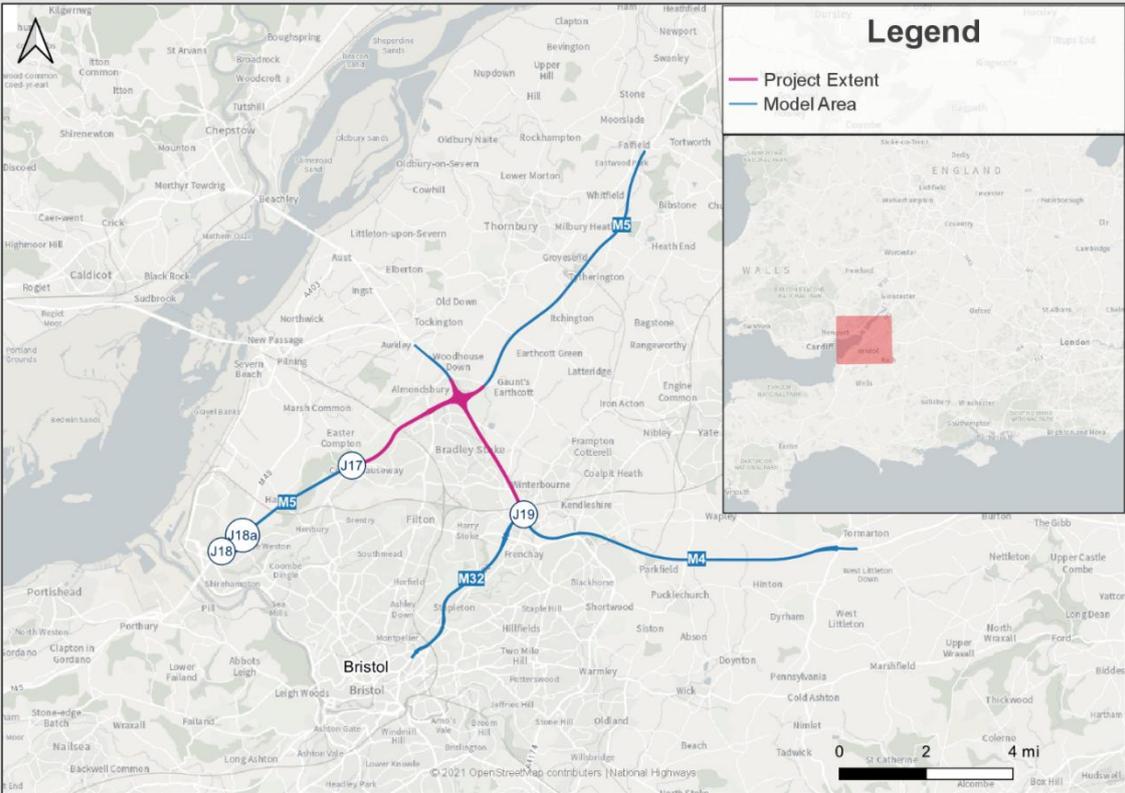
Source: National Highways and OpenStreetMap contributors

Road user safety on the project extent

What impact did the project have on road user safety?

Safety data was obtained from the Department for Transport road safety data[24]. This records incidents on public roads that are reported to the police. This evaluation considers only collisions that resulted in personal injury via this dataset.

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[23] Projects are appraised over a 60-year period. This conclusion is based on the findings at five years after the project opened for traffic
[24] https://data.gov.uk/dataset/cb7ae6f0-4be6-4935-9277-47e5ce24a11f/road-safety-data

The safety analysis was undertaken to assess changes over time looking at the trends in the five years before the project was operational to provide an annual average. We have then assessed the trends five years after.

The analysis draws on the following data collection periods:

- Pre-construction: 1 January 2007 to 31 December 2011
- Construction: 1 January 2012 to 29 January 2014
- Post-opening: 30 January 2014 to 29 January 2019

The evaluation found the number of personal injury collisions on the project extent[25], had decreased. Over the five years after the project was operational, there were an average of 19 personal injury collisions per year, 18 fewer than the average 35 per year over the five years before the project was constructed.

Figure 20 Annual Personal Injury Collisions
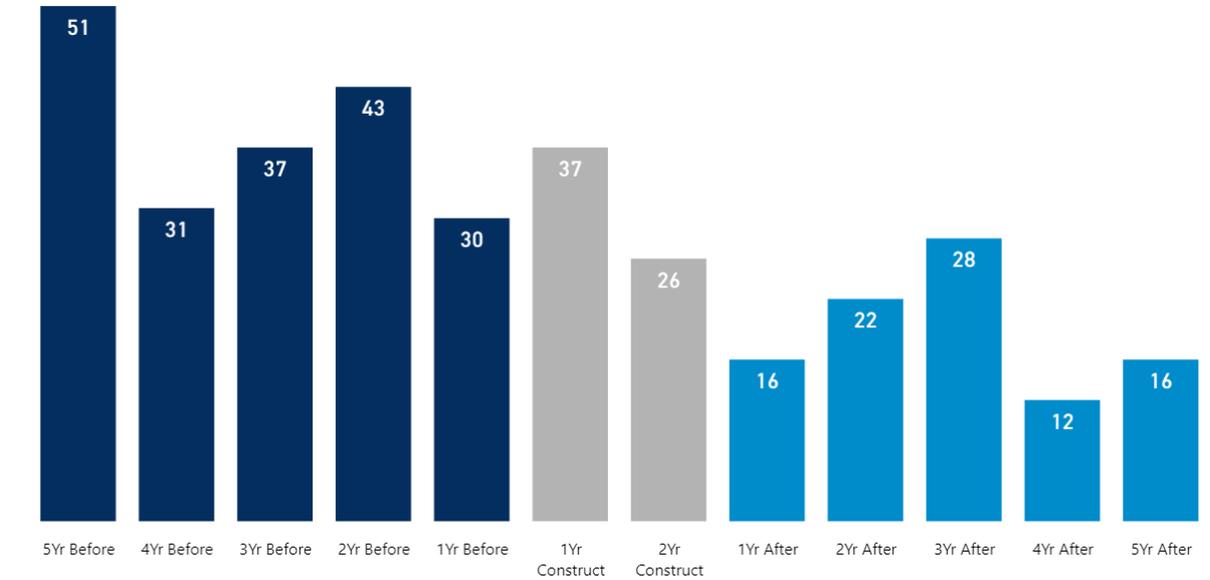
Source: STATS19: 1st January 2007 to 29th January 2019

As part of the safety evaluation, we look to assess what changes in personal injury collisions might have occurred due to factors external to the project over this timeframe. To do this we estimate the trend in personal injury collisions which might have occurred if the road had remained a conventional motorway (this is referred to as a counterfactual - see Appendix 7.B.1). This is based on changes in regional safety trends for conventional motorways with a high volume of roads users.

Based on this assessment we estimate that if the road had not been converted to a smart motorway, the trend in the number of personal injury collisions would likely have increased, and collision rates would remain stable as shown in Figure 22 below.

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[25] impacts on the wider area are discussed later in section 5.4

Figure 21- What does the Counterfactual show?

The Counterfactual is an estimation to what we think would have occurred without the scheme taking place. We estimate a range of collisions that follow regional trends.

The chart shows:
1. Annual average number of collisions from before the project
2. Annual average number of collisions after the project
3. Estimated counterfactual range

If the number of collisions after the project fall within the range, it is likely that the project has had no significant impact on safety. If the project falls outside the range it is likely the project has had a significant impact on safety.

| Outside Counterfactual Range | Before Collisions | Counterfactual Range | After Collisions |

Without the project, a range of between 22 and 47 personal injury collisions[26] during the five-year post project period would be expected, as shown in Figure 22.

Figure 22 - Observed and expected range of personal injury collisions (annual average)
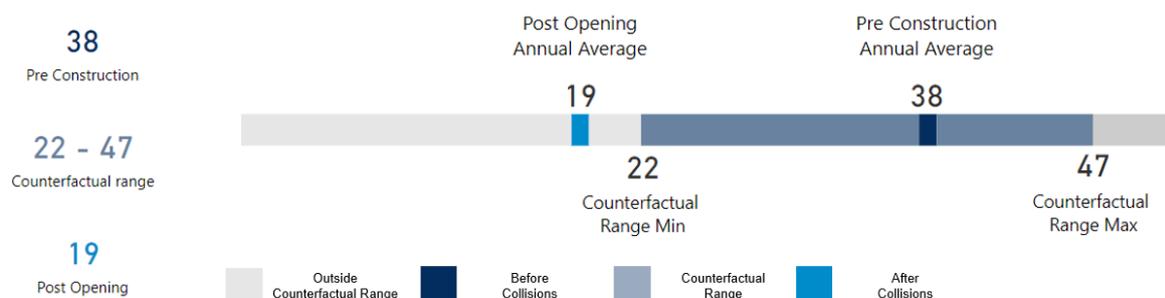
Source: STATS19: 1st January 2007 to 29th January 2019

An annual average of 19 personal injury collisions were observed over the five-year post-opening period, this falls below the expected range. Therefore, the observed changes are significant, which means the decline in personal injury collisions could be attributed to the project.

How has traffic flow impacted collision rates?

Smart motorways are implemented on some of England's busiest routes. It is therefore important to contextualise collisions against the volume of traffic using this stretch of road. To do this we calculated a collision rate, the number of collisions per annual hundred million vehicle miles (hmvm), and we identified a decrease in the rate of collisions per hmvm.

Prior to the project, there was an annual average of 10 personal injury collisions per hmvm. After the project improvements were made there was a decrease to 5 per hmvm, a decrease of 5 personal injury collisions per hmvm.

The distance travelled before a personal injury collision occurred increased from 10 to 22 million vehicle miles per personal injury collision.

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[26] The safety methodology is different from one year to five-year evaluation. We still have confidence in the accuracy of the previous methodology but have made suitable changes that will ensure a methodology fit for purpose for the future.

A counterfactual test was undertaken. It found that the collision rate would likely have been 6 collisions per hmvm in the counterfactual scenario. Statistical testing indicates this reduction could be due to the project.

What impact did the project have on the severity of collisions?

Collisions which result in injury are recorded by severity as either fatal, severe or slight. During 2016, there was a transition in how severity of incidents were recorded (more information on this can be found in Appendix7.B.2).

The evaluation found, after the project there was an average of 17 fewer collisions resulting in slight injuries per year (the annual average before the project was 35, compared to 18 after), and serious incidents have also decreased (as the annual average before the project was 2, compared to 1 after). There was also a reduction of fatal incidents (with a total of 2 in the 5 years before the project, and 1 in the 5 years after). Figure 23 shows the severity of personal injury collisions.

Figure 23 - Severity of personal injury collisions within the project extent
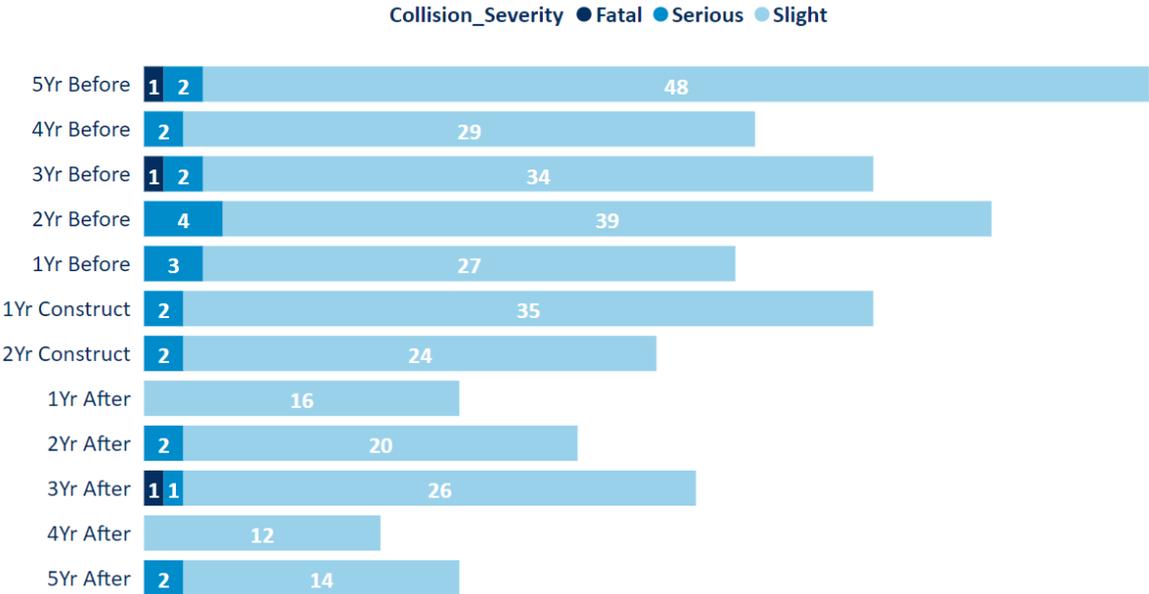
Source: STATS19: 1st January 2007 to 29th January 2019

How has traffic flow impacted casualty severity?

Like other transport authorities across the UK the key measure we use to assess the safety of roads, is Fatal Weighted Injuries (FWI). This gives a fatality 10 times the weight of a serious casualty, and a serious casualty 10 times the weight of a slight casualty[27]. In effect, it takes all non-fatal injuries and adds them up using a weighting factor to give a total number of fatality equivalents. This is represented by an annual average and a rate that standardises casualty severities against flow to show the likelihood of a fatality equivalent occurring per distance travelled.

A reduction of 0.7 fatality equivalents has been observed. Before the project the average 1.3 fatality equivalents was observed. After the project this had reduced to 0.6

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[27] The FWI metric weights collisions based on their severity. A fatal collision is 1, a serious collision is 0.1 and a slight collision is 0.01. So 10 serious collisions, or 100 slight collisions are taken as being statistically equivalent to one fatality.

The combined measure showed an extra 394 million vehicle miles was travelled before a fatality. Before the project, 294 million vehicle miles was needed to be travelled before a fatality (0.3 fatalities per hmvm[28]). After the project this increased to 688 million vehicle miles (0.1 fatalities per hmvm).

This indicates that we are observing a reduction in the severity of injuries occurring after the project was completed.

Road user safety on the wider area

What impact did the project have on safety for the wider area?

Personal injury collisions were observed for a wider impact area, which is derived from the safety appraisal for the project as shown in Figure 19.

Before the project an annual average of 82 collisions were observed in the wider area. After the project, this had fallen to 50, a reduction of 32.

The counterfactual analysis indicated that it is likely that an annual average of between 64 and 103 personal injury collisions would have occurred. The observed annual average of 50 personal injury collisions falls below the range, therefore we can be confident that the observed reduction is significant and is likely due to the project.

What impact did the project have on the severity of collisions in wider area?

Collision severity analysis was undertaken for the local and wider area using the same method as for the project extent.

In the wider area, collisions resulting in slight injury had reduced by 27 personal injury collisions per year (from 72 to 45), for fatal or serious injury collisions there had been a reduction of five personal injury collisions per year (from 10 to 5).

How has traffic flow impacted casualty severity in the wider area?

To understand the impact of the increased traffic flow on collision severity, the measure we use is fatality weighted injuries[29] (FWI).

A reduction of 1 fatality equivalents has been observed. Before the project the average 4 fatality equivalents were observed. After the project this had reduced to 3.

The combined measure showed an extra 93 million vehicle miles was travelled before a fatality. Before the project, 192 million vehicle miles needed to be travelled before a fatality (0.5 fatalities per hmvm). After the project this increased to 285 million vehicle miles (0.4 fatalities per hmvm).

This indicates that we are observing a reduction in the severity of injuries occurring after the project was completed.

Is the project on track to achieve its safety objective?

The appraisal for the project estimated that there would be a reduction of collisions of 15% on the M4 and 26% on the M5 The observed reduction in personal injury

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[28] Hundred Million Vehicle Miles
[29] See section 5.3.4 for explanation of the FWI

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collisions has outperformed expectations. We have observed a 34% reduction of personal injury collisions on the M4 and a 55% reduction on the M5.

The projects safety objective was to reduce the frequency and rate of collisions. The evaluation found personal injury collisions and rates have both decreased. The counterfactual indicated the reduction was lower than what would be expected had the road remained a conventional motorway. The five-year evaluation concludes that the objective has been met[30].

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[30] Projects are appraised over a 60-year period. This conclusion is based on the findings at five years after the project opened for traffic

6.   Environmental evaluation

Summary

The evaluation of environmental impacts used information on the predicted impacts gathered from the environmental appraisal and the environmental assessment report which informed the investment decision. Information from the one-year after evaluation was also used. This information was then compared with findings observed five years after the project opened for traffic. Observed impacts were determined during a site visit in June 2019 and supported by desktop research. The results of the evaluation are recorded against each of the appraisal environmental sub-objectives.

The water environment was scoped out of the evaluation at five-years after. This was because no new drainage assets were required by the project and there were no outstanding issues following the one-year after report. The three society sub-objectives of physical activity, severance and journey quality were also scoped out as there were no outstanding issues following the one-year after evaluation and no new information to inform any further evaluation. A summary comparing appraisal forecast against outcome is presented in Table 2.

Our five-years after evaluation confirmed many of the findings reported at one-year after. The impacts of the project on the sub-objectives were mostly restricted to within the highway boundary and were either neutral or slight adverse, as expected by the assessment.

At five-years after, two-way traffic flows were between 13% and 29% lower than predicted and so it was anticipated that impacts on air quality and noise along the project extent were better than expected. Similarly for greenhouse gases, but the absence of the required traffic data prevented us from quantifying the impact or understanding what influence speeds or numbers of HGVs may have had on our conclusion.

The predicted slight adverse impacts on landscape and townscape were observed to be as expected. Impacts on biodiversity and the heritage of historic resources were observed to be worse than expected. For biodiversity this was due to the absence of evidence on the measures taken to offset adverse impacts and to maintain habitat linkages that had been recommended in the environmental assessment. For heritage this was because the historic survey report recording the historic value of the locally listed Pegwell footbridge was not available and so the benefits from the knowledge contained could not be shared.

Noise

The pre-construction environmental assessment considered the impacts of the project on noise environment and included modelling to determine what changes would occur. This included at individual residential properties and other sensitive receptors[31]. The assessment predicted that on the opening of the project there would be no locations where residential properties or other sensitive receptors

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[31] Other sensitive receptors includes locations such as schools, footpaths and parklands.

would experience changes in noise greater than 1db(A)[32]. Changes less than 1db(A) were not considered to be perceptible and so the assessment concluded that the impacts would be neutral. By the design year (15 years after opening) noise was predicted to have reduced due to a predicted decrease in the proportion of heavy goods vehicles. However, this would happen irrespective of the project. As the opening year impacts were predicted to be neutral no additional mitigation measures were proposed.

To evaluate noise impacts at five-years after opening, we compared the traffic data used in the original environmental assessment against the available observed traffic data. We then determined if the change in data would be likely to change the outcome of the assessment. We did not do any noise monitoring but, as part of our normal site visit, we did consider the condition of any noise mitigation provided.

The one-year after evaluation reported that the observed traffic flows were (annual average weekday traffic AAWT), on average, 18% lower than the forecast flows used in the environmental assessment. It concluded that, whilst lower than forecast, they were not low enough[33] to change the predicted outcome. At five-years we repeated this exercise and identified that observed two-way traffic flows were between 13% and 29% lower than those forecast. Our site visit also identified that, although no new mitigation had originally been proposed, a new noise barrier was built by the project alongside the M5 near Falcon Close[34]. This was expected to provide additional noise benefits to nearby properties.

Overall, we concluded that noise impacts were better than expected. This was because observed traffic flows were more than 20% lower than forecast[35] for most of the project length and that a new noise barrier had been provided when one had not been originally proposed.

Air Quality

The pre-construction Environmental Assessment presented an overview of the air quality in the project study area and modelled the predicted impacts caused by changes in traffic when the project opened. The assessment highlighted that there were two air quality management areas (AQMA)[36] relevant to the project. One was adjacent to M5 at junction 17 and the other was in the wider study area and covered parts of the city of Bristol. The air quality assessment predicted that both with and without the project there would be no exceedances of the air quality standards in the opening year along the M4/M5 project extent. It also predicted that within the Bristol wider study area, the project would reduce the number of locations exceeding the air quality standards. Overall, the assessment predicted that the air quality impacts of the project would be neutral along the M4/M5 project extent and beneficial in the wider Bristol City area.

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[32] db(A) This refers to A weighted decibels which is a measurement of noise typically used in noise assessment.
[33] The POPE methodology requires flows of more than 20% lower to result in a better than expected outcome.
[34] Image from google street view July 2019
[35] The POPE methodology requires flows of more than 20% lower to result in a better than expected outcome.
[36] Air Quality Management Areas are locations a local authority determines that air quality is poor and where the national air quality objectives are not likely to be achieved. https://uk-air.defra.gov.uk/aqma/

To evaluate air quality impacts, we considered monitoring information from South Gloucestershire Council and Bristol City Council and also the conclusions of the one-year after evaluation. We also compared observed traffic data at five-years after against that used in the original environmental assessment to consider what changes in traffic may have had on the outcome of the assessment.

The one-year after evaluation reported that observed traffic flows were on average 18% lower than forecast. It concluded that air quality impacts were better than expected.

At five years after we reviewed the annual air quality status reports for South Gloucestershire Council[37] and Bristol City Council[38].

Nitrogen dioxide (NO_2) is the principal pollutant of concern for human health. South Gloucestershire reported that concentrations of NO_2 within the Cribbs Causeway AQMA had consistently been below the annual mean objective since 2010. As a result, the AQMA was revoked in July 2020. Monitoring data from South Gloucestershire Council indicated that there had been a continual decline in NO_2 since the project opened. However, as NO_2 concentrations were below the air quality standard in 2010 prior to the start of construction of the project, we cannot directly attribute the revocation of the AQMA to the project.

The Air Quality Status Report also stated that there were no exceedances of the NO_2 annual mean objective outside of AQMAs. This included areas within 200 metres of the project extent. We had insufficient evidence to directly attribute these reductions in NO_2 to the project. However, the results do support the prediction that the project would not cause new exceedances along the project extent or lead to significant environmental effects.

The Bristol City Council 2020 Annual Quality Status Report stated that "NO_2 concentrations have demonstrated a slightly improving trend since 2010; however, exceedances of objectives for this pollutant are still measured widely in the city. 2019 NO_2 concentrations at diffusion tube sites show an improvement when compared to 2018 concentrations with improvements in all of the 85 diffusion tube monitoring locations for which both 2018 and 2019 monitoring data were available." We had insufficient evidence to attribute the improving trend reported to the beneficial impacts predicted by the project environmental assessment. However, the data did suggest that the project did not cause a significant environmental effect.

At five-years after, analysis of the forecast and observed two-way traffic data (24-hour AAWT) within the project extent indicated that observed flows were between 13% and 29% lower than forecast (between 18,400 and 53,600 vehicles). Following the criteria used by POPE, this suggested that air quality impacts were likely to be better than expected along the project extent. This was because traffic flows were lower than forecast.

Overall, based on our traffic flow analysis supported by the information in the Air quality status reports, we concluded that air quality impacts were better than expected.

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[37] 2020 Air Quality Status Report South Gloucestershire Council
[38] 2020 Air Quality Status Report Bristol City Council

Greenhouse Gases

The appraisal predicted that the project would cause an increase in greenhouse gas emissions of 1,997 tonnes in the opening year and of 275,579 tonnes over the full 60-year appraisal period. These increases were due to increases in traffic growth.

It was not possible to effectively evaluate greenhouse gas emissions of the project because to replicate the extent of the appraisal we would require forecast and observed traffic data for all the road links used in the appraisal study area. This data was not available. Instead, we normally calculate a new forecast emission and an observed emission for the extent where traffic data was available (usually just the project extent). We would then comment on the accuracy of the forecast and observed emission along this section. We were unable to calculate a new forecast emission as we didn't have the necessary traffic data for heavy goods vehicles (HGVs) nor forecast speeds to do this.

No quantification was possible. The overall traffic flows (2-way AAWT) along the project extent at five-years after were between 13% and 29% lower than forecast. This suggested that greenhouse gas emissions were likely to be lower than forecast along the project extent. However, we were unable to consider the potential impact of changes in speed and HGVs and so we don't know what effect this may have had on our conclusion.

Landscape

The environmental appraisal reported that the existing motorways run through a landscape containing both rural and urban fringe sections. The project would involve the construction of new infrastructure including gantries, message signs and emergency refuge areas. The construction of these items would cause short term landscape and visual impacts as existing trees and other vegetation along the highway would need to be cleared to make space for them. Careful siting of gantries and the minimisation of vegetation clearance would help avoid adverse effects to the landscape character. New mitigation planting would be provided but the narrow width of the highway verge meant that in places only partial mitigation would be possible. Some localised visual impacts to nearby properties would remain. Overall, the appraisal predicted that the landscape character and pattern would remain unchanged but, even after mitigation planting had matured, there would be some slight adverse visual impacts in the long term.

The one-year after evaluation confirmed the expect impacts had arisen and that mitigation was in place. However, the mitigation planting was too small at one-year after to provide any screening and the report recommended that screening and planting establishment should be reconsidered at five-year after.

Our five-years after evaluation focused on a sample of key impacts including the viewpoint locations reported in the environmental assessment. We also revisited many of the locations evaluated at one-year after stage to see how the mitigation planting was establishing.

Our site visit confirmed that the project works had been limited to within the highway boundary. Existing mature vegetation had been lost to accommodate new gantries and emergency refuge areas, but new planting was in place. Our visit identified that little maintenance appeared to have been undertaken and at the few locations where access to the highway verge was possible, trees guards remained

in place around the new planting and some dead planting was found. However, the mitigation planting overall did still appear to be establishing and should still achieve its design outcome. The construction of new gantries had opened up new views to visual receptors including residential properties, users of local footpaths and recreational areas. The gantries had also slightly increased the sense of urbanisation. This was predicted, and new planting was in place to help mitigate the impacts. We found locations where the outcomes were better than expected but also where they were worse than expected. Examples where better than expected outcomes were identified include properties along Fernhill Road. Here, the superspan gantry which was predicted to cause slight adverse impacts was found to be barely visible through the tree line. Visual impacts were likely to be worse than expected for users of the footpath west of Pegwell Bridge. Here, mitigation planting was expected to reduce the visual impacts of the new gantry to slight adverse. However, our site visit confirmed the findings at one-year after in that the planting was unlikely to achieve this by the design year.

Figure 24 Views from Fernhill Road towards M4. Gantry barely visible through the tree line

Source: Site visit 2019

Figure 25 Views from footpath beside Pegwell bridge towards M5. New gantry and signage clearly visible. Some mitigation planting in place but unlikely to screen views

Source: Site visit 2019

Whilst there were better than expected outcomes at some locations, there were worse than expected outcomes too. Overall, on balance the outcome was likely to be as expected by the design year.

Townscape

The appraisal reported that the project works were all within the highway boundary and would not directly affect adjacent urban areas. However, it predicted that new gantries and message signs would be visible from some adjacent urban areas and in these locations their scale and appearance would not quite fit the scale and appearance of the townscape. The urban townscapes adversely affected were reported to be of low value comprising commonplace residential, commercial and retail developments. Visual impacts and impacts on townscape character were predicted to be difficult to mitigate due to the limited space within the motorway corridor to accommodate any planting. Overall, the appraisal predicted slight adverse impacts.

The one-year after evaluation confirmed that the project had introduced new infrastructure and that habitats along the verge had been lost to accommodate it. It highlighted that in locations where the motorways were in cuttings or where vegetation was retained, there were limited effects on adjacent townscape but in more open and rural areas the new infrastructure was more visible, and the motorway had become a more prominent feature.

At five-years after our site visit confirmed that the one-year after findings remains. The townscape adjacent to the M4 and M5 was largely unaffected as sections of the road were in a cutting and much of the existing vegetation retained. This limits new views and new impacts on much of the adjacent townscape.

Figure 26 View east from Trench lane overbridge. Urban areas of Bradley Stoke to south screened by retained trees along the boundary. Open views towards rural areas to north east.

Source: site visit 2019

However new infrastructure had impacted on low value townscape around Cribbs Causeway retail area particularly where narrow verges limit scope for mitigation.

Figure 27 View west towards the M5 at Cribbs Causeway. Narrow verges had prevented the planting of significant planting to screen views from the retail area.

Source: Site visit 2019

Overall, this had limited impacts on townscape. At five-years after townscape was as expected and likely to remain so by the design year.

Heritage of Historic Resources

The appraisal reported that there were listed buildings and a prehistoric enclosure adjacent to the project. There were predicted to be neutral impacts on the immediate settings of the listed buildings and scheduled monuments. It predicted that the view from and general appreciation of one listed building would be marginally compromised. The environmental assessment noted that Pegwell footbridge, which was a locally listed historic structure, would be demolished but its loss would be mitigated by a historic building record survey. Overall, the impact on heritage and historic resource would be neutral.

The appraisal did not record which listed building would have its view and general appreciation marginally compromised. At one-year after it was assumed that this was a reference to one of the listed buildings close to the M5 at Hollywood Towers and St Swithins Farm. The one-year after considered that intervening vegetation would block views towards the M5 and the new gantry and so impacts were considered to be as expected.

At five-years after we revisited the two listed buildings but no access to St Swithins was possible. We did access Hollywood Towers which confirmed the conclusions of the one-year after evaluation in that the superspan gantry was not visible through the trees. It may be visible from the top of the Tower, but this was not accessed. Views from the Tower were likely to be dominated by view across Cribbs Causeway and the gantry was unlikely to have had an appreciable additional adverse effect. The proposed historic survey of the Pegwell bridge is understood to have been done but the report was not available for the evaluation. This meant that the knowledge and understanding of this asset was not accessible and could not be shared with the wider community. Overall because the building survey of Pegwell bridge was not available, the impacts were worse than expected at five-years after.

Biodiversity

The environmental appraisal and assessment reported that there were no predicted effects on statutory or non-statutory sites and only low value roadside habitats would be affected. A small area of habitat along the verge (approx. 2% of the verge) would be permanently lost to accommodate the new gantries and emergency refuge areas and this may affect habitat connectivity along the route. However, mitigation measures would be implemented during construction to minimise impacts on species such as reptiles and great crested newts caused by the habitat loss. A grassland management plan would be implemented to minimise impacts on habitats including within Almondsbury Interchange. New planting would also be designed to ensure opportunities for creating suitable habitats and connectivity were fully realised. Overall the impacts to biodiversity by the design year were anticipated to be slight adverse.

The one-year after evaluation found that no information was available to confirm the total area of habitat lost. No information was available either to confirm what the planned maintenance regimes was and so recommended that biodiversity was reconsidered at five-years after.

At five-years after we undertook a site visit to evaluate the biodiversity impacts of the project. However due to limited access to the soft estate, observations were restricted to those that could be made from the car whilst driving along the project, from overbridges along the project and at one location on the soft estate near the Old Gloucester Road where access was possible.

Our site visit confirmed that the observed impacts had occurred broadly as predicted. However, not all the proposed mitigation had been undertaken. As these mitigations were designed to minimise the adverse effects of these impacts, the outcome was worse than expected at five-years after.

The overall effects on biodiversity were predicted to be slight adverse. However, the project did not produce a handover environmental management plan setting out long term maintenance arrangements nor was there any record of the proposed grassland management plan.

Figure 28 Dead planting within planting plot adjacent to Old Gloucester Road and plot overgrown with brambles at Trench lane.

Source: Site visit June 2019

No documentary evidence had been found to suggest active grassland management around Almondsbury Interchange had taken place and the site visit saw no evidence either. Trees guards were found still in place along the project suggesting maintenance was limited to swathe cuts behind barriers and visibility splays around signs. There was no evidence that steps had been taken, as proposed in the assessment, to offset some of the impacts of habitat loss. There was also no evidence that landscape planting proposals had been maintained as proposed to ensure opportunities were created to ensure suitable habitats and linkages were being fully realised.

Overview

The results of the evaluation are summarised against each of the Transport Appraisal Guidance (TAG)[39] environmental sub-objectives and presented in Table 2Table 2. In the table we report the evaluation as expected if we believe that the observed impacts at five years after were as predicted in the appraisal. We report them as better or worse than expected if we feel the observed impacts were better or worse than expected.

Table 2 Environmental Impacts – M5 Junction 15-17 & M4 junction 19-20

Sub Objective	Appraisal Score	Five-year Evaluation	Summary
Noise	People annoyed: Do Min 1010, Do	Better than expected	Two-way traffic flows were between 13% and 29% lower than forecast. Overall it was

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[39] TAG provides guidance on appraising transport options against the Government's objective for transport.

	Something 1010. Net population win/lose (yr 15) = 0		likely that noise impacts were lower than expected along most of the project extent.
Air Quality	NO$_2$ Properties with improvement 3183, Deterioration 520, No change 4816.	Better than expected	Observed 2-way traffic flows were between 13% and 29% lower than forecast. Monitoring data from Bristol and South Gloucestershire Councils suggested the project did not cause any significant adverse effects.
Greenhouse Gases	Increase in greenhouse gas emissions. 275,579 over 60-years	-	Observed 2-way flows were lower than forecast which may suggest lower than predicted carbon emissions along project footprint. We had insufficient data to quantify the change or consider the potential impact of changes in HGVs or speeds.
Landscape	Slight adverse	As expected	The project had further urbanised the corridor through the introduction of new gantries and vertical features. The narrow verges had limited scope to mitigate the impacts. An evaluation of viewpoint comparisons observed both slight adverse and neutral effects which were broadly consistent with the effects predicted.
Townscape	Slight adverse	As expected	The townscape adjacent to the project was largely unaffected. Sections of the road were in a cutting limiting new views and new impacts. Where appreciable impacts had occurred, it was to low value commercial and retail townscapes at Cribbs Causeway.
Heritage of historic resource	Neutral	Worse than expected	Impacts to listed buildings were broadly as expected. However, the mitigation for the demolition of the locally listed Pegwell bridge (historic survey report) along with the knowledge and understanding of this asset was not made available.
Biodiversity	Slight adverse	Worse than expected	The observed impacts occurred broadly as predicted but as not all the proposed mitigation was undertaken including works to maintain habitat linkages, the outcome is worse than expected at five-years after.

7.   Value for money

Summary

As part of the business case, an economic appraisal was conducted to determine the project's value for money. This assessment was based on an estimation of costs and benefits over a 60-year period.

The project was delivered at a cost of £92million, close to the forecast cost[40]. In the first five years, the road provided additional capacity to support more road users (an increase of around 11%), whilst improving the safety of those journeys. If this trend continues, the project is reforecast to deliver £56million of safety benefits over the 60-year period[41]. There are also likely to be journey time reliability benefits.

Overall the evaluation indicated that in the first five years this investment was not on track to deliver the value for money anticipated over the 60 year life of the project. If the journey time trends observed within the first five years continue, the project is expected to deliver 'poor' value for money[42].

Forecast value for money

An economic assessment is undertaken prior to construction to determine a project's value for money and inform the business case. The assessment is based on an estimation of costs and benefits. The impacts of project such as journey time savings, changes to user costs, safety impacts and some environmental impacts are able to be monetised. This is undertaken using standard values which are consistent across government. The positive and negative impacts over the life of the project[43] are summed together and compared against the investment cost to produce a benefit cost ratio (BCR). The monetised impacts are considered alongside additional impacts which are not able to be monetised, to allocate the project a 'value for money' category.

The monetised benefits forecast by the appraisal which supported M4 junctions 19 to 20 and M5 junctions 15 to 17 smart motorway business case are set out in Table 3. We have also included an indication of what proportion of the monetised benefits each impact accounted for and a summary of how we have treated the monetisation of each impact in this evaluation.

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[40] Present value of costs in 2010 prices and values.
[41] Based on impacts on the Strategic Road Network.
[42] The value for money categories referenced are defined by the Department for Transport https://www.gov.uk/government/publications/dft-value-for-money-framework
[43] Typically project life is taken to be 60 years.

Table 3 - Monetised benefits of the project (£ million)

	Forecast (£M)	% forecast monetised benefits[44]	Evaluation approach
Journey times	943	81%	Re-forecast for the project area only (not the wider area) using observed and counterfactual[45] traffic flow and journey time data
Vehicle operating costs	-36	-3%	Re-forecast using observed and forecast traffic flow and journey time data
Journey time & VOC during construction & maintenance	-48	-4%	Not evaluated (assumed as forecast)
Journey time reliability	210	18%	Monetised benefits assumed as forecast
Safety	53	5%	Re-forecast using observed and counterfactual[46] safety data
Carbon	-19	-2%	Monetised benefits assumed as forecast
Noise	0	0%	Monetised benefits assumed as forecast
Indirect tax revenues	59	5%	Re-forecast using observed and forecast traffic flow and journey time data
Total present value benefits	**1162**		

Note: 2010 prices discounted to 2010. Due to rounding the numbers and percentages may not always add up exactly to the presented totals.

The costs anticipated in the appraisal are set out in Table 4. Based on this information, the project was anticipated to give 'very high' value for money over the 60-year appraisal period.

Evaluation of costs

The project was delivered at a cost of £92 million[47], very close to the anticipated cost of £90 million (see Table 4).

The appraisal expected that the project would result in an increase in maintenance costs over the life of the project. As the vast majority of this maintenance is still in the future, the evaluation uses the maintenance costs forecast within the business case.

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[44] Disbenefits are presented as negative numbers and percentages. The total of the positive and negative contributions total to 100%

[45] We calculated the vehicle hours saved by comparing outturn journey times with an estimate of how journey times would have continued to deteriorate had the project not been implemented (ie a 'counterfactual').

[46] We compared observed trends with an estimation of the trends if the road had remained a conventional motorway (ie a 'counterfactual')

[47] This is the PVC (present value cost) of the project. This means it is presented in 2010 prices, discounted to 2010 to be comparable with the other monetary values presented.

Table 4 - Cost of the project (£ million)

	Forecast (£M)	% of forecast costs	Evaluation approach
Construction costs	90	71%	Current estimate of project cost
Maintenance costs	36	28%	Not evaluated (assumed as forecast)
Total present value costs	**127**		

Note: 2010 prices discounted to 2010. Due to rounding the numbers and percentages may not always add up exactly to the presented totals.

Evaluation of monetised benefits

Once a project has been operating for five-years, the evaluation monitors the construction costs and the trajectory of benefits to reforecast these for the 60-year project life. Once a project has been operating for five-years, the evaluation monitors the construction costs and the trajectory of benefits to reforecast these for the 60-year project life. It is not proportionate to replicate modelling undertaken at the appraisal of a project or to monitor benefits over the entire lifecycle, so we take an assessment based on the trends observed over the first five years of operation and estimate the trend over the project life, based on these observations. This provides a useful indication and help to identify opportunities for optimising benefits. In instances where it was not feasible to robustly compare forecast and observed impacts, the findings have been presented with relevant caveats.

Monetised journey time benefits

As can be seen in Table 3, journey time benefits made up the majority of the justification for investing in this smart motorway. The forecasts within the business case generally overestimated the level of traffic increase[48]. The business case was based on growth assumptions before the 2008 global economic downturn, which slowed the rate of traffic growth. So, whilst the number of road users has grown by an average of 11%, the additional capacity provided by the smart motorway is not always required to support the number of road users.

Our evaluation estimates the overall impact on vehicle hours[49], on the project section, in the fifth year, to have been negative[50]. Without the detail of the original forecasts to compare to it is difficult to draw conclusions, but given the lifetime positive monetised impact presented in the pre-construction appraisal, this is unlikely to be in line with what was anticipated. Without further intervention, journey time benefits are unlikely to on track to be realised.

This is likely to be due to a combination of reasons including:

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[48] By between 13% and 29% on the project extent (equivalent of 18,400 to 53,600 vehicles per weekday). Refer to section 4 for further details.
[49] An overall measure taking account of both changes in numbers of road users and their journey times.
[50] A disbenefit of 313,000 vehicle hours in the fifth year.

- lower than forecast levels of traffic due to the 2008 economic downturn[51] resulting in the hard shoulder being required less frequently than may have been expected. This means that the additional capacity provided by the smart motorway is not yet being fully optimised to realise the benefits to customer journeys. However, the capacity is available to support an increase in road users in the future.

- when the hard-shoulder is open, the levels of flow may not always warrant it and at therefore in some periods people may be travelling slower than they otherwise would, although still experiencing the associated safety benefits.

If the trends observed at the fifth year continue over the 60-year period, without any further action to optimise benefits, the monetised impact on journey times, for those using the road, would be -£144million[52]. This figure reflects only journey time trends observed on the project area, not the surrounding road network which would have been considered in the appraisal. The evaluation has not monitored the journey time impact on the surrounding roads and can only directly quantify a proportion of the journey time impacts[53].

Analysis of traffic flows in the wider area imply that the removal of the Severn River Crossing toll has had a significant impact on traffic patterns in the area. This makes it difficult to establish the impact of the smart motorway on the wider road network.

Other reforecast impacts

We reforecast total safety benefits to be £56 million. This figure relates to the benefit on the strategic road network over 60-years (see Figure 19). The reforecast is slightly higher than the appraisal forecast. The observed personal injury collision savings are slightly greater than those forecast in the appraisal.

There are two further impacts associated with the changes in numbers and speeds of vehicles – indirect tax revenues and vehicle operating costs. Indirect tax revenues are the benefit to the government (and therefore society) of the additional tax income from the additional fuel consumed due to increased speeds and distances travelled. This was forecast to be positive because more vehicles were forecast and they were forecast to be travelling at higher speeds, and therefore using more fuel and paying more tax. We have reforecast that the impact would be smaller than expected, an increase in tax revenues (£6 million). The impact is smaller because our evaluation has shown that there wasn't as much traffic growth as forecast and the change in speeds was mixed. Vehicle operating costs refer to the fuel and other costs borne by the user (such as the wear and tear on vehicles). This generally increases with increased distance travelled. There was a disbenefit forecast. Based off the changes we have seen in our estimate of fuel consumption and indirect tax revenue, we estimate the outturn impact to be a small disbenefit of -£4million.

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[51] The 2008 economic downturn was not anticipated within the appraisal but led to recession which stalled traffic growth between 2008 and 2011 as a consequence of impacts on fuel price and travel demand.

[52] This is against a counterfactual where we have estimated what the journey time is likely to have been if the road had remained a conventional motorway.

[53] Without detailed forecast information it is not possible to quantify what proportion of the expected impacts our observations relate to.

Impacts assumed as forecast

The evaluation has not been able to reforecast the monetary value of journey time reliability[54], noise and carbon benefits[55], and instead these were reported as forecast. For noise and carbon impacts, this assumption is conservative because lower than forecast traffic flows are likely to mean that these impacts are better than forecast[56]. However, for journey time reliability this assumption might be generous because the impact on reliability is mixed, but there was an improvement in reliability for most road users[57].

Journey times and vehicle operating costs during future construction and maintenance have been assumed as forecast. As the vast majority of this maintenance is still in the future, the evaluation uses the impacts forecast within the business case.

Overall value for money

When considering an investment's value for money we also take into account benefits which we are not able to monetise. For this project biodiversity and wider economic benefits might be relevant considerations.

- wider economic benefits might be relevant given the project's proximity to a functional urban area, but these are usually dependent on delivering journey time savings. As the journey time savings have not been realised, there are unlikely to be additional benefits in this area.
- Biodiversity was forecast to be slightly adversely impacted. Our evaluation concluded the impact was worse than forecast because not all the mitigation designed to manage the adverse impacts was implemented as expected. However, whilst the outcome was worse, we do not believe it was of a scale to significantly alter the value for money rating of the project.

With few non-monetised benefits to take into consideration, it is likely that this project has offered 'poor' value for money.

Based on the evidence from the first five years, this project is not on track to realise the anticipated value for money. However, there have been benefits delivered - construction of the project was delivered very close to budget, it is delivering safety and some journey reliability benefits to road users and many of the environmental benefits are as expected, or better.

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[54] It has not been possible to re-forecast the monetised reliability impact for this project because our evaluation method reuses the INCA files used in the appraisal and these were not able to be located for this project.
[55] We do not have a method for reforecasting the monetised impact of noise or carbon impacts. These generally have a small contribution to the monetised benefits of projects and therefore the impact of assuming as forecast is unlikely to impact on the value for money rating of the project.
[56] Refer to section 6 for further detail on noise and greenhouse gas impacts.
[57] Refer to section 4 for further detail on reliability

Appendix A.

A.1. Speed over distance

The following graphs contain the harmonic average speed over distance, for both directions and all time periods.

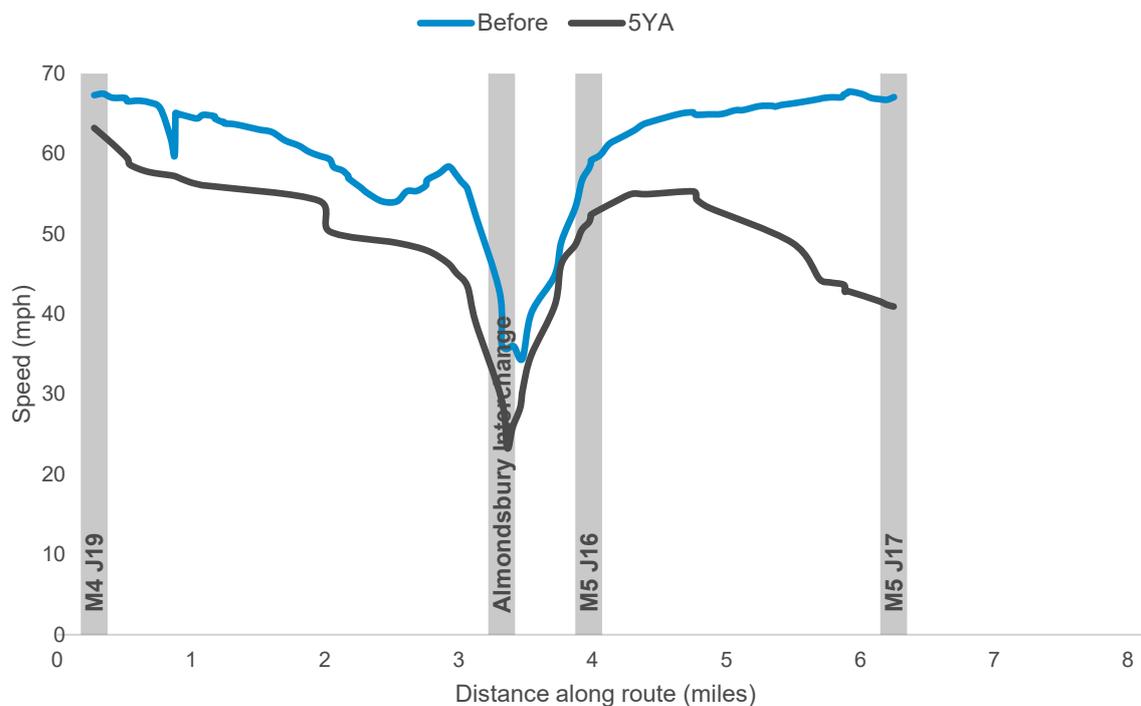**Figure 29 - M4 to M5 (westbound) speed over distance 7-8am**

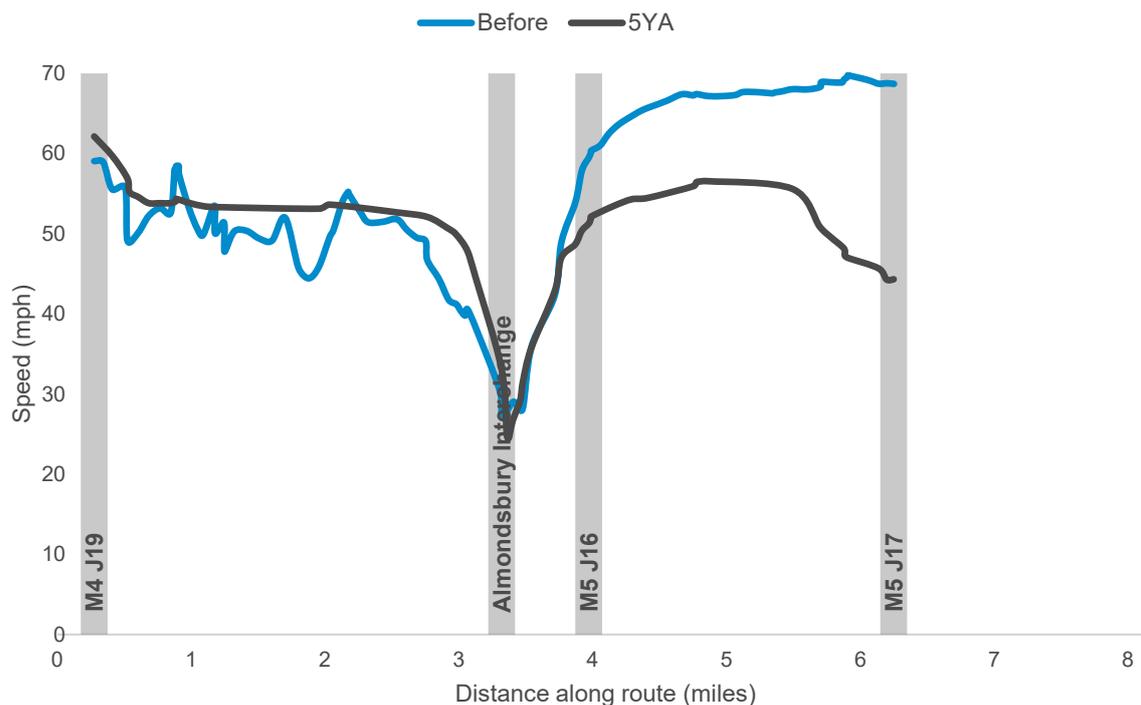**Figure 30 - M4 to M5 (westbound) speed over distance 8-9am**

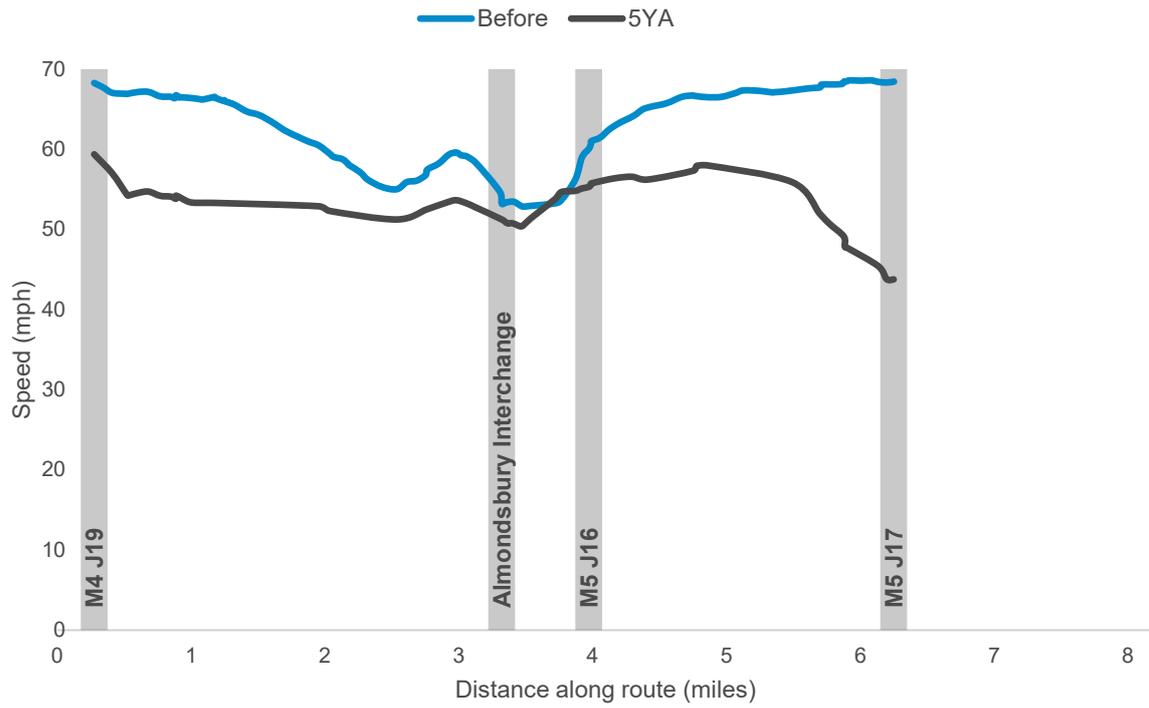**Figure 31 - M4 to M5 (westbound) speed over distance 10am-4pm**

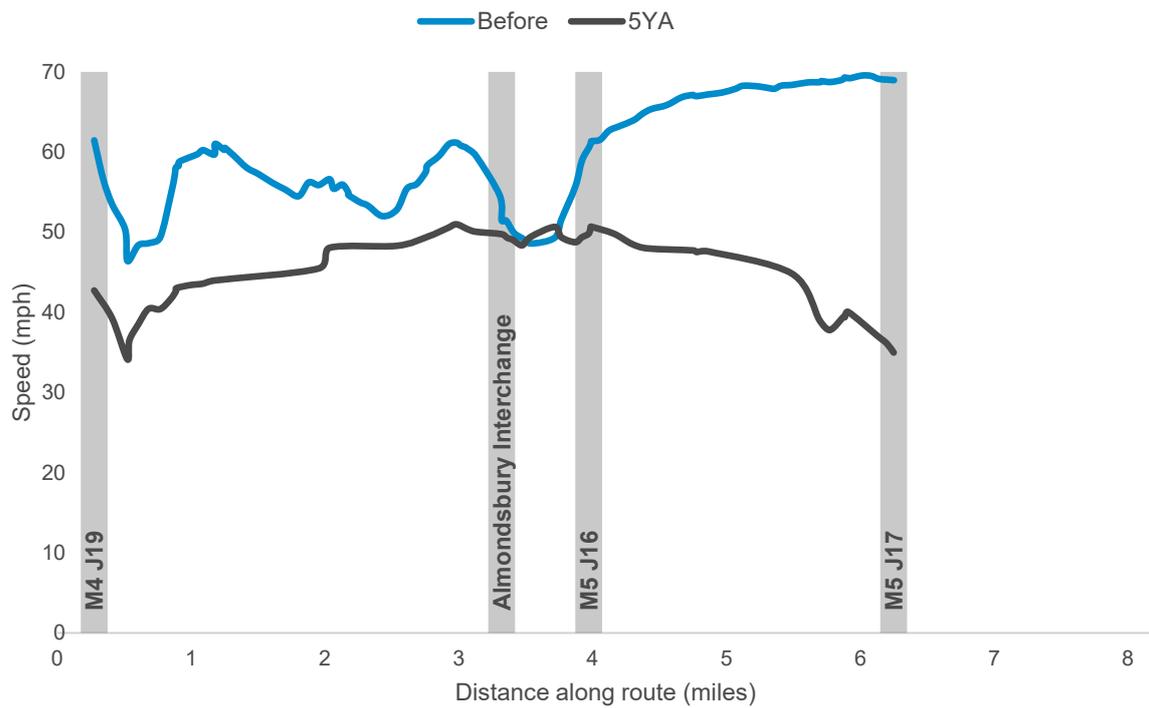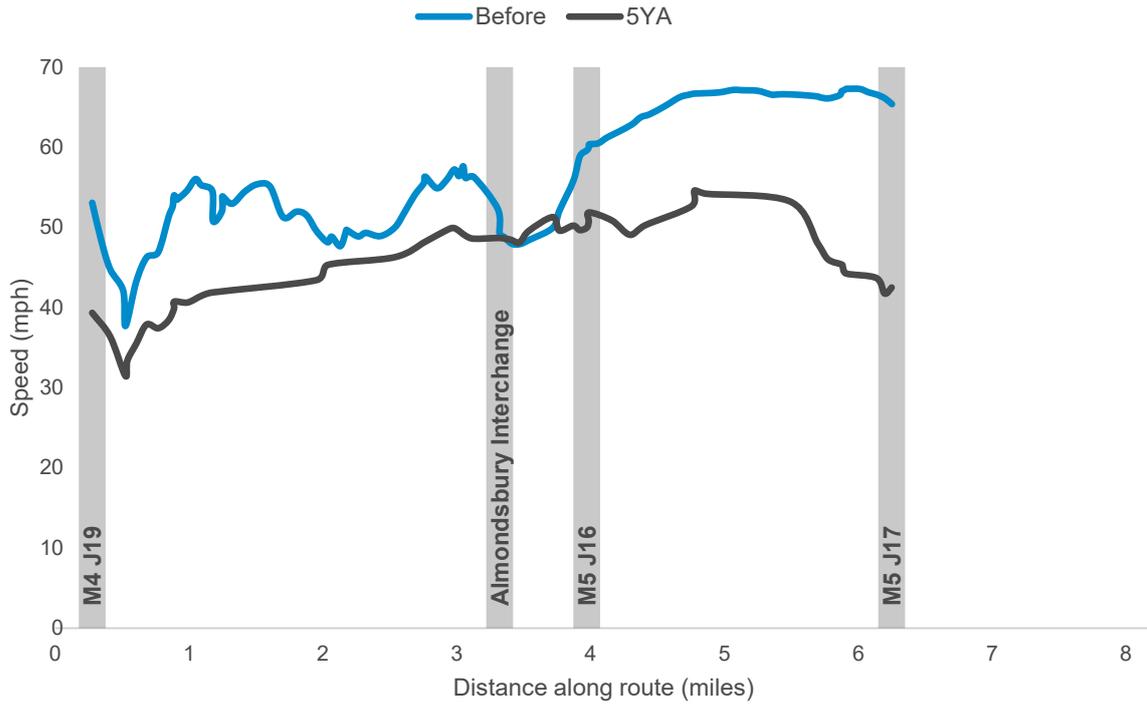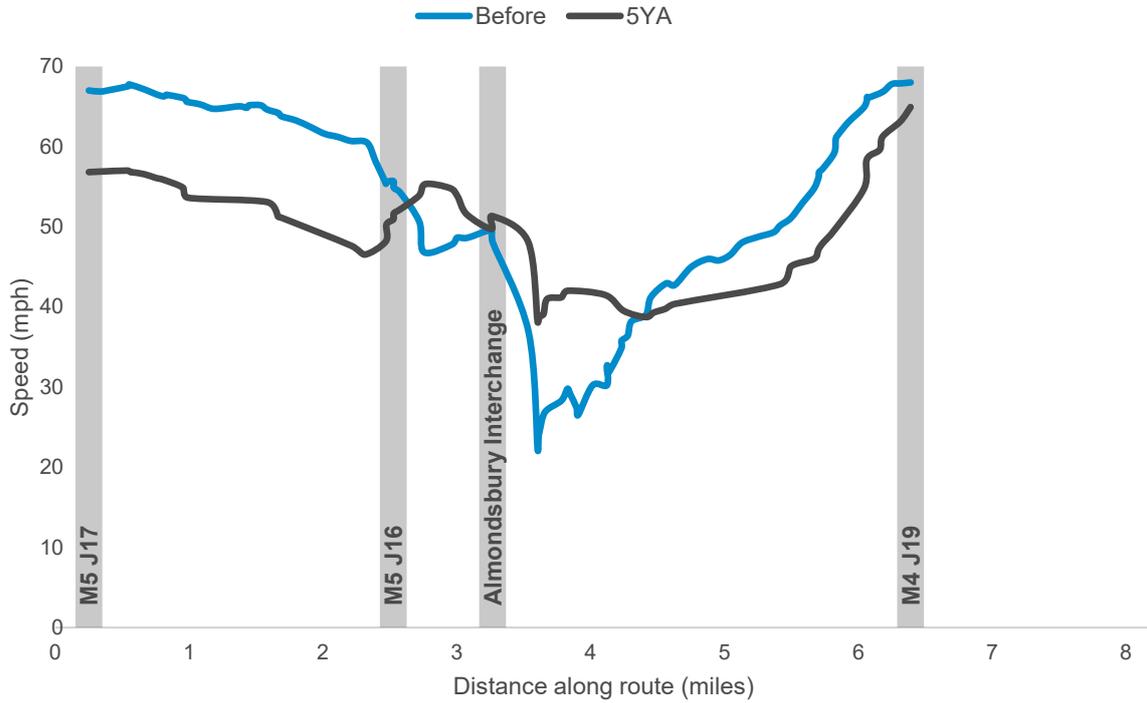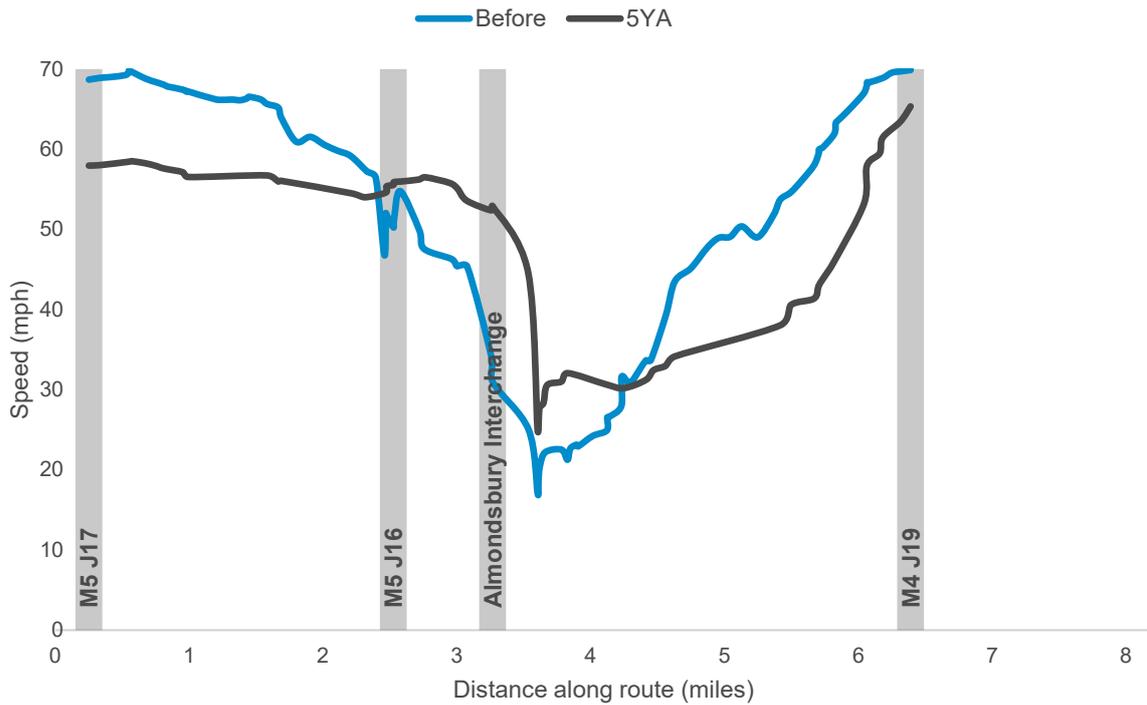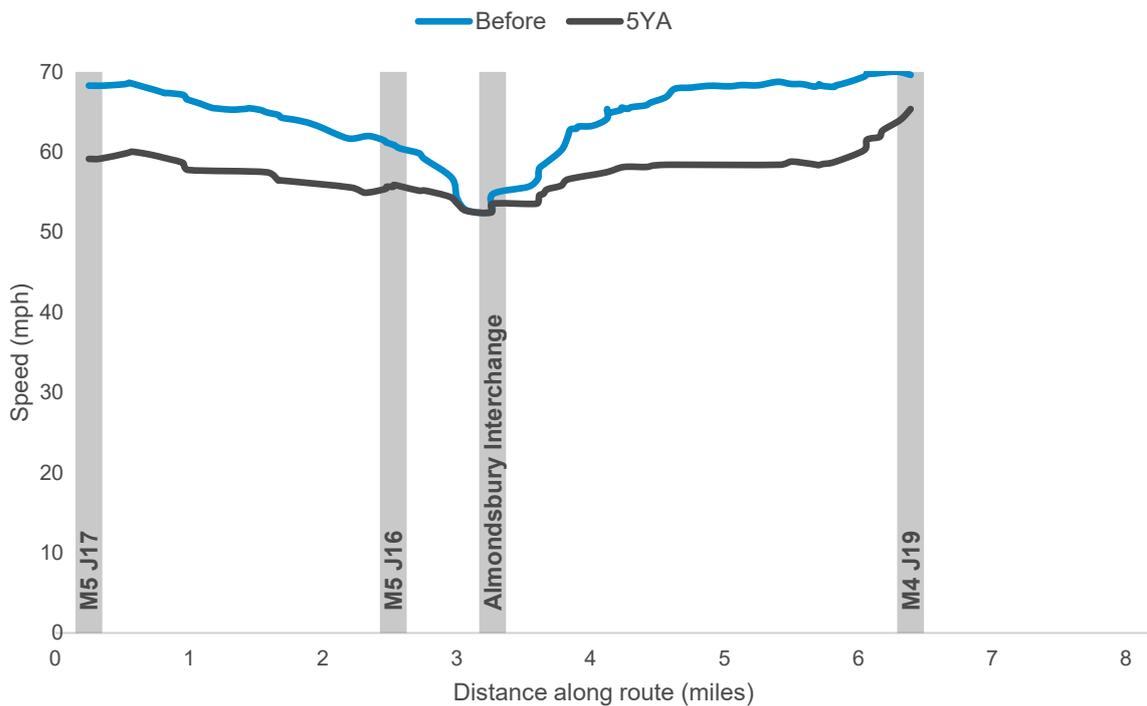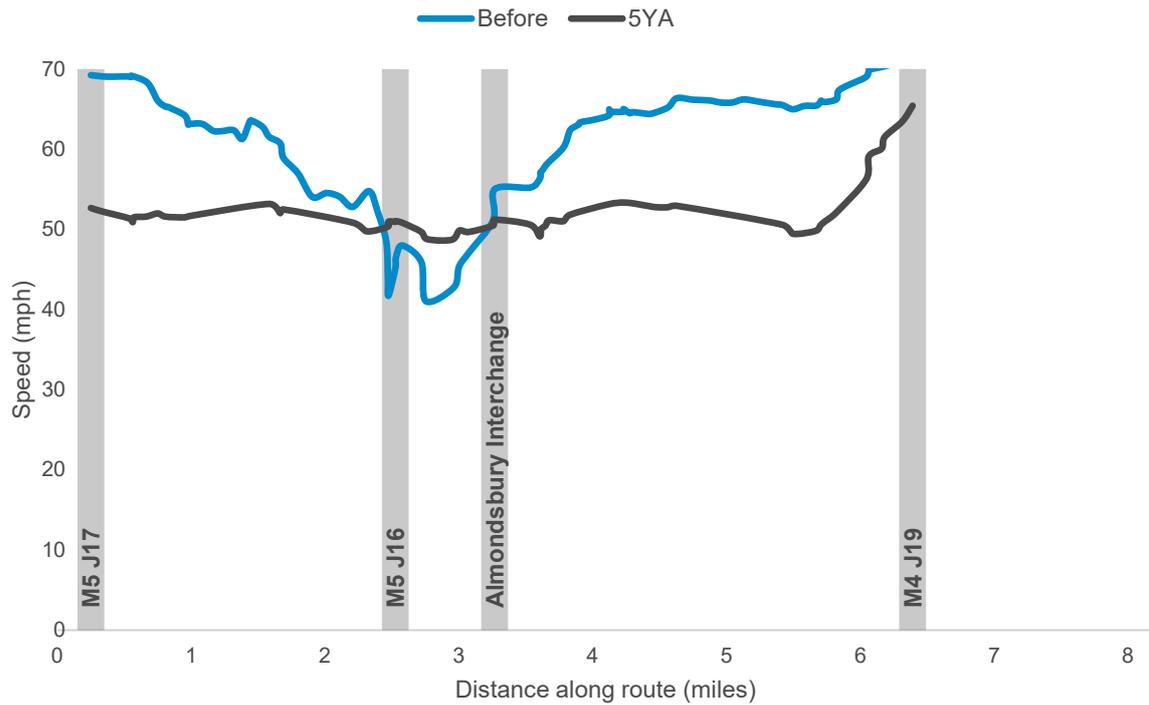**Figure 32 - M4 to M5 (westbound) speed over distance 4-5pm**

Figure 33 - M4 to M5 (westbound) speed over distance 5-6pm

Figure 34 - M5 to M4 (eastbound) speed over distance 7-8am

Figure 35 - M5 to M4 (eastbound) speed over distance 8-9am

Figure 36 - M5 to M4 (eastbound) speed over distance 10am-4pm

Figure 37 - M5 to M4 (eastbound) speed over distance 4-5pm

Figure 38 - M5 to M4 (eastbound) speed over distance 5-6pm
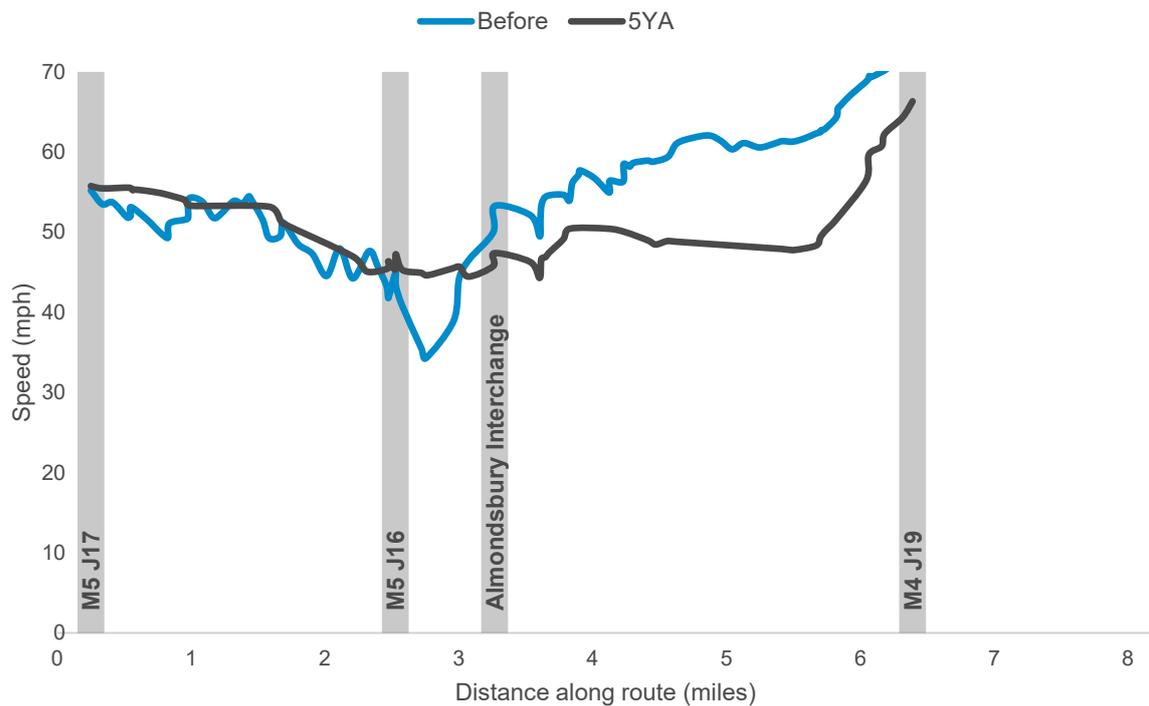
Appendix B.

B.1. Safety counterfactual methodology

Personal injury collisions (hereafter referred to as collisions) on the strategic road network are rare and can be caused by many factors. Due to their unpredictable nature, we monitor trends over many years before we can be confident that a real change has occurred as result of the project.

To establish whether any change in collision numbers is due to the project or part of wider regional trends we have established a test we call the Counterfactual. The Counterfactual answers the question: What would have likely occurred without the project being implemented? To answer this question, we estimate the range of collisions that could have occurred without the project in place. Previous Post Opening Project Evaluations answered this question by looking at national trends in collisions. Adjustments have been made to the methodology for estimating the Counterfactual. These have been made to address the following areas:

Amended Data Collection Method

- Revised method for identifying collisions that occurred on the network.
- Only validated STATS19 information is used for reporting purposes.

Adjusting for Traffic Flows

- Baseline traffic flows are an important factor when determining the counterfactual. We now assume that without the changes made to the network, the trends would follow regional background traffic growth patterns.
- We can now calculate the collision rate for the busiest stretches of conventional motorways.

Better Differentiation between different types of Motorway

- The existing methodology only had one definition of motorway.
- The new method allows us to differentiate between conventional motorways, conventional motorways with high traffic flows and smart motorways.

Assessing Regional Trends

- The new method uses regional rather than national trends for collision rates and background traffic growth, which provides greater granularity and makes the hypotheses more realistic.

We have found that the adjustments have resulted in a slight change from the previous methodology. We still have confidence in the accuracy of the previous methodology but believe we have made suitable changes that will ensure a methodology fit for purpose for the future.

Since this project, smart motorways have evolved. More recent all lane running projects have demonstrated that they are making journeys more reliable for those travelling during congested periods, enabling us to operate the road at a higher speed limit for longer periods, whilst maintaining safety.

B.2. Incident Reporting

Police forces choose how they collect STATS19 data. Some police forces do this electronically, for example using mobile devices, while others complete paper forms which are later digitised. In addition, some collisions are reported by members of the public after the event. Since 2016, new data collection systems (called CRaSH and COPA) have been introduced by some police forces.

Before these new systems, reporting police officers categorised the severity of non-killed casualties as either serious or slight according to their own judgment of the injuries sustained. This was based on information available within a short time of the collision, and often did not reflect the results of medical examination. This sometimes led to casualties being incorrectly classified as slight injuries when they were serious, or vice versa.

In April 2016 Bedfordshire and Hertfordshire police constabularies transferred from Stats19 to CRaSH (Collision Recording and Sharing) system for reporting personal injury collisions. In CRaSH reporting, police officers record the types of injuries suffered by the casualty rather than the severity. In previous systems the determination of severity was at the discretion of the reporting police officer. CRaSH automatically converted the injury type to a severity classification. This led to implications for reporting on collision severity as there had been an increase in the number of serious collisions recorded[58].

These changes make it difficult to monitor trends in the number of KSI casualties over time or between different police forces. To help with this, the Office for National Statistics (ONS) has undertaken research to identify methods of estimating and adjusting for the increased recording of serious injuries in the new systems. Based on this work, DfT have published an adjusted time series of KSIs at the national level and statistical adjustments at the record level. These adjustments are based on estimates of how casualty severities may have been recorded had injury-based severity reporting systems always been used.

The adjustments will be reviewed by the ONS and DfT as more data becomes available, and it is possible that further refinements will be made to the adjustment methodology in the future. Currently it is not possible to reliably adjust collision severity information at the granular level required for this project.

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[58]
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/820588/severity-reporting-methodology-final-report.odt

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