M25 junctions 5 to 7 all lane running

Five-year post-opening project evaluation

The methodology used to generate the data in this document should only be considered in the context of this publication. This methodology, and its subsequent outputs may differ from methodologies used in different analyses at different points in time. This is due to continuous improvements of data mapping, capture, and quality. As these factors evolve over time any comparison with earlier data or data from other sources, should be interpreted with caution.

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 M25 junctions 5 to 7 all lane running (ALR) 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 M25 junctions 5 to 7 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

[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

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1. Executive summary

The M25 junctions 5 to 7 smart motorway opened for traffic in April 2014, providing additional capacity on one of the remaining sections of London's orbital motorway which had yet to be upgraded to accommodate future traffic growth. Before the project, road users of this section of the M25 were subject to slow average speeds and increasing congestion. The project converted junctions 5 to 6, and a short section on the clockwise carriageway west of junction 6, to all lane running[2]. The section between junctions 6 and 7 of the route was already four lanes and was upgraded to a controlled motorway[3]. Gantries were installed along the project extent to enable it to function as a smart motorway, including the use of variable mandatory speed limits (VSML). Emergency areas are now available at regular intervals, providing places to stop in an emergency, where there is no permanent hard shoulder.

This scheme aimed to provide additional capacity to reduce congestion, better manage traffic conditions and improve journey time reliability while maintaining safety for road users and minimising adverse environmental effects of the project.

There was an overall improvement in safety; whilst accommodating an increase in the number of road users between 2% and 9% across the project, both the number and rate at which personal injury collisions occur has decreased compared to before implementation. We also observed a decrease in collision severity when accounting for traffic.[4]

The reliability of road users' journeys had generally improved in the anticlockwise direction; they had declined in the clockwise direction. VMSL were used more during the weekday morning peak on the clockwise carriageway; they were rarely used on the anticlockwise carriageway.

At five years after, we found that road users' journey times were longer at almost every time. However, when considering that journey times would have deteriorated anyway, with an increase in traffic, road users have seen quicker journeys in the anticlockwise direction than would have been likely without the smart motorway. When accounting for the observed increase in traffic, if the section of road had remained a 3-lane motorway it would have been unable to support the additional road users, without experiencing a reduction in speed.

The upgrade to the motorway was carried out within the highway boundary, so in most cases the evaluation of environmental impacts was as expected or slightly better than expected, largely due to the traffic flows being below forecast. For landscape, heritage and biodiversity, a lack of maintenance of the planting plots created to help mitigate impacts around the project was found at five years after. Despite this, the impacts were broadly as expected.

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[2] All lane running (ALR) motorways apply technology to control speeds, and permanently convert the hard shoulder to a running lane. Emergency areas are available at regular intervals providing places to stop in an emergency.

[3] A controlled motorway applies technology to control speeds but retains a permanent hard shoulder.

[4] FWI – Fatal and Weighted Injuries decreased from 3 to 2. The measure showed an extra 21 million vehicle miles was travelled before a fatality.

Based on the evidence from the first five years, at this stage the M25 junctions 5 to 7 ALR scheme 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 2008 financial crisis and lower population growth than originally forecast). and slower journey times. It is nevertheless delivering benefits - construction of the project was delivered under budget, it is delivering safety benefits to road users and most of the environmental benefits are as expected, or better, with the additional capacity being able to accommodate more traffic now and on into the future.

2. Introduction

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

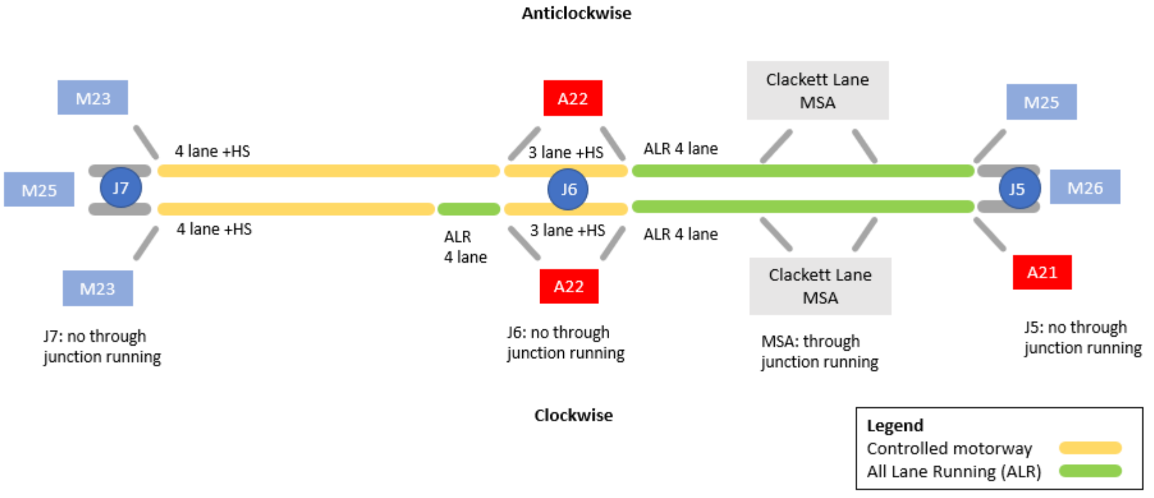
M25 junctions 5 to 7 smart motorway was a major project completed in April 2014. This report presents a five years after (5YA) evaluation of this project and has been prepared as part of the National Highways post-opening project evaluation (POPE) programme. The purpose of this report is to present a comparison of the longer-term project impacts with the pre-project and one year after (1YA) conditions, and to assess the extent to which the project has met the objectives identified during the project appraisal.

Capacity on the M25 has been a longstanding issue. To address the increasing congestion, widening projects were proposed on five three-lane sections of the motorway; three of these sections were completed and opened to traffic between 2008 and 2012. A decision was taken to upgrade the remaining two sections of carriageway to a smart motorway. Junctions 5 to 7 is one of these sections and was converted to an all lane running motorway, increasing capacity to four lanes by permanently converting the hard shoulder to a running lane and installing technology including variable message signs and signals. The section between junctions 6 and 7 of the route was already four lanes and was converted to a controlled motorway, retaining the hard shoulder and technology including installing variable message signs and signals. Construction of the project began in September 2012 and completed in April 2014.

The project features are shown in Figure 1. Between junctions 5 and 6, through the Clacket Lane Motorway Services Area (MSA) and a short section of the clockwise carriageway west of junction 6, the existing motorway was converted to all lane running[5] providing four lanes in each direction. Ten emergency refuge areas were also installed. Through junction 6 the existing three lanes and hard shoulder were retained, and between junctions 6 and 7 the existing four lanes and hard shoulder were retained. These two stretches were converted to controlled motorway[6].

[5] All lane running (ALR) motorways apply technology to control speeds, and permanently convert the hard shoulder to a running lane. Emergency areas are available at regular intervals providing places to stop in an emergency.
[6] A controlled motorway applies technology to control speeds but retains a permanent hard shoulder.

Figure 1: M25 junctions 5 to 7

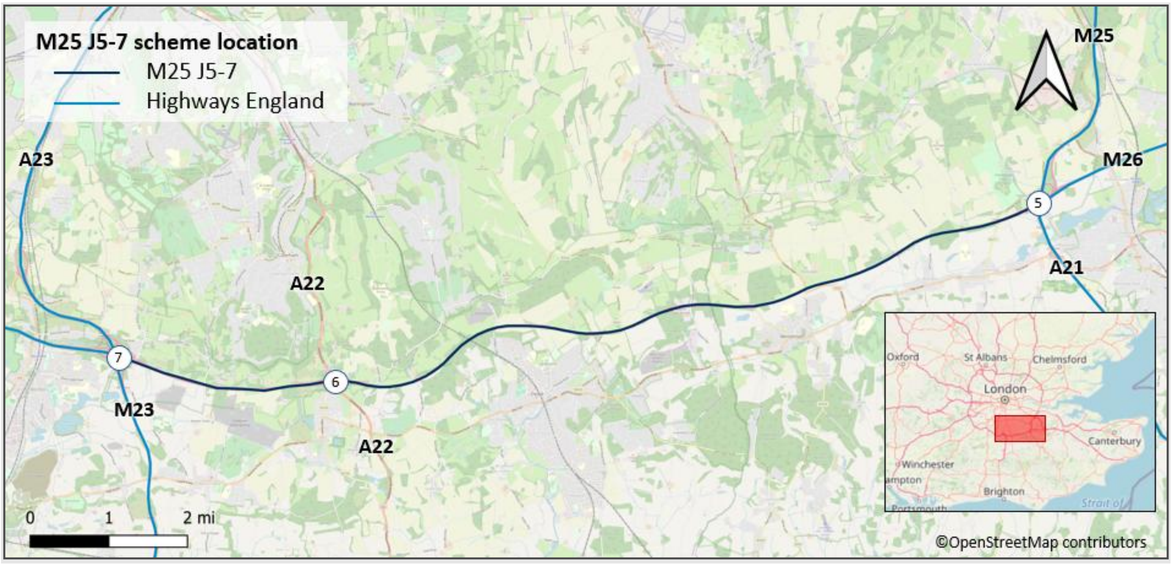


Project location

M25 junctions 5 to 7 is located to the south of London, running through the counties of Surrey and Kent. Within the project area, the M25 joins the M26 at junction 5 (Sevenoaks, Kent) and the M23 at junction 7 (Redhill, Surrey). It also links with the A21 (at junction 5) and the A22 (at junction 6). Most of the project runs through green belt land.

The M25 is one of the busiest routes in Europe[7] and is a key strategic route in the UK. It provides access both to and around the capital, as well as a link to the coast. The location of the project is shown in Figure 2.

Figure 2: M25 junctions 5 to 7 project location



Source: National Highways and OpenStreetMap contributors

How has the project been evaluated?

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[8] 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.[9]

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[7] INRIX Research (2016) *Europe's Traffic Hotspots: Measuring the impact of congestion in Europe* (https://inrix.com/wp-content/uploads/2017/01/INRIX_Europes-Traffic_Hotspots_Research_FINAL_lo_res.pdf)
[8] Key impact areas include safety, journey reliability and environmental impacts.
[9] 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 were being identified. The M25 junctions 5 to 7 objectives are outlined below in Table 1.

Table 1: Objectives and Evaluation Summary

Objective	Five-year evaluation
To reduce congestion and to develop solutions that provide additional capacity.	Conversion of junction 5 to 6 from three to four lanes all lane running has provided additional capacity. However, journey times have increased whilst reliability has decreased in the clockwise direction.
To improve journey time reliability by improving and better managing traffic flow conditions.	Journey time reliability improved on the anticlockwise carriageway, but largely decreased on the clockwise carriageway.
To achieve a safety objective under which the "after" collision numbers (per annum) are no greater than those in the "before" and the severity ratio is not increased.	The evaluation found there has been a reduction in the number, rate and severity of personal injury collisions. The five-year evaluation concludes that the objective has been met. However, we cannot be confident that this is because of the project itself and not part of observed wider regional trends.[10]
To make best use of existing infrastructure providing additional capacity within the existing highway boundary, other than in exceptional circumstances.	This project provided the M25 with additional capacity within the existing highway boundary.
To minimise detrimental environmental effects of the smart motorway project by mitigation measures, taking account of costs, availability of funding and statutory obligations.	Air quality and greenhouse gases outcomes were as expected or better than expected due to lower than forecast traffic volumes. Mitigation measures for the landscape objective had been undertaken, but improved maintenance and aftercare would be needed. Biodiversity impacts were confined to the carriageway. Historic resources were largely unaffected by the project.

[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.

Objective	Five-year evaluation
To improve the currency and quality of information provided to drivers about the state of traffic flow on the motorway.	The gantries provided by the project had improved driver information.
To support the current role of the M25 as a major national and inter-urban regional transport artery.	The project had provided additional capacity to support the M25's key role on the network.

4. Customer journeys

Summary

At five years after, this smart motorway was supporting more customers, with between 2 and 9% more traffic over pre-construction levels, on the project extent and also increased traffic on the surrounding major roads. However, this is lower than the increase anticipated in the business case. The slower pace of growth is likely due to the 2008 economic downturn.[11]

We found traffic on the anticlockwise carriageway to be free-flowing, but with some congestion hotspots on the clockwise carriageway, notably around junction 6, with the steep gradient of the approach to the junction, and increased weaving of road users due to the dedicated lanes for the A21 and M23 likely to be influencing factors.

We found that road users' journey times were longer in almost every time period, reversing the trend at one year after. It was likely due in part to the increased traffic volumes. When considering that journey times would have deteriorated if the section had remained a conventional motorway, due to the increased number of road users, journeys in the anticlockwise direction have shown an improvement. However, this is not the case for the clockwise carriageway and when considered together, it is not offering an overall improvement.

The reliability of road users' journeys had generally improved in the anticlockwise direction, but had declined in the clockwise direction.

As in the one-year evaluation, variable mandatory speed limits (VMSL) were found to be used during the weekday morning peak on the clockwise carriageway over 50% of the time, however they were rarely used on the anticlockwise carriageway. This indicated that the slower journeys on the clockwise carriageway were likely due to better compliance with VMSL as opposed to increased congestion, particularly when this direction saw lower traffic growth.

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 examine if the traffic levels changed over the evaluation period and to what extent the forecast traffic levels were realised.

National and regional

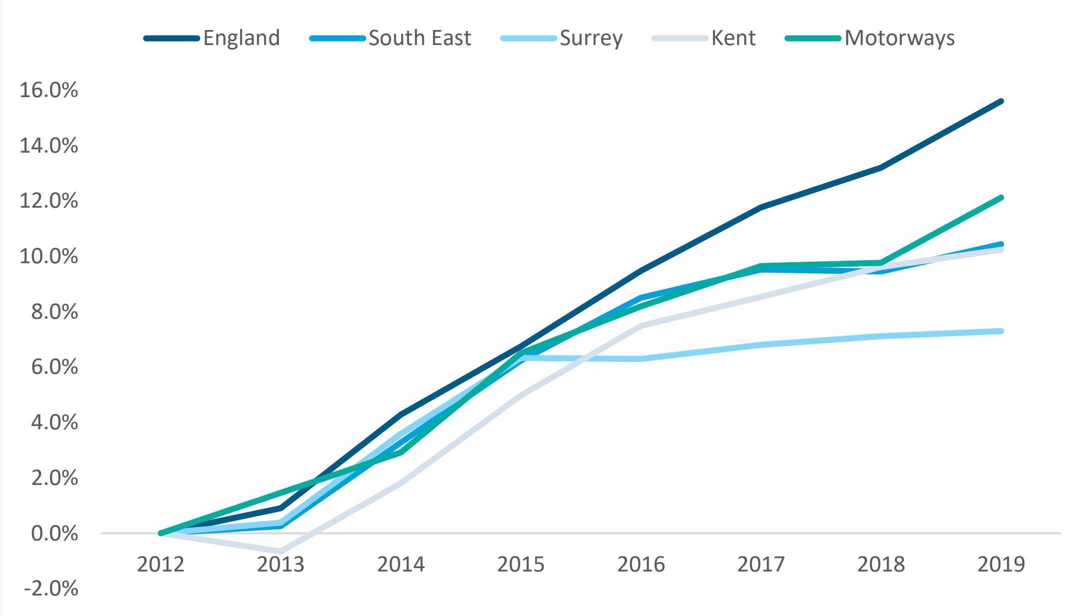
To assess the impact of the project on traffic levels, it is useful to understand the changes within the context of national and regional traffic. To do this, we use the Department for Transport annual statistics. The data is reported by local authority and road type, recording the total number of million vehicle kilometres travelled.[12] This data is used as a baseline, and we attribute any growth observed on roads in the project area which is above national and regional trends to the project. We

[11] The Local Model Validation Report indicated that although the model was developed in 2012, the base year was prior to the 2008 economic downturn

[12] Motor vehicle traffic (vehicle kilometres) by region in Great Britain, annual from 1993 to 2019, Table TRA 8904, Department for Transport.

assessed the change from the year before the project began construction (2012) to five years after the project opened to traffic (2019). Figure 3 shows the results.

Figure 3: National, regional and local traffic trends (2012-2019)



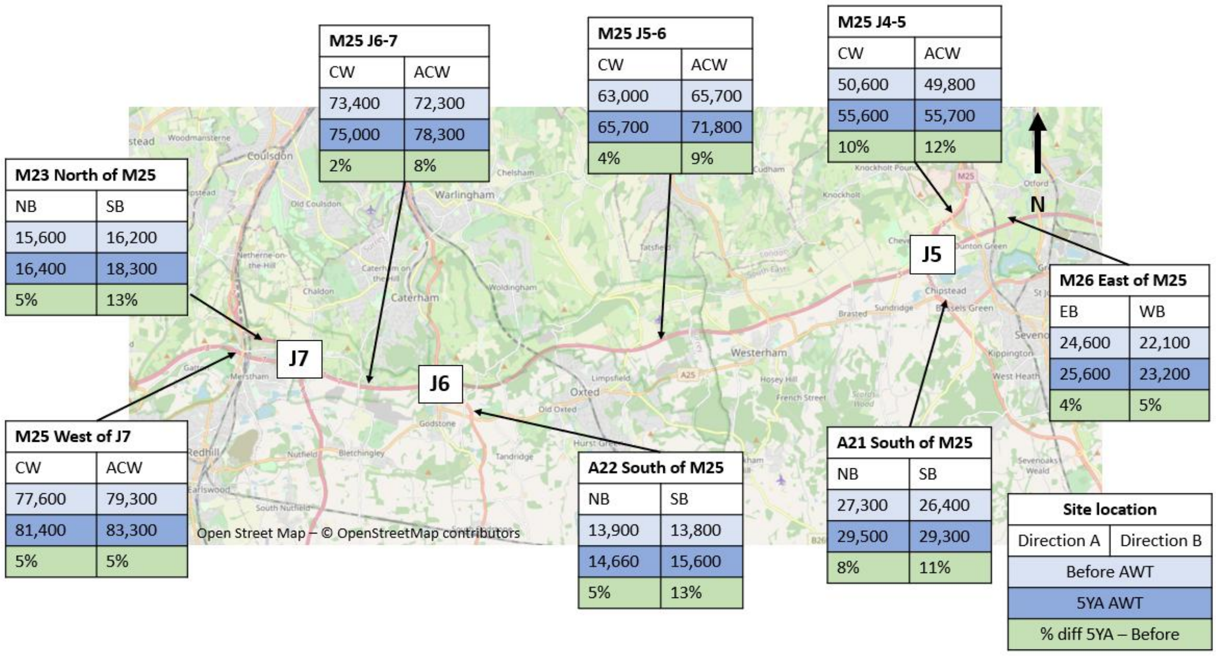
Source: DfT traffic statistics TRA8904 and TRA4112, accessed Dec 2020

Considering local, regional and motorway traffic trends, around 11% growth might be expected to have occurred regardless of the project being implemented. The analysis in the following sections should be considered in this context as no adjustments have been made to take account of background traffic growth.

How did traffic volumes change?

At five years after we found traffic volumes on the project extent had increased by between 2% (1,600 vehicles) and 9% (6,100 vehicles), similar to or below the local and regional background growth trends (7-10%), and below those for our motorways (12%) and for England (16%) as a whole. Disproportionately more growth occurred on the anticlockwise carriageway than on the clockwise carriageway. Figure 4 shows the changes on the project extent and across the wider network.

Figure 4: Changes in average weekday traffic (AWT) from before to five-years after



Note: Before: 2012; Five-years after: 2019. Source: National Highways and OpenStreetMap contributors

The growth observed on the project has been slower since the one-year evaluation, likely to have been affected by other projects in the surrounding area. These were:

- conversion of M23 junctions 8 to 10 to smart motorway (2018 to 2020);
- improvements on the A21 between Tonbridge and Pembury (2014 to 2017); and
- Dartford Crossing (north of M25 junction 5) introduced a free-flow ticketing system (2014).

Was traffic growth as expected?

The investment decision for this project was supported by a project appraisal which included forecasts about the likely impact on traffic. To understand the project's forecast traffic impacts, whether they were realised and to get a measure of their accuracy, we compared interpolated forecasts from the Traffic Forecasting Report (TFR)[13] with equivalent observed data.[14] The impacts of a range of projects were incorporated into the project's traffic appraisal forecasts. Two of the three projects detailed above were included in the list.[15]

We found that the forecasts were higher than observed flows, by on average 16%, for all but one location (northbound on the M23, north of M25 junction 7). This was a

[13] Skanska –Balfour Beaty Joint Venture (2012) *M25 LUS – Sections 2 & 5 Traffic & Economics Section 2 Traffic Forecasting Report*.
[14] The forecasts in the TFR were produced using the M25 Assignment Model. Its base year was 2004 and the three forecast years were 2015, 2030 and 2040. There were no forecasts available for the five-years after period (2019) so we used interpolation from the figures for 2012 and 2030 forecasts and the 2015 'with project' data and adjustment factors from TEMPro 7.2 to produce figures for 2019. This method was similar to that used for the analysis for the one-year after report.
[15] The conversion of M23 junctions 8 to 10 to smart motorway project was not included.

continuation of the pattern seen at one-year after where the forecasts were 11% higher on average.

The evidence implied that the traffic model produced forecasts based on flows that were too high, as the 'without project' forecasts were higher than observed in 2012.

This can be partly explained by the impact of the recession which stalled traffic growth in 2008-2011 because of impacts on fuel price and travel demand. We can be confident that this is the cause as the discrepancy also impacted the without project forecasts. The business case, completed before signs of an economic recession, forecast a higher demand in travel, due to using projected growth trends observed before 2008.

Table 2 and Note: Figures are annual average daily traffic flows. Source: Forecasts: Skanska –Balfour Beaty Joint Venture (2012) *M25 LUS – Sections 2 & 5 Traffic & Economics Section 2 Traffic Forecasting Report*; Observed: National Highways traffic count data

Table 3 summarise respectively the results for the sites in Figure 4 with forecasts included for comparison.

Table 2: Observed and forecast traffic flows on the project extent

Location	Dir	Without project (2012)			With project (2019)		
		Forecast	Observed	% diff	Forecast	Observed	% diff
M25 J6-7	CW	75,100	68,900	-8%	87,000	72,000	-17%
	ACW	77,000	68,000	-12%	88,300	74,700	-15%
M25 J5-6	CW	69,100	60,700	-12%	81,500	63,600	-22%
	ACW	70,400	62,800	-11%	82,700	68,800	-17%

Note: Figures are annual average daily traffic flows. Source: Forecasts: Skanska –Balfour Beaty Joint Venture (2012) *M25 LUS – Sections 2 & 5 Traffic & Economics Section 2 Traffic Forecasting Report*; Observed: National Highways traffic count data

Table 3: Observed and forecast traffic flows in the wider area

Location	Dir	Without project (2012)			With project (2019)		
		Forecast	Observed	% diff	Forecast	Observed	% diff
M25 W of J7	CW	84,400	74,800	-11%	94,900	79,000	-17%
	ACW	89,800	76,300	-15%	99,300	80,400	-19%
M25 J4-5	CW	55,500	48,700	-12%	63,200	53,800	-15%
	ACW	57,300	48,100	-16%	64,900	53,700	-17%
M23 N of M25 J7	NB	13,900	15,200	9%	15,300	16,200	6%
	SB	17,100	15,600	-9%	18,900	17,600	-7%
M26 E of M25 J5	NEB	26,600	23,000	-14%	30,800	24,100	-22%
	WB	26,200	20,900	-20%	30,300	21,700	-28%

Location	Dir	Without project (2012) Forecast	Observed	% diff	With project (2019) Forecast	Observed	% diff
A22 S of M25 J6	NB	18,100	13,200	-27%	19,900	14,200	-29%
	SB	17,000	13,400	-21%	18,900	15,100	-20%
A21 S of M25 J5	NB	28,600	26,100	-9%	31,800	28,600	-10%
	SB	28,800	25,100	-13%	32,000	28,400	-11%

Note: Figures are annual average daily traffic flows. Source: Forecasts: Skanska – Balfour Beaty Joint Venture (2012) *M25 LUS – Sections 2 & 5 Traffic & Economics Section 2 Traffic Forecasting Report*; Observed: National Highways traffic count data

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.

Did the project deliver journey time savings?

We found customers were experiencing improvements in speed and faster journey times compared to before the project was constructed, when travelling anticlockwise in the Friday evening peak, they were faster by over a minute. More widely though, we found that journey times had increased by around half a minute. (Figure 5).

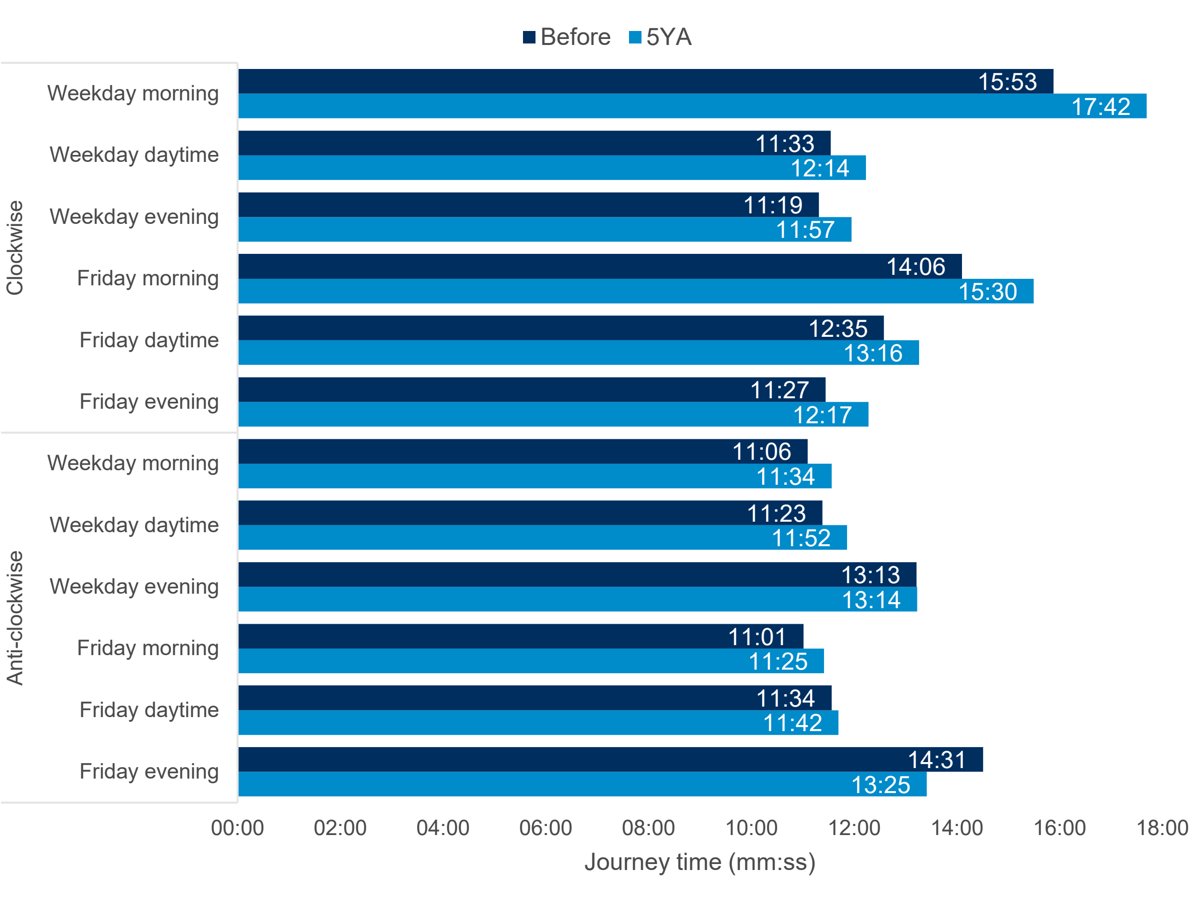
In the weekday morning peak on the clockwise carriageway, the period when congestion was most apparent, road users' journey times increased by nearly two minutes. As variable mandatory speed limit (VMSL) use had not changed substantially since the one-year after evaluation, the increased traffic volumes (as discussed earlier) over the period were the cause.

We typically see journey times improve after the introduction of all lane running, but the journey times tend to increase thereafter as traffic levels increase over time. This is what we are seeing in our five-year evaluation. Calculations undertaken to support the value for money analysis (section 7) have shown that when considering how conditions were likely to deteriorate had the project not been implemented (the 'counterfactual'), the project was showing an improvement for the anticlockwise carriageway, but not the clockwise carriageway. However, when considered together, it is not offering an overall improvement at five years after[16]. When accounting for the observed traffic growth seen at five years after, if the section of

[16] In this section we are presenting before and after journey times unadjusted. For section 7 (value for money) we have compared outturn journey times against a counterfactual estimate of what journey times are likely to have been without the scheme. 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 80,800 vehicle hours in the fifth year after opening.

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[17].

Figure 5: Average observed journey times before and five years after project opening (mm:ss)



Note: For reference, in free-flow conditions, a road user travelling unhindered at 70mph would take 10 minutes and 27 seconds to complete the 12.2 miles length of the route. Source: TomTom satellite navigation data, March 2012 and 2019

Were journey time savings in line with forecast?

We produced forecast journey times from the forecast average speeds to enable comparison with those observed before and after the project.[18] Table 4 compares the predicted and observed journey times by direction. In both the 'with project' and 'without project' scenarios journey times were expected to decline over time. The project was expected to mitigate the declines.

On the clockwise carriageway, the journey times observed in the interpeak and evening periods in 2012 were faster than the 2015 'without project' forecast, but slower in the AM peak. In 2019 the morning and interpeak journey times were slower than the 2030 'with project' forecast, but still just over a minute faster in the evening. The forecasts expected journey times to decline as capacity on the project is filled,

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[17] 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.

[18] Expected average speeds along the project extent in the future forecast years were provided. We converted these into journey time forecasts (for 2015 and 2030) and compared them to observed journey times (for 2012 and 2019).

but the clockwise journey times observed in 2019 were more in line with the 2030 'without project' than the 'with project' forecasts.

The results for the anticlockwise carriageway were slightly different, with both the observed journey times before and after the project being faster than their respective comparative forecasts, the 2015 'without project' forecasts and the 2030 'with project' forecasts. The anticlockwise observed journey times showed improvement after the project's implementation, and this was emphasised when compared to the forecasts. The project has yet to reach capacity and increases in traffic flow will likely increase journey times in future years.

Table 4: Observed and forecast journey times by direction[19]

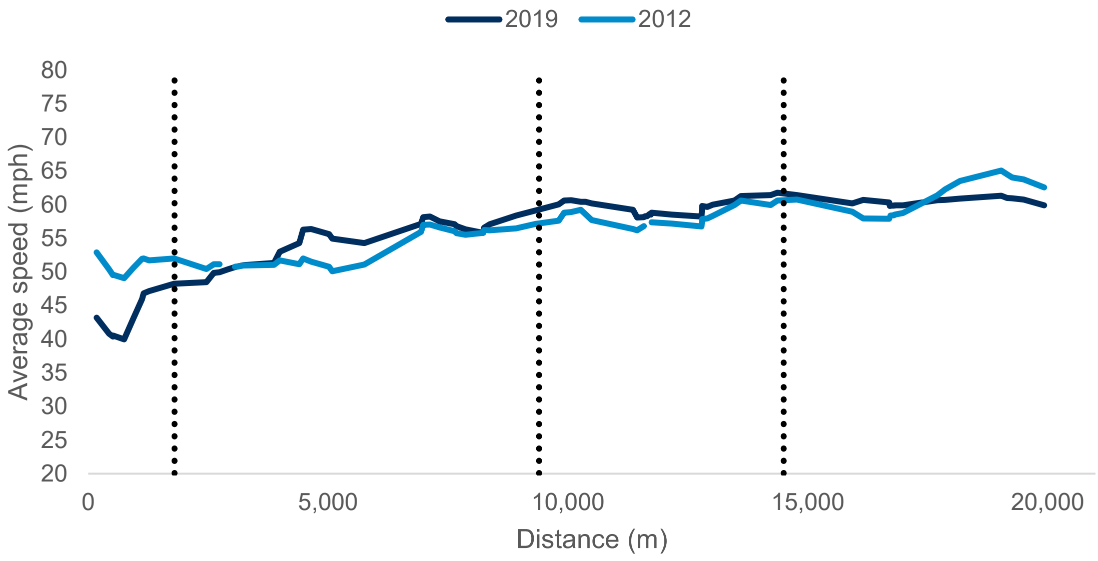
Direction	Time Period	Observed journey time (mm:ss)		% diff	Forecast journey time – w/o project (mm:ss)		Forecast journey time – with project (mm:ss)	
		2012	2019		2015	2030	2015	2030
CW	AM	15:32	16:52	9%	14:48	16:48	13:39	14:44
	IP	11:46	15:06	28%	12:48	14:07	12:07	13:06
	PM	11:22	12:29	10%	13:25	14:26	12:38	13:28
ACW	AM	11:06	11:36	5%	13:22	13:57	12:31	13:35
	IP	11:25	11:46	3%	13:25	14:23	12:31	13:35
	PM	13:29	12:11	-10%	13:44	13:58	12:54	13:58

How did the project impact road user's speeds?

We analysed speeds along the length of the project at different times of the day to understand the impact on journey times in more detail. Figure 6 and Figure 7 illustrate average speed for the busiest time period along the project extent.

[19] 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 scheme. 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 -80,773 vehicle hours in the fifth year after opening.

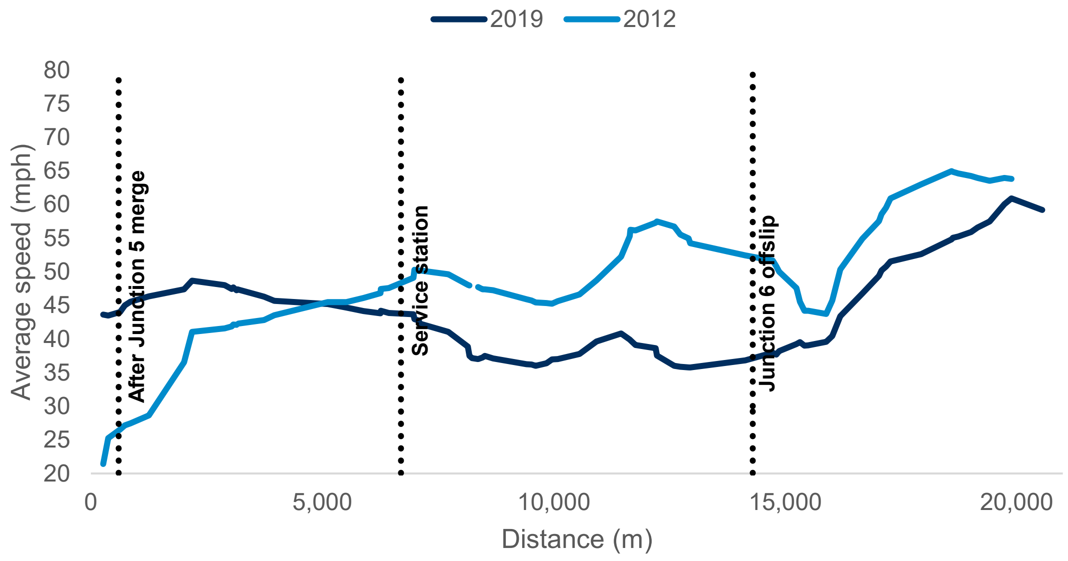
Figure 6: Monday to Thursday evening peak speed by distance (anticlockwise)



Note: Before: March 2012; Five years after: March 2019. Source: TomTom satellite navigation data.

On the anticlockwise carriageway we found evidence to indicate the capacity provided by the project had ensured road users' speeds at five years after remained high and consistent, despite the higher volumes of traffic. It had also brought improvements in the evening peak on Friday, where before average speeds had been relatively low, after the junction 6 entry slip (Figure 26). We inferred there were few instances of congestion on the anticlockwise carriageway.

Figure 7: Monday to Thursday morning peak speed by distance (clockwise)



Note: Before: March 2012; Five years after: March 2019. Source: TomTom satellite navigation data.

On the clockwise carriageway the evidence indicated that there was greater variability in speeds over the day, with congestion occurring between the motorway service area (MSA) and junction 6 on weekday mornings (Figure 7 and Figure 25). No congestion indicators were seen at junction 7, which has a similar layout to junction 6. It seemed likely the congestion at junction 6 was an accumulation of factors, including:

- the steep gradient leading up to junction 6 and on the clockwise on-slip to the M25 impacting speeds, notably for HGVs;
- the lane-drop at junction 6 (lane one becomes the slip road to leave three lanes through the junction);
- the dedicated single lane for the A22 exit at junction 6 causing road users to weave between lanes;
- the high level of HGV movements between lanes at the location;[20] and
- the reintegration of road users exiting the services into the flow of traffic.

Consultation with the operations team determined that the issues at junction 6 were not cause queuing on the slip road. In contrast, the anticlockwise carriageway remained free flowing with no congestion.

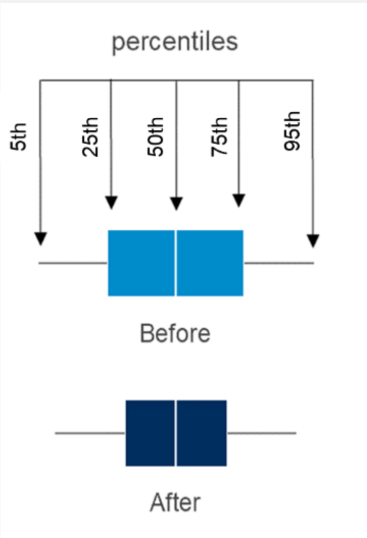
Did the project make journeys more reliable?

One of the project's objectives was to improve journey time reliability. Our assessment of reliability looks at the variability of journey times along the project extent.

Congestion can make journey times unreliable. If the time taken to travel the same journey each day varies a lot, journey times are unreliable, and road users will be less confident in planning their journeys. Conversely, if journey times vary only a little, they are more reliable and road users will be more confident in planning their journeys.

Using the percentiles of journey times derived from the satnav data, we sought to establish whether they had become more reliable since the project's implementation. The results of our analysis are shown in the box plots in Figure 9 and Figure 10. Box plots are explained in Figure 8 below.

Figure 8: What does a box plot show?



The lowest point is the 5th percentile, this means 5% of journeys take less than this amount of time 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.

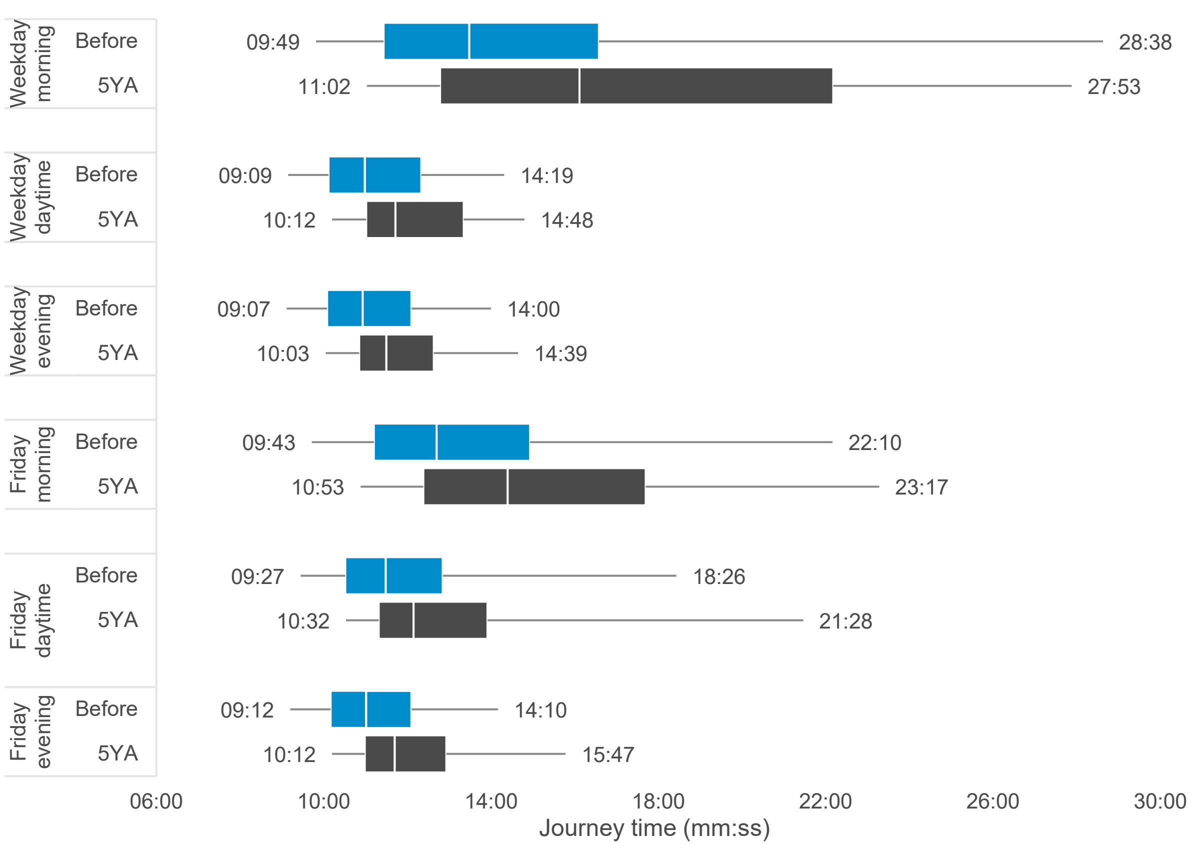
The length of the box shows how the journey times vary between the 25th and 75th percentile (the journey time 25% and 75% of journeys are faster than). The narrower the box the less variable, and hence more reliable, the journey.

[20] This was reported by stakeholders at the five-years after workshop.

We found that reliability for most road users on the clockwise carriageway during the daytime and evening had not changed significantly. However, in the morning it had declined.

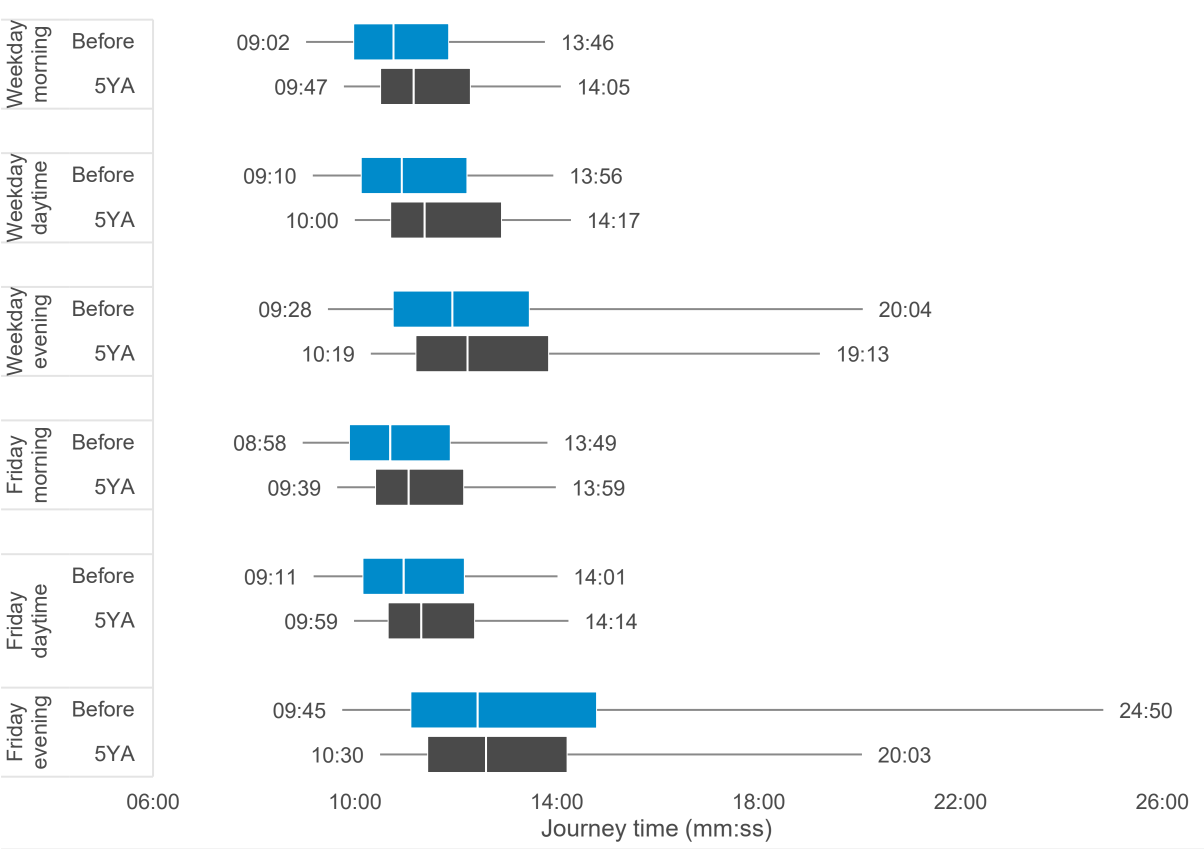
In contrast reliability on the anticlockwise carriageway had mostly improved. This is consistent with the evidence which showed it was less congested, with higher, more stable average speeds. The additional capacity provided by the project is likely to have contributed to these improvements.

Figure 9: Clockwise journey time reliability



Source: TomTom satellite data, March 2012 and 2019

Figure 10: Anticlockwise journey time reliability



Source: TomTom satellite data, March 2012 and 2019

There had also been changes for the slowest journey times. Although journey time reliability had declined on the clockwise carriageway in the weekday morning, the slowest journeys had improved. A similar result was observed on the anticlockwise carriageway in the evening peak, with greater improvement on the Friday.

How was the smart motorway operated?

We have shown evidence of journey times along the project extent slowing alongside moderate (and lower than expected) traffic growth. This section presents analysis of the operational aspects of the smart motorway to gain insight into how it may have affected overall performance and journey times.

To understand the project's impacts on speeds and congestion we examined the use of Variable Mandatory Speed Limits (VMSL) on the project extent.[21]

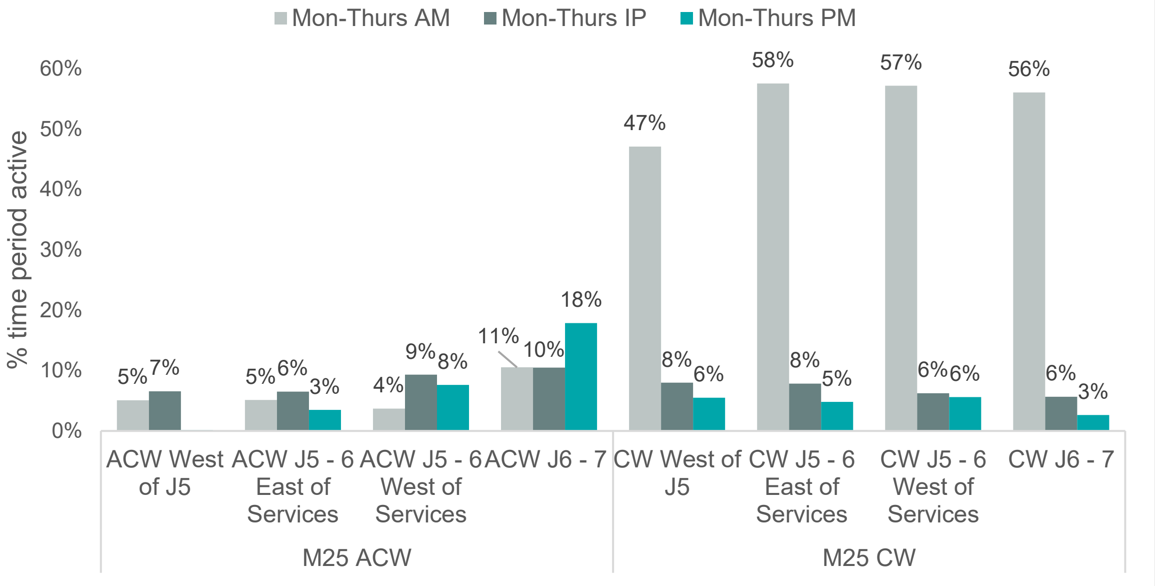
We found the patterns of VMSL use on weekdays[22] had not changed greatly from the one-year after evaluation, suggesting the changes in journey times observed were likely linked to increasing traffic volumes rather than to more frequent use of VSML. Figure 11 shows the percentage of time variable messaging signs were active in each time period.

[21] Our analysis used data from National Highways' Logging Environment database which logs real-time data from roadside equipment including variable message sign settings and equipment locations.

[22] We define the weekdays as Monday to Thursday.

Overall, variable speed limits were deployed most in the morning period on the clockwise carriageway (50-60% of the period between 6 am and 10 am). There was proportionately less deployment on the anticlockwise carriageway. The instance of highest usage (18-19%) occurred between junction 6 and 7 between 3 pm and 8 pm.

Figure 11: Variable Mandatory Speed Limit active setting by time period



Source: HALOGEN data, March 2019

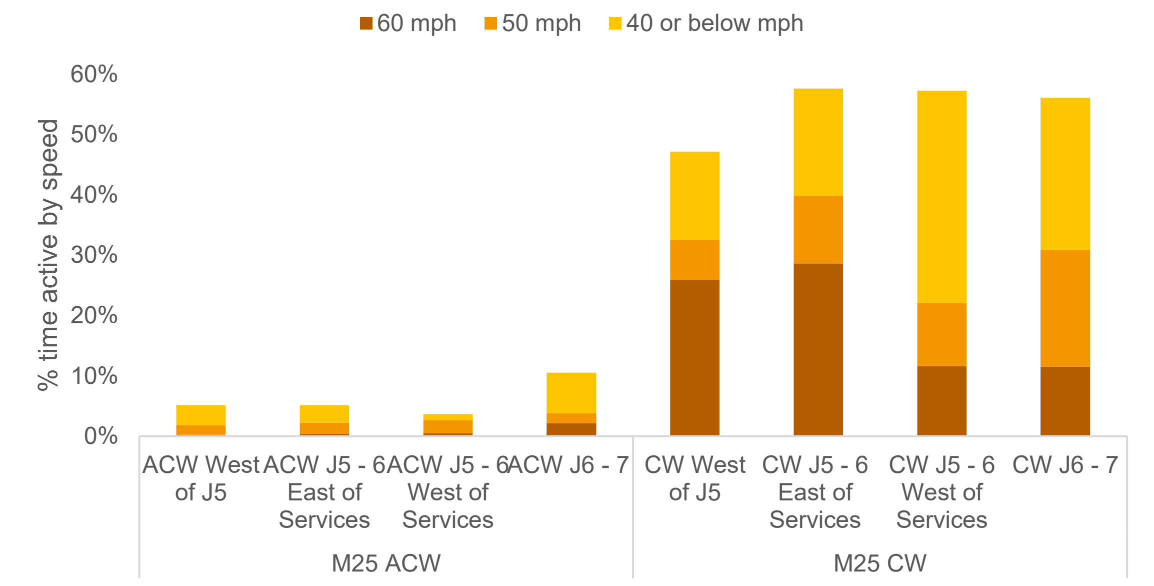
We found greater variability in the deployment of speed limits in the weekday mornings on the clockwise carriageway (Figure 12). Traffic was allowed to travel at 60 mph more often on the carriageway before the motorway service area (MSA). Whereas after, traffic was more often limited to speeds of 40mph or below. This was similar to what was seen at one year after.

We found a different pattern for the evening peak (

Figure 13). VMSL was used more often on the anticlockwise carriageway compared to the morning peak, likely reflecting increased numbers of road users returning home from work. The more

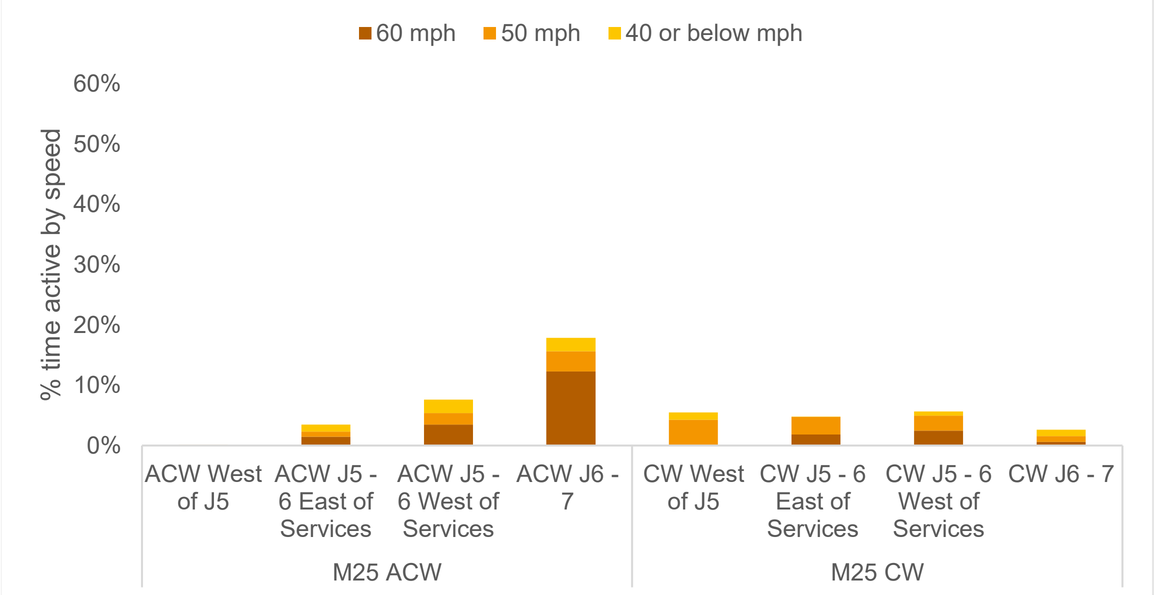
frequent use of speed limits between junctions 6 and 7 could be explained by the additional traffic movements as road users leave and re-join at the junction.

Figure 12: Variable Mandatory Speed Limit speed setting (Mon-Thurs, AM peak)



Source: HALOGEN data, March 2019

Figure 13: Variable Mandatory Speed Limit speed setting (Mon-Thurs, PM peak)



Source: HALOGEN data, March 2019

5. Safety evaluation

Summary

The projects safety objective is to achieve after collision numbers (per annum) that are no greater than those in the before baseline period and the severity ratio is not increased.

The number of personal injury collisions[23] and the rate of these collisions per hundred million vehicle miles were analysed to track a change over time. There has been a reduction in the rate and number of personal injury collisions 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 12 personal injury collisions, which is in line with the appraised business case for the project. This is based on an annual average of 65 personal injury collisions after the project was operational compared with 77 before the project. If the road had not converted to all lane running, we estimate that the number of personal injury collisions would have been between 58 and 95 (Figure 17).

When accounting for the increased volume of road users over this period, the annual average rate of personal injury collisions per hundred million vehicle miles had also improved over time. The average collision rate had decreased to 12 personal injury collisions per hundred million vehicle miles, this equates to travelling nine million vehicle miles before seeing an accident. Before the project the collision rate was 14 personal injury collisions per hundred million vehicle miles, this equates to traveling seven million vehicle miles before a personal injury collision occurs. If the road had not converted to all lane running, we estimate the collision rate would remain at 13 personal injury collisions per hundred million vehicle miles. This counterfactual scenario indicates that there would be a reduction in the rate that collisions occur. The project has outperformed this scenario.

Collisions which result in injury are recorded by severity as either fatal, serious, or slight. The way the police record the severity of road safety collisions changed within the timeframes of the evaluation, following the introduction of a standardised reporting tool, so an adjustment factor has been used for comparisons to be made (see *What impact did the project have on the severity of collisions?*). The number of collisions resulting in slight or fatal injuries had both reduced, while those resulting in serious injuries increased slightly. The Fatal and Weighted Injuries (FWI) metric takes all three types of injuries into accounts and applies weightings as well as the amount of traffic. When accounting for this, the number of fatality equivalents had reduced from three to two. This means a further 21 million vehicle miles would need to be travelled before a fatality would likely occur.

On the surrounding network[24] there was an average increase of three personal injury collisions per year (based on an annual average of 305 personal injury collisions observed after the project had opened compared with 303 before the project). If the

[23] A collision that involves at least one vehicle and results in an injury to at least one person.
[24] 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.

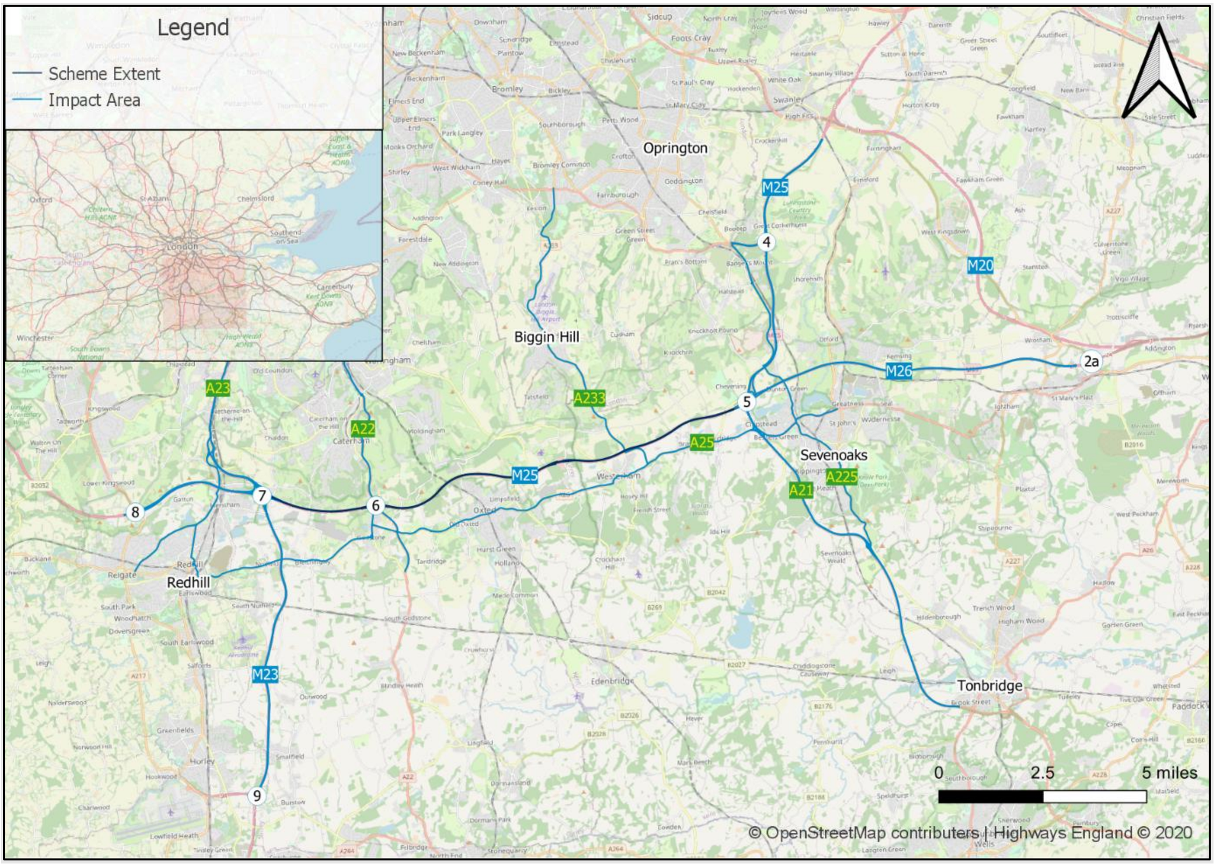
road had not been converted to a smart motorway, we estimate that the number of personal injury collisions would be between 241 to 321 (see *How has traffic flow impacted collision rates in the wider area?*).

Based on this analysis at the five-year evaluation we consider that the project has met its safety objective.[25] However, we cannot be confident that this is because of the project itself and not part of observed wider regional trends for a reduction in collisions and rates.

Safety study area

The safety study area, shown in Figure 14 was defined as the project extent on the M25 between junctions 5 to 7 and a wider area including adjacent roads on the local 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 14: Safety study area



Source: National Highways and OpenStreetMap contributors

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

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.[26] 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.

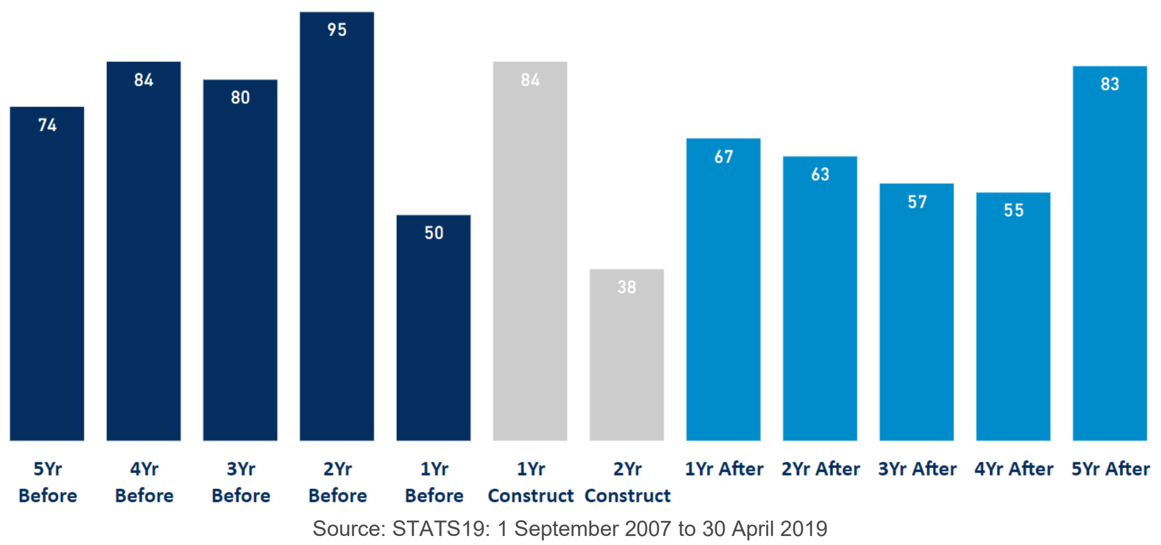
The safety analysis was undertaken to assess changes over time looking at the trends in the five years before the project was operational to provide an annual average. We have then assessed the trends five years after.

The analysis draws on the following data collection periods:

- Pre-construction: 1 September 2007 to 31 August 2012
- Construction: 1 September 2012 to 30 April 2014
- Post-opening: May 2014 to 30 April 2019.

The evaluation found the number of personal injury collisions on the project extent, had decreased (impacts on the wider area are discussed later in. Over the five years after the project was operational, there were an average of 65 personal injury collisions per year, 12 fewer than the average 77 per year over the five years before the project was constructed.

Figure 15: Annual Personal Injury Collisions



Source: STATS19: 1 September 2007 to 30 April 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 B: Safety Counterfactual Methodology). This is based on changes in regional safety trends for conventional motorways with a high volume of roads users.

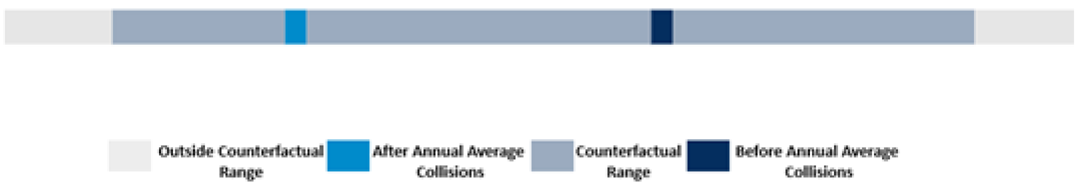
[26] https://data.gov.uk/dataset/cb7ae6f0-4be6-4935-9277-47e5ce24a11f/road-safety-data

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 17 below.

Figure 16: What does the Counterfactual show?

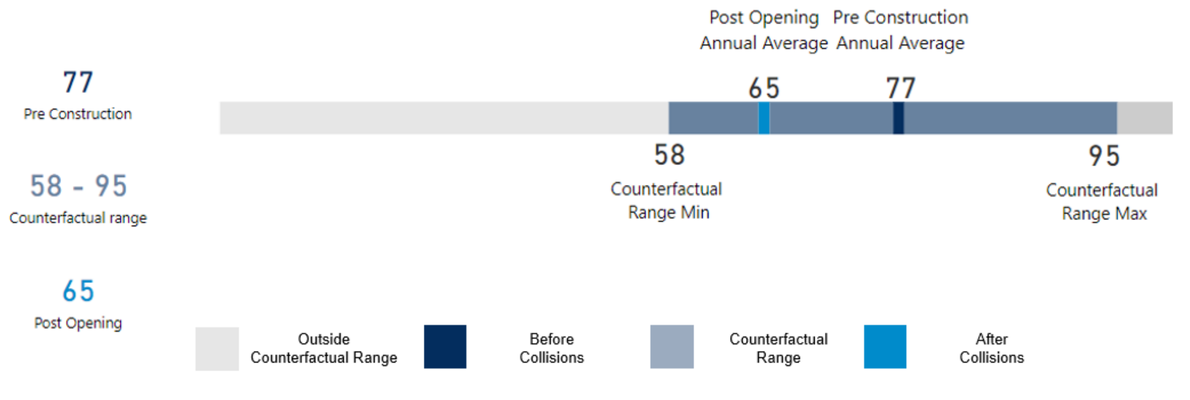
The counterfactual is an estimation of what we think would occur without the project taking place. We estimate a range of collisions that follow regional trends. The chart shows:

1. Annual average number of collisions from before the project
2. Annual average number of collisions after the project
3. Estimated counterfactual range, which comes from a X^2 hypothesis test on one degree of freedom using a significance level of 0.05. More details can be found in the POPE Methodology Manual.
4. National Highways are developing new statistical methods to compare collision and casualty rates. We anticipate adopting these once the methods are finalised.



A range of between 58 and 95 personal injury collisions[27] during the five-year post project period would be expected, as shown in Figure 17.

Figure 17: Observed and expected range of personal injury collisions (annual average)



Source: STATS19: 1 September 2007 to 30 April 2019

An annual average of 65 personal injury collisions were observed over the five-year post-opening period, this falls within the expected range. Therefore, the observed

[27] 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.

changes were not statistically significant. We cannot be confident that the decline in personal injury collisions could be attributed to the project.

How had traffic flow impacted collision rates?

Smart motorways are implemented on some of England's busiest routes. It is therefore important to contextualise any incidents in the volume of traffic seen on this stretch via a collision rate, the number of personal injury collisions per annual hundred million vehicle miles (hmvm).

The evaluation has identified a decrease in the rate of personal injury collisions per annual hmvm.

Prior to the project, there was an annual average of 14 personal injury collisions per annual hmvm. After the project improvements were made there was a decrease to 12 personal injury collisions per annual hundred million vehicle miles.

The average distance travelled before a personal injury collision occurred increased from 7 to 9 million vehicle miles per personal injury collision.

A counterfactual test was undertaken. It found that the collision rate would likely have been 13 collisions per annual hmvm in the counterfactual scenario. This indicates that we predicted a decrease in the number of collisions and a reduction in the rate that they occur despite increased traffic flows.

What changes in the severity of collisions did we see?

Collisions which result in injury are recorded by severity as either fatal, serious, or slight. The way the police record the severity of road safety collisions changed within the timeframes of the evaluation, following the introduction of a standardised reporting tool – Collision Recording and SHaring. This is an injury-based reporting system, and as such severity is categorised automatically by the most severe injury. This has led to some disparity when comparing trends with the previous reporting method, where severity was categorised by the attending police officer.[28] As a consequence, the Department for Transport has developed a severity adjustment methodology[29] to enable robust comparisons to be made.

For this evaluation, one reporting mechanism was largely used prior to the smart motorway conversion and another afterwards. The pre-conversion collision severity has been adjusted, using the Department for Transport's severity adjustment factors, to enable comparability with the post-conversion safety trends.[30]

After the project we have observed a total reduction of two collisions resulting in fatalities (the total before the project was three, compared to one after). There was an average of two more collisions resulting in serious injuries per year (the annual average before the project was nine, compared to 11 after). There was an average of 13 fewer collisions resulting in slight injuries per year (the annual average before

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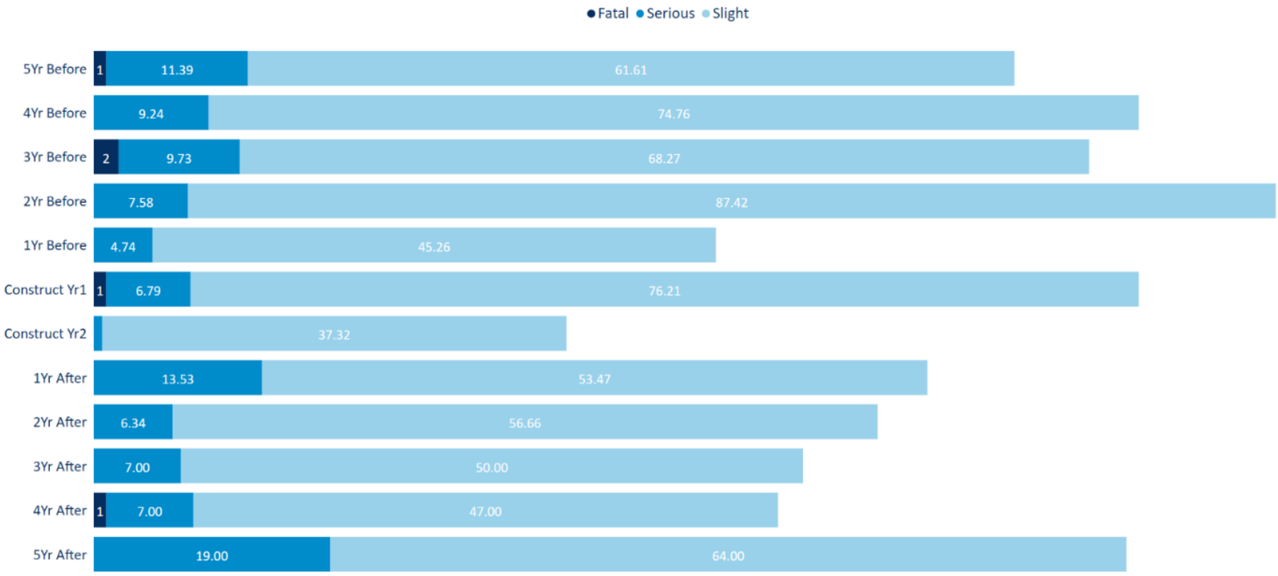
28 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/820588/severity-reporting-methodology-final-report.odt

29 https://www.gov.uk/government/publications/guide-to-severity-adjustments-for-reported-road-casualty-statistics/guide-to-severity-adjustments-for-reported-road-casualties-great-britain#guidance-on-severity-adjustment-use

30 Collision Severities within this report use the 2020 adjustment factor.

the project was 67, compared to 54 after), Figure 18 shows the severity of personal injury collisions.

Figure 18 Severity of personal injury collisions within the project extent



Source: STATS19: 1 September 2007 to 30 April 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 and 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[31]. In effect, it takes all non-fatal injuries and adds them up using a weighting factor to give a total number of fatality equivalents[32]. This is represented by an annual average and a rate that standardise casualty severities against flow to show the likelihood of a fatality equivalent occurring per distance travelled.

A reduction of one fatality equivalents has been observed annually. The severity of casualties occurring after the project became operational has reduced in the project extent. Before the project an annual average three fatality equivalents were observed. After the project this had reduced to an annual average of two fatality equivalents.

The combined measure showed an extra 21 million vehicle miles was travelled before a fatality. Before the project, 214 million vehicle miles needed to be travelled before a fatality equivalent (0.5 fatality equivalents per hmvm[33]). After the project this increased to 235 million vehicle miles (0.4 fatality equivalents per hmvm). The rate of fatality equivalents per hmvm has reduced. This suggests that taking into account changes in traffic the project is having a positive safety impact on the severity of casualties within the project extent[34].

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[31] The FWI weights Casualties based on their severity. This gives a fatality 10 times the weight of a serious casualty, and a serious casualty 10 times the weight of a slight casualty.
[32] Casualty Severities within this report use the 2020 adjustment factor.
[33] Hundred million vehicle miles.
[34] Due the the observed numbers being small we have been unable to test the statistical significance of these results.

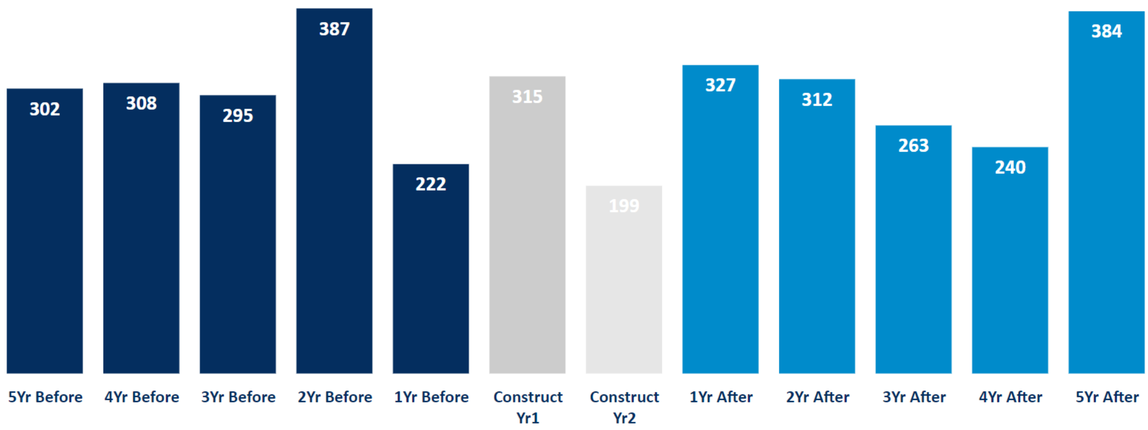
Road user safety on the wider area

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. The appraised wider area was split into two areas as shown in Figure 14. The local area, comprising of roads adjacent to the project extent and a wider area, to check any potential wider impacts from the intervention.

Before the project an annual average of 303 collisions were observed. After the project, this had risen to 305, an increase of 2.

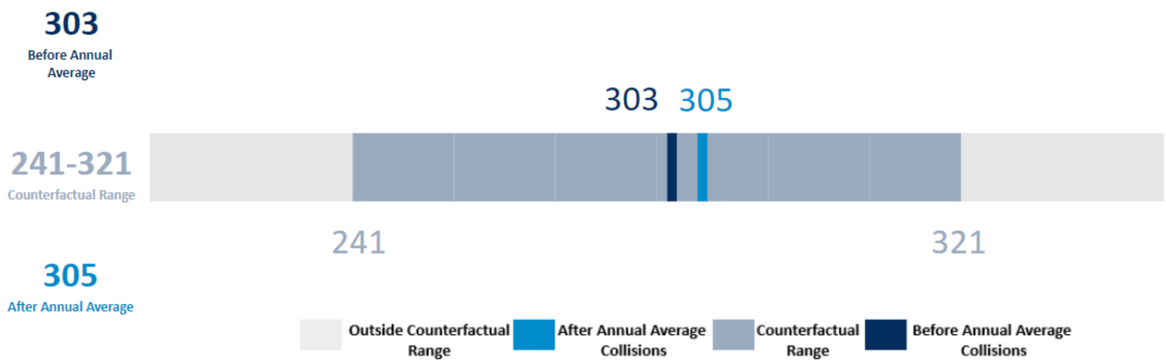
Figure 19: Annual Personal Injury Collisions in Wider Area



Source: STATS19: 1 September 2007 to 30 April 2019

The counterfactual analysis indicated that it is likely that an annual average of between 241 and 321 personal injury collisions would have occurred. The observed annual average of 305 personal injury collisions fall within the range. The project appears to have had no impact on the safety performance of the wider area.

Figure 20: Observed and expected range of personal injury collisions in wider area



Source: STATS19: 1 September 2007 to 30 April 2019

How had traffic flows impacted collision rates in the wider area?

The evaluation has identified a decrease in the rate of collisions per hmvm.

Prior to the project, there was an annual average of 26 personal injury collisions per hundred million vehicle miles. After the project improvements were made there was a decrease to 25 personal injury collisions per hmvm. A decrease of 1 personal injury collisions per hmvm.

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

A counterfactual test was undertaken. It found that the collision rate would likely have been 23 collisions per hundred million vehicle miles in the counterfactual scenario. This indicates that we expected a greater reduction in the rate of personal injury collisions than we have observed if the conversion to smart motorway had not taken place.

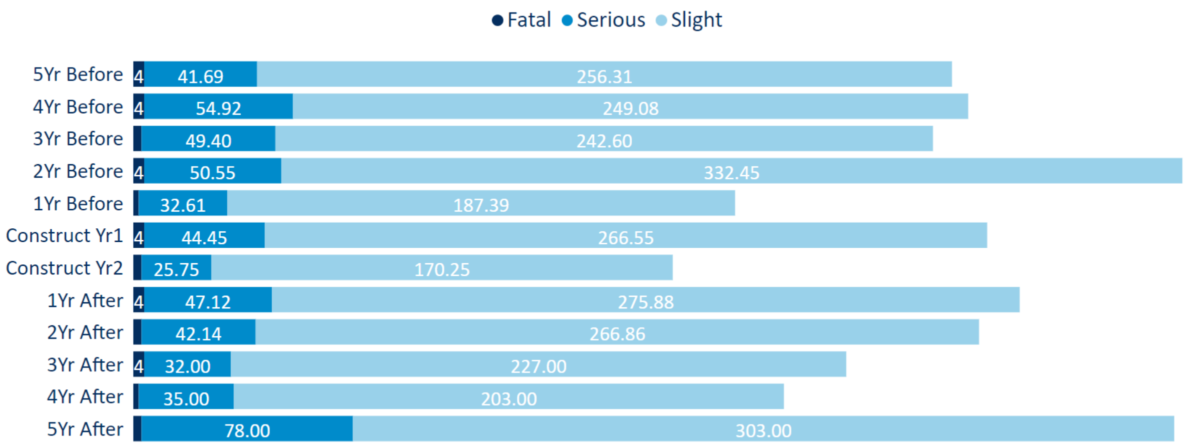
Statistical testing indicates this reduction is insignificant suggesting that the project is having a neutral impact on the wider area.

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

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

After the project we have observed a reduction of one collision resulting in fatalities (the total before the project was 17, compared to 16 after). There was an average of one more collision resulting in serious injuries per year (the annual average before the project was 46, compared to 47 after). There was an average of one more collisions resulting in slight injuries per year (the annual average before the project was 254, compared to 255 after). Figure 21 shows the severity of personal injury collisions.

Figure 21: Personal Injury Collisions by Severity in wider area



Source: STATS19: 1 September 2007 to 30 April 2019

How had traffic flows impacted casualty severity in the wider area?

To understand the impact of the increased traffic flow on collision severity, the measure we use is fatalities and weighted injuries (FWI)[35].

There has been an increase in the average number of fatality equivalents observed. Before the project an average of 11.2 FWI was observed. After the project this had increased to an average of 12.6 FWI.

The combined measure showed an decrease of 9 million vehicle miles was travelled before a fatality. Before the project, 107 million vehicle miles needed to be travelled before a fatality (0.9 FWI fatality per hmvm). After the project this decreased to 98 million vehicle miles (1 FWI per hmvm).

Is the project on track to achieve its safety objective?

Appraised expectation for the project forecast an improvement in the collision rate. This translates into an annual saving of 190 personal injury collisions for the project extent and wider area over the 60-year appraisal period.

The projects safety objective is to achieve after collision numbers (per annum) that are no greater than those in the before baseline period and the severity ratio is not increased. Analysis has shown that both the numbers and rate of PIC for the project extent have fallen since the project however these results were found not to be significant. A similar picture was found for the wider safety area. At the five-year evaluation we consider that the project has met its safety objective.[36] However, we cannot be confident that this is because of the project itself and not part of observed wider regional trends for a reduction in collisions and rates.

[35] See *How has traffic flow impacted casualty severity?* for explanation of the FWI.
[36] 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

The environmental evaluation focuses on the environmental sub-objectives (noise, air quality, greenhouse gas emissions, landscape, heritage and biodiversity and the water environment). No townscape features were expected to be affected as settlements are well separated from the road and no townscape issues were identified from design changes. Thus, townscape was incorporated under the landscape objective. Only construction impacts on water resources were highlighted in the environmental assessment. Thus, the longer-term impact of the project on water resources were scoped out of the five-year evaluation.

Environmental evaluation also treats transport appraisal guidance[37] social impacts on severance, physical fitness and journey ambience (quality) are usually evaluated in POPE. But as there were no new severance issues generated by the project and no outstanding issues were experienced for physical fitness and journey quality from one year after evaluation, these three aspects have been scoped out of the five-year after evaluation in line with our POPE methodology manual[38].

Summary

The five-year after evaluation confirms that the impacts of the project on most of the aspects evaluated (noise, landscape, heritage and biodiversity) were as expected and better than expected for air quality. Issues were found with landscape (mitigation planting) management at the Clacket Lane bund and the absence of maintenance and species monitoring information. But detail design work to optimise the number, type and location of gantries (an overall reduction of 17.8% in the amount of smart motorway infrastructure) led to vegetation retention around gantries and emergency refuge areas reducing visual impacts, particularly at Brasted and Titsey without significantly worsening impacts elsewhere.

Noise

The project appraisal stated that 2,123 dwellings and 17 other noise sensitive receptors were considered in the pre-project study of M25 section 2 and found that:

- On opening, 10 dwellings would experience a minor increase in noise, with all other changes being negligible or no change;
- Over the design period, three dwellings were predicted to experience a minor increase and two dwellings a minor decrease in noise, with all other changes being negligible or no change;

Overall, the appraisal reported that there would be 17 more people affected by noise due to the project than would be without the project, leading to a monetised impact of -£0.6m. Overall, the appraisal concluded that the impact of the project on noise would be slight adverse.

[37] **TAG** provides guidance on appraising transport options against the Government's objective for transport
[38]https://nationalhighways.co.uk/media/exypgk11/pope-methodology-note-jan-2022.pdf

The five-year after evaluation confirmed that a low noise surface had been installed largely as expected to help reduce noise impacts. A comparison of observed two-way annual average daily traffic flows against forecast flows suggests that, whilst flows are lower than predicted, they are not low enough to change the predicted impact. The overall impact of the project on noise was likely to be as expected.

Air quality

The appraisal reported that with the project there would be an overall slight improvement in Nitrogen dioxide (NO_2) and Particulate Matter (PM_{10}) concentrations, and that:

- In terms of local air quality, there were four Air Quality Management Areas (AQMAs) for annual average NO_2, and 2 AQMAs for 24-hour PM_{10} within 200m of the affected road network;
- Annual average air quality standards for NO_2 and PM_{10} were not expected to be exceeded, and no properties demolished or constructed as part of the project. Changes in NO_2 concentrations were predicted to be between -0.1 µg/ m^3 to +1.9 µg/m^3.

The overall significance of the impact of the project on air quality was predicted to be an overall benefit. This was based on the difference between those receptors experiencing an improvement and those a deterioration.

At five years after, local air quality results[39] from monitoring, especially data for relevant AQMAs (Station Road, Brasted), did not shown any exceedances of the air quality standards for NO_2.

Annual average daily traffic flows for all links from M25 junction 5 to junction 7 were lower than forecast. Thus, as a result, overall emissions and pollutant concentrations at receptors were likely to be lower than expected. The impact of traffic on local air quality was likely to be better than expected.

Greenhouse gases

The appraisal predicted an overall increase in carbon emissions with the project due to an increase of +16,587 million vehicle kilometres per day travelled over the 60-year appraisal period. Calculated using non-TUBA[40] method, the non-traded carbon dioxide (CO_2) emissions in 2015 were expected to be +0.037 MtCO2e indicating an increase in CO2 emissions in opening year. Change in emissions in MtCO2e for 2013-2017 (actually 2015-2017) was expected to be +0.12 and change for 2018 to 2022 was expected to be +0.21. The monetised impacts for greenhouse gases (GHGs) over the 60-year appraisal period was predicted to be -£91.2m.

To evaluate the GHG emissions of the appraised project, forecast and observed traffic data is required for the appraised study area. Traffic data is not usually available for the whole study area and typically we only have data for the project extent. This means that the evaluation considers just the opening year emissions for the project extent itself. This approach has limitations as it means direct comparisons

[39] Sevenoaks District Annual Air Quality Status Report (2019)

[40] Transport users benefit appraisal (TUBA) the software that undertakes the economic appraisal of transport schemes in accordance with the Department for Transport's cost benefit analysis guidance.

with the forecast emissions reported in the appraisal, which are for the whole study area, cannot be made. However, it does provide some understanding of the accuracy of the forecast emissions along this section of the project.

To allow for comparison, a new forecast emission and an observed emission for the project extent was calculated using the emission factor toolkit version 10.1 published by the Department for Environment, Food and Rural Affairs. The total forecast and observed emissions along the project extent are reported in Table 5.

Table 5: Tonnes of greenhouse gases: forecast and observed

	Forecast (CO_2 tonnes per annum in fifth year post opening)	Observed (CO_2 tonnes per annum in fifth year post opening)	Difference (CO_2 tonnes per annum in fifth year post opening)
M25 junctions 5 to 7	254,680.17	216,468.62	38,211.56

This approach has limitations as it doesn’t consider traffic changes and the emission changes that would result along the wider network and so can be affected by issues such as reassignment. However, we can see that the observed carbon impacts are lower than forecast, which is due to traffic flows being below forecast levels. This was better than expected and in line with the reduction compared to forecast at one-year after.

Landscape

The environmental appraisal reported that the project is within an area of outstanding natural beauty and an area of great landscape value. Landscape and visual impacts were considered likely to increase due to the presence of new infrastructure, some loss of planting from the construction of emergency refuge areas (ERAs) and associated retaining structures. About 38 properties were expected to experience slight adverse effects and 12 properties were expected to experience moderate adverse effects in the opening year. The overall impact of the project on local landscape character was expected to be slight adverse.

The environmental assessment also reported that the effects of the project on landscape character and visual amenity were expected to be generally neutral or slight adverse due to the location of all proposed works being within the existing M25 highway boundary. However, the project was expected to result in an increase in visual intrusion and an increased perception of urbanisation in the countryside resulting from the proposed signage and gantries. Where slight/moderate adverse effects or greater were identified, mitigation measures to alleviate these effects were proposed, especially during detail design. This was expected to include the removal and relocation of some gantries.

Following the environmental assessment, further detail design work was undertaken to optimise the number, type and location of gantries. Although more super-span gantries were provided there was an overall reduction (17.8%) in the amount of smart motorway infrastructure.

From the evaluation site visit, it appeared that more vegetation was retained reducing visual impacts particularly at Brasted and Titsey without significantly worsening impacts elsewhere. As reported at the one-year after evaluation, there remain issues with landscape management with weeds in many of the plots and failed planting at the Clacket Lane bund which at the five-year evaluation had not been replaced. Poor maintenance could affect the achievement of the design year outcome. Overall, despite concerns with maintenance, the reduction in infrastructure used means the impact on landscape and visual amenity and the setting of cultural heritage assets was broadly as expected.

Figure 22: Traffic on M25 seen from SR300

Source: Evaluation visit, 10 October 2019

Figure 23: Vegetation plot on the embankment of the M25 near SR300 at five years after

Source: Evaluation visit, 10 October 2019

Figure 24: Established planting at five years after on the northern aspect of the bund facing Croydon Road. Entire row of trees on top of bund was dead.

Source: Evaluation visit, 10 October 2019

Heritage of historic resources

The environmental appraisal reported that the project would have a slight adverse impact on the setting of two registered historic parks and gardens – Combe Bank and Titsey Place. The project was also expected to have a slight adverse impact on the historic settings of two listed buildings and one conservation area. The overall impact of the project was considered to be slight adverse.

The appraisal reported that the new gantries along this section of the M25 will reinforce the presence of the highway corridor in the wider context and in views. However, the general context of these registered historic parks and gardens, listed buildings and conservation area would only slightly change. This was predicted to cause a slight adverse effect to a limited number of heritage assets.

Evidence gathered as part of the five years after site visit suggests, archaeological resources and most historic monuments were unaffected by the project as expected. For historic building and historic landscapes or conservation areas, mitigation by way of vegetation retention around gantries and new emergency refuge areas meant that views for most receptors were unchanged as expected. However, it was likely that around the Brasted Church conservation area, the relocation of gantries, and mitigation provided, would mean impacts on some views of the church would better than expect whereas some would be as expected. On balance, the impacts overall were as expected.

Biodiversity

The environmental appraisal anticipated no long-term impacts on the seven statutory designated sites, including one internationally designated site, present. It anticipated risks of a slight adverse effect on eleven adjacent non-statutory sites, including wet wood SNCI[41]. The construction phase impacts of the project were considered to be slight adverse on dormice and great crested newts. During the construction phase, a neutral effect was expected on habitats of lower value within the soft estate and their associated protected species. Overall, the project was expected to have a 'slight adverse' effect on ecological resources. This was due to the reduction of buffering the soft estate provided to adjacent designated sites and loss and severance of habitat within the highway soft estate that, although itself of lower value, contributed to the habitat of protected species. The impacts were not considered significant.

At five years after the evaluation confirmed that the impacts were confined to within the highway boundary. Wildlife refuges, such as dormice boxes were present and asset data confirmed hibernacula for amphibians were provided. As at one-year after, no information had been provided regarding any species monitoring, such as aftercare monitoring reports. The draft handover environmental management plan (HEMP) confirmed that the proposed mitigation and advanced works for species under licences were undertaken. Whilst impacts were likely to be as expected, the absence of aftercare monitoring reports meant that it was not possible to fully evaluate all the effects and so some uncertainty remains.

Overview

The results of the evaluation are summarised against each of the Transport Appraisal Guidance (TAG) environmental sub-objectives and presented in Table 6.

[41] Site of nature conservation interest https://www.wildlifetrusts.org/protected-areas

Table 6: Environmental outcomes

Sub-objective	Appraisal summary table score	5YA evaluation outcome	Summary
Noise	Slight Adverse	As expected.	The evaluation confirmed that low noise surfacing had been installed largely as expected to meet the noise objectives. Two-way AADT[42] flows suggested that outturn flows were lower than forecast for all links of the project and within the threshold, i.e. varying from -15% to -22%. This suggested that the impact of traffic on noise was likely to be as expected.
Air quality	Moderate Beneficial	Better than expected.	Local air quality results from the monitoring reported for Sevenoaks District in 2019 have not shown any breaches of the UK Air Quality standards for Nitrogen Dioxide. AADT traffic flows for all links from M25 junctions 5 to 7 were lower than forecast by more than 10%. Thus, the effects of the project in terms of local air quality are likely to be better than expected.
Greenhouse gases	3.14MtCO_2e increase over 60 years.	Better than expected.	Due to lower-than-forecast flows, the carbon impacts of the project (along the project extent) at five years after was better than expected, with observed carbon outputs being 22,592 tonnes per annum lower than forecast. Therefore, the outcome was better than expected.
Landscape	Slight Adverse.	As expected.	The outcome at 5YA was broadly as expected. The project had caused loss of vegetation although design changes had meant that the impact of greater urbanisation had been reduced. As reported at 1YA, maintenance remained an issue with weeds common in many of the plots, planting establishment variable and dead trees at Clacket Lane bunds not replaced. With improved aftercare, the design outcome should still be met.

[42] Annual average daily traffic

Sub-objective	Appraisal summary table score	5YA evaluation outcome	Summary
Heritage of historic resource	Slight Adverse	As expected.	The evidence gathered during the 5YA site visit suggested that as expected, archaeological resources and most historic monuments were unaffected by the project. For historic building and historic landscapes or conservation areas, mitigation by way of vegetation retention around gantries and emergency areas had mitigated the impact on the setting of most receptors as expected.
Biodiversity	Slight Adverse	As expected.	The impacts were confined to within the highway boundary. Wildlife refuges for dormouse and for amphibians were provided. The draft handover environmental management plan confirmed that proposed mitigation had been undertaken, although no further information to confirm success was available at 5YA. Overall its likely impacts were as expected.

Source: adapted from 1YA evaluation, 5YA evaluation visit and appraisals). Note: townscape was treated under the landscape objective. Water resources, severance physical fitness and journey ambience (quality) have been scoped out of the 5YA evaluation.

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 within the original budget, at a cost of £131million[43]. In the first five years, the road provided additional capacity to support more road users (an increase of 2-9%), whilst improving the safety of those journeys. If this trend continues, the project is reforecast to deliver £19million of safety benefits over the 60-year period, which is higher than originally anticipated within the business case. The section between junctions 5 and 6 where all lane running was implemented was close to capacity prior to the project, so without the improvement this additional traffic could not have been accommodated without the road being over capacity[44].

Journey time benefits made up the majority of the anticipated monetised impacts of this project. The appraisal forecast significant traffic growth and improving journey times; the observed data suggested much more modest traffic growth accompanied by slower journey times and this affected the projected value for money. Safety is at the forefront of every decision we make. Monetised safety benefits were re-forecast to be better than expected, but these only contributed a small proportion of the value for money case.

Overall the evaluation indicated that in the first five years this investment is 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 'low' value for money[45].

Forecast value for money

An economic appraisal is undertaken prior to construction to determine a project's value for money and inform the business case. The appraisal is based on an estimation of costs and benefits. The impacts of a project, such as journey time savings, changes to user costs, safety impacts and some environmental impacts can be monetised. This is undertaken using standard values which are consistent across government. The positive and negative impacts over the life of the project[46] 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 M25 junctions 5 to 7 smart motorway business case are set out in Table 7. We have also included

[43] Present value of costs in 2010 prices and values.
[44] Before the conversion, road users experienced high levels of congestion. During the peak hours traffic flow was at 5,600 vehicles per hour, as a three-lane motorway this was very close to capacity. After the conversion traffic flow was 6,200 vehicles per hour. Had the route remained a three-lane motorway this would be above capacity.
[45] The value for money categories referenced are defined by the Department for Transport https://www.gov.uk/government/publications/dft-value-for-money-framework
[46] Typically scheme life is taken to be 60 years.

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.

Table 7: Monetised benefits of the project (£million)

	Forecast (£m)	% of forecast monetised benefits	Evaluation approach
Journey times	560	70%	Re-forecast for the project area only (not the wider area) using observed and counterfactual[47] traffic flow and journey time data
Vehicle operating costs (VOC)	-128	-16%	Re-forecast using observed and forecast traffic flow and journey time data
Journey time & VOC during construction and maintenance	-57	-7%	Not evaluated (assumed as forecast)
Journey time reliability	413	52%	Re-forecast using observed traffic flow data
Safety	12	1%	Re-forecast using observed and counterfactual safety data
Carbon	-161	-20%	Monetised benefits assumed as forecast
Air quality	0	0%	Monetised benefits assumed as forecast
Noise	-1	0%	Monetised benefits assumed as forecast
Indirect tax revenues	160	20%	Re-forecast using observed and forecast traffic flow and journey time data
Total present value benefits	**798**	**100%**	

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

The anticipated costs from the appraisal are set out in Table 8. Based on this information, the project was anticipated to deliver high value for money over a 60-year appraisal period.

[47] 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’).

Table 8: Forecast cost of the project (£millions)

	Forecast (£m)	Evaluation approach
Construction costs	135	Current estimate of project cost
Maintenance costs	21	Not evaluated (assumed as forecast)
Total present value costs	**156**	

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 costs

We obtained an up-to-date estimate of the project construction cost which came in slightly under budget at £110million.[48]

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, we did not have any information with which to update the estimate for this part of the cost and therefore the forecast from the appraisal remains our best estimate.

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 re-forecast 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

Monetised benefits were primarily driven by forecasted reductions in journey times over the modelled period compared to a ‘do-minimum’ scenario, what would be expected to happen if the smart motorway were not built. Therefore, in this section of our study, we have compared the ‘after’ journey times to an estimate of the ‘counterfactual’ - 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 evaluation of this project identified that journey times, while becoming more reliable in some instances,[49] have increased since the road was converted to a

[48] Present value of costs in 2010 prices and values
[49] Reliability had generally improved on the anticlockwise direction but had deteriorated on the clockwise direction.

smart motorway.[50] This was likely due to several factors, including, supporting an increase in the number of road users, as well as speed restrictions during the busiest peaks.

We estimated a re-forecast journey time disbenefit of £27million. We are only presenting journey time benefits observed on the project area, not the wider area which would have been considered in the appraisal.[51] The reason for this is that our findings relating to the project area are very different from those forecast for that area. We therefore did not feel we had sufficient confidence in the forecasts to use them to make an estimate of the outturn impact in the wider area (where we did not have observed journey time data). Our observations only cover the project extent, which saw growth between 2% and 9%. There is no evidence of decongestion in the wider area, though there is also none in the contrary. Other strategic routes such as the A21 and A22 saw similar mixed growth between 5% and 13%. We acknowledge that the monetised value presented above does not represent the full impact of the project.

Monetised journey reliability benefits

Journey time reliability was a main objective of this project. Our evaluation showed an improvement in reliability on the anticlockwise carriageway, with the slowest journeys taking almost five minutes less than before during the Friday evening peak (Figure 10). Variability in the middle 50% of journeys for the weekday and Friday morning peaks on the clockwise carriageway had worsened, but other times of the day had remained stable (Figure 9).

Monetisation of journey reliability benefits is calculated differently from those shown in section 4. It uses the Department for Transport's (DfT) Incident Cost Benefit Assessment (INCA)[52] programme and is re-run using observed traffic flow data obtained in the evaluation. Our estimate of the monetised journey reliability is £403million, slightly lower than what was forecast.

Other reforecast impacts

Our evaluation of outturn safety benefits is based on the forecast 60-year appraisal period and a comparison between the forecast and observed number of collisions saved at five years after.

A monetary benefit of £12million over the 60-years appraisal period was forecast. This was estimated by assuming a 15% reduction in personal injury collisions (PICs) and assigning monetary benefits to the predicted reduction in the number and severity of PICs over the 60-year appraisal period.

If the project section had remained as a conventional motorway, safety on the project extent and surrounding network would most likely have seen an increase in accidents. Fewer PICs were observed, and there was a reduction in the rate and severity of PICs compared to before the project. The evaluation concluded there were fewer personal injury collisions than forecast (Figure 17), and this produced a

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[50] When considering that journey times would have deteriorated without the smart motorway with an increase in traffic, road users have seen quicker journeys in the anticlockwise direction than would have been likely, though these are worse for the clockwise carriageway.

[51] We estimate that the expected monetised benefit on the scheme section in the fifth year was £3.9million, compared with an estimated disbenefit of £0.8million based on our observations.

[52] Incident Cost Benefit Assessment can be used to estimate the benefits of reduce delay and travel time variability caused by unforeseen incidents that reduce capacity such as breakdowns, accidents and debris on the carriageway and major disruptions such as spillages.

monetary outturn benefit of £19million, a greater benefit than the appraisal expected.

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, and we have evaluated it to be slightly higher at £52million. The impact is lower than forecast because our evaluation has shown that absolute volumes of traffic are lower than forecast, with the rate of growth lower than expected too. 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 disbenefit of £42million.

Impacts assumed as forecast

The evaluation has not been able to reforecast the monetary value of noise, air quality and carbon benefits[53], and instead these were reported as forecast. For these impacts, this assumption is conservative because lower than forecast traffic flows are likely to mean that these impacts are better than forecast.[54]

Journey times and vehicle operating costs during construction and maintenance are not evaluated and therefore assumed as forecast. As the vast majority of this maintenance is still in the future, we did not have any information with which to update the estimate for this and therefore the forecast from the appraisal remains our best estimate.

Overall value for money

The main reason for the overall reduced level of benefits from this project is the lack of journey time savings. The appraisal forecast significantly more traffic with an improvement in journey times; the observed data showed there was more traffic, this was lower than expected and has been accompanied by slower journeys which has affected the projects' value for money[55]. This is likely due to the increased usage of variable mandatory speed limits and compliance from road users along the smart motorway.

When considering an investment's value for money we also take into account benefits which we are not able to monetise. Although not included in the appraisal, wider economic benefits might be relevant given the project's proximity to functional urban areas and significant transport hubs such as London and Gatwick Airport. These benefits are usually dependent on the project delivering journey time savings which have not been realised. Positive impacts on local decongestion and wider economic impacts could improve the value for money category, but as there

[53] 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 schemes and therefore the impact of assuming as forecast is unlikely to impact on the value for money rating of the project.
[54] Refer to section 6 for further detail on noise and greenhouse gas impacts.
[55] The value for money categories referenced are defined by the Department for Transport https://www.gov.uk/government/publications/dft-value-for-money-framework

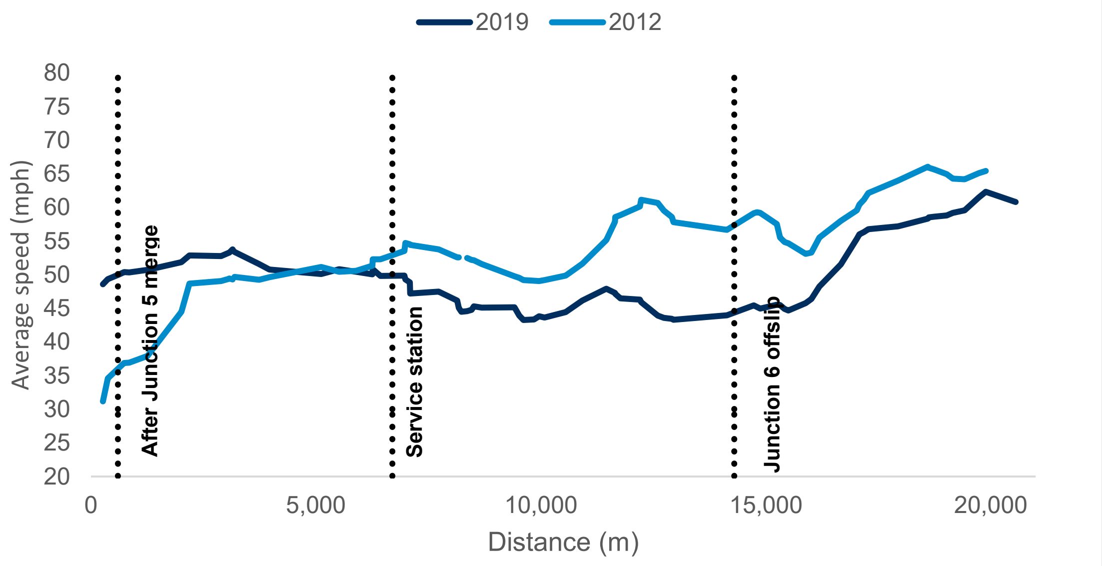
is no evidence of this it is likely that this project will offer ‘low’ value for money[56] over the project life.

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 under budget, it is delivering safety benefits to road users and most of the environmental benefits are as expected, or better.

Appendix A

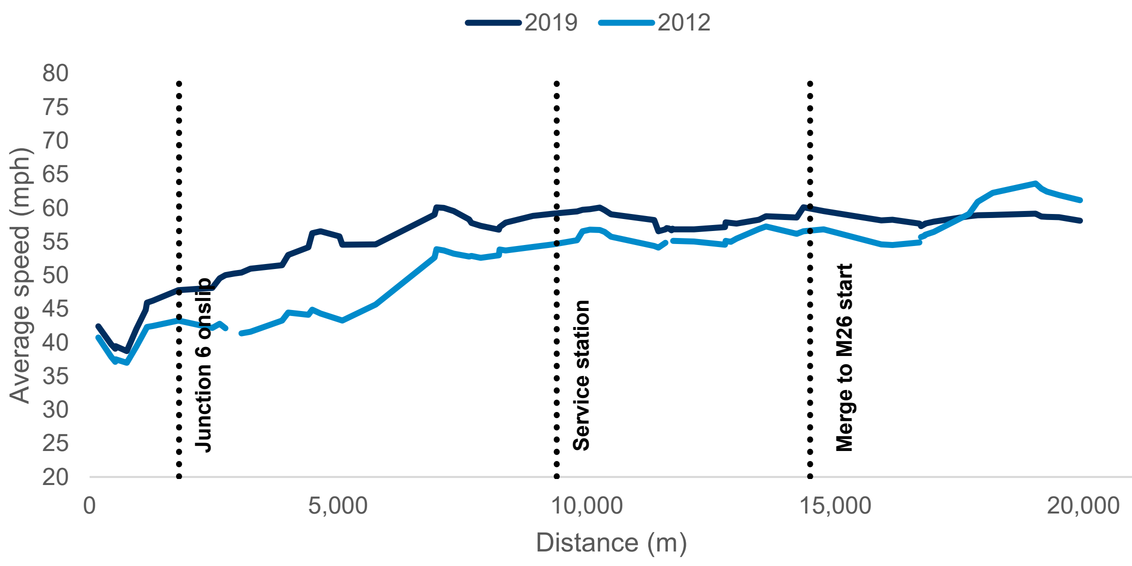
Speed over distance graphs

Figure 25: Friday morning peak speed by distance (clockwise)



Note: Before: March 2012; Five years after: March 2019. Source: TomTom satellite navigation data.

Figure 26: Friday evening peak speed by distance (anticlockwise)



Note: Before: March 2012; Five years after: March 2019. Source: TomTom satellite navigation data.

Appendix B

Counterfactual safety 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 POPEs 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.

Appendix C

Incident reporting mechanisms

Since 2012, many police forces have changed the way they collect STATS19 data (for more information see here). These changes mean casualty severity is now categorised automatically based on the most severe injury, rather than the judgement of an attending police officer.

Police forces using the new systems, called injury-based severity reporting systems, (also known as Collision Recording and SHaring (CRaSH) and Case Overview Preparation Application (COPA)) report more seriously injured casualties than those which don't. These changes make it particularly difficult to monitor trends in the number of killed and seriously injured casualties over time, or between different police forces. In response to these challenges, DfT and the Office for National Statistics (ONS) have developed an approach to adjust the data collected from those police forces not currently using injury-based reporting systems.

These adjustments are estimates for how casualty severity may have been recorded had the new injury-based reporting system been used. These adjusted estimates apply retrospectively from 2004 and adjust historical data to show casualty severity 'as if' this was recorded under the new injury-based system. Until all police forces have started using the new systems, these historical adjustments will continue to be updated every year. Using these adjusted totals allows for more consistent and comparable reporting when tracking casualty severity over time, across a region, or nationally. While there is no impact on total casualties or collisions, and no impact on total fatalities, these adjustments do impact serious and slight casualties and collisions.

Appendix D

Unadjusted collision severity

The project extent is covered by two police constabularies who transferred from Stats19 to injury-based reporting system for reporting personal injury collisions. Surrey police constabulary transferred to CRASH in November 2012. Kent police constabulary transferred to CRASH in January 2016.

Figure 27 shows the unadjusted collision severities on the project extent:

Figure 27: Unadjusted Collision by Severity on Project Extent

Observation Year	Fatal	Serious	Slight
5Yr Before	1	10	66
4Yr Before		7	78
3Yr Before	2	7	74
2Yr Before		5	93
1Yr Before		3	49
1Yr Construct	1	5	80
2Yr Construct			39
1Yr After		12	59
2Yr After		6	58
3Yr After		8	52
4Yr After	1	8	46
5Yr After		19	69

Source: STATS19: 1st July 2004 to 31st May 2017

Part of the wider safety area of the M25 J5-7 project is covered by three police constabularies who transferred from Stats19 to injury-based reporting system for reporting personal injury collisions. Surrey police constabulary transferred to CRASH in November 2012. Kent police constabulary transferred to CRASH in January 2016. Metropolitan Police constabulary transferred to COPA in January 2015.

Figure 28 shows the unadjusted collision severities on the wider safety area:

Figure 28: Unadjusted Collision by Severity on Wider Safety Area

Year_Type	Fatal	Serious	Slight
5Yr Before	4	31	267
4Yr Before	4	44	260
3Yr Before	3	41	251
2Yr Before	4	38	345
1Yr Before	2	25	195
Construct Yr1	4	33	278
Construct Yr2	3	20	176
1Yr After	4	38	285
2Yr After	3	37	272
3Yr After	4	32	227
4Yr After	2	41	197
5Yr After	3	79	302

Source: STATS19: 1st July 2004 to 31st May 2017

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