M1 junctions 10 to 13 hard shoulder running & junction improvements

Five-year post opening project evaluation

Foreword

Highways England's motorways are among the safest in the world[1].

In terms of fatality rates, smart motorways are the safest roads in the country. All road journeys involve risk, but the chance of death on smart motorways is less than on any other major road. It is less than on conventional motorways, and it is far less than on any SRN[2] A-road. But that does not mean that we do not need to do more.

As Executive Director, Strategy and Planning, I want to know that developments on our network are meeting their objectives and are putting the needs of drivers first. Post Opening Project Evaluation reports are a vital part of that assessment.

The M1 between junctions 10 and 13 is a dynamic hard shoulder running smart motorway and junction improvement. The scheme aimed to deliver capacity improvements, improve journey time reliability, reduce congestion and improve safety.

This report evaluates the scheme performance within the first five years of operation[3] following the conversion from a three-lane motorway.

Overall, Post Opening Project Evaluations of smart motorways show that all schemes are, at least partially, meeting their overall objectives.

This report shows that during the first five years of the smart motorway there have been fewer personal injury collisions on average each year[4], and a reduction in the rate and severity[5] of personal injury collisions.

Collisions involving injuries are rare on the strategic road network and can be caused by many factors. But since the time period considered by this report, there have sadly been further fatalities on this stretch of motorway. We will use the lessons learned from these tragic events and include them in our longer-term assessment of the schemes.

Before the conversion, road users on this section experienced high levels of congestion, with the road at near capacity as a three-lane motorway for the busiest periods of the day[6].

The analysis shows reliability of journeys was maintained, and speeds become more consistent, reducing stop-start traffic for drivers. This is against a 10% increase in traffic. It is unlikely that the conventional three-lane motorway would have been able to support the increased number of road users and would have reached capacity, leading to slower and less reliable journeys. The evaluation

[1] https://www.gov.uk/government/statistical-data-sets/ras52-international-comparisons
[2] Strategic Road Network – the roads Highways England manages
[3] First five years of operation up to December 2017
[4] collision that involves at least one vehicle and results in an injury to at least one person
[5] The first three years after the scheme opened have been used for severity analysis using unadjusted collision severities. More information can be found in A.3 Collisions by severity.
[6] A typical one-way flow on this section of the M1 was 5,500 vehicles per hour. As a three-lane motorway this would be a little over 1,800 per lane, very close to capacity

highlighted that all environmental objectives were either better than expected or as expected within the business case for the scheme.

The evaluation findings indicate further action is required over the scheme's 60-year lifecycle for it to meet its appraised value for money objectives. We are addressing this. We are upgrading all dynamic hard shoulder motorways to all lane running by March 2025. Work to convert this section is due to start next year and be complete by March 2024. This will provide a more consistent experience for drivers and help to unlock journey saving benefits and achieve its long-term objectives.

In addition, we are continuing to deliver further measures as set out in the Department for Transport's Smart motorway safety evidence stocktake and action plan[7], published in March 2020, and our Progress Report[8] published in April 2021, setting out our progress in delivering the actions.

Elliot Shaw

Executive Director, Strategy and Planning

July 2021

[7] https://www.gov.uk/government/publications/smart-motorway-evidence-stocktake-and-action-plan
[8] https://highwaysengland.co.uk/media/bb4lpkcp/smart-motorways-stocktake-first-year-progress-report-2021.pdf

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1. Executive summary

1.1 Background

The M1 junctions 10 to 13 dynamic hard shoulder running and junction improvement scheme opened to traffic in December 2012. The scheme runs between Luton and Milton Keynes in the county of Bedfordshire and was one of the earlier generation of smart motorways.

Before the conversion to dynamic hard shoulder, road users on this section of the M1 experienced high levels of congestion, with the road at near capacity as a three-lane motorway for the busiest periods of the day.

Dynamic use of the hard shoulder allows the hard shoulder to be used as an additional live running lane during busy periods, providing extra capacity and easing congestion. Electronic signs guide drivers when it is safe to use for live running. A lower speed limit is in force to smooth the flow of traffic, reducing congestion and emergency areas provided at regular intervals.

The scheme aimed to deliver capacity improvements, improve journey time reliability, reduce congestion and improve safety.

1.2 Evaluation findings

This report indicates how the scheme was performing within its first five years of operation[9]. With a focus on the impact of the scheme on customer journeys, safety and the environment to indicate whether the scheme is on track to deliver its expected benefits over the 60-year period.

1.2.1. Customer Journeys

The additional lane available to road users at busy periods had provided extra capacity and led to some improvements in customer journeys.

Traffic growth on the route had increased by an average of 10%[10] from 2009 to 2018, this was in line with the average growth across the strategic road network (SRN). With the greatest growth to the southern part of the scheme from junction 10 to junction 11a, attributed to the opening of the A5-M1 link road in 2017 with road users using this section to bypass the town of Dunstable (see section 4.2).

Journeys had become more reliable[11] for road users travelling northbound in the pm peak period. For all other time periods the level of reliability was broadly consistent compared with the levels for the conventional three-lane motorway, whilst accommodating an increased number of road users (see section 4.3).

There was evidence that road users were traveling at more steady speeds for longer, without needing to brake and accelerate as frequently. This was contributing to delivering smoother journeys and improving reliability of journeys. When the hard shoulder was used as a live running lane, speed restrictions required road users to slow down to a speed limit determined by the level of

[9] First five years of operation up to December 2017. Safety data up to 1st December 2017. Traffic data up to March 2018 to be comparable with baseline and one year after evaluation data.
[10] Comparing average weekday traffic (AWT) between 2009 and 2018

[11] The extent to which journey times vary from the average journey time indicates how reliable a journey is.

congestion on the road, up to a maximum of 60 miles per hour. This was to smooth the flow of traffic in order to reduce congestion and improve journey time reliability (see section 4.3.4).

The increase in the number of road users and the speed restrictions required to run smart motorway, meant that journey times were longer after the conversion. Before the conversion, the route was operating very close to capacity and road users experienced high levels of congestion. Without the additional capacity of the fourth lane, it was unlikely that the existing three-lane motorway would have been able to support the increased number of road users. Leading to slower journeys, and congestion, as drivers would have had to frequently brake, forming queues and unreliable journeys. There would have been minimal scope for future traffic growth, potentially impacting development and safety in the surrounding area.

Traffic growth and journey time forecasts were found to be over optimistic; this was due to the modelling and appraisal being undertaken prior to any signs of the 2008 UK recession. Also, at that time the available evidence on how dynamic hard shoulder schemes would operate was limited to a single pilot study. Since then, we have refined the assumptions made when assessing new schemes and consider systematic events, such as a recession with high and low growth scenarios.

1.2.2. Safety

Over the five-year evaluation period following the opening of the scheme, there had been a reduction in the annual average number and rate of personal injury collisions[12] on the M1 junctions 10 to 13, and on the surrounding network.

On the scheme extent there had been an annual average reduction of three personal injury collisions.

- This was based on an annual average of 95 personal injury collisions after the scheme had opened compared with 98 before the scheme was constructed.
- It is estimated that if the road had remained as a conventional motorway over this period a range of 98 to 124 personal injury collisions per year would have been expected.

Therefore, there had been a statistically significant reduction in the number of personal injury collisions within the first five years of operating the smart motorway, compared with the estimated trend if the scheme had remained a conventional motorway.

When accounting for the increased volume of road users over this period, the annual average rate of personal injury collisions (per million vehicle km) had also improved over time.

- Before the scheme was constructed there was an average of one personal injury collision per 11.4 million vehicle kms travelled.
- In the five years after the scheme opened to traffic, this improved to an average of one personal injury collision per 12.1 million vehicle kms travelled.

This result shows that proportionately to the number of additional road users, the likelihood of a personal injury collision had reduced.

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

On the surrounding road network there had been an annual average reduction of 197 personal injury collisions.

- This was based on an annual average of 677 personal injury collisions observed after the scheme had opened compared with 874 before the scheme.
- It is estimated that if the road had remained a conventional motorway over this period, a range of 1,105 and 1,217 personal injury collisions per year would have been expected.

Therefore, there had been a statistically significant reduction in the number of personal injury collisions within the first five years of operating the smart motorway, compared with the estimated trend if the scheme had remained a conventional motorway.

This indicates that the surrounding road network might have experienced an increase in personal injury collisions if the M1 junctions 10 to 13 had remained a conventional motorway. The traffic forecast within the business case for the scheme, predicted that it would become a more attractive route for vehicles traversing through the area and therefore would result in lower traffic flows on the surrounding network[13]

Since the conversion to smart motorway, there had been a reduction in the severity of collisions when accounting for the increased number of road users. This analysis is based on three-year[14] pre and post construction periods. During the three years before the scheme was constructed, there was an annual average of one fatal collision and there was an annual average of one fatal collision in the three-year period after the scheme had opened to traffic.

On average there were 15 fewer personal injury collisions leading to slight injuries per year but five more collisions leading to serious injuries per year. When accounting for the increased number of road users over this time period, severity had reduced. From an annual average of 4.3 fatality equivalents[15] per billion vehicle kms travelled to 3.7 since the conversion (see section 5.4).

1.2.3. Environment

The evaluation of environmental impacts compares the predicted impact from appraisal to observed impacts determined during a site visit. The site visit was undertaken in August 2018. Post opening evaluations provide an opportunity for such findings to be captured early and ensure improvements are made, so the design outcome can be achieved.

For the scheme extent, all environmental objectives were either better than expected or as expected. The observed growth in traffic levels was lower than forecast, suggesting that the impacts on noise, air quality and greenhouse gas emissions were better than expected. Landscape and townscape impacts were as expected; however, the evaluation highlighted the need for further maintenance if

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

[14] In April 2016 Bedfordshire Police Constabulary transferred to Collision Recording and Sharing (CRaSH). Recording the severity of collisions is no longer left to the discretion of the reporting police officer which has resulted in a change how collision severity is recorded. This occurred in the 4th year after the scheme opened, consequently the first 3 years after the scheme opened have been used for severity analysis using unadjusted collision severities. More information can be found in A.2 Incident reporting.

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

the design outcome for the 60-year appraised period of the scheme was to be achieved.

The evaluation highlighted that on the junctions, landscape and townscape mitigation was implemented, but this had not fully established at the time of the site visit. Partly as a result of an exceptional heatwave in Summer 2018, which hindered some of the mitigation planting (see section 6).

1.2.4. Value for Money

As part of the business case for the scheme an economic appraisal was used to determine the scheme's value for money. This assessment was based on an estimation of costs and benefits over a 60-year appraisal period. The scheme came under budget at £489m compared with a forecast of £606m[16]. This was due to lower construction costs than forecast.

The post opening project evaluation of economic impacts assumes that benefits are derived from two main sources, improvements in journey times and reduction in personal injury collisions. The appraisal had forecast that the scheme would deliver greater benefits for journey times over the 60-year assessment period for a larger number of road users. In the first five years of the road being opened to road users, the evaluation had not observed the level of benefit in line with the assumptions within the business case. This is because key assumptions used in the appraisal were based on limited evidence from one smart motorway pilot study and since then the objectives and assumptions of smart motorways have been evolving as more evidence and data has become available. Smart motorway schemes' appraisal now better reflects delivery and operational assumptions, and sensitivities to external systemic events, such as recessions.

The methodology for evaluating the economic value of benefits arising from journey time is based upon comparing the observed vehicle hour savings in the opening year against the original forecast of the savings developed in the business case. It is then assumed that the ratio between these at five years after is indicative of the long-term trend. Whilst this gives an indication of the proportion of forecast benefit realised, it does not give an accurate picture of the outturn Value for Money as it is based on appraisal assumptions no longer considered valid. In this scenario, the anticipated core journey timesaving benefits were not realised, and the scheme therefore is not on track to deliver its value for money objective[17] as defined in the original appraisal.

In this case, the monetisation of journey time benefit is not a good measure of value for money and the qualitative evidence presented in the evaluation is considered a more robust measure. The scheme has provided increased capacity, safety improvements and maintained levels of reliability whilst supporting an increase in the number of road users. The traditional method of producing a benefit to cost ratio (BCR) is presented in Appendix 4.

Although speeds are lower and journey times longer than initially predicted for this scheme, the assumptions behind the forecasts have been improved with the availability of greater evidence of smart motorway operation. Moreover, we are committed to continual improvement as part of the smart motorway safety evidence

[16] 2010 prices discounted to a present year of 2010

[17] Value for money objective - the project shall provide high value for money against its whole of life costs in accordance with the Department's TAG guidance

stocktake and action plan[18], we are converting all dynamic hard shoulder schemes to all lane running (ALR). All lane running schemes have seen delay lower than the overall delay across the smart motorway network[19]. As the scheme is already dynamic hard shoulder running, the works needed would not require significant costs compared to an upgrade from the conventional motorway. The conversion is anticipated to unlock journey saving benefits for the M1 junction 10 to 13 and provide further value to the scheme (see section 7).

[18] In March 2020, the Department for Transport published its smart motorway safety evidence stocktake and action plan https://www.gov.uk/government/publications/smart-motorway-evidence-stocktake-and-action-plan

[19] Delay metric 2019/20 and 2020/21, delay - seconds per vehicle per mile. This is a new metric and is being validated.

2. Introduction

2.1 What is the scheme and what was it designed to achieve?

The M1 junctions 10 to 13 dynamic hard shoulder running, and junction improvement scheme opened to traffic in December 2012. The scheme runs between Luton and Milton Keynes in the county of Bedfordshire and was one of the earlier generation of smart motorways.

Prior to the scheme, road users on this section of the M1 experienced high levels of congestion. The stretch of motorway was already close to capacity causing speeds to fall below free flow conditions during peak and inter-peak periods. The scheme aimed to deliver capacity improvements, improve reliability, reduce congestion and improve safety through dynamic use of the hard shoulder and managed motorway technology.

The scheme also included improvements at junctions 11 and 12. Junction 11 provides access to Luton and Dunstable via the A505, the main east-west corridor in the area linking Dunstable and Luton town centres. The improvements comprised the widening of slip roads and additional traffic signals at the junction itself, including the circulatory main carriageway and the A505.

Junction 12 is to the north of the Toddington motorway service area, where the motorway passes under the A5120 Harlington Road. Four slip roads connected the motorway with the A5120, and traffic signals operated to control traffic movements between the slip roads and the A5120. The improvements comprised a new bridge over the M1, installation of new traffic signals and new slip roads built to the north of the junction to increase capacity.

2.2 Scheme Location and Local Transport Strategy

The M1 is a strategic route in England, linking London with the Midlands and the North. The scheme section is in the county of Bedfordshire, starting just south of Luton, junction 10 and finishing at junction 13 to the east of Milton Keynes. At 15 miles long, the scheme facilitates traffic passing through key urban areas including Bedford, Milton Keynes, Luton and Dunstable.

As part of Central Bedfordshire's strategy to bring business and housing growth into the area several major transport schemes have been implemented to provide infrastructure improvements and address congestion in the local towns. To support the growth in local housing and employment between 2011 and 2026[20] the local area was expected to see increasing demand for travel.

The additional capacity provided by the M1 junctions 10 to 13 scheme would relieve congestion from local towns and villages with lower traffic flows forecast for the surrounding network. Without the additional lane there would be little scope to accommodate future traffic growth on the strategic network. Adversely impacting the local road network as road users find alternative routes, with the potential to increase local congestion and potential development in the surrounding area could be limited.

The M1 junctions 10 to 13 facilitated the provision of the A5-M1 Link (Dunstable Northern Bypass), which opened in May 2017. A dual carriageway which connects

[20] Central Bedfordshire Council Transport Strategy, Local Transport Plan 3, April 2011 to March 2026

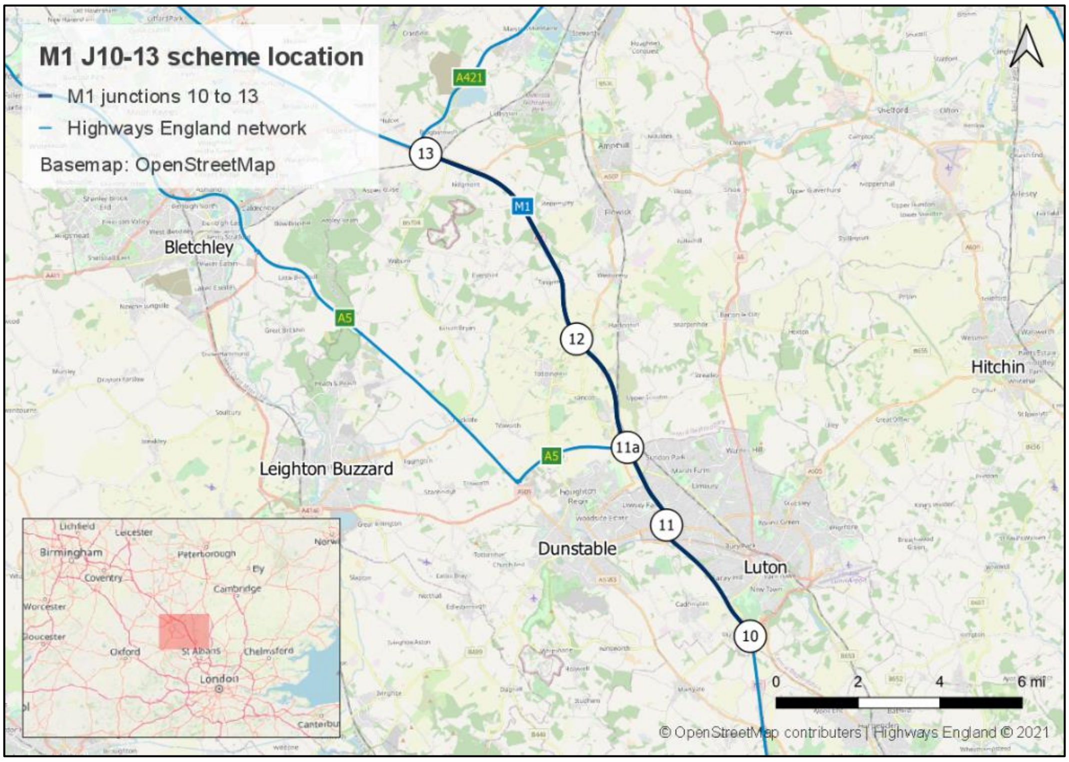
the M1 at the new junction 11a north of Luton, to the A5 at Thorn Turn north of Dunstable. As part of the scheme the A5 was de-trunked[21] to take heavy goods vehicles away from the town centres.

In April 2017, the Woodsite Link opened, which connects Houghton Regis and the Dunstable industrial estates to the M1 junction 11a. The scheme delivered by Central Bedfordshire will provide access to a new development area north of Houghton Regis, where 5,000 houses are to be built and 30 hectares of employment land developed by 2031.

The M1 corridor running through Central Bedfordshire is a strategic location for the warehousing and transportation industry. Several national and regional distribution centres are located close to the M1 between junctions 9 to 13 and along the A421 linking Bedford to the M1, impacting upon freight flows on the M1. Approximately 15% of traffic on the M1 is freight.

The geographical location of the scheme in relation to the region and surrounding highway network is shown in Figure 1 below.

Figure 1: M1 junctions 10 to 13 scheme location and surrounding highway network



Source: Highways England and OpenStreetMap contributors

2.3 How has the scheme been evaluated?

Post-opening project evaluations are carried out for major schemes, to understand the impact the scheme had on the journey experience for road users. We compare the impact in key areas, including journey reliability, safety and on the environment.

During the business case for the scheme, the impacts were assessed to be delivered over a period of 60 years after scheme opening[22]. The evaluation

[21] De-trunking - the transfer of strategic roads from Highways England to local authority control
[22] https://www.gov.uk/guidance/transport-analysis-guidance-tag

provides an early mechanism to ensure the scheme is on track to deliver the anticipated benefits over this assessment period.

Impacts were assessed by observing trends on the route before the scheme was constructed (baseline) and evaluating these after the scheme improvements had been completed and the route was fully operational to traffic. Impacts of the scheme were also assessed against the expected impacts presented in the forecasts made during the project planning process.

This report covers the period up to five years after opening, which is December 2017.

3. Delivering against objectives

3.1 How has the scheme performed against objectives?

All Highways England major schemes have specific objectives which are defined early in the business case when scheme options are being identified. These objectives are appraised to be realised over 60 years.

Table 1 below summaries the impact of the scheme as observed at five years after scheme completion, covering the period up to December 2017. This provides an early indication if the anticipated benefits will be realised over the full assessment period (60 years).

Table 1: Objectives and Evaluation Summary

Objective	Five-year evaluation
The scheme shall provide additional capacity	The scheme delivered capacity improvements with the operation of the hard shoulder as an extra lane at busy periods. Prior to the scheme the M1 junctions 10 to 13 was operating at near capacity as a three-lane motorway.
The scheme shall improve journey time reliability on the M1 between junctions 10 to 13 for both southbound and northbound traffic	There had been little change in journey reliability. The greatest benefit was seen in the pm peak for northbound journeys, with reliability improving by 1 minute 48 seconds. For journeys made in the am peak, journey times become more variable in each direction by 10 seconds, however this was while accommodating an increase in the number of users.
The scheme shall reduce the number of fatalities, casualties and incidents on the M1 between junctions 10 to 13, per vehicle kilometre.	There had been improvements in safety on the scheme extent and the wider area, with fewer personal injury collisions after the scheme improvements were implemented. When accounting for the increased volume of road users over this period, the annual average rate of personal injury collisions per million vehicle km also improved.
The scheme should reduce the regularity and severity of queuing on to the mainline due to congestion at junctions 11 and 12.	Journey speeds improved at junction 12 compared with before the scheme. This indicates congestion and queuing had reduced. Junction 11 speeds increased for road users exiting the M1 main carriageway but decreased when joining.
Mitigate the detrimental environment effects of the scheme where technically feasible and economic to do so	Noise, Air Quality and Greenhouse Gases were all better than expected (due to lower than forecast traffic levels). Most of the observed environmental impacts are on track to be as expected when compared against those predicted in the appraisal, subject to appropriate maintenance.

4. Traffic Evaluation

4.1 Summary

Multiple sources of traffic data were analysed to understand the impact of the smart motorway on road users.

Journey reliability[23] had slightly improved for northbound journeys made in the pm peak with half of all journeys (depicted by 25th to 75th percentile[24]) being less variable. An average saving of 1 minute 48 seconds was observed. For all other time periods and direction, there was little change, with an average of 8 to 12 second improvements observed. For journeys made in the am peak, journey times become more variable by only 10 seconds, this was whilst accommodating an increased number of road users.

Journey times were taking longer when compared with journeys before the scheme. When the additional capacity provided by the dynamic hard shoulder running is required, speeds are regulated to a maximum of 60 miles per hour. This reduction in speed was observed. There is evidence, however, that road users were traveling at more consistent speeds for longer without needing to brake and accelerate as frequently. This is contributing to the delivery of smoother journeys, suggesting the scheme eased some of the fluctuations in speeds seen before the scheme. For road users travelling during the commuter peaks, southbound am peak and northbound pm peak showed smoother journeys with less stop-start traffic.

The route is now supporting an increased number of road users. Traffic growth on the route had increased by an average of 10%[25] from 2009 to 2018. This was in line with the average growth across the strategic road network. The greatest growth was observed to the southern part of the scheme from junction 10 to junction 11a. The growth can be attributed to the opening of the A5-M1 link road in 2017 with road users using this section of the M1 as an alternative route to bypass the town of Dunstable.

Before the conversion, road users experienced high levels of congestion. During the pm peak traffic flows was at 5,700 vehicles per hour, as a three-lane motorway this was 1,900 vehicles per lane, very close to capacity. After the conversion traffic flow was 6,300 vehicles per hour, just over 2,100 vehicles per lane. The scheme delivered additional capacity improvements with the operation of the dynamic hard shoulder as an extra lane at busy times. Had the route remained a three-lane motorway the route would be above capacity. However, with the additional lane in operation, traffic flows on the four-lane motorway was within capacity, at just under 1,600 vehicles per lane.

Without the additional capacity of the fourth lane it is unlikely that the existing three-lane motorway would have been able to support the increased number of road users, leading to even slower journeys, and congestion as drivers would have to frequently brake forming queues and unreliable journeys. There would be

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[23] The extent to which journey times vary from the average journey time indicates how reliable a journey is.

[24] A percentile indicates the value below which a given percentage of observations falls. For example, the 25th percentile is the value below which 25% of the observations may be found. Equivalently, 75% of the observations are found **above** the 25th percentile.

[25] Comparing average weekday traffic (AWT) between 2009 and 2018.

minimal scope for future traffic growth, potentially impacting development and safety in the surrounding area.

Traffic growth and journey time forecasts were found to be over optimistic; this was due to the modelling and appraisal being undertaken prior to any signs of the 2008 UK recession. Also, at that time, the available evidence on how dynamic hard shoulder schemes would operate was limited to a single pilot study. Since then we have refined the assumptions made when assessing new schemes. We consider systematic events, such as a recession with high and low growth scenarios, and we assume no change in a speed-flow curve[26], the graphical relationship between flow and speed.

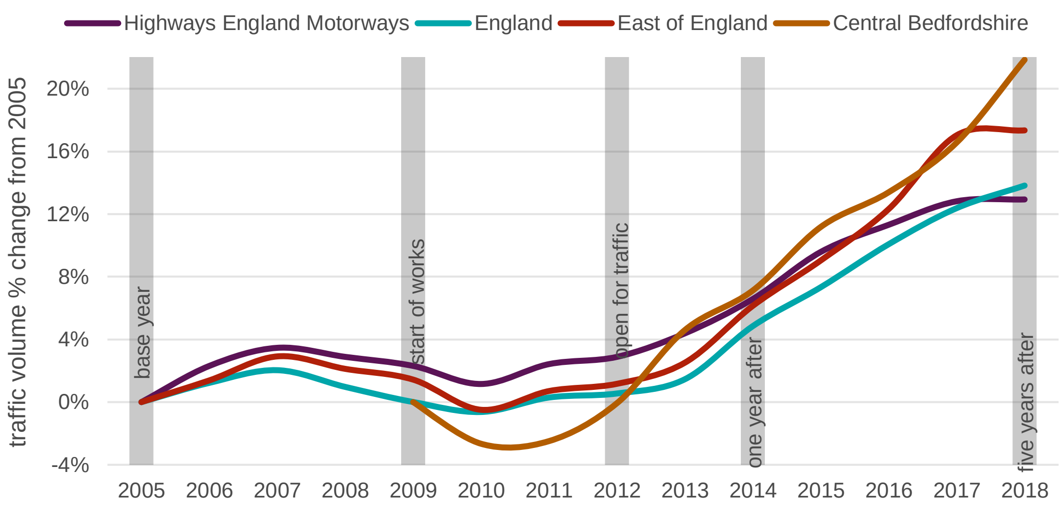
4.2 How have traffic levels changed?

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

4.2.1. National and regional context

To assess the impact of the scheme on traffic levels, it is helpful to understand the changes within the context of national and regional traffic. During the construction period, traffic decreased due to the UK economic recession in 2008, which impacted fuel price and travel demand. This is important to note as the business case, completed before signs of an economic recession, forecast a higher demand in travel due to the projected growth trends observed before 2008. Recovery was evident in 2011, and a steady increase had been seen since, as seen in Figure 2.

Figure 2: National and regional traffic volume changes since 2005[27]



Source: Department for Transport road traffic statistics Table TRA8904
https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra.

[26] A speed flow curve is a graphical representation of the relationship between flow and speed for a road. As flow increases, there is little impact at first as there is plenty of capacity, but with further flow increases, congestion starts to impact speeds (and eventually speeds get so slow they start to influence flow and traffic comes to a standstill). The relationship is different for different types of road.

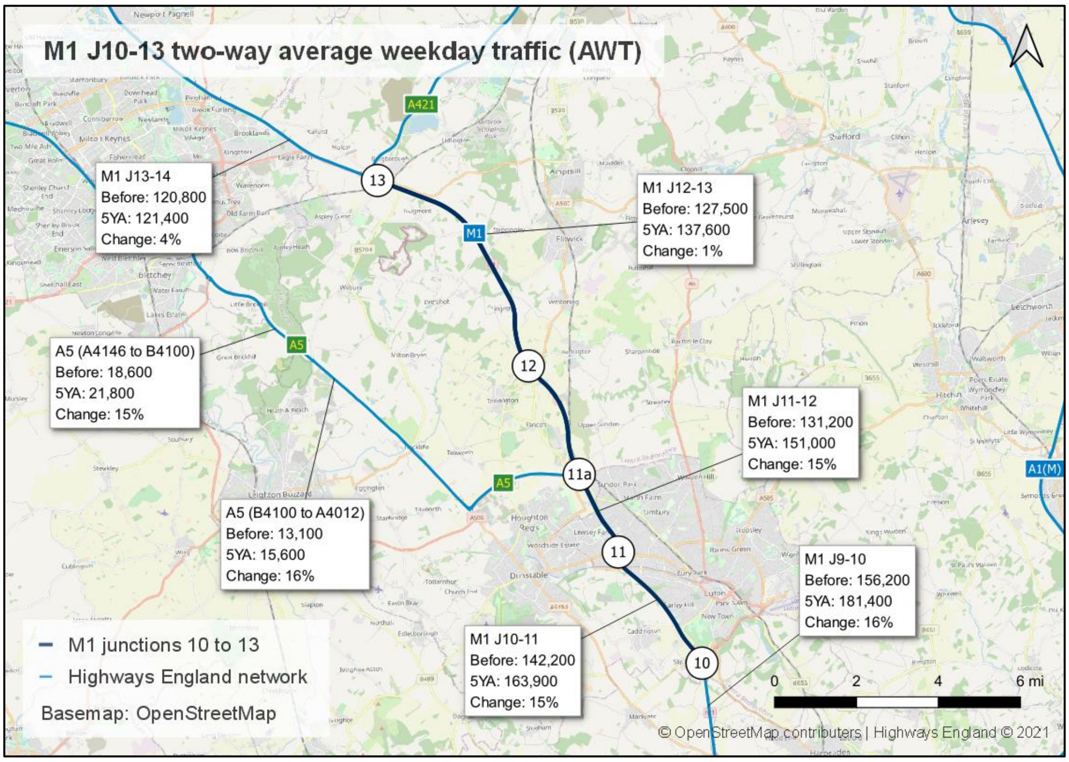
[27] Central Bedfordshire is a unitary authority area in the county of Bedfordshire. It was created from the merger of Mid Bedfordshire and South Bedfordshire District Councils on 1 April 2009. The chart therefore captures traffic volumes for Central Bedfordshire from 2009.

In the areas surrounding the scheme, significant housing and employment growth are expected. In the Central Bedfordshire unitary authority area, 40,000 new dwellings and 45,000 new jobs are set to be created between 2011 and 2026[28]. Associated with such growth will be an increase in the demand to travel and an increase in the number of trips on the transport network.

4.2.2. Strategic and Local Road Network

The evaluation found that traffic growth on the route had increased by an average of 10%[29] from 2009 to 2018. This was in line with the average growth across the strategic road network. The greatest growth was seen to the southern part of the scheme from junction 10 to junction 11a. Since the opening of the A5-M1 link road in 2017 there had been an increase in the number of road users between junctions 10 to 11a who are using this section of the road to bypass the town of Dunstable, as shown in Figure 3.

Figure 3: Changes in traffic volumes for strategic locations



Source: Highways England WebTRIS, commissioned counts 2009 and 2018 and OpenStreetMap contributors

Before the conversion, road users experienced high levels of congestion. During the pm peak traffic flows was at 5,700 vehicles per hour, as a three-lane motorway this was 1,900 vehicles per lane, very close to capacity. After the conversion traffic flow was 6,300 vehicles per hour, just over 2,100 vehicles per lane. Had the route remained a three-lane motorway this would be above capacity. However, with the additional lane in operation, traffic flows on the four-lane motorway was within capacity, at just under 1,600 vehicles per lane.

Without the additional capacity of the fourth lane it is unlikely that the existing three-lane motorway would have been able to support the increased number of

[28] Central Bedfordshire Council Transport Strategy, Local Transport Plan 3, April 2011 to March 2026.

[29] Comparing average weekday traffic (AWT) between 2009 and 2018

road users, leading to even slower journeys, and congestion as drivers would have to frequently brake forming queues and unreliable journeys. There would be minimal scope for future traffic growth, potentially impacting development and safety in the surrounding area.

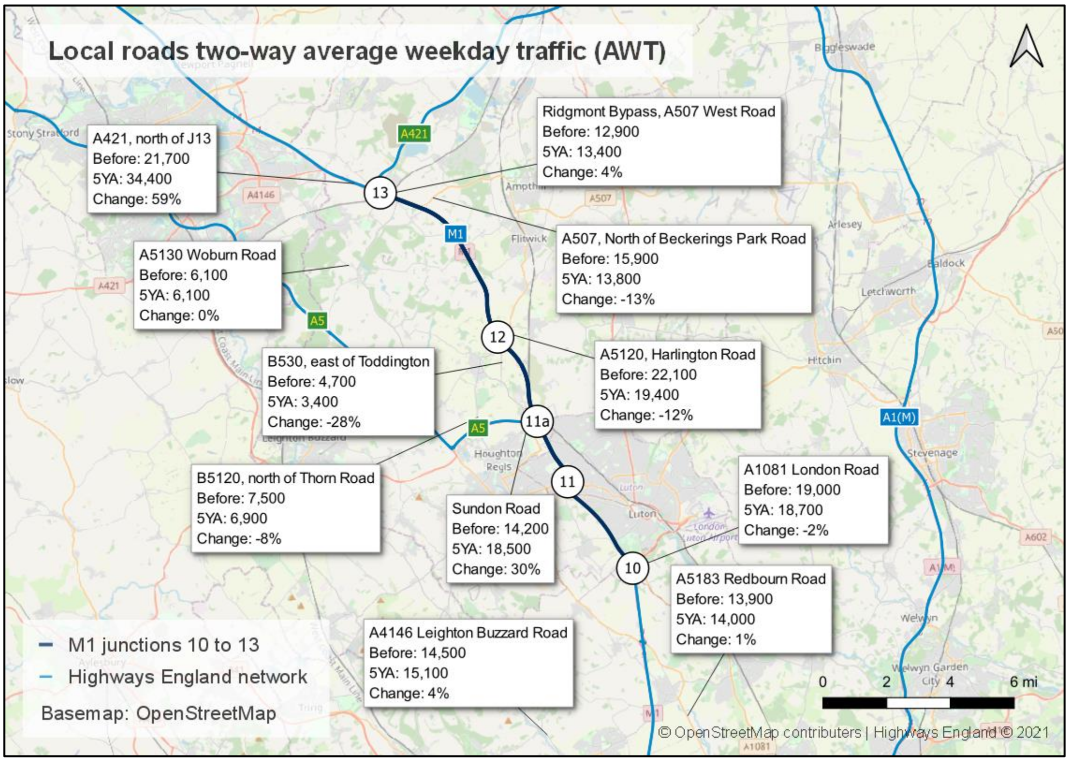
With the introduction of the bypass and junction 11a on the M1, realignment of traffic was expected with an increase on the A5 to the north of the bypass and on the M1 between junctions 11 to 11a. Traffic was expected to reduce on the A505 through Dunstable and on the M1 between junctions 11a and 12. The evaluation found that the expected realignment occurred, with the exception of junctions 11a to 12 that saw a slight increase compared to an expected 8% reduction.

There was a reduction in traffic on the local roads, including the B530 east of Toddington Services, and B5120, this may be attributed to the A5-M1 Link road and junction 11a now providing an alternative route for these journeys.

A large increase (59%) in traffic was observed on A421 north of junction 13. In December 2010 a new A421 dual two-lane main carriageway was constructed and de-trunking of the former A421. The five-year evaluation for the scheme (A421: M1 junction 13 to Bedford) reported a similar increase in traffic. This was primarily a result of traffic reassigning along the new A421 as the scheme became recognised as a key strategic route.

Traffic growth on the local road network is shown in Figure 4.

Figure 4: Changes in traffic volumes for the wider area



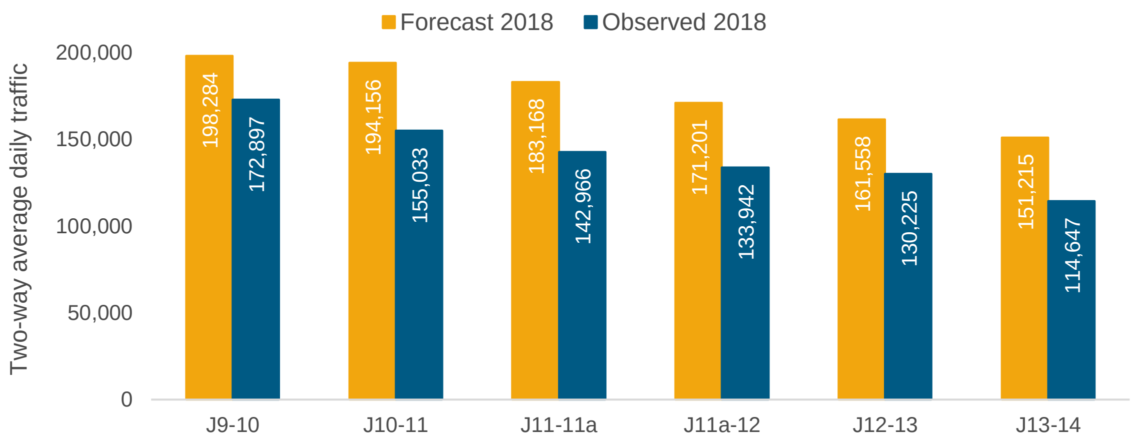
Source: Highways England WebTRIS, commissioned counts 2009 and 2018 and OpenStreetMap contributors

4.2.3. Was traffic growth as expected?

Traffic growth forecasts were found to be over optimistic. As noted earlier, during the construction period of the scheme, traffic demand decreased due to the UK economic downturn in 2008. The modelling and appraisal undertaken to forecast travel demand was completed before signs of an economic downturn and therefore did not account for the reduction in traffic.

Since then we have refined the assumptions made when assessing new schemes. The method for forecasting traffic growth includes adjustments for high and low growth scenarios to account for external systemic events, for example a financial crisis, or other scenario that could adversely impact the demand for travel.

Figure 5: Forecast and observed traffic volume



Source: Forecasts from traffic forecast report. Observed data from Highways England traffic count data, March 2018

4.3 Relieving congestion and making journeys more reliable

The routes selected for conversion to smart motorways are often some of the busiest and most congested routes on the strategic road network. A key aim of smart motorways is to improve the reliability[30] of journeys, making them more predictable for road users.

Analysis of journey times and speeds indicate the impact of the scheme on congestion. This section evaluates how the scheme impacted the reliability of journeys and journey times.

4.3.1. Did the scheme make journeys more reliable?

To measure journey time reliability, we examine how much journey times vary from the average journey time, on any day or time-period. Where journeys are less variable, road users can allow a smaller window of time to travel through the stretch of smart motorway, when travelling at a similar time.

Journey reliability had slightly improved for northbound journeys made in the pm peak with half of all journeys being less variable. An average saving of 1 minute 48 seconds was observed. For all other time periods and direction, there was little change, with an average of 8 to 24 second improvement. For journeys made in the am peak, journey times become more variable by only 10 seconds, whilst accommodating an increased number of road users. The journey time reliability, referenced as half of all journeys, is depicted by 25th to 75th percentile[31] boxes in

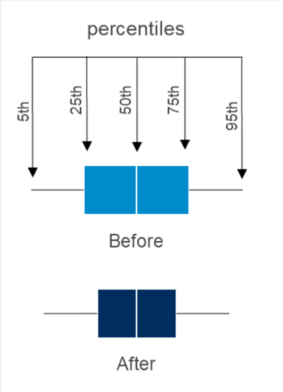
[30] The extent to which journey times vary from the average journey time indicates how reliable a journey is.

[31] A percentile indicates the value below which a given percentage of observations falls. For example, the 25th percentile is the value below which 25% of the observations may be found. Equivalently, 75% of the observations are found **above** the 25th percentile.

Figure 7 and Figure 8. (If the boxes get shorter than journeys become more reliable).

Analysis of the longest journey times (5% of journeys which took the longest to complete, depicted as the 95th percentile) found that for road users travelling northbound in the pm peak, journeys decreased by 1 minute. For all other time periods, there had been no improvement, with 5% of the longest journeys taking longer to complete. This is depicted as the 95th percentile in Figure 7 and Figure 8; the line extending to the right of the boxes.

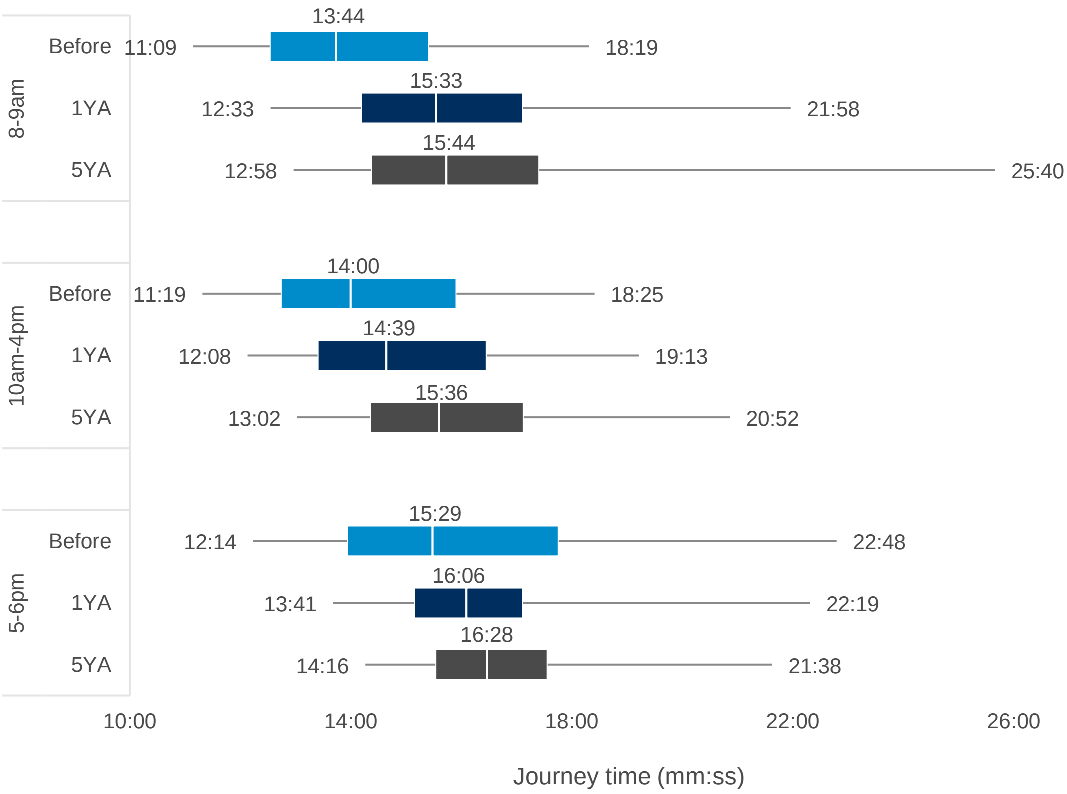
Figure 6: What does a Box Plot Show?



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

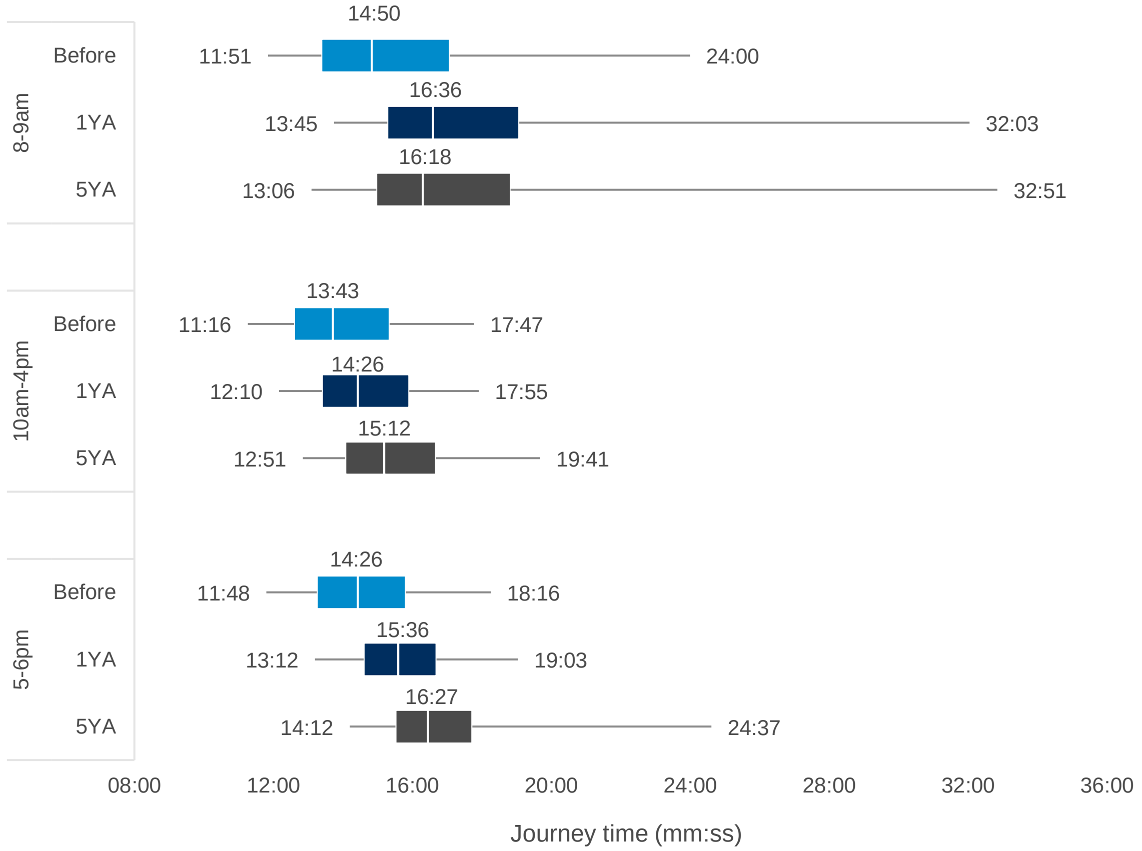
The length of the block shows how the journey times vary between the 25th and 75th percentile (25% and 75% of journeys). The shorter the block the less variable and hence more reliable a journey would be.

Figure 7: Journey time reliability (northbound) (time taken to drive through the scheme mm:ss)



Source: Satellite navigation (TomTom) March 2009, 2014, 2018

Figure 8: Journey time reliability (southbound)
(time taken to drive through the scheme mm:ss)

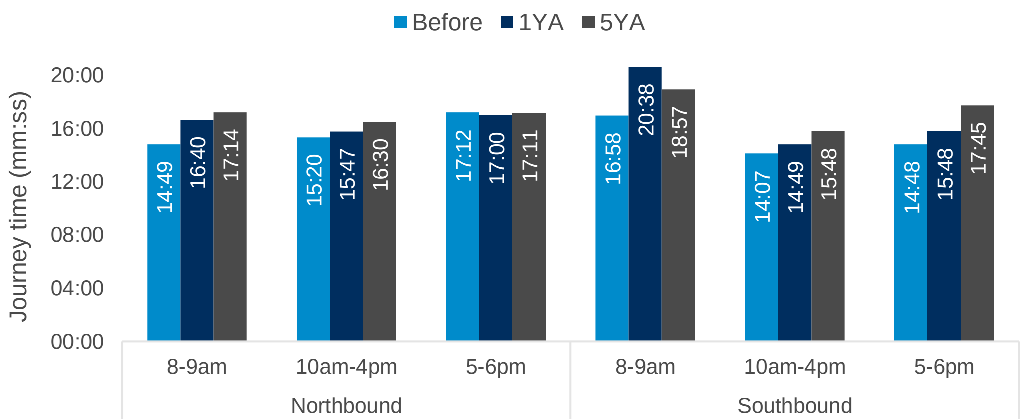


Source: Satellite navigation (TomTom) March 2009, 2014, 2018

4.3.2. What was the impact of the scheme on journey times?

The evaluation observed little change in journey times for road users travelling northbound in the pm peak. For all other time periods, in both directions journey times have increased as shown in Figure 9. However, without the increased capacity that the scheme provided, we would expect the journey times to be longer and potentially less reliable.

Figure 9: Observed average journey times by peak period



Source: Satellite navigation (TomTom). March 2009, 2014 and 2018

The increase in journey times is likely to a combination of increased traffic, and speed restrictions applied as part of the dynamic hard shoulder operation.

When the hard shoulder running is open to traffic a speed limit is set using the variable mandatory speed limit (VMSL) technology to smooth the flow of traffic, reducing stop-start movement. A 60mph is automatically set, however, a 40mph or 50mph speed limit can also be set when congestion is significant enough for the smart motorway to implement these lower speed limits as queue protection. There are rare occasions where either a 20mph or 30mph speed limit will be set, these are associated with incidents rather than being enforced by the queue protection system.

As expected, the am and pm peak with the greatest level of traffic, saw the greatest use of the dynamic hard shoulder operation and the periods of time where we have seen the largest increase in journey times.

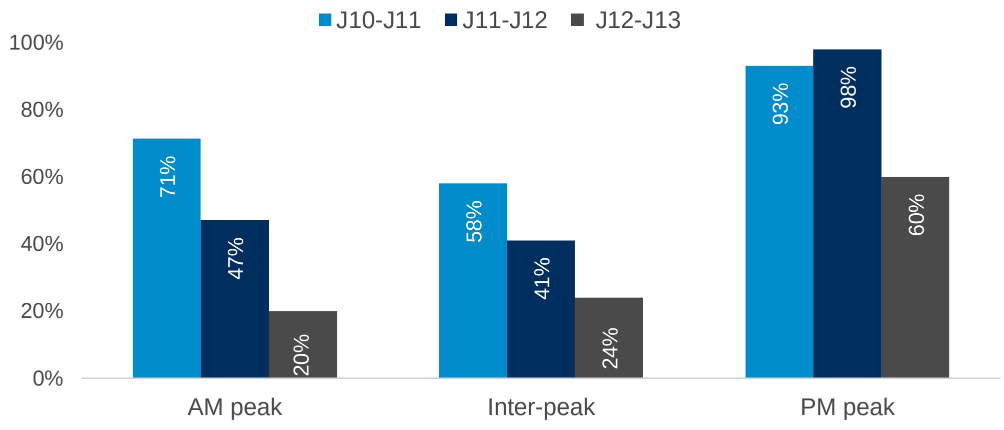
The appraisal expected the dynamic hard shoulder running to be operational up to 48% of the peak hours (7am to 7pm). In the subsequent years the hours of operation would be expected to increase as traffic growth increased. The one-year evaluation showed the dynamic hard shoulder was in operation for 40% of the time. This increased to 61% of the time at five-years after.

The evaluation observed am peak operating for an average of 66% of the time (1hr 59m of 3-hour peak period) pm peak for 81% of the time (2hrs 25m of 3-hour peak period), and inter-peak 36% (2hrs 10m of 6-hour peak period).

Figure 10 and Figure 11 below show the proportion of time that the hard shoulder was open to traffic by direction, and peak period. For road users travelling northbound the hard shoulder was open for most of the pm peak at junctions 10 to 12. Southbound between junctions 10 to 11 and junctions 11 to 12.

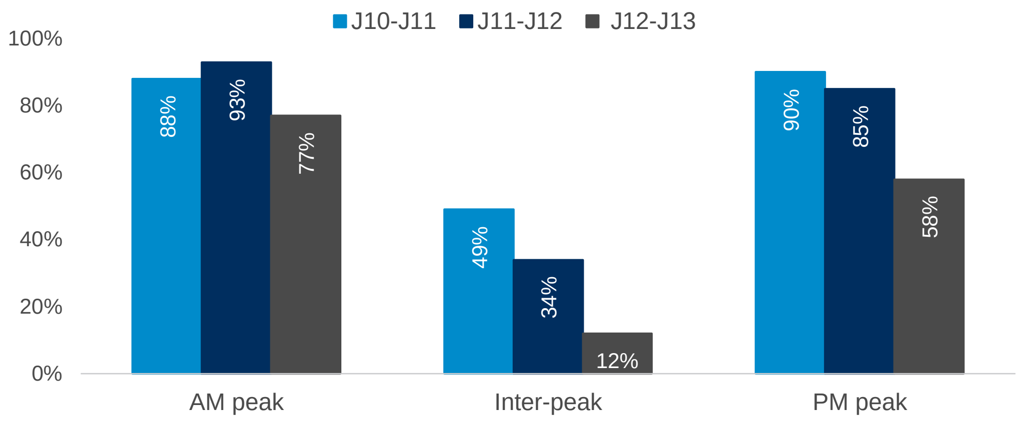
During the am peak the lower speed limit of 40mph was set for 38% of the 3-hour peak (just over 1 hour). This is consistent with the journey time analysis for periods and locations where speeds are lower and consistent with journey reliability where we observed journeys becoming most reliable in the pm peak, travelling northbound.

Figure 10: Operation of hard shoulder running (northbound)



Source: Halogen data, weekday March 2018

Figure 11: Operation of hard shoulder running (southbound)

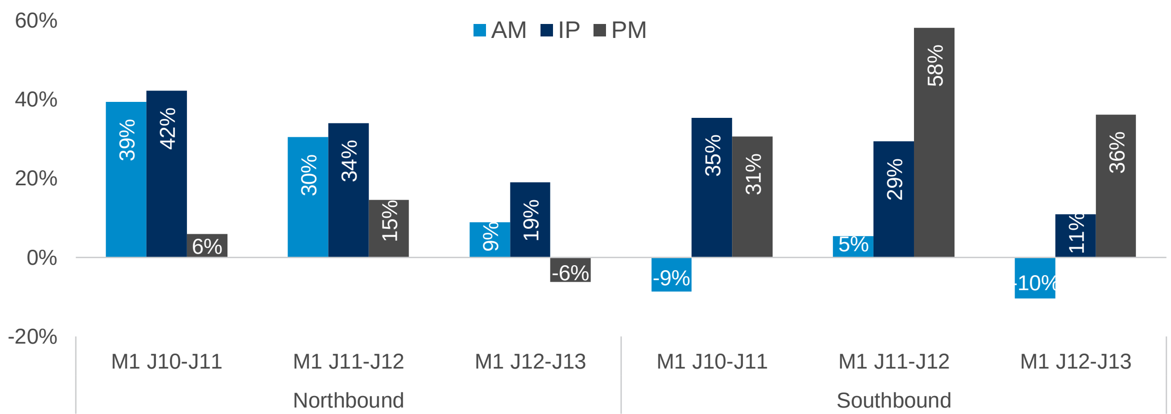


Source: Halogen data, weekday March 2018

Since the one-year after evaluation, the proportion of time that the hard shoulder was in operation had increased across most areas of the scheme during all time periods, as shown in Figure 12. This is in line with the expectations at the appraisal of the scheme.

This adds context to the further increase in journey times and the reduction in speeds following the one-year evaluation.

Figure 12: % change in weekday operational time of the hard shoulder



Source: Satellite navigation (TomTom) data. March 2014 and 2018

4.3.3. Were journey time savings in line with forecast?

Journey time savings were forecast on the scheme extent. An average saving of 1 ½ minutes was expected in the opening year and an average saving of 2 ½ minutes by 2028. The modelled travel times were converted to speeds, this showed an increase in average speed was expected on the M1 due to the scheme.

The evaluation found that the forecasts for both journey times and speeds were over optimistic. At the time of the appraisal of the M1 junctions 10 to 13, the available evidence on how dynamic hard shoulder schemes would operate was limited to a single pilot study. Assumptions have been refined when assessing smart motorway schemes and no change in a speed-flow curve is now assumed. A speed flow curve is a graphical representation of the relationship between flow and speed for a road. As flow increases, there is little impact at first as there is plenty of capacity, but with further flow increases, congestion starts to impact speeds (and eventually speeds get so slow they start to influence flow and traffic comes to a standstill). The relationship is different for different types of road.

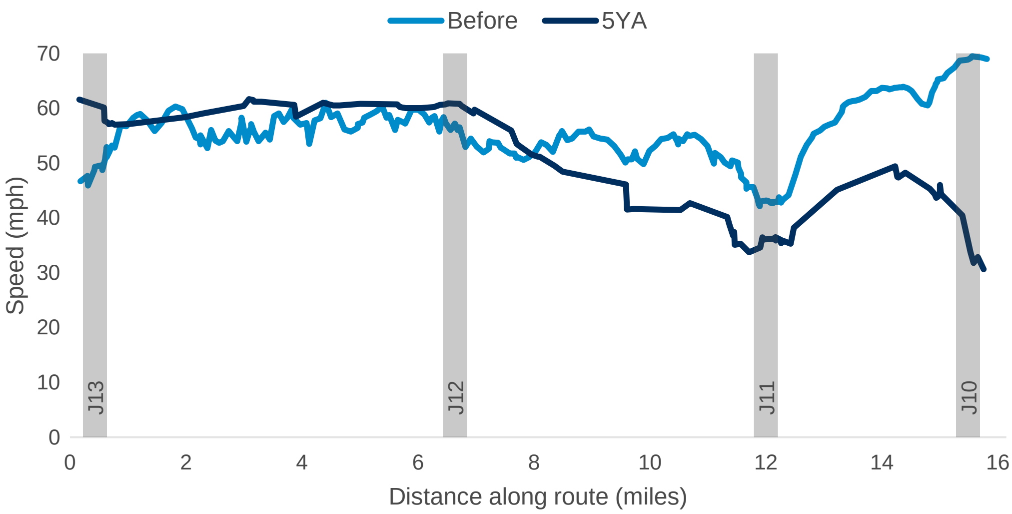
4.3.4. How did the scheme impact speed?

In combination with journey time analysis, speed can help to determine the impact the smart motorway had on congestion. Speeds are not necessarily quicker as a result of a smart motorway. Smart motorways are often implemented where there is congestion, and/or an increase in traffic is expected in the coming years. Instead, smart motorways aim to make journeys smoother, and therefore speeds should be more consistent, with road users less likely to be accelerating and braking leading to unnecessary queuing.

As mentioned above in section 4.3.3 modelled travel times were converted to speeds, this showed an increase in average speed was forecast on the M1 due to the scheme.

The evaluation observed some periods of improved speed, but on average an overall reduction consistent with the variable speed limits introduced by the scheme. However, there was evidence of traffic becoming smoother, suggesting the scheme is easing some of the fluctuations in speeds seen before the scheme. For road users travelling during the commuter peaks, southbound am peak (towards London) and northbound pm peak saw smoother journeys and less stop-start traffic, as shown in Figure 13 and Figure 14.

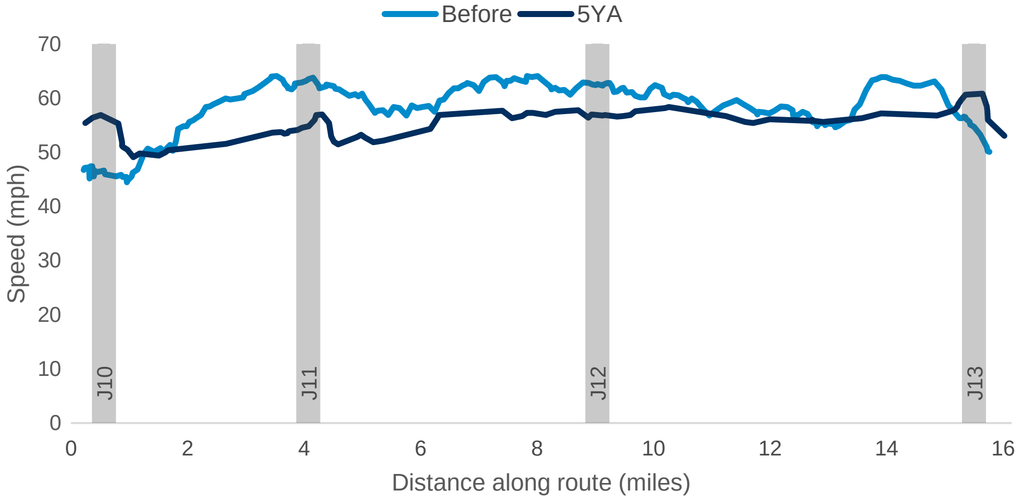
Figure 13: Average speed comparison (southbound 8am to 9am)



Source: Satellite navigation (TomTom) March 2009, 2018

Journey times had improved for road users travelling northbound in the pm peak, with an average of 17 second benefit for journeys travelling the scheme extent. As shown in Figure 14, journey speeds towards the start and end of the scheme have increased. Journeys have become more consistent throughout with fewer fluctuations in speed.

Figure 14: Average speed comparison (northbound 5pm to 6pm)



Source: Satellite navigation (TomTom) March 2009, 2018

4.3.5. What impact did the scheme have on congestion and reliability at junctions?

Improvements to junction 11 comprised the widening of slip roads and the introduction of more traffic signals, the circulatory carriageway and the A505.

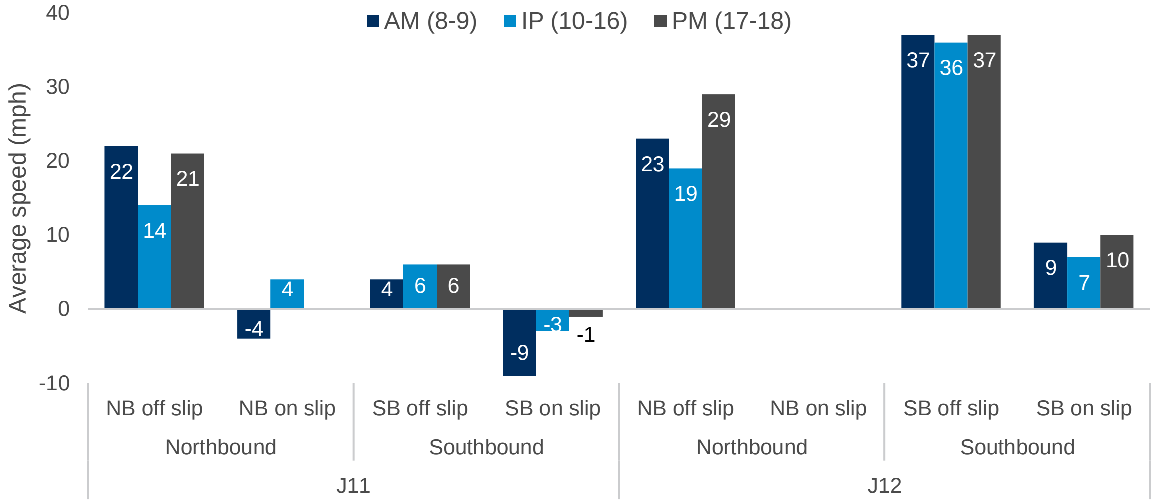
The evaluation found journey times and speeds for road users using junction 11 had improved when travelling northbound and exiting the M1, most notably during the PM peak. This indicates that the additional capacity had helped to reduce congestion. Figure 15 shows the change in speed at junctions since the scheme.

All other movements, exiting and entering the M1 at junction 11 had little change in journey times and speeds. This may be due to an increase in traffic flows at junction 11. More traffic was using the junction to enter and exit the M1 travelling both northbound and southbound compared with before the scheme, as shown in Figure 16. This increase in traffic flow is likely due to the increased capacity provided by the junction improvement.

Improvements at junction 12 comprised a new bridge over the M1, installation of new traffic signals, and new slip roads built to the north of the junction to increase capacity. Journey times and speeds for road users using junction 12 have improved compared with before the scheme, this suggests that congestion had reduced, and customer journeys have become more reliable.

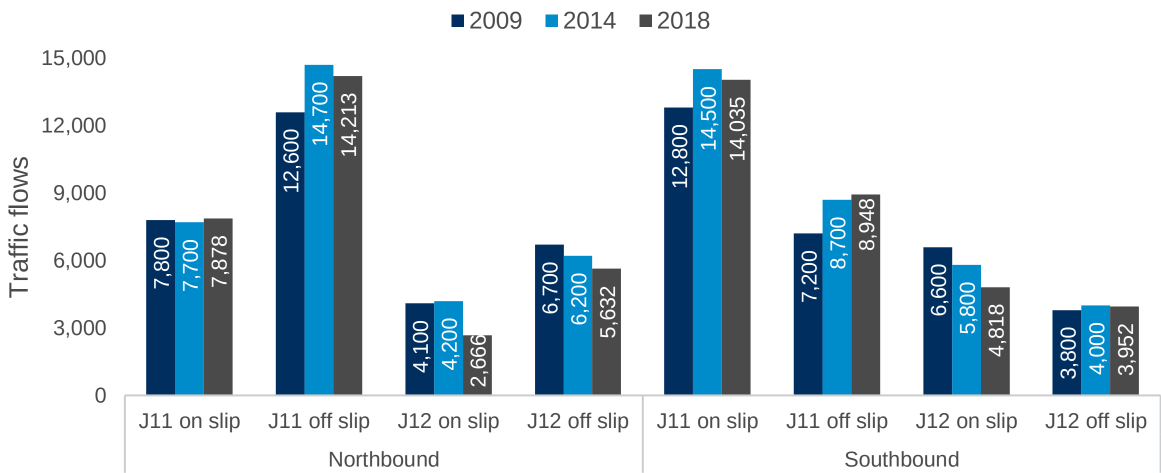
The evaluation found that traffic using junction 12 had decreased, except for southbound journeys exiting at junction 12, where there was a slight increase. Roads joining junction 12 had also seen a decrease in traffic. The A5120 Harlington Road north-east of M1 junction saw traffic decrease by 12% compared with before the scheme and the B530 east of Toddington saw traffic decrease by 28%. This may suggest that the new junction at junction 11a, provided an alternative to accessing the M1 at junction 12. As junction 11a was a new junction we are unable to evaluate the impact of the scheme on traffic flows at junction 11a.

Figure 15: Speed improvement on junctions 11 and 12 (before and after scheme)



Source: Satellite navigation (TomTom) 2009 compared against 2018

Figure 16: Traffic volume on junctions 11 and 12



Source: Highways England WebTRIS, commissioned counts 2009, 2014 and 2018

5. Safety Evaluation

5.1 Summary

The safety objective for this scheme was to improve safety performance. The number and rate per million vehicle kilometres of personal injury collisions[32] were analysed to identify a trend over time. The evaluation concluded that the scheme had met its safety objective.

In the first five years of the smart motorway being operational, there had been a reduction in the rate and number of personal injury collisions on both the scheme extent and the surrounding network. This is compared with the annual average for the five years before the scheme improvements.

On the scheme there had been an annual average reduction of three personal injury collisions, which is in line with the appraised business case for the scheme. This is based on an annual average of 95 personal injury collisions after the scheme was operational compared with 98 before the scheme. If the road had not been converted to a smart motorway, we estimate that the number of personal injury collisions would have been between 98 and 124 (Figure 18).

When accounting for the increased volume of road users over this period, the annual average rate of personal injury collisions per million vehicle km had also improved over time. The average collision rate had decreased to 0.08 personal injury collisions per million vehicle km, this equates to travelling 12.1 million vehicle kms before seeing an accident. Before the scheme the collision rate was 0.09 per million vehicle km, this equates to traveling 11.4 vehicle km before seeing an accident. If the road had not been converted to a smart motorway, we estimate the collision rate would be the same as before the scheme at 0.09. This counterfactual scenario indicates that even though an increase in the number of collisions would be seen without the scheme, there would be no change in the rate that collisions occur, so the principle cause would be due to increased traffic flows (section 5.3.2).

The severity of collisions had also reduced since the scheme was operational. During the three years[33] before the scheme was constructed there was on average 15 fewer collisions leading to slight injuries per year, five more collisions leading to serious. Fatal collisions remained at an average of one before and after the scheme was operational. When accounting for the increased number of road users over this period, there had been a reduction from 4.3 to 3.7 fatality equivalents[34] per billion vehicle kms travelled. Reducing the risk of a fatality equivalent by 0.6 for every billion vehicle kms travelled (section 5.3.3)

Before the scheme an annual average of 196 collisions were observed within the local area. After the scheme the observed collisions had fallen to 150, a reduction of 46. If the road had remained a conventional motorway, the counterfactual estimated the number of personal injury collisions would have been between 190 and 226. The observed annual average of 150 personal injury collisions falls outside the range. Therefore, the observed changes are significant, which means

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

[33] In April 2016 Bedfordshire Police Constabulary transferred to Collision Recording and Sharing (CRaSH). Recording the severity of collisions is no longer left to the discretion of the reporting police officer which has resulted in a change how collision severity is recorded. This occurred in the 4th year after the scheme opened, consequently the first 3 years after the scheme opened have been used for severity analysis using unadjusted collision severities. More information can be found in A.2 Incident reporting.

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

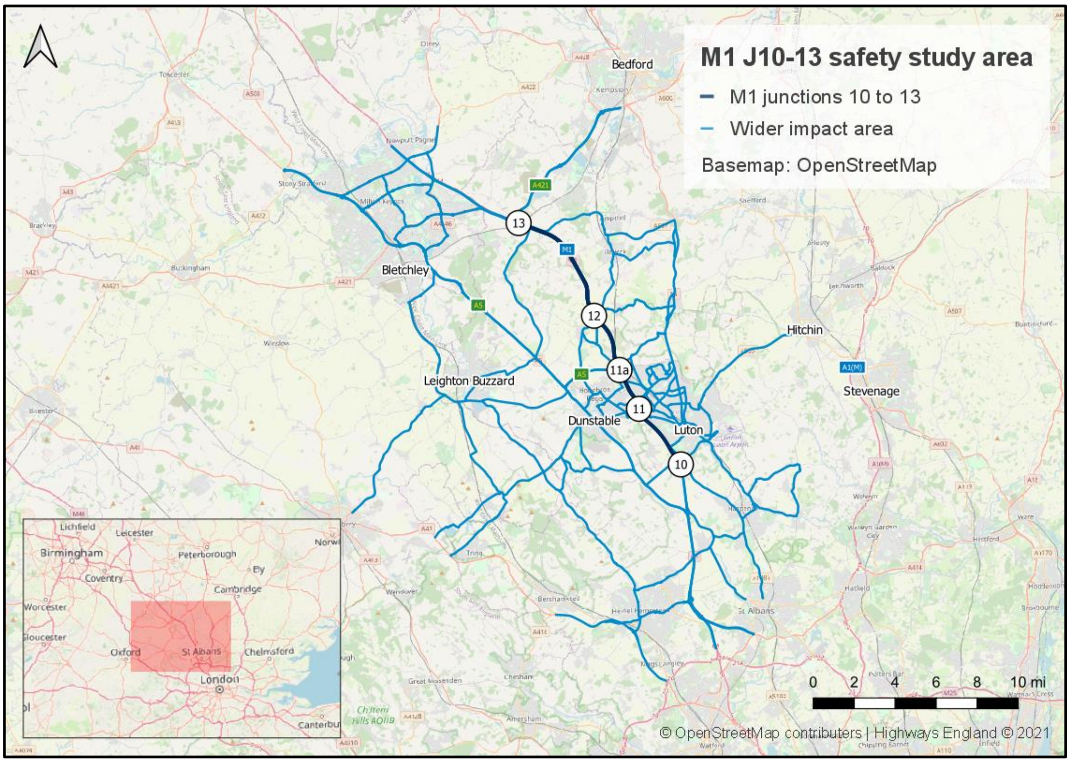
the decline in personal injury collisions within the local area could be attributed to the scheme.

In the wider area surrounding the smart motorway, there were an annual average of 678 collisions observed before the scheme improvements. After the scheme, this had fallen to 527, a reduction of 151. If the road had remained a conventional motorway, the counterfactual estimated the number of personal injury collisions would have been between 915 and 991. The observed annual average of 527 personal injury collisions falls outside the range. Therefore, the observed changes are significant, which means the decline in personal injury collisions within the wider area could be attributed to the scheme (section 5.4.2).

5.2 Safety study area

The safety study area is shown in Figure 17. The appraisal considered impacts of the scheme improvements on the smart motorway and on roads surrounding the smart motorway. A local and wider area was assessed. The local area, comprising of roads adjacent to the scheme extent and a wider area, to check any potential wider implications for the intervention.

Figure 17: Safety study area



Source: Highways England and OpenStreetMap contributors

5.3 Scheme extent

5.3.1. What impact did the scheme have on user safety?

Safety data was obtained from the Department for Transport road safety data[35]. 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.

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

The safety analysis was undertaken to assess changes over time looking at the trends in the five years before the scheme 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:

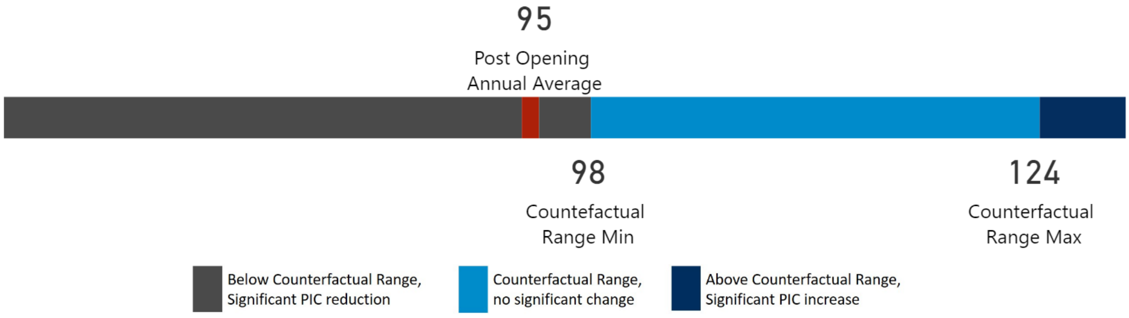
- Pre-construction: 1st December 2004 to 30th November 2009
- Construction: 1st December 2009 to 30th November 2012
- Post-opening: 1st December 2012 to 30th November 2017

The evaluation found the number of personal injury collisions on the scheme extent, junctions 10 to 13 had decreased (impacts on the wider area are discussed later in section 5.4). Over the five years after the scheme was operational, there were an average of 95 personal injury collisions per year, three fewer than the average 98 per year over the five years before the scheme was constructed.

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 scheme 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 A.1 Safety counterfactual methodology). This is based on changes in regional safety trends for conventional motorways with a high volume of roads users. Based on this assessment we estimate that if the road had not been converted to a smart motorway, the trend in the number of personal injury collisions would likely have increased, and collision rates would remain stable.

A range of between 98 and 124 personal injury collisions[36] during the five-year post scheme period would be expected. An annual average of 95 personal injury collisions were observed over the five-year post-opening period, this falls below the expected range. Therefore, the observed changes are significant, which means the decline in personal injury collisions could be attributed to the scheme.

Figure 18: Observed and expected range of personal injury collisions (annual average)



Source: STATS19: 1st December 2004 to 30th November 2017

5.3.2. How has 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

[36] 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.

this stretch via a collision rate, the number of collisions per annual million vehicle kilometres (mvkm).

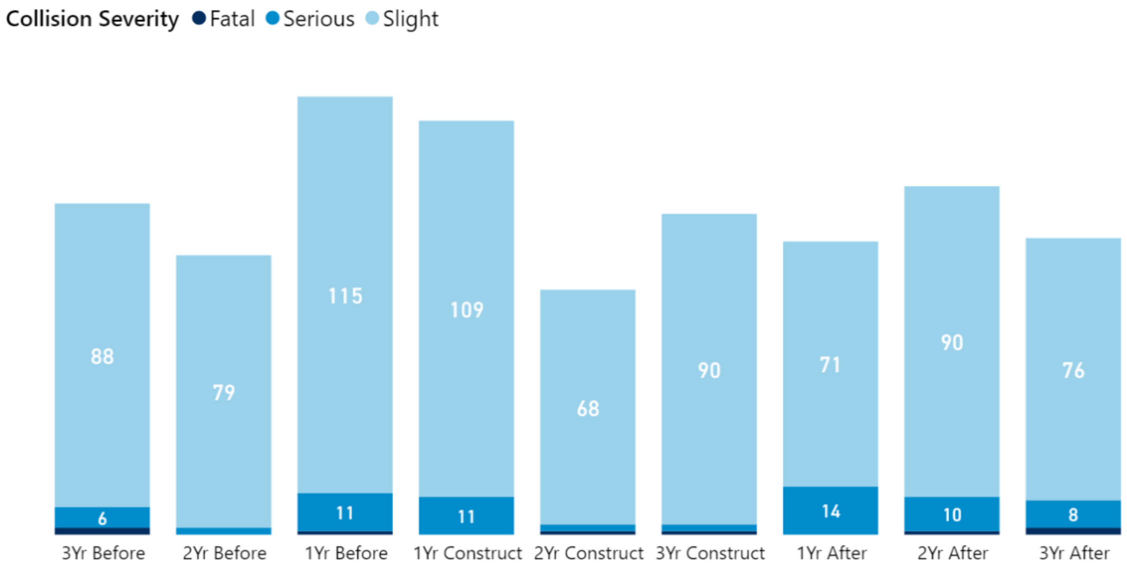
The average collision rate had decreased to 0.08 personal injury collisions per million vehicle km, this equates to travelling 12.1 million vehicle kms before seeing an accident. Before the scheme the collision rate was 0.09 per million vehicle km, this equates to traveling 11.4 vehicle km before seeing an accident. The estimated rate if the smart motorway had not been built was the same as before the scheme at 0.09, this counterfactual scenario indicates that even though an increase in the number of collisions would be seen without the scheme, there would be no change in the rate that collisions occur, so the principle cause would be due to increased traffic flows.

5.3.3. What impact did the scheme have on the severity of collisions?

Collisions which result in injury are recorded by severity as either fatal, severe or slight. During 2016, there was a transition in how severity of incidents were recorded (more information on this can be found in A.2 Incident reporting). To ensure consistency, we compared three years of collision severity data before the scheme and three years after the scheme, so that all collisions were recorded using the same method (STATS19 database).

After the scheme there were an average of 15 fewer collisions resulting in slight injuries per year (the annual average before the scheme was 94, compared to 79 after), five more collisions resulting in serious injury per year (the annual average before the scheme was six, compared to 11 after). Fatal incidents remain the same (one before the scheme, and one after). Figure 19 shows the severity of personal injury collisions.

Figure 19: Severity of personal injury collisions within the scheme extent



Source: STATS19: 1st December 2006 to 30th November 2015

5.3.4. How has traffic flow impacted collision 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[37]. In effect, it takes all non-fatal injuries and adds them up using a weighting factor to give a total number of fatality equivalents.

The combined metric is used to standardise the collision categories against flow to show the likelihood of a fatality equivalent occurring per distance travelled. The combined measure showed an extra 55 million vehicle kms was travelled before a fatality. Before the scheme, 224 million vehicle kms needed to be travelled before a fatality (4.3 fatalities per bvkm[38]). After the scheme this increased to 272 million vehicle kms (3.7 fatalities per bvkm).

5.4 How did safety trends impact junctions, and the local road network?

5.4.1. What impact did the scheme have on safety for junctions?

The scheme had an objective to improve safety on the junction slip roads at junctions 11 and 12.

Prior to the scheme an annual average of six personal injury collisions occurring at the junctions[39] were observed. During construction this increased to eight, after the scheme this remained at eight personal injury collisions. An increase of an annual average of two personal injury collisions since the scheme was implemented.

Collision severity analysis was undertaken for junctions using the same method as for the mainline M1. For slight collisions it was found there had been an increase from five to seven personal injury collisions per year, for killed or seriously injured personal injury collisions there had been no change.

A counterfactual was not undertaken. Due to the small numbers this may show a natural fluctuation rather than an impact of the scheme.

5.4.2. What impact did the scheme have on safety for the local and wider area?

Personal injury collisions were observed for a wider impact area, which is derived from the safety appraisal for the scheme. The appraised wider area was split into two areas as shown in Figure 17. The local area, comprising of roads adjacent to the scheme extent and a wider area, to check any potential wider impacts from the intervention.

Before the scheme an annual average of 196 collisions were observed within the local area. After the scheme the observed collisions had fallen to 150, a reduction of 46. If the road had remained a conventional motorway, the counterfactual estimated the number of personal injury collisions would have been between 190 and 226. The observed annual average of 150 personal injury collisions falls outside the range. Therefore, the observed changes are significant, which means the decline in personal injury collisions within the local area could be attributed to the scheme.

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

[39] We have collected all collisions that have been classified as occurring on slip and adjoining roads. Following the amendments of junction 11 and 12 we observed PICs that occurred on entry/exit slip roads and adjoining junctions.

In the wider area surrounding the smart motorway, there were an annual average of 678 collisions observed before the scheme improvements. After the scheme, this had fallen to 527, a reduction of 151. If the road had remained a conventional motorway, the counterfactual estimated the number of personal injury collisions would have been between 915 and 991. The observed annual average of 527 personal injury collisions falls outside the range. Therefore, the observed changes are significant, which means the decline in personal injury collisions within the wider area could be attributed to the scheme.

5.4.3. What impact did the scheme have on the severity of collisions in wider area?

Collision severity analysis was undertaken for the local and wider area using the same method as for the mainline M1[40].

In the local area, slight collisions had reduced by 17 personal injury collisions per year (from 150 to 133), for killed or seriously injured collisions there had been a reduction of four personal injury collisions per year (from 24 to 20).

In the wider area, slight collisions had reduced by 79 personal injury collisions (from 547 to 468), for killed or seriously injured collisions there had been a reduction of 13 (from 98 to 85).

5.4.4. How has traffic flow impacted collision severity in the wider area?

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. In effect, it takes all non-fatal injuries and adds them up using a weighting factor to give a total number of ‘fatality equivalents’.

To understand the impact of the increased traffic flow on collision severity, the measure we use is fatalities and weighted injuries[41] (FWI).

Before the scheme was constructed, the FWI for the local area was seven fatality equivalents per billion vehicle km travelled. Following the scheme improvements, the FWI was 5.9 fatality equivalents per billion vehicle km travelled. This is an observed reduction of 1.1 fatality equivalents for every billion vehicle kilometres travelled.

Before the scheme was constructed, the FWI for the wider area was 7.6 fatality equivalents per billion vehicle km travelled. Following the scheme improvements, the FWI was 6.2 fatality equivalents per billion vehicle km travelled. This is an observed reduction of 1.4 fatality equivalents for every billion vehicle kilometres travelled.

5.5 Has the scheme achieved its safety objectives?

The schemes safety objective was to reduce the frequency and rate of collisions. The evaluation found personal injury collisions and rates have both decreased. The counterfactual indicated the reduction was lower than what would be expected had

[40] Due to the transition of how severity of incidents was recorded, we compared three years before scheme and three years after, when all collisions were recorded using a consistent method (STATS19 database).

[41] See section 5.3.4 for explanation of the FWI

the road remained a conventional motorway. Therefore, we can be confident that the changes observed can be contributed to the scheme.

5.6 How has the scheme performed compared to expectations?

The appraisal assumed an improvement in the accident rate of 15% for the mainline M1 as a result of the scheme. The observed rate for the scheme extent was 7%. The difference could be attributed to the lower than anticipated traffic flows.

The appraisal assumed a reduction of 192 collisions (three annually) over the 60-year appraisal period. The evaluation found that the appraisal estimation was as anticipated for this scheme.

6. Environmental Evaluation

The evaluation of environmental impacts compares the predicted impact from appraisal to observed impacts determined during a site visit. Post opening evaluations provide an opportunity for such findings to be captured early and ensure improvements are made, so the design outcome can be achieved.

The evaluation of environmental impacts used information on the predicted impacts gathered from the environmental appraisal within the business case, the environmental assessment report (EAR) and in consideration of the findings of the one-year after opening evaluation, compares them with findings obtained five-years after the schemes opened for traffic.

Observed impacts have been determined during a site visit, supported by desktop research. The site visit was undertaken in August 2018.

6.1 Summary

The environmental assessment for the scheme predicted that there would be generally adverse impacts on the environment, principally due to the introduction of dynamic hard shoulder running (DHSR) along the scheme extent and junction improvements, i.e., the removal of the overbridge and creation of a new junction 12 and improvement of junction 11 in parallel with the DHSR Scheme.

The main carriageway widening (HSR) and junction improvements were expected to consider impact mitigation measures. The scheme designs included mitigations on environmental sub objectives such as noise (low noise surfacing along the scheme and a noise barrier at junction 11 Dunstable), improvements in local air quality improvements and greenhouse gas emissions, environmental enhancements to maintain biodiversity, landscape character and visual amenity (e.g. via woodland and species-rich grassland replanting at junction 12), drainage enhancement (e.g. by way of oversized culverts and balancing ponds at junction 12).

For most aspects of the appraisal, the environmental assessment concluded that with mitigation establishing, all the ecological mitigation and compensation measures are likely to be fully functioning by the design year (2028). The assessment predicted that some of the re-instated habitats, such as grasslands and mitigations for protected species would be well established at this stage. Impacts on these features are likely to be neutral by this stage. The only exception was woodland creation around junction 12.

The five-year evaluation highlighted that for the M1 main carriageway, the environmental impacts on the local landscape, townscape, historic resources and biodiversity are broadly on track to be realised as expected. The impacts are better than expected for noise, air quality and greenhouse gases due to traffic levels being lower than predicted within the business case[42]

The evaluation highlighted that the junction improvements were also likely to have better than expected outcomes on noise, air quality and greenhouse gas

[42] Appraisal Summary Table (AST) & Web TAG Worksheets: M1 J10-J13 Improvement – HSR Scheme (PCF Stage 6 Version 6) (April 2012) and HSR Improvements Environmental Assessment Report Volume 1 – Main Text and Appendices Report No: D123845/5/04, October 2009

emissions. Three of the environmental objectives for the junction improvements were assessed as worse than expected.

- Landscape mitigation was implemented, but not fully established and maintenance was seen to be limited. Summer 2018 experienced a heatwave which hindered the success of mitigation (planting) measures.
- Townscape mitigation planting failed at junction 11 and had not been replaced, and the scheme increased the sense of urbanisation.
- Water Environment - poor maintenance resulted in overgrown vegetation which had impaired the drainage system.

The evaluation found that the asset data for the scheme extent had not been fully updated to reflect those assets removed, for example, old vegetation plots or new ones added such as noise barriers. This information is important for long term asset management.

6.2 Noise

The business case for the scheme predicted the scheme would result in a negligible decrease in the number of people annoyed by traffic noise in the study area by implementing an enhanced noise barrier to the M1 and low noise surfacing. These were installed as expected. However, the observed traffic levels and number of Heavy-Goods vehicles within the first five years were lower than predicted and if this trend continues, the noise impacts are likely to be better than expected.

Traffic flows at most locations (5 of the 6) were more than 20% lower than predicted. At the one location where the 20% threshold[43] was not met the flow reduction was 14%. Therefore, as traffic flows are lower than predicted it is likely that overall noise impacts were better than expected.

6.3 Air Quality

The scheme was predicted to cause negligible net increases in emissions from the M1 and surrounding roads. This was expected to translate into a negligible worsening in air quality but would not cause significant air quality effects. The appraisal also noted that there were air quality management areas (AQMA) adjacent to the M1 either side at junction 11 and on Dunstable road.

According to data observed after the scheme, the traffic flows show a reduction of between 25,000 and 40,000. and thus, greater than the threshold of 1,000 annual average reduction in daily traffic (AADT) indicating that overall emissions are likely to be lower than expected. In addition, HGV flows are more than 200 AADT and lower than predicted. This further supports the view that overall emissions are likely to be lower than expected.

Data from the Air Quality Annual Status Report 2016[44] had been compared to the predicted concentrations in the scheme environmental assessments and although the number of shared data locations is small it is broadly consistent. The 2016 Annual Status Report also states that all monitoring locations within the AQMAs

[43] Where flows are more than 20% lower than forecast, we assume that the noise impacts will be lower than expected
[44] Luton Borough Council

adjacent to the M1 have been under the UK air quality threshold of 40µg/m^3 since 2009 including in 2015 which was the latest monitored year.

As the traffic flows are lower than forecast air quality impacts of the scheme are likely to be better than expected.

6.4 Greenhouse Gases

The scheme predicted a net dis-benefit for Greenhouse Gases due to the additional vehicle kilometres travelled, i.e.an increase in vehicle flows and speeds were forecast, leading to an increase in carbon emissions. The appraisal for junction improvements (junction 11 and junction 12) also predicted that the scheme would result in a slight increase in emissions.

The approach for evaluating the carbon emissions arising from the scheme recognises that it is not possible to make a direct comparison between the carbon emission predicted in the appraisal which is based on the entire modelled area (extending beyond the scheme) over 60 years as all the traffic information is not usually available. Instead the evaluation assesses the forecast and observed traffic data available for the scheme extent to calculate a reforecast[45] and an observed carbon emission at five-years after, as shown in Table 2 below.

Table 2: Re-forecast and observed carbon emission

	Reforecast after five years (CO_2 tonnes per annum)	Observed (CO_2 tonnes per annum)
M1 junctions 10-13	316,871	270,018

This figure can only be used to compare against the appraised emissions along the scheme and does not provide an assessment across the wider network. Whilst no data had been provided specifically for the junction, it's likely that changes on the M1 were likely to influence those at the junction.

From the available traffic data, it can be concluded that at five-year after the predicted increase in traffic had not occurred. The lower than forecasted traffic flows mean that whilst we cannot quantify the change with certainty, carbon emissions were likely to be lower than expected.

6.5 Landscape

The scheme was expected to involve relatively minor amendments to the existing M1 main carriageway other than the addition of gantries. Some loss of screening vegetation was expected, but this would be offset by mitigation planting. Overall, the impact on the landscape was predicted to be neutral 15 years after the scheme opened.

The appraisal for junction improvements reported that at junction 12 the existing motorway had a significant adverse effect on local landscape character. Impacts of the works on the adjacent landscape were expected to be mitigated by the woodland planting associated with the realigned slip roads. This would help to fully integrate the junction into the landscape. Overall impacts were expected to be neutral. The appraisal did not consider landscape impacts at junction 11.

[45] Based on the Defra Emission factor toolkit V9. Data obtained at five years after opening was used to generate data for the whole period

The environmental assessment for the main carriageway predicted that, infrastructure, including gantries and signs, would cause landscape and visual impacts. 15 years after the scheme, once mitigation planting had established, impacts would be reduced although some gantries would still be visible. Overall, the impacts were predicted to be neutral. Based on the site visit undertaken for the five-year evaluation, the predicted impacts were observed to be mostly as expected. General landscape character change was minimal for the smart motorway and provided mitigation is maintained and continues to establish, the design outcome should be met.

At junction 12, the predicted impacts appeared to have arisen and the mitigation planting installed. However, although a landscape management plan was produced, no signs of recent maintenance activity was observed during the site visit. This is likely to affect establishment, reducing the likelihood that junction 12 will integrate into the landscape to the level expected.

Figure 20: An example of the landscape changes at junction 12

Source: Site Visits one-year Sept 2014 & five-year July 2018

6.6 Townscape

The business case reported that prior to the scheme, the existing motorway corridor had a negative and dominating effect upon the townscape and whilst the scheme would add to the infrastructure, principally through gantries, the overall magnitude of change would be small. There was no land take associated with the scheme but overall a slight adverse impact was predicted. The five-year evaluation confirmed the impacts to be as expected.

The appraisal for junction improvements reported that junction 11 is in an urban townscape. The scheme was expected to be fully integrated into the townscape and with better planting design and treatment of hard surfaces would provide some townscape benefits. The appraisal did not consider Townscape impacts at junction 12.

The one-year after evaluation found that properties adjacent to the exit and entry routes of junction 11 (especially on the south side) experienced the greatest cumulative impacts due to changes and views of gantries and lighting. Around junction 11, planting to replace the loss of mature trees was undertaken as expected. However, at five -years after, there were examples of failed mitigation planting that had not been replaced. The increase in gradient of the roundabout appeared to limit plant growth.

Figure 21: Tree failure in the plot between the property adjacent to J11 on Dunstable Road and the northbound diverge slip road at FYA

Source: five-year Site Visit July 2018

Wildflower seeding was done along Dunstable Road East and observed establishing well at one year after. But at five years, lack of maintenance and effects of dry weather were apparent. These issues, together with and the timber noise barriers had generally led to an increased sense of urbanisation of the immediate junction area. It is unlikely that the predicted benefits will arise and overall, the impacts are worse than expected.

Figure 22: Changes in the wildflower seeded plot along Dunstable Road East (foreground) and steepness of the roundabout limiting the establishment of understorey planting at junction 11

Source: one-year Site Visit Sept 2014

Source: five-year Site Visit July 2018

6.7 Heritage of Historic Resources

The appraisal for the M1 main carriageway junctions 10 to 13 anticipated overall slight adverse impacts on heritage. The appraisal for junction improvements reported a neutral effect at junction 11, which was already within an urban setting before the scheme was constructed, and a slight adverse impact at junction 12. These adverse impacts were due to the construction of the north and southbound slip road embankments at junction 12, the demolition of the existing overbridge, the creation of new overbridge foundations and associated landscaping which were likely to affect unknown archaeological remains around the junction.

The environmental assessments and appraisals suggest that both archaeological investigations were undertaken as expected. As with one-year evaluation, the impacts of the scheme on the historic environment are in line with predictions in the environmental assessments. The evidence gathered during the site visit suggests that as expected, most historic monuments were unaffected by the cumulative effects of the scheme. A few historic buildings were predicted to be adversely affected by the environmental assessment and this was observed to be the case. Mitigation planting had been provided along the highway boundary. However, it was yet to establish at the time of the five-year evaluation. Provided the plots are managed and they establish, M1 junctions 10 to 13 should achieve its intended mitigation by the design year 2028.

6.8 Biodiversity

The appraisal predicted that the scheme would cause the permanent loss of undesignated habitat within the highway verge. This loss and disturbance would also impact on any species present. Proposed woodland habitat replacement would represent an improvement in habitat quality but was unlikely to have reached enough maturity 15 years after the scheme to have fully mitigated for loss of mature vegetation and its value. Overall, the impacts were predicted to be slight adverse. At the five-year evaluation the loss of discreet areas of habitat around new infrastructure including gantries was evident. Mitigation planting had been undertaken but as expected was yet to mature. Overall, the impacts were as expected.

The appraisal stated that the junction 11 improvements would not have any direct or indirect effects on biodiversity, resulting in a neutral effect. At the five-year evaluation, this was observed to be the case. At junction 12 improvements would result in indirect effects on wildlife in the River Flit tributary[46] and River Flit county wildlife site[47] due to the loss of open-channelled watercourses caused by the culverting of the Redhill Brook. Direct effects were expected on Poplars Nursery county wildlife site due to land take leading to loss of a small area (~0.1ha) of neutral grassland. No direct adverse effects were anticipated for protected fauna within the scheme extent. It was considered unlikely that the proposed woodland and tree mitigation planting would have matured by 15 years so slight adverse effects were likely to remain. The five-year evaluation confirmed many of the observations from the one-year evaluation. The impacts were broadly as expected and most of the proposed mitigation was in place. However, there was little evidence of effective maintenance. The wetland habitat was overgrown, and the proposed species rich grasslands was dominated by tall ruderals and grasses. No

[46] A tributary is a stream or river that flows into and joins a main river

[47] County Wildlife Sites (CWSs) are areas of land important for their wildlife. CWS recognition is non-statutory but is recognition of a site’s high value for biodiversity.

information was available to comment on the potential impacts on species and some of the proposed mitigation had not been provided (for example a proposed Otter ledge). Although overall the observed impacts were as expected. Maintenance will need to be improved if the environmental benefits of the mitigation are to be fully realised.

Figure 23: one-year evaluation establishment of wet/marshy areas at junction 12 and at five year after marshy balancing pond (ecological area) overgrown

Source: one-year evaluation Site Visit Sept 2014

Source: five-year evaluation Site Visit July 2018

6.9 Water Environment

The appraisal for the main carriageway M1 junctions 10 to 13 reported that due to increased traffic flows, more efficient delivery of runoff to receiving watercourses, and potential for reduced infiltration, the overall impact of the scheme on the water environment would be slight adverse. The impact of the scheme on drainage could not be confirmed due to limited access to the drainage infrastructure and lack of drainage flow, pollution control/monitoring and maintenance data.

The appraisal for junction improvements (junction 11 and junction 12) anticipated additional road drainage due to increased pavement at junction 11 to be attenuated in oversized pipes. This would mean that there would be no increase in discharge flows to surface watercourse. Attenuation of road drainage in attenuation ponds at junction 12 was proposed to provide some treatment and improvement of runoff quality. Thus, the overall impact of junction improvements on water quality was expected to be neutral.

Based on the available information, it appeared the drainage network for the junction 12 improvement had been implemented as expected. However, the impacts of junction improvements on the water environment were worse than expected at junction 12: poor maintenance had affected the integrity of the drainage system and its likely performance. Vegetation had grown into the balancing ponds, drainage ditches and culverts which were likely to be hindering the functioning of the drainage system.

6.10 Severance

No new severance issues were raised during the preparation for the five-year evaluation. As impacts were predicted to be neutral and confirmed as neutral at one-year evaluation, the impact of the scheme on severance was not evaluated at the five-year evaluation.

The appraisal for junction improvements noted that the existing route through junction 11 was well used by pedestrians and cyclists. The route through junction

12 was less frequently used but it was an important community link. Both junctions were expected to be improved by the provision of signalised pedestrian facilities across the bridges to reduce severance.

The environmental assessment expected that non-motorised users[48] at junction 11 and junction 12 would benefit from the junction improvements. In order to evaluate these benefits on severance of the schemes, these locations noted in the assessment and observed by the one-year evaluation were visited to experience impacts.

In line with the assessment, the five-year evaluation site visit confirmed that the signalised pedestrian crossing route through junction 11 and dedicated footways at junction 12 had been improved and currently used by pedestrians and cyclists as anticipated.

6.11 Overview

The results of the evaluation are summarised against each of the Transport Appraisal Guidance (TAG)[49] environmental sub-objectives and presented in Table 3 for junction Improvements and Table 4 for M1 main carriageway.

Table 3: Environmental Impacts – Junction Improvements

Sub Objective	Appraisal Summary Table Score	Five-year Evaluation	Summary
Noise	Change in population annoyed (year 15) = -6 NPV of noise proposal = +£0.226m	Better than expected	Noise mitigation appears to have been implemented as expected. As the available traffic data is lower than predicted traffic noise impacts are likely to be lower. There was no evidence on the ground to suggest that junction 11 noise is different from predicted, barriers were in place and in good working order. junction 12 noise impacts were likely to be lower due to better outturn layout when compared to pre-construction
Air Quality	PM10 = +95 NO2 = +274	Likely to be better than expected	Observed traffic flows including HGV numbers on the M1 are significantly lower than predicted which suggests overall emissions are likely to be lower than predicted.
Greenhouse Gases	NPV = -£0.207m	Likely to be better than expected	Observed traffic flows on the M1 are lower than forecasted. The lower flow should lead to lower carbon emissions.
Landscape	Neutral	Worse than expected	Landscape mitigation was implemented as expected, but still needs to fully establish. The site visit found little evidence of recent landscape management which combined with the heatwave presents a risk that design outcomes will not be met.
Townscape	Slight beneficial	Worse than expected	Some of the mitigation planting failed at junction 11 and not been replaced. The scheme increased the sense of urbanisation and had not delivered all the benefits predicted.

48 pedestrians, cyclists and equestrians
49 TAG provides guidance on appraising transport options against the Government's objective for transport

Sub Objective	Appraisal Summary Table Score	Five-year Evaluation	Summary
Heritage of Historic Resource	Slight adverse	As expected	Five-year evaluation site visit confirms expected impacts at junction 11 and junction 12 on setting of two listed buildings due to more open layout and view of Toddington Overbridge and related structures.
Biodiversity	Slight adverse	As expected	Most habitats are establishing at five-year evaluation, but influence of the Summer 2018 heatwave and absence of the planned/stipulated maintenance and monitoring of the ecological mitigation have limited progress of the various habitats
Water Environment	Neutral	Worse than expected	Balancing ponds and drainage ditches in the loops of junction 12 are overgrown with vegetation and show no sign of recent management. The performance of the drainage system had been impaired. Urgent maintenance is required of design outcome is to be met.
Severance (junction 11/12)	Moderate beneficial	As expected	Although the site visit did not find evidence of intensive use, non-motorised user facilities provided at junction 12 were in place.

Table 4: Environmental Impacts – M1 main carriageway

Sub Objective	Appraisal Summary Table Score	Five-year Evaluation	Summary
Noise	Change in population annoyed (year 15) = -100 NPV of noise proposal = +£7.5m	Better than expected	Traffic data suggests that there is lower than expected traffic. Low noise surface and noise barriers have been implemented
Air Quality	PM10 = +164 NO2 = +120	Likely to be better than expected	Observed traffic flows including HGV numbers on the M1 are significantly lower than predicted which suggests overall emissions are likely to be lower than predicted.
Greenhouse Gases	NPV = -£45.1m	Better than expected	Observed traffic flows on the M1 are lower than forecasted. The lower flow should lead to lower carbon emissions.
Landscape	Neutral	As expected	The scheme appears to have been implemented and mitigation provided broadly as expected. However, at five-year evaluation, there was little evidence of any recent landscape management. Assuming maintenance is improved, the design outcome will probably be met.
Townscape	Slight adverse	As expected	Gantries, DHS technology structure, higher noise barriers and lighting columns still visible although in an existing urban townscape that was already dominated by the motorway.

Sub Objective	Appraisal Summary Table Score	Five-year Evaluation	Summary
Heritage of Historic Resource	Slight adverse	As expected	At five-year evaluation, site visit evidence suggests that planting was not matured enough along the DHS scheme to screen heritage resources where appraisals found negative effects but should achieve the design outcome by year 15. Glimpse views of gantries, lighting and DHS technology were still possible at five-year evaluation
Biodiversity	Slight adverse	As expected	Highway verge had been lost because of the scheme. Impacts are likely to be as expected
Water Environment	Slight adverse	N/A	No asset data was available on the drainage system or its performance. On this basis, we were unable to evaluate

7. Value for money

7.1 Summary

As part of the business case for the scheme an economic appraisal was used to determine the scheme's value for money. This assessment was based on an estimation of costs and benefits over a 60-year appraisal period. The scheme came under budget at £489m compared with a forecast of £606m[50]. This was due to lower construction costs than forecast.

The post opening project evaluation of economic impacts assumes that benefits are derived from two main sources, improvements in journey times and reduction in personal injury collisions. The appraisal had forecast that the scheme would deliver greater benefits for journey times over the 60-year assessment period for a larger number of road users.

In the first five years of the road being opened to road users, the evaluation had not observed the level of benefit in line with the assumptions within the business case. This is because key assumptions used in the appraisal were based on limited evidence from one smart motorway pilot study and since then the objectives and assumptions of smart motorways have been evolving as more evidence and data has become available. Smart motorway schemes' appraisal now better reflects delivery and operational assumptions, and sensitivities to external systemic events, such as recessions.

The methodology for evaluating the economic value of benefits arising from journey time is based upon comparing the observed vehicle hour savings in the opening year against the original forecast of the savings developed in the business case. It is then assumed that the ratio between these at five years after is indicative of the long-term trend. Whilst this gives an indication of the proportion of forecast benefit realised, it does not give an accurate picture of the outturn Value for Money as it is based on appraisal assumptions no longer considered valid. In this scenario, the anticipated core journey timesaving benefits were not realised, and the scheme therefore is not on track to deliver its value for money objective[51] as defined in the original appraisal.

In this case, the monetisation of journey time benefit is not a good measure of value for money and the qualitative evidence presented in the evaluation is considered a more robust measure. The scheme has provided increased capacity, safety improvements and maintained levels of reliability whilst supporting an increase in the number of road users. The traditional post opening project evaluation method of producing a benefit to cost ratio (BCR) therefore is not considered a good indication of value for money as it is based on the original appraisal assumptions. However for transparency, the economic performance using the post opening project evaluation approach is presented in Appendix 4.

Although speeds are lower and journey times longer than initially predicted for this scheme, the assumptions behind the forecasts have been improved with the availability of greater evidence of smart motorway operation. Moreover, we are committed to continual improvement as part of the smart motorway safety evidence

[50] 2010 prices discounted to a present year of 2010
[51] Value for money objective - the project shall provide high value for money against its whole of life costs in accordance with the Department's TAG guidance

stocktake and action plan[52], we are converting all dynamic hard shoulder schemes to all lane running (ALR). All lane running schemes have seen delay lower than the overall delay across the smart motorway network[53]. As the scheme is already dynamic hard shoulder running, the works needed would not require significant costs compared to an upgrade from the conventional motorway. The conversion is anticipated to unlock journey saving benefits for the M1 junction 10 to 13 and provide further value to the scheme.

7.2 Scheme Benefits

7.2.1. Journey Time Benefits

The appraisal expected an increase in speeds from 55mph to 60mph and an average saving of 1.5 minutes in the opening year, increasing up to 2.5 minutes by 2028. This equated to a monetary benefit forecast of £996m[54]. This was driven by the change in the speed-flow curve[55] that was applied based off evidence from the pilot study. However, as more evidence and knowledge of dynamic hard shoulder operation has been collected, this practice is no longer used and no changes to speed-flow curves are applied.

The evaluation identified that average speeds, while becoming more consistent, have reduced since the road was converted to a smart motorway, resulting in increased average journey times. This was likely due to a combination of factors, including, the road supporting increased numbers of road users, and the speed restrictions applied as part of the dynamic hard shoulder operation (maximum 60mph when the hard shoulder is used as a running lane).

To evaluate the monetary impact, we compare the observed journey times against a forecast of the savings then assume the ratio is indicative of the long-term trend to derive the 60-year outturn monetised benefits. Applying this to the observed journey time impacts in the first five years indicates that if the scheme remained on this trajectory the monetised impact on journey times would be -£225m. However, the assumptions used in the appraisal were based on limited evidence from one smart motorway pilot study and since then the objectives and assumptions of smart motorways have been evolving as more evidence and data has become available. This means that the forecast scenario is not reliable for comparing the impacts of the scheme.

Before the conversion, road users experienced high levels of congestion. During the pm peak traffic flow was at 5,700 vehicles per hour, as a three-lane motorway this was 1,900 vehicles per lane, very close to capacity. After the conversion traffic flow was 6,300 vehicles per hour, just over 2,100 vehicles per lane[56]. Had the route remained a three-lane motorway this would be above capacity. Consequently, journey times would have deteriorated from the observed levels. However, with the additional dynamic hard shoulder lane in operation, traffic flows on the four-lane motorway was within capacity, at just under 1,600 vehicles per lane.

[52] In March 2020, the Department for Transport published its smart motorway safety evidence stocktake and action plan https://www.gov.uk/government/publications/smart-motorway-evidence-stocktake-and-action-plan
[53] Delay metric 2019/20 and 2020/21, delay - seconds per vehicle per mile. This is a new metric and is being validated.
[54] 2010 prices discounted to a present year of 2010
[55] Speed-flow curves are used within the model to reflect constraint on demand in line with available network capacity. This is achieved by applying a speed flow curve relationship which represents decreases in link speeds with flow increases, with the characteristics of the road determining the nature of this relationship.
[56] Data taken from WebTRIS, March 2009 and March 2018. Northbound pm peak.

Without the additional capacity of the fourth lane it is unlikely that the existing three-lane motorway would have been able to support the increased number of road users, leading to even slower journeys, and congestion as drivers would have to frequently brake forming queues and unreliable journeys. There would be minimal scope for future traffic growth, potentially impacting development and safety in the surrounding area. Evidence of the capacity constraints is demonstrated by the frequency of the dynamic hard shoulder operation and the frequency at which VMSL have been set at 40mph to maintain smooth traffic flow.

7.2.2. Journey Reliability Benefits

A scheme objective was to improve journey time reliability. The evaluation identified little change in journey reliability. The greatest benefit was seen in the pm peak for northbound journeys, with reliability improving by 1 minute 48 seconds. For journeys made in the am peak, journey times become more variable in each direction by 10 seconds, however this was while accommodating an increase in the number of users.

The scheme appraisal estimated the reliability benefits for the scheme using the Department for Transport's (DfT) Incident Cost Benefit Assessment (INCA)[57] program. However, the monetised reliability benefit was not included in the Analysis of Monetised Costs and Benefits table (AMCB) as there was less confidence in the method used for calculating reliability benefits than Transport Economic Efficiency TEE benefits, hence reliability benefits were not included in the total benefits calculation used to calculate the BCR. This evaluation report has therefore not included the monetised reliability benefit.

7.2.3. Safety Benefits

The evaluation of outturn safety benefits is based on the forecast 60-year appraisal period safety benefits and the comparison between the forecast and observed number of collisions saved at five years after. The evaluation found there were less personal injury collisions than forecast, this produced a monetary outturn benefit of £39m, a greater benefit than the appraisal expected.

The economic impact of changes in safety is calculated by assigning monetary benefits to the predicted reduction in the number and severity of personal injury collisions over the 60-year appraisal period. A monetary benefit of -£6m[58] over the 60-years appraisal period was forecast[59].

The appraisal assumed a 15% reduction in personal injury accidents. The assumption was based on reductions achieved on the M25 using variable speed limits following guidance at the time, that until long term data on the effects of Managed Motorways – Dynamic Hard shoulder accident rates is available to assume a 15% reduction[60]. The appraisal forecast that these savings would be countered by forecast increases in traffic on the motorway. However, it was expected that the scheme would further improve the accident rate by more than assumed for the quantitative appraisal[61].

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[57] 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.

[58] 2010 prices discounted to a present year of 2010

[59] Number of Personal Injury Accidents saved: Deaths: 1.8; Serious: - 10.8; Slight: -1,062. Source: Appraisal Summary Table (AST) M1 J10 to J13 HSR Scheme (22/09/09) Version 3

[60] informed by the DfT guidance note for Stage 2 Assessment of Dynamic Hard Shoulder titled 'Assessment of the Economy Impacts of Managed Motorways – Dynamic Hard Shoulder (MM-DHS) on the HA Network'.

[61] Economic Appraisal Report PCF Stage 5 Update, February 2010.

The safety evaluation concluded that if the scheme had remained as a conventional motorway safety on the scheme extent and surrounding network would most likely have seen an increase in accidents. Fewer personal injury collisions were observed, and a reduction in the rate and severity of personal injury collisions compared to pre-scheme.

Appendix 1: Safety counterfactual methodology

A.1. Safety counterfactual methodology

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

To establish whether any change in collision numbers is due to the scheme 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 scheme being implemented? To answer this question, we estimate the range of collisions that could have occurred without the scheme in place. Previous Post Opening Project Evaluations answered this question by looking at national trends in collisions. Adjustments have been made to the methodology for estimating the Counterfactual. These have been made to address the following areas:

Amended Data Collection Method

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

Adjusting for Traffic Flows

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

Better Differentiation between different types of Motorway

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

Assessing Regional Trends

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

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

Since this scheme, smart motorways have evolved. More recent all lane running schemes 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 2: Incident reporting

A.2. Incident reporting

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

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

In April 2016 Bedfordshire and Hertfordshire police constabularies transferred from Stats19 to CRaSH (Collision Recording and Sharing) system for reporting personal injury collisions. In CRaSH reporting, police officers record the types of injuries suffered by the casualty rather than the severity. In previous systems the determination of severity was at the discretion of the reporting police officer. CRaSH automatically converted the injury type to a severity classification. This led to implications for reporting on collision severity as there had been an increase in the number of serious collisions recorded[62].

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

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

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

Appendix 3: Collisions by severity

A.3. Collisions by severity

Pre-scheme and post-scheme personal injury collisions by year for the scheme extent, local area and wider area.

Table 5: Scheme extent collision severity

Period	Time period		Collision severity			Total
			Fatal	Serious	Slight	
Before scheme	3 years before	1 Dec 2006 - 30 Nov 2007	2	6	88	96
	2 years before	1 Dec 2007 - 30 Nov 2008	0	2	79	81
	1 year before	1 Dec 2008 - 30 Nov 2009	1	11	115	127
After scheme	3 years before	1 Dec 2012 - 30 Nov 2013	0	14	71	85
	2 years before	1 Dec 2013 - 30 Nov 2014	1	10	90	101
	1 year before	1 Dec 2014 - 30 Nov 2015	2	8	76	86

Table 6: Local area collision severity

Period	Time period		Collision severity			Total
			Fatal	Serious	Slight	
Before scheme	3 years before	1 Dec 2006 - 30 Nov 2007	6	18	178	202
	2 years before	1 Dec 2007 - 30 Nov 2008	4	21	139	164
	1 year before	1 Dec 2008 - 30 Nov 2009	0	22	134	156
After scheme	3 years before	1 Dec 2012 - 30 Nov 2013	3	14	151	168
	2 years before	1 Dec 2013 - 30 Nov 2014	1	28	116	145
	1 year before	1 Dec 2014 - 30 Nov 2015	4	10	131	145

Table 7: Wider area collision severity

Period	Time period		Collision severity			Total
			Fatal	Serious	Slight	
Before scheme	3 years before	1 Dec 2006 - 30 Nov 2007	17	82	558	664
	2 years before	1 Dec 2007 - 30 Nov 2008	11	103	564	678
	1 year before	1 Dec 2008 - 30 Nov 2009	8	74	544	626
After scheme	3 years before	1 Dec 2012 - 30 Nov 2013	5	83	457	545
	2 years before	1 Dec 2013 - 30 Nov 2014	7	73	496	576
	1 year before	1 Dec 2014 - 30 Nov 2015	11	78	464	553

Appendix 4: Summary of economic performance

A.4. Summary of Economic Performance

The economic performance of the M1 junction 10 to 13 is based on the original appraisal assumptions and needs to be considered within the wider value for money narrative as detailed in section 7. All monetary figures are in 2010 prices and values[63].

		Forecast[63] £m	Re-forecast based on five-year outturn Impacts £m
Benefits	Journey Time Benefits	996	-225
	Vehicle Operating Costs (VOC)	-411	-65
	Safety Benefits	-6	39
	Indirect Tax Revenues	503	80m
	Noise[64]	13	13
	Carbon[64]	72	72
	Journey time and vehicle operating costs impact during construction[65]	-148	-148
	Journey time and vehicle operating costs impact during maintenance[65]	-8	-8
Costs	Investment Cost	462	345
	Maintenance Cost[66]	177	177
	Do Minimum Cost[66]	-34	-34
	BCR – Indirect Tax as a Benefit[67]	1.4	-0.8

[63] Cost-benefit analysis requires all the costs to be considered for the whole of the appraisal period and they need to be expressed on a like-for-like basis with the benefits. This is termed 'present value'. Present value is the value at one point in time of an amount of money in the future. In cost-benefit analysis, values in differing years are converted to a standard base year by the process of discounting to give a 'present value'. Treasury guidance is to use discount rates of 3.5% for first 30 years and 3% thereafter. Appraisals (and therefore evaluations) are currently given in '2010 prices discounted to a present year of 2010.

[64] Monetisation of carbon and noise are assumed as forecast, these are not within the scope of post-opening project evaluations.

[65] The evaluation of journey time and vehicle operating costs during construction and maintenance is not in the scope of post-opening project evaluations. It has been assumed therefore costs remain as forecast as we have no new information to improve this estimate.

[66] After completion of construction, the scheme was forecast to incur additional costs in the form of maintenance of the additional equipment, operational costs and technology refresh costs over the 60-year appraisal period. At appraisal allowance has been made for costs that would otherwise be incurred if no scheme option was chosen. These costs have been classed as 'Do-Minimum' maintenance costs and are deducted from the scheme cost. For this evaluation, these costs are still almost entirely in the future and no evaluation has been done of maintenance costs to date. It will therefore be assumed that the outturn maintenance costs are the same as forecast.

[67] At the time of scheme appraisal, Treasury guidance was to include indirect tax as a cost. However, the most recent guidance on indirect tax impacts is to include these as a benefit, rather than a reduction in cost. This means that when a scheme leads to increase fuel consumption and hence increase tax revenue, the PVB is increased rather than the PVC being decreased. Annex D presents the BCR calculated according to current methodology.

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Registered office Bridge House, 1 Walnut Tree Close, Guildford GU1 4LZ

Highways England Company Limited registered in England and Wales number 09346363