5 DESIGN EVOLUTION

5.1 Background to the development of the Scheme

5.1.1 The following section outlines the chronology of events that has led to the development of the Scheme and a design solution that reflects these emerging Design concepts. In particular it identifies the decisions made with respect to the selection of Through Junction Running ("TJR") or No-Through Junction Running ("No-TJR"), also known as Dual 3 Lane Motorway ("D3M"), for each junction.

January 2003

5.1.2 The strategic case for providing additional capacity on the M4 within the Thames Valley was first identified in the Thames Valley Multi-Modal Study ("TVMMS") (2003) (Ref 7), prepared by the Government Office for the South East. The TVMMS sought to identify the most effective means of addressing current and future transport-related problems in the Thames Valley by understanding the root causes of transport problems within the area and how these problems were likely to develop and change in future. The TVMMS was predicated on the strong links between transport and wider economic, environmental and social policy, not just on improving transport provision itself. The TVMMS ensured that its recommended strategies were supportive of the then draft Regional Transport Strategy that had recently been published for consultation, and also consistent with two other studies, namely:

a) London Orbital multi-modal study ("ORBIT") (Ref 8) undertaken on behalf of the Government Office for the South-East; and

b) London to South West and South Wales multi-modal study ("SWARMMS") (Ref 9) undertaken on behalf of Government Office for the South West.

5.1.3 The TVMMS recommended against widening the M4 prior to 2016 in favour of traffic flow management through design and technology, including the uses of Intelligent Transport Systems ("ITS") and Integrated Demand Management ("IDM"). Box 1 contains an extract from the recommended strategy.

Box 1 Extract from TVMMS recommended strategy

> IDM is a term used by Highways England to cover a variety of measures to improve journey time reliability, reduce congestion and possibly marginally increase highway capacity without general widening. These measures might include better incident detection measures, more electronic traffic signs to manage incidents, more CCTV coverage, and variable speed limits.
>
> This study recognises the need and strongly supports the implementation of such measures in advance of, and alongside, other key elements of the Thames Valley strategy, recognising the continuing need throughout and beyond the strategy implementation period to tackle road-based congestion.

5.1.4 The Secretary of State for Transport subsequently endorsed these recommendations in early 2003 and, in July of that year, the M4 through the Thames Valley was included in a DfT discussion paper, Managing our Roads (Ref 10), which examined options for managing the road network in the light of the forecast increase in traffic.

March 2008

5.1.5 Subsequently, the Advanced Motorway Signalling and Traffic Management Feasibility Study ("AMSTMFS") (Ref 11), published by the DfT in March 2008, made extensive use of the DfT's National Transport Model ("NTM") (see Figure 2) to analyse the business case for hard shoulder running at various locations on the Highways Agency (now known as Highways England) network, following the encouraging early results from the dynamic all lane running scheme implemented on the M42 between junction 3a and junction 7 ("M42 Pilot").

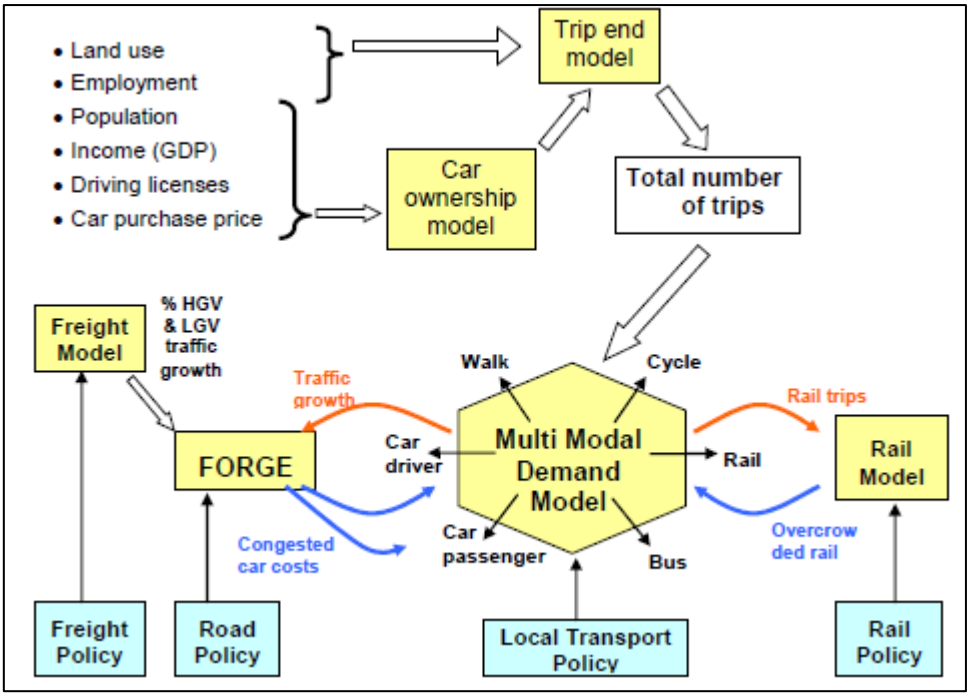

Figure 2 Outline structure of NTM

5.1.6 The AMSTMFS identified the M4 junction 3 to junction 12 as a priority for the provision of additional capacity and highlighted the following causes of congestion in the area of the proposed Scheme:

a) the large number of commuters using the strategic road network;

b) the number of commuters willing to travel significant distances;

c) low vehicle occupancy;

d) widely dispersed origins and destinations; and

e) a low proportion of trips starting or ending in urban centres

5.1.7 In addition, the AMSTMFS also concluded that both the number of trips and trip- miles would increase significantly over time, therefore exacerbating the existing situation. Ministers agreed that hard shoulder running, as an alternative to widening, should be investigated.

July 2008

5.1.8 Highways Agency (now known as Highways England) Command Paper ('Roads – Delivering Choice and Reliability') (Ref 12) confirmed the need to address the particularly fast growth of traffic on motorways. The Paper supported the approach of making better use of existing assets and proposes pursuing Active Traffic Management ("ATM") measures, including making use of the hard shoulder as a running lane, in conjunction with IDM.

January 2009

5.1.9 In January 2009, the DfT detailed the approach planned for improving capacity and

reliability on the motorway network ('Britain's Transport Infrastructure Motorways and Major Trunk Roads') (Ref 13). The paper presented the Managed Motorways concept, developed with the aim of further reducing capital and operating costs whilst optimising the benefits for road users and maintaining a high level of safety. The NTM was used again to perform a strategic analysis of the impacts on traffic, congestion and emissions of the revised roads programme.

5.1.10 The paper also detailed a programme of Managed Motorways schemes to commence construction by 2015, which included the M4 junction 3 to junction 12.

February 2010

5.1.11 Scheme development commenced for improvements to the M4 motorway. Following a strategic review of the Scheme scope and objectives, Ministerial and Highways Investment Board ("HIB") approval was granted in February 2010 to extend the scope and investigate a range of options. The four operational regime options and design concepts were identified (Table 4), developed and reviewed, by the Highways Agency (now known as Highways England) based on the knowledge gained from delivering Managed Motorway schemes and incorporating the latest emerging concepts.

Table 4 Operational Scheme options

Option	Description
Option 1: Interim Advice Note 111/09 Managed Motorways implementation guidance - Hard shoulder running solution	Dynamic hard shoulder operating regime utilising the hard shoulder as a running lane during peak periods or for event management
Option 2: Cantilever message signs Message Sign with bookend gantries	Dynamic hard shoulder operating regime with gantries at the start and end of the managed motorway section (bookend gantries). Inter-visibility, i.e. distances between gantries achieved through message signs at a nominal distance of 800m
Option 3: All lane running	All lane running incorporating the controlled use of the hard shoulder as a permanent running lane. Gantry mounted overhead lane signals displaying warning and information provided at nominal 800m intervals along the main Scheme section
Option 4: Light message signs more widely spaced with no bookend gantries	Dynamic hard shoulder operating regime utilising absolute minimal infrastructure implemented in order to operate the dynamic hard shoulder, whilst meeting the overall objectives of the Scheme, including highway safety. This option relies on the intuitive behaviour of the motorist, with message signs more widely spaced (at intervals of up to 3km).

5.1.12 Design and cost assessments were undertaken in 2010 for each of the above design

solutions, although work on developing engineering options was halted pending the completion of a traffic model and the development of a second generation Managed Motorway solution.

July 2011

5.1.13 Following verification of the traffic model for the Scheme for forecasting purposes in July 2011, Highways Agency (now known as Highways England) held a design strategy workshop in August 2011 to review emerging second generation Managed Motorway designs for the schemes identified in 'Britain's Transport Infrastructure Motorways and Major Trunk Roads' (Ref 13).

5.1.14 In order to optimise opportunities for identifying efficiency savings, while maintaining safety, the design options were further examined and a single scheme design for all such schemes, Managed Motorways, was established based on providing dynamic hard shoulder running (i.e. use of the hard shoulder during periods of congestion) and a complementary Controlled All Lane Running design solution.

5.1.15 A detailed operational review of the design concept applied to the M4 Managed Motorway Scheme was undertaken which recommended that the Managed Motorway Controlled All Lane Running design was the optimum solution for the Scheme. The Controlled All Lane Running Scheme was taken through Option Identification stage in December 2011.

May 2012

5.1.16 In May 2012, the Roads Minister announced the Scheme as one of six Highways Agency (now known as Highways England) Major Road schemes for development, at which point work commenced on the Option Selection stage.

February 2013

5.1.17 In February 2013 Highways Agency (now known as Highways England) Roads Programme Steering Group ("RPSG") reviewed the three TJR options available for the Scheme (see Table 5).

Table 5 TJR options reviewed in February 2013

	Junction/Access										
Option	12	MSA	11	10	8/9	7	6	5	4b	4	3
1	N	Y	Y	N	N	N	N	N	N	N	N
2	N	Y	Y	N	Y	Y	Y	Y	N	N	N
3	N	Y	Y	N	Y	Y	Y	Y	N	Y	N

5.1.18 In February 2013 the RPSG determined that the Scheme should be based on the operational principles of Managed Motorways all-lane running (“MM-ALR”), as set-out within the then current Interim Advice Note ("IAN") 161/13. It provided the following direction for future development of the Scheme:

a) no additional TJR Options were suggested other than the three options proposed;

b) Option 1 should not be progressed any further so as to maximise TJR as much as possible;

c) the project team should focus their attention on Option 2 because of air quality concerns at junction 4; and

d) TJR should be implemented at junction 4 (Heathrow) unless significant operational disbenefits justify otherwise. It was seen as possible that issues over air quality might provide a significant disbenefit. It was considered that Option 3 would provide useful comparative output to ensure a robust decision as to whether to exclude TJR at junction 4 at a later date.

5.1.19 The design solution proposed for the Scheme at this stage was a controlled all lane running scheme. This was in line with the emerging second generation of Managed Motorway design criteria that maintain safety whilst minimising the technology and infrastructure required to support the proposed operational regimes. The Scheme contained the following key features:

a) operate verge mounted electronic signage advising of the start and end of the Scheme;

b) portal gantries positioned near the start of each link, capable of providing lane specific signalling Advanced Motorway Indicator and supporting information on message signs;

c) verge mounted cantilever variable message signs at a maximum spacing of 1500m capable of providing the same types of information but using pictograms, wickets, etc.;

d) additional intermediate gantries may be provided on links in excess of 5km;

e) EAs (previously known as ERAs) at up to 2.5km intervals with potentially less monitoring equipment than the previous design of EAs;

f) no hard shoulder as the existing hard shoulder becomes a full-time permanent running lane (not just a temporary running lane during periods of congestion as previously considered); and

g) the operational regime runs at variable speed to the national speed limit.

June 2013

5.1.20 In the June 2013 Spending Review, the Government announced the M4 junction 3 to junction 12 as a pipeline scheme, to which the Government committed itself to providing funding support, subject to consideration of value for money and deliverability.

September 2013

5.1.21 A Managed Motorways All Lane Running Scheme was taken through Option Selection stage in September 2013. Although that stage was termed Option Selection, the Scheme was classified as a single option scheme in terms of the overall concept – that of a Managed Motorway. Within the scope of the various elements which comprise the Scheme design, there were alternative options, such as different options for bridge replacement. These alternative options were further explored during the development of the current Preliminary Design.

November 2013

5.1.22 In November 2013, Highways Agency (now known as Highways England) changed the terminology of Managed Motorways to "smart motorways".

January 2014

5.1.23 The current stage of work commenced in January 2014 to take the M4 junction 3 to junction 12 Smart Motorway Scheme through the Development phase which includes Preliminary Design and preparation of the Application.

December 2014

5.1.24 The Scheme was included in the top 40 priority infrastructure investments in the Government's National Infrastructure Plan (Ref 14) which accompanied the Chancellor's Autumn Statement (Ref 15). It was also included in the Government's first Roads Investment Strategy (Ref 16).

September 2016

5.1.25 The Scheme's DCO was granted based upon a preliminary design by the Secretary of State on 2nd September 2016 subject to 26 Requirements.

5.1.26 Detailed design of M4 junction 3 to junction 12 commenced based upon Interim Advice Note 161/13.

July 2018

5.1.27 As the design was further developed, Highways England submitted 18 of the 26 requirements to the Department for Transport (DfT) for discharge, and these were approved by the Secretary of State between May 2017 and July 2018. The remaining 8 did not require discharging.

5.1.28 At this time the Scheme design was based upon Option 3 from Table 5 above.

March 2020

5.1.29 Highways England concluded a review of the operational arrangement of the Scheme based upon updated guidance provided within Interim Advice Note 161/15, which superseded 161/13 (upon which the design was originally based), following feedback from other operational Smart Motorway schemes.

5.1.30 Interim Advice Note 161/15 advised Smart Motorway Schemes to implement the most appropriate junction layout based on operational and safety factors for each junction (whereas the default position within 161/13 was for TJR for the entire Scheme).

5.1.31 The review using the original traffic model (verified using observed traffic volumes), considered operational, environmental and safety factors and determined that junctions 5, 6, 8/9 and 11 would operate more effectively as No-TJR. Therefore, a fourth operating option (Table 6) emerged which was adopted by the Scheme. This meets the criteria set out in the Scheme objectives to reduce congestion and provide capacity to meet traffic flows in the design year, 2037.

Table 6 Fourth TJR Option reviewed

	Junction/Access										
Option	12	MSA	11	10	8/9	7	6	5	4b	4	3
4	N	Y	N	N	N	Y	N	N	N	Y	N

The Safety Control Review Group ("SCRG") reviewed and endorsed Option 4 due to the operational and safety considerations. The SCRG provides a forum for reviewing and endorsing 'safety work' associated with the design and planning of a scheme /project/programme before it is submitted for formal approval. It is a cross-functional group within Highways England that reviews 'safety work' to agree that safety risks are correctly identified, reviewed and managed appropriately.

5.1.32 Design guidance (TD 22/06) states that where Variable Mandatory Speed Limit ('VMSL') is implemented the capacity per lane in peak hour can be 2000 VPH per lane before flow breakdown, i.e. where forecast flows will not exceed 6000 VPH in either direction of a 3 lane motorway is sufficient where VMSL is implemented. Flows have been forecast in 2022, 2037 and 2041.

5.1.33 At junction J5 traffic through the junction is forecast to be less than 6000 Vehicles Per Hour ('VPH') in 2037, without TJR (less than 2000 VPH per lane). Therefore, the current arrangement of no-TJR at junction 5 will provide sufficient capacity beyond the design year of the Scheme.

5.1.34 At junction 6 traffic through the junction is forecast to be less than 6000 vph in 2037 without TJR. Therefore, the current arrangement of no-TJR at junction 6 will provide sufficient capacity beyond the design year of the Scheme. Since no improvements to the junction 6 slip road, roundabout or nearby local road network are proposed as part of the Scheme, the mainline queuing currently present at peak hours would still be present at Scheme opening and may be worse due to the potential for increased

upstream mainline flow arriving at the junction. Therefore, a lane drop layout at the diverge with D3M intra-junction is better suited to this junction than TJR. A safety risk assessment comparing TJR and no-TJR was undertaken in November 2019 and concluded that no TJR was safe at this junction. This risk assessment was endorsed by the SCRG.

5.1.35 At junction 8/9 traffic through the junction is forecast to be less than 6000 VPH in 2037 without TJR. Therefore, the current arrangement of no-TJR at junction 8/9 will provide sufficient capacity beyond the design year of the Scheme. Forecast flows for the merge and diverge in the design year are in excess of 1800 VPH (the limit within TD22/06 which allows 2000 VPH per lane with VMSL), and therefore a lane drop/lane gain layout with D3M intra-junction will continue to be beneficial at this junction. A safety risk assessment comparing TJR and no-TJR was undertaken in November 2019 and concluded that no-TJR was safe at this junction. This risk assessment was endorsed by the SCRG.

5.1.36 At junction 11 traffic through the junction is forecast to be less than 6000 VPH in 2037 without TJR. Therefore, the current arrangement of no-TJR at junction 11 will provide sufficient capacity beyond the design year of the Scheme. There is regular congestion in the AM peak originating at the westbound diverge resulting in queueing traffic in lane one of the mainline upstream. Recognising the constraints and capacity of the local network the most appropriate layout is a lane drop at the diverge, which will improve segregation of traffic leaving at junction 11, or continuing on the motorway. A safety risk assessment comparing TJR and no-TJR was undertaken in November 2019 and concluded that no-TJR has potential to reduce exposure of road users to occasional queuing hazards on the approach to this junction. This risk assessment was endorsed by the SCRG.

5.1.37 The existing layout at junctions 5, 6, 8/9 and 11 remains as no TJR, i.e. Dual 3 lane motorway (“D3M”) which means that the intra-junction hard shoulder is retained by the Scheme at these locations.

5.1.38 No-TJR will be retained at Junctions 3 and 12 as they are terminal junctions. Equally No-TJR will also be retained at junctions 4b and 10 as they are motorway-to-motorway interchanges. TJR will be retained at junction 4b and 7 as the operational assessment demonstrated it is the best operating regime.

5.2 Alternatives considered for specific Scheme elements

5.2.1 The technical details and further explanation of the range of details relating to the Scheme elements is presented in sections 6.3 and 6.4 of this EDR.

Structures

5.2.2 A number of alternative options were considered for the replacement of each of the overbridges affected by the Scheme. These included:

a) replacement online with the bridge closed for the duration of the works and traffic diverted onto suitable diversion routes agreed with the local authority;

b) replacement of the existing bridge offline. The local road would remain open for the duration of the works, except for short closures (with shuttle working) that would be necessary to accommodate highway works where the new road ties back into the existing road; for operations involving lifting of elements of the new structure into position using cranes; and for demolition of the existing structure. Local traffic will be diverted onto the new bridge prior to demolition of the existing bridge.; and

c) non-replacement of a structure if it was considered to be redundant by the local authority – although none of the existing structures were found to be in this category.

5.2.3 A number of different span arrangements were considered: These included:

a) A single-span bridge supported on full height abutments located at the back of the M4 verges;

b) A conventional two-span bridge supported on a central reserve pier and abutments located within the embankments;

c) A three-span bridge with piers at the back of the M4 verges and bank seats at the top of the embankments; and

d) An asymmetric two-span bridge with one abutment located at the back of the M4 verge, a pier located within the opposite M4 verge and the other abutment located within the side road embankment, to facilitate a secondary span above existing utility corridors.

5.2.4 As part of detailed design, it was concluded that single, two or three-span structures provided the most buildable and economic solution, considering site constraints, particularly existing utilities. Cost analysis and buildability consideration showed that the single-span generally had a cost and programme advantage and was therefore the preferred solution at most sites.

5.2.5 Conventional two and three span structures have benefits in terms of reduced construction depths and the impact on side road construction. However, it was decided from a health and safety perspective to avoid pier construction within the central reserve. In the case of the offline construction, there is, also, insufficient space to create a safe working zone to build the piers whilst maintaining three lanes of traffic in each direction on the M4. Working in the central reserve would also have had a significant impact on the construction programme, as it was considered likely that overnight working would be necessary. Therefore, where a single span was not viable, the three span option became preferred.

5.2.6 Steel-concrete composite deck construction was considered the most suitable form of construction for the replacement overbridges. This form of deck provides a cost-effective solution for the spans required to cross the M4. The use of weathering steel (steel that does not need to be painted) reduces the cost and impact on traffic associated with the maintenance and repainting of non-weathering steel structures.

5.2.7 During detailed design, the design philosophy stated in 5.2.5 and 5.2.6 was adopted.

5.2.8 Changes during detailed design included:

a) span arrangements, where temporary works and detailed cost estimates demonstrate significant benefits;

b) reinforced concrete abutments/wing-walls replaced by sheet piles where appropriate and where a cost saving was identified;

c) online solutions changed to offline solutions where diversion routes are considered undesirable; and

d) online solutions changing to offline solutions if significant costs are associated with utility diversions and, directional drilling of services under the M4 carriageways is not feasible.

e) changing offline to online solutions to minimise land take and simplify construction

5.2.9 Tables 7 and 8 describe the main alternatives considered in relation to particular overbridge and underbridge structures respectively. For further information of changes in the table refer to Chapter 7 of this EDR.

Table 7 Overbridges to be demolished and replaced

Structure	Alternatives considered	Option selected
Ascot Road Overbridge	Online/Offline construction	Offline construction as the high traffic volumes on the A330 prevent a suitable diversion which is acceptable to the local authority. An offline replacement to the east provides an improved highway alignment compared to a solution to the west, and it avoids impacting on the residential properties and communication masts.
	One/two/three-span construction	Single-span option selected, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours, also providing cost and programme advantages.
Monkey Island Lane	Online/Offline construction	Offline construction to the east required. This bridge is the only means of access into the properties on Monkey Island. Realignment to

Structure	Alternatives considered	Option selected
		the east avoids impacting on adjacent residential properties.
	One/two/three-span construction	Three-span option selected, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours also providing cost and programme advantages. Compared to a single-span structure a three-span overbridge has a reduced impact on two existing flood relief culverts located behind the existing motorway verges.
Marsh Lane	Online/Offline construction	Online construction, to minimise land-take, with Lake End Road being the diversion route.
	One/two/three-span construction	Single-span option selected, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours.
Lake End Road	Online/Offline construction	Offline construction to maintain suitable access to Dorney for buses and boat trailers.
	One/two/three-span construction	Asymmetric two-span option selected, with a main span over M4 and a secondary span over existing utilities. The absence of a pier within the motorway central reserve improves safety for construction workers and removes a significant construction constraint. It also enables three lanes of traffic to be maintained during peak hours.
Huntercombe Spur	Online/ construction	Online replacement to minimise land-take and simplify construction. A temporary bridge will be built to the east of the main structure to facilitate the movement of traffic during construction.
	One/two/three-span construction	Single-span option selected, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours also providing cost and programme advantages.
Oldway Lane	Online/offline construction;	Online replacement to minimise land-take.

Structure	Alternatives considered	Option selected
	Footbridge/vehicular bridge.	Lightweight footbridge; a like-for-like vehicular replacement is unnecessary as the route is not accessible for unrestricted vehicle usage from either north or south.
Wood Lane	Offline construction only.	Offline to the east - Wood Lane is the only means of providing vehicular access to the Sewage Treatment Works and residential properties on the south side of the motorway. This precludes the online option which would require temporary closure of the road.
	One/two/three-span construction	Asymmetric two-span option selected, with a main span over M4 and a secondary span over existing utilities. The absence of a pier within the motorway central reserve improves safety for construction workers and removes a significant construction constraint. It also enables three lanes of traffic to be maintained during peak hours.
Datchet Road	Online/offline construction.	Offline solution required. There is no acceptable diversion route during construction. A diversion along the A4 via either junction 6 or junction 5 would be over five miles (8.047km) long and the only other available diversion would be via B3026 Pococks Lane which is not considered to be suitable for the level of traffic on Datchet Road. The new road will be realigned to the east to avoid impacting on residential properties. Online solution utilising traffic running across the structure with contraflow in a partially-demolished state was rejected. There is insufficient width for safety, and the structural form of the existing bridge is unsuitable, so this approach is not feasible.
	One/two/three-span construction	Asymmetric two-span option selected, with a main span over M4 and a secondary span over existing utilities. The absence of a pier within the motorway central reserve improves safety for construction workers and removes a significant construction constraint. It also enables three lanes of traffic to be maintained during peak hours.
Recreation Ground	Online/offline construction.	Online replacement to minimise land-take. Refer to Chapter4 of the ES for proposed diversion route.

Structure	Alternatives considered	Option selected
	One/two/three-span construction	Single-span option, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours also providing cost and programme advantages.
Riding Court Road	Online/offline construction.	Offline construction. The side road in the vicinity of the existing bridge is re-aligned to the west to achieve an improved horizontal alignment. The new alignment has been developed to avoid impacting on property and communications masts on the southern side of the motorway. An online replacement was considered with a potential diversion route identified. However, a planning application has been submitted to extract aggregate from the land around Riding Court Farm. The volumes of traffic and defined routing of vehicles would cause considerable disruption on the surrounding local road network if the existing bridge was closed to traffic during replacement. This combined with the long vehicular diversion and requirement for diversion of statutory undertakers' apparatus has resulted in a preferred offline bridge replacement solution.
	One/two/three-span construction	Single-span option, to eliminate the need for a central pier, thereby improving safety for construction workers and enabling three lanes of traffic to be maintained during peak hours.
Old Slade Lane	Online/offline construction	Online replacement. Offline replacement constrained by slip-roads to M25 and presence of a lake to the south-east; While a temporary diversion route is available, extensive additional works would be required to bring the route to an appropriate standard for use by the public. The route would also be lengthy.
	One/two/three-span construction	Single-span option selected – multi-span options were rejected because of the proximity to the M25 junction, leading to high-vehicular turning movements, so an increased likelihood of an incident involving the workforce.

Structure	Alternatives considered	Option selected
	Footbridge/vehicular bridge	A replacement with a lightweight footbridge structure was rejected after initial consultation with local authorities because of the need to maintain access for vehicles.

Table 8 Underbridges and culverts to be widened

Structure	Alternatives considered	Option selected
Thames Bray	Asymmetric widening to north/south side.	Asymmetric 7.8m widening to north side selected due to savings in construction operations, reduced vegetation clearance, reduced traffic disruption and overall reduced complexity. North widening selected to minimise impact on the local school and residential properties located to the south.
	Symmetric widening both sides.	Symmetric widening on both sides was rejected due to the increased number and complexity of construction operations, and the greater impact on road users, vegetation, the local school and nearby residents.
Chalvey Culvert	Symmetric widening both sides.	Symmetric widening rejected as asymmetric widening of both ends minimises highway realignment.
	Asymmetric widening to north/south side.	Asymmetric widening of 4.65m to south and 4.11m to the north selected.
Railway Culvert	Symmetric widening both sides.	Symmetric widening rejected as asymmetric widening of both ends minimises highway realignment.
	Asymmetric widening to north side	Asymmetric widening of 7.6m to north end selected.
Windsor Branch Railway	Bridging slab between existing bridges	The existing central reserve is to be reconstructed. This is achieved by joining the two existing bridge decks together. Asymmetric widening is no longer required due to the removal of TJR at J6.

Structure	Alternatives considered	Option selected
Water and Gas Main Culvert	Symmetric widening both sides.	Symmetric widening rejected as asymmetric widening of both ends minimises highway realignment.
	Asymmetric widening to west/east side.	Asymmetric widening of 1.35m to west and 2m to the east ends selected.
	Infilling of structure with possible service diversions.	Alternative option to infill and possibly divert services away from this structure was discussed with Thames Water; however, this was not pursued due to the cost of diverting the Thames Water mains.
Water Main Culvert	Symmetric widening both sides.	Symmetric widening rejected as asymmetric widening reduces need for highway realignment.
	Asymmetric widening to west/east side.	Asymmetric widening of 2m to the west and 3.8m to the east selected to minimise highway realignment.
	Infilling of structure with possible service diversions.	Alternative option to infill and possibly divert services away from this structure was discussed with Thames Water; however, this was not pursued due to the cost of diverting the Thames Water main.
Ashley's Arch Culvert	Asymmetric widening to north/south side.	Asymmetric 1.25m widening to the north selected and dictated by proposed highway alignment.
	Symmetric widening both sides.	Symmetric widening on both sides rejected due to significant highway realignment and associated widening of the adjacent culvert structure.
Sipson Road North Subway	Widening to north side.	Widening of Sipson Subway by 1.2m to the north, within the existing highway boundary has been selected to avoid the extensive existing utilities and gas regulator on the south side. The widening to the north reduces the vegetation clearance required, reduces disruption to users of the subway as the widening is less extensive and has negligible environmental impact. The works will be within the highway boundary and the pre-cast solution will minimise both noise and disruption. In operation the highway boundary will not change and will result in negligible change to noise and air quality compared to works taking place on the south side. Further information on this

Structure	Alternatives considered	Option selected
		design change is provided in Chapter 7. Although the revised location is closer to sensitive receptors than twidening to the south side, the environmental assessment has indicated no significant effects arise from the works taking place at this location. Furthermore, the proposed solution for Sipson Subway offers a reduced works programme compared to works taking place to the south side, and therefore will likely cause less disruption to users of the subway.
	Symmetric widening both sides.	Symmetric widening on both sides rejected due to the increased number and complexity of site operations, greater impact on vegetation, the local school and nearby residents.

Central Reserve

5.2.10 It is proposed to provide a 900mm high Rigid Concrete Barrier ("RCB") and paved central reserve throughout the Scheme. Provision of steel safety barrier in the central reserve was rejected as an alternative, as it would not comply with the Highway England design standards. However, a safety assessment of constructing the RCB on an unpaved central reserve was undertaken. After consulting the Highway England maintenance service provider for Area 3 (Highway England maintenance area through which this section of the M4 passes) and presenting the options to the Project Safety Control Review Group in November 2013, it was decided that the RCB should be constructed on a paved central reserve as this would:

a) eliminate stone scatter caused by errant vehicles and the need to sweep back scattered stones;

b) avoid the need for maintenance of the storm drain (provision of a hardened central reserve would allow a mobile sweep);

c) avoid the need for vegetation control (expected to be undertaken three times per year);

d) avoid the risk of rutting in the soft central reserve and accidents due to loss of control of vehicles as result of rutting;

e) provide better control of planned and unplanned maintenance as maintenance of hardened central reserve can be undertaken within Traffic Management ("TM") for technology maintenance;

f) provide a refuge for workers walking along the central reserve (especially at night as a paved central reserve is safer to walk on than a soft central reserve);

g) reduce the time required for lane closures to remediate the RCB after a vehicle impact;

h) lower whole life cycle costs; and

i) provide consistency with M3 and M25 maintenance and operating regimes.

Junction 4b to 5 Number of Lanes

5.2.11 The original design option for junction 5 to junction 4b eastbound was for four lanes with a fifth lane for the final 500m before the exit to the M25 (auxiliary lane drop) and three lanes continuing towards London. A fifth lane has been introduced, on the eastbound carriageway, directly east of Sutton Lane Bridge providing two exit lanes dedicated to the M25, to reduce the potential for queuing traffic to tail back on the M4 mainline.

5.3 Iterative design process for the Scheme

5.3.1 Chapter 6 of this EDR describes the Scheme based on the current design. The Scheme design was produced through an iterative design process involving:

a) review of Scheme objectives and emerging requirements for smart motorways;

b) consultation with relevant statutory consultees and other interested parties;

c) engagement with the public through public consultation, and review of responses from the consultation; and

d) collaborative working between the environmental disciplines and engineering teams to address any environmental effects including mitigation measures, as required, and take into consideration consultation responses as part of the on-going environmental assessment process.

5.3.2 The preliminary design of the Scheme is the design upon which the granted Application is based. Detailed design commenced in parallel with the examination of the Application. This was necessary in order to ensure delivery of the Scheme in a timely manner. However, where alternatives were still currently under consideration, all potential options were included within the Application. The design assessed in the ES may be considered to represent a worst-case scenario, in terms of environmental impact and required land-take, so as to ensure that all foreseeable significant environmental effects of the Scheme have been assessed. Where changes were made post consent, an assessment of the effects of this change in comparison to those reported in the ES was carried out to ensure that no new, or materially different environmental effects arise from those reported in the ES.