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Wiltshire Council

# M4 Junction 17 OBC

WC_M4J17-ATK-GEB-XX-RP-TB-000005

# B6_Economic Appraisal Report

26/08/2022

# Notice

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# 1. Introduction

## 1.1 Background

Wiltshire Council is promoting improvements to M4 Junction 17 as part of an application to the Major Road Network (MRN) fund administered by the Department for Transport (DfT). The scheme is one of three complementary proposals identified by the Western Gateway Sub-national Transport Body (STB) on the A350 corridor (the other two being at Chippenham and Melksham).

Following DfT review of the SOBC, in March 2020 the Government awarded Wiltshire Council funding to further develop the scheme and progress the business case to an Outline Business Case (OBC).

The Outline Business Case (OBC) represents the next business case milestone in the decision-making process. The OBC builds upon the SOBC and updates and enhances the evidence in relation to each of the five cases: Strategic Case; Economic Case; Financial Case; Commercial Case; and Management Case. The OBC Economic Case considers the overall Value for Money (VfM) of the scheme, taking into account the scheme cost and impacts against a number of economic, social and environmental criteria. The appraisal of scheme impacts includes monetised impacts, which form the basis of a Benefit Cost Ratio (BCR), and non-monetised impacts (assessed in a qualitative manner). Both types of impact inform the overall VfM assessment and determination of a VfM category.

## 1.2 Document purpose

This Economic Appraisal Report (EAR) provides supporting information to the M4Junction 17 OBC (WC_M4J17-ATK-GEN-XX-RP-TB-000001). More specifically, it supplements the Economic Dimension and provides additional details in relation to the economic appraisal.

The EAR focuses on the economic appraisal setting out additional detail on the approaches used to generate outputs which have been presented as well as further detail of those outputs and quality assurance which has been applied. Much of the appraisal work is underpinned by transport modelling. Whilst key elements of the modelling approach are covered in the EAR, the full details of the transport modelling are addressed in other supporting documents, including the:

- Local Model Validation Report (WC_M4J17-ATK-GEN-XX-RP-TR-000001 – main OBC Appendix B1)
- SATURN Traffic Forecasting Report (WC_M4J17-ATK-GEB-XX-RP-TR-000003 – main OBC Appendix B2); and
- Vissim Forecasting Report (WC_M4J17-ATK-GEB-XX-RP-TR-000004 – main OBC Appendix B4).

## 1.3 Document structure

This document is structured as follows:

- **Chapter 2** provides a brief overview of the scheme context and objectives
- **Chapter 3** provides a summary of the scheme scope, as context to the appraisal of the impacts
- **Chapter 4** provides a brief overview of the transport modelling approach
- **Chapter 5** provides details of key assumptions and analysis of outputs for each of the monetised impacts, the overall Benefit Cost Ratio, and relevant sensitivity tests
- **Chapter 6** provides an overview of non-monetised impacts
- **Chapter 7** provides a summary of the analysis undertaken and the results and outcome which it has produced.

# 2. Context and scheme objectives

Comprehensive details of the scheme context can be found within the OBC Strategic Case. This section provides a summary of key points.

## 2.1 Scheme context

M4 Junction 17 connects the M4 to: the A350 (to west Wiltshire and the South Coast); the A429 (towards Malmesbury and Cirencester); and the B4122 (connecting rural Chippenham). The junction is located approximately five kilometres north of Chippenham, and between Junction 18 (Bath) 16 kilometres to the west, and Junction 16 (Swindon) 20 kilometres to the east. There is evidence of congestion and delays occurring at M4 Junction 17, particularly during the peak periods.

Evidence from traffic modelling demonstrates that a significant deterioration in junction performance is expected by 2036, even before taking into account the more intensive growth strategy associated with the emerging Local Plan Review.

It has been a longstanding priority for Wiltshire Council to improve north-south connectivity via the A350 corridor, including alternatives to road travel such as rail. A number of improvements to the A350 corridor have been delivered by Wiltshire Council in recent times. The M4 Junction 17 proposal, in conjunction with further proposed MRN schemes at Chippenham and the A350 Melksham Bypass scheme, reflects Wiltshire Council's continued, co-ordinated and strategic approach to the improvement of the corridor. In combination, these investments complement each other and would represent a substantial upgrade to the A350.

## 2.2 Scheme rationale

A notable feature of the transport network serving the area is that east-west connectivity by road and rail is strong, whereas north-south connectivity is relatively weak in comparison. This places a lot of emphasis on the A350 corridor, between the South Coast and M4. However, investment in the corridor has not kept pace with its increasing significance (particularly given the significant constraints associated with the main alternative route; the A36/A46). M4 Junction 17 represents a key intersection between the main east-west and north-south axis.

Failure to address the problems arising from the existing arrangements at M4 Junction 17 (presently, and in future years) would result in adverse consequences for the MRN/SRN, affecting transport users, businesses and wider society. Of particular relevance are those regarding: regional connectivity; economic growth and productivity; and local housing and jobs delivery.

A major priority for the area is for the transport network to provide reliable strategic connections between its key economic centres and wider markets to prevent transport from becoming a constraint to growth. North-south connectivity is a primary focus. The investment strategy for the A350 corridor reflects the need to ensure that the A350 route can serve its strategic role efficiently whilst further enhancing overall travel choices, particularly for short to medium distance journeys within the corridor.

A strategic and holistic intervention at M4 Junction 17 is required to fully meet the identified business needs of Wiltshire Council, National Highways and DfT. The 'Business as Usual' scenario would result in a reactive, piecemeal approach to mitigating the impacts of individual development sites on M4 Junction 17 over time. This has a number of limitations and undesirable outcomes, including:

- greater disruption to users, due to multiple construction / works phases;
- not fully addressing the problems (in particular as new development is only required to mitigate the specific development impact); and
- a lack of strategic planning and certainty, which would adversely impact business confidence and inward investment and could impact the viability of the preferred growth strategy for Wiltshire (through the Local Plan Review process).

Wiltshire Council is not able to fully fund a strategic intervention from its own resources (including existing / anticipated developer contributions). As demonstrated within the Strategic Dimension the proposal presents a strong alignment with the DfT's MRN fund and complements other MRN / LLM scheme proposals on the A350 corridor. Intervention is required now to avoid the 'Business as Usual' issues identified above and to ensure that upgrades to the A350 are delivered in a co-ordinated manner which provides the best overall value against investment.

## 2.3 Strategic fit

The scheme has a strong strategic alignment with local and national policy and strategic priorities, including:

- Strategic priorities of the Western Gateway Sub-national Transport Body for enhanced north-south connectivity within the region to improve links between the M4 and south coast (including the ports) and increase economic productivity levels.
- Facilitating further jobs and housing growth within the A350 Growth Zone, which is a major component of Swindon and Wiltshire Local Enterprise Partnership's economic growth strategy.
- The need for a continued focus on housing delivery (in a sustainable manner) within the West Wiltshire towns in the A350 corridor in order to meet required housing targets, as established through Wiltshire Council's emerging Local Plan Review (to 2036).
- National priorities within the Transport Investment Strategy relating to creating a more reliable, less congested, and better connected transport network and building a stronger, more balanced economy.
- National Highway's M4 to Dorset Coast Connectivity strategic study (as part of RIS2), which is reviewing the function and role of key north-south routes, including the A350.
- Local priorities and outcomes for Melksham, Chippenham and the surrounding area, to maintain, manage and selectively improve the A350 corridor to support development growth.

## 2.4 Options considered

A broad range of potential solutions has been considered, including public transport and active mode options, and stakeholder input has informed the option sifting and assessment process. A highway scheme to improve M4 Junction 17 was found to be the most effective in addressing the particular issues and objectives.

Different scales of intervention to widen the junction were taken forward for shortlist assessment, in all cases providing full signalisation. These options were reviewed, with initial appraisal undertaken for the SOBC.

At the outset of this OBC the shortlisted options were re-examined using traffic modelling, resulting in a variant of the options considered at SOBC being identified, enabling much of the benefit of the highest cost option to be achieved but with a significantly reduced investment cost.

This variant option has been taken forward for Value for Money (VfM) assessment with this OBC.

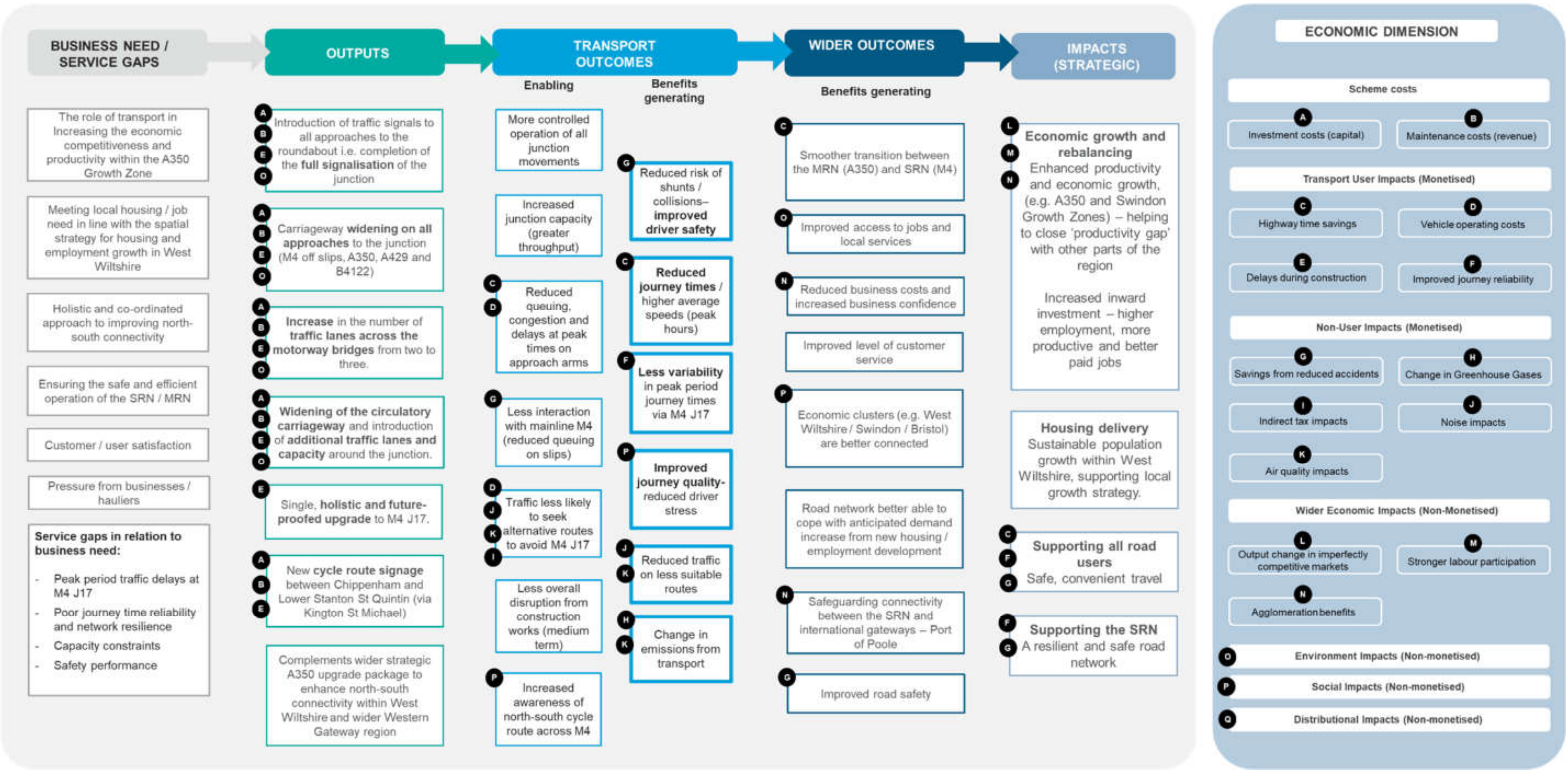
## 2.5 Scheme outcomes and impacts

The scheme is expected to be effective in addressing all five of the identified transport objectives:

- Reducing delay and improve journey time reliability at M4 Junction 17, supporting journeys on the SRN / MRN.
- Enhancing the wider package of MRN/LLM improvements for the A350, which would be most effective when delivered in combination.
- Improving north-south connectivity on the A350 through improvements to M4 Junction 17, the gateway to the A350 / South Coast from the SRN.
- Ensuring that M4 Junction 17 has the capacity to accommodate planned and future growth in the A350 Corridor and in the A350 and Swindon M4 SWLEP Growth Zones, including the Wiltshire Local Plan Review.
- Increase safety levels at M4 Junction 17, taking into account forecast traffic growth.

A clear causal chain has been established linking: business need / service gaps (problems); project inputs (resources and activities); project outputs (specific deliverables); transport outcomes; intermediate outcomes; and strategic impacts. This is illustrated in Figure 2-1 in the form of a logic map. This extends the logic map presented within the Strategic Dimension to illustrate the linkages between the scheme inputs, outcomes and impacts and the relevant parts of the economic appraisal (based on the typical TAG appraisal criteria). This ensures that the scope of the Economic Dimension is clearly informed by the Strategic Case. Indicators have been used within this logic map to set out how each of the each of the outputs, outcomes and impacts have been represented within the different sections of appraisal throughout the Economic Dimension and this Economic Appraisal Report.

**Figure 2-1 – Scheme outcomes and impacts**



# 3. Overview of the scheme appraised

## 3.1 Preferred option for appraisal

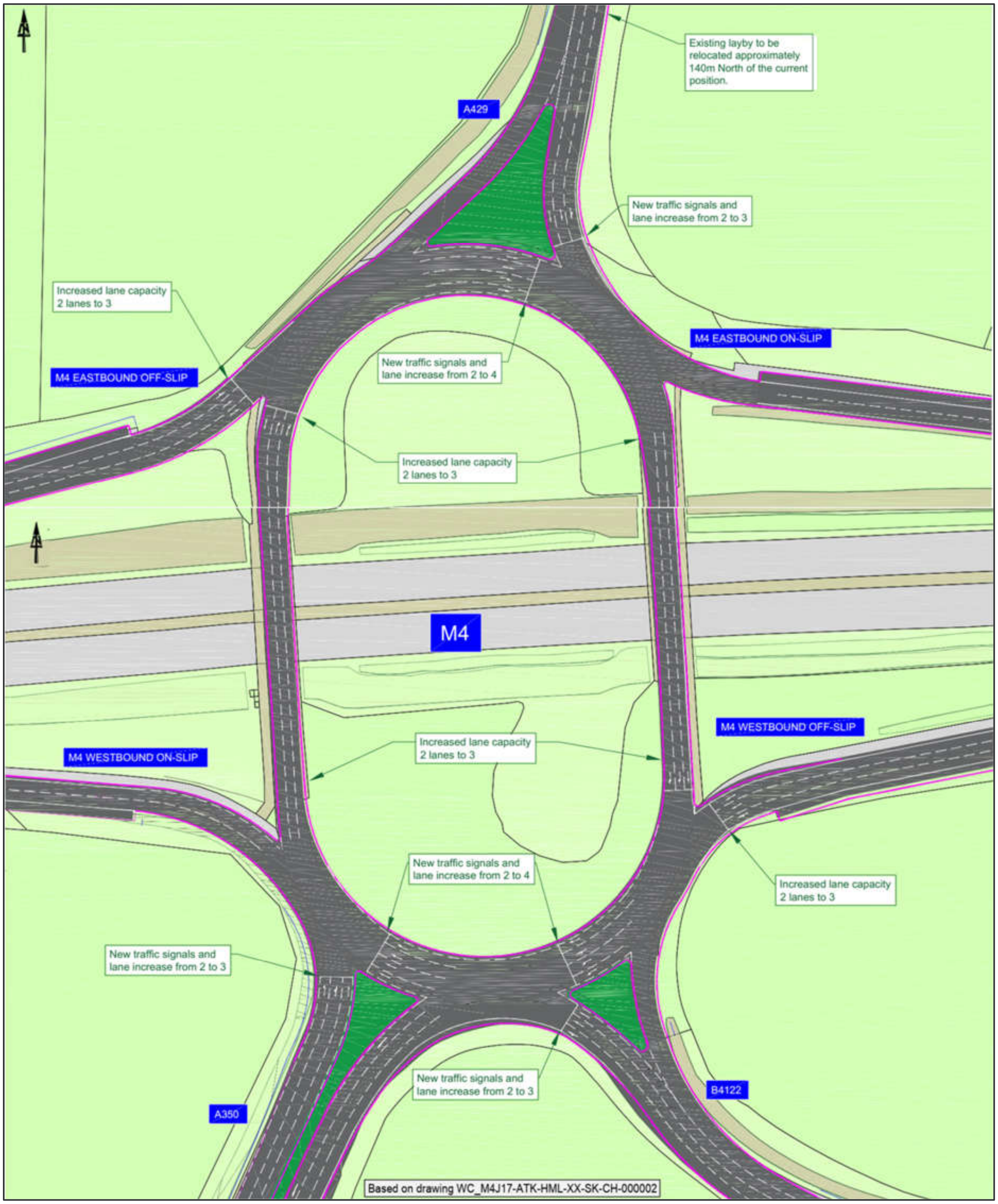
The M4 Junction 17 scheme subject to economic appraisal for the OBC comprises:

- Introduction of traffic signals to all approaches to the roundabout (i.e. completion of the full signalisation of the junction);
- Carriageway widening and additional traffic capacity on all approaches to the junction (M4 off slips, A350, A429 and B4122);
- Increase in the number of traffic lanes across the motorway bridges from two to three (with no physical changes to the structures);
- Widening of the circulatory carriageway and introduction of additional traffic lanes and capacity around the junction;
- Repositioning of the layby along the A350 to allow for carriageway widening work; and
- A signage strategy for a north-south quiet cycle route, providing access across the M4 between Chippenham and Lower Stanton St Quintin

## 3.2 The junction

M4 Junction 17 and its key features within the proposed scheme are illustrated in **Figure 3-1**.

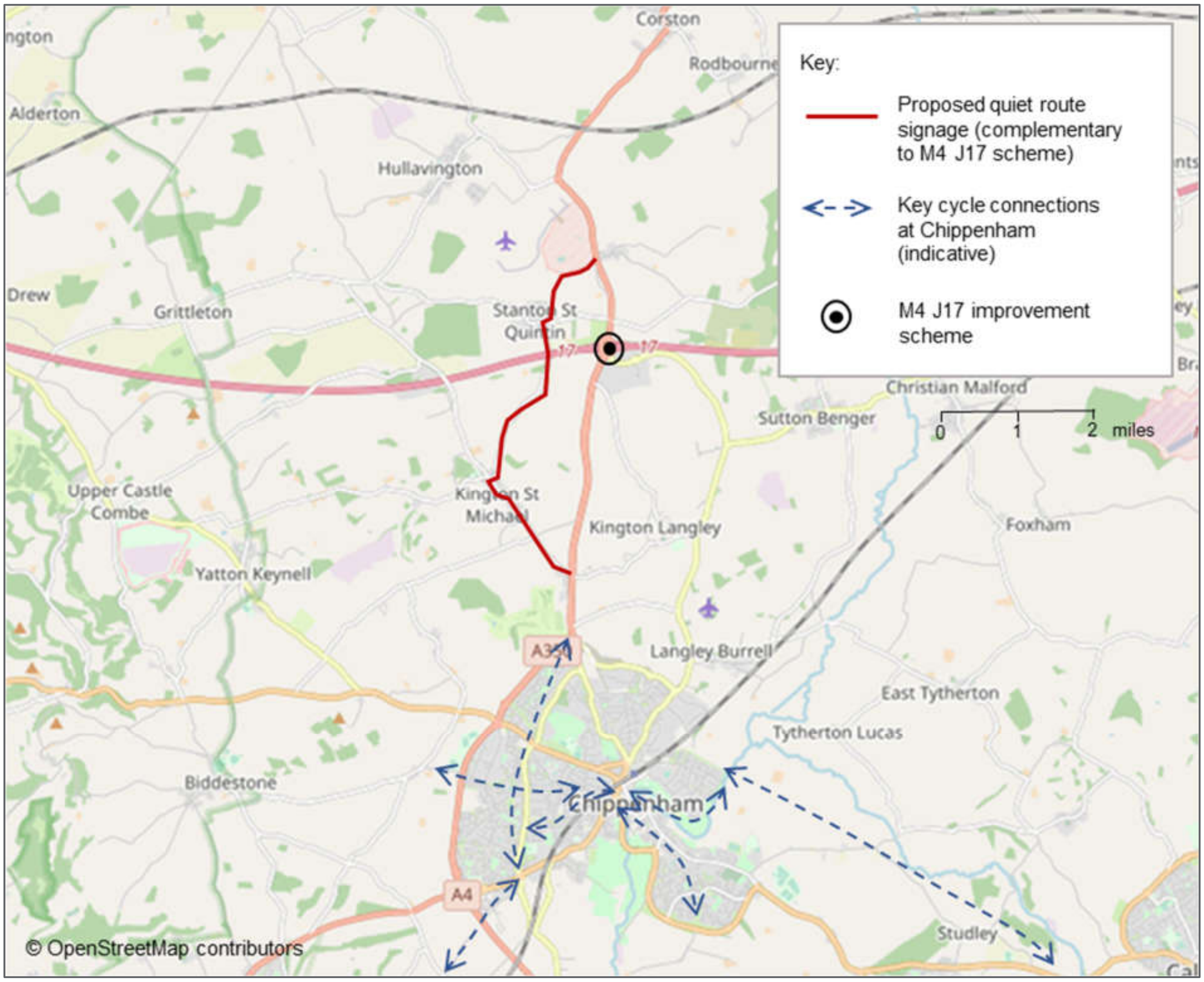
**Figure 3-1 – M4 Junction 17 key features**




## 3.3 Complementary cycling measures

In addition to the junction improvements, the scheme includes a north-south quiet cycle route, providing access across the M4 between Chippenham and Lower Stanton St Quintin (**Figure 3-2**). This will support access to the Hullavington Airfield area, the site of the Dyson technology campus, with scope for further development/ expansion.

**Figure 3-2 – Complementary cycling measures**



# 4. Overview of transport modelling

This chapter provides a summary of key elements of the transport modelling approach underpinning the economic appraisal. Full details of the transport modelling are addressed in other supporting documents, in particular:

- Wiltshire Transport Model Local Model Validation Report (WC_M4J17-ATK-GEN-XX-RP-TR-000001– main OBC Appendix B1) covering the development, calibration and validation of the model.
- Wiltshire Transport Model Traffic Forecasting Report (WC_M4J17-ATK-GEB-XX-RP-TR-000003– main OBC Appendix B2) covering the development of traffic forecasts and the outcomes of scenarios with and without the scheme; and
- M4 Junction 17 MRN VISSIM Traffic Forecasting Report (WC_M4J17-ATK-GEB-XX-RP-TR-000004 – main OBC Appendix B4) – covering development of the operational Vissim model and its findings on performance of the proposed scheme.

## 4.1 Modelling package

In 2021 strategic modelling of the M4 Junction 17 scheme was undertaken using the SATURN-based Wiltshire Transport Model (WTM), with the intention of informing the economic appraisal for OBC. This modelling was based on an average peak period level of flow.

In parallel to this, a microsimulation model was developed using Vissim as an Operational Model to enable testing and ensure sufficient capacity would be provided to meet the demand requirement up until at least the design year for the scheme.

These two models had different purposes and a range of different specifications related to the scope and level of detail of each in the M4 Junction 17 area, so an exact match between the two would not be expected. However, both models were intended to provide forecasts of the future performance of the junction and so a degree of consistency in outputs was anticipated.

Having reviewed the levels of delay which each model was forecasting would occur, the level of divergence was found to be significant enough as to cast considerable doubt over the findings of the economic analysis which had been informed by SATURN. In particular, the Vissim modelling was indicating high levels of delay during busier parts of peak periods in the 2036 DM scenario, much of which would be relieved by the proposed scheme. The SATURN modelling however, with flows averaged across each of the peak periods, showed little delay in either DM or DS scenarios.

A review was therefore undertaken to better understand why this large difference was occurring. Details of this review and its findings are set out in Appendix A. A broad overview of the findings of this review was that, while Vissim provides a higher level of detail of the network at M4 Junction 17 and of the distribution of traffic through the peak periods, it is unable to capture the effects of the scheme on traffic rerouting across the wider network as a result of changing costs of travel.

The outcome of this review was therefore that, to achieve a higher level of confidence in the economic appraisal and make best use of the tools available, a ‘hybrid’ modelling approach was developed whereby SATURN and Vissim models were used together providing a feedback loop to each other. This enabled the Vissim model to provide the most detailed representation of Junction 17 itself while the SATURN model represented the wider network, enabling rerouting of traffic between Junction 17 and alternative routes.

Sections 4.2 and 4.3 describe the individual models which have contributed to this package. Section 4.4 provides an overview of how these have been used to develop the hybrid modelling approach and how they have been used to inform the appraisal, full details of which are set out in Appendix A.

## 4.2 Wiltshire Transport Model

Transport modelling underpins much of the assessment and appraisal of scheme impacts reported within the Economic Case. The selection of an appropriate modelling tool has taken into account the nature of the scheme and its expected impacts. The Wiltshire Transport Model (WTM) is a highways-based SATURN model (full Variable Demand Model) with a base year of 2018. It has been developed from the A303 Stonehenge / South West Regional Transport model originally built by Highways England. The WTM includes improvements to the network and demand in the Wiltshire area and has been developed in accordance with TAG guidance. It is the primary strategic tool to assess and appraise infrastructure schemes and development planning within the Wiltshire region; it has been used to provide the transport evidence for Wiltshire Council’s Local Plan

Review and to support other business case submissions. For this OBC, the WTM has been further refined within the study area appropriate for the M4 Junction 17 scheme in order to further enhance its suitability.

### 4.2.1 Validation and calibration of base

The model has been developed in accordance with DfT Transport Appraisal Guidance (TAG). For the purposes of this OBC, the WTM was reviewed in terms of its attributes, coverage, segmentation and level of detail with respect to the scheme study area. Full details of the model standards, development, Variable Demand Modelling (VDM) and realism testing are provided in the WTM Local Model Validation Report. The LMVR demonstrates that the model provides a robust basis upon which to assess the impacts of the scheme.

A small number of refinements were made to enhance the validation and calibration of the model within the study area, including:

- Addition of local minor roads;
- Refinements to the speed flow curves for links representing rural roads / lanes;
- Optimisation of signal timings and stages for certain junctions; and
- Refinements to link lengths, speed limits and saturation flows.

### 4.2.2 Modelled time periods

The WTM is a strategic model which is based on average peak hours. It consists of four modelled hours:

- Weekday AM Peak average hour – 3-hour period between 07:00 and 10:00;
- Weekday Inter-Peak average hour – 6-hour period between 10:00 and 16:00;
- Weekday PM Peak average hour – 3-hour period between 16:00 and 19:00; and
- Weekday Off-Peak average hour – 12-hour off-peak and overnight period between 19:00 and 07:00

The AM, IP and PM are based on fully developed demand matrices and validated against observed data. The Off-Peak model is based on the Inter-Peak demand matrices. Observed data at a selection of sites has been analysed to determine the representative relationship between the Inter-Peak and Off-Peak demand. This has derived a global factor 0.25, applied to the Inter-Peak matrices to produce the Off-Peak matrices. For the purposes of this study the Off-Peak model has not been used.

### 4.2.3 Forecast years

Two forecast model years inform the assessment of scheme impacts:

- **2024** – representing the scheme opening year; and
- **2036** – representing the future forecast year.

### 4.2.4 Forecast modelling

The forecast models for 2024 and 2036 have been developed from the validated base model, in line with guidance from the DfT TAG units M2 (Variable Demand Modelling) & M4 (Forecasting & Uncertainty). Full details are documented in the WTM Traffic Forecasting Report (TFR).

- The forecast models are derived from assumptions regarding projected national and local uncertainties. These are used to scale the validated base year trip matrices (demand) to reflect a given forecast year, whilst the highway network is modified to encompass any proposed transport infrastructure schemes (supply).
- National uncertainty reflects national projections of population, employment, car ownership, GDP growth and fuel price trends. Assumptions regarding national travel cost projections (value of time and fuel costs) are based on the DfT TAG Databook v1.14 (May 2020), reflecting the latest information at the time of the model development.
- Local uncertainty reflects local assumptions regarding committed / proposed developments and highway infrastructure schemes, as per the Uncertainty Log included in the TFR.
- Overall growth in forecast year demand is constrained to national projections, which is derived from the DfT National Trip End Model (NTEM) v7.2.

- Variable Demand Modelling (DIADEM) is applied to calculate changes in demand as a result of changes in travel times and costs. This can lead to car trip redistribution, trip generation, modal switch and changes in macro time period choice. The methodology is consistent with Appendix B of TAG Unit M2.

### 4.2.5 Model scenarios

The use of different model scenarios allows the impacts of the scheme to be understood under alternative demand and supply assumptions. This enhances the robustness of the Economic Case. Five different scenarios modelled within WTM are reported in the TFR. Each scenario is tested without the M4 Junction 17 scheme ('Do minimum') and with the scheme ('Do something') in order to allow an assessment of the impacts attributable to the scheme. Section 6 provides further details of the definition of each of the scenarios.

**Table 4-1 – Transport modelling scenarios**

| Scenario | Description |
|---|---|
| **'Core'** | Including only committed or near certain developments and network changes (as per the Uncertainty Log), with overall growth constrained to TEMPro (Version 7.2) |
| **'High Growth' & 'Low Growth'** | To reflect uncertainty around annual forecasts from the National Transport Model, tested in accordance with TAG guidance[1] |

## 4.3 Operational Model

### 4.3.1 Purpose

The need for an operational assessment of the proposed MRN scheme at the M4 Junction 17 was agreed with Wiltshire Council and National Highways. This model was identified as being required to:

- Provide evidence to Wiltshire Council and National Highways to inform consideration around the optimal M4 Junction 17 MRN scheme option;
- Provide assurance that the scheme is expected to operate within capacity based on an appropriate planning horizon; and
- Provide supporting information to ensure that the SRN (Strategic Road Network) and local road network would operate safely with the scheme in place.

The operational assessment has been completed using a microsimulation traffic model, using the software Vissim, and follows previous scheme assessment using the junction modelling software LinSig.

### 4.3.2 Modelled time periods

The model was developed to cover a morning and evening peak time period, of 0700-1000 and 1600-1900 respectively.

Whereas the strategic model represents these peak periods based on average hour traffic flows, the operational model represents 15-minute intervals throughout each of the peak periods. In forecast years, the total levels of flow in each 3-hour peak period have been varied using processes described below, but the proportion of that flow in each of the 15-minute intervals has been assumed to remain consistent with current observed profile.

### 4.3.3 Forecast years

As the primary purpose of the operational model was to provide assurance of the scheme's resilience to future growth up to the horizon year, it was originally developed with a single forecast year of 2036, using growth in demand flows from WTM. As it has been identified as a means to better inform the economic appraisal additional modelling in Vissim has been undertaken using forecast flows for 2026.

[1] TAG Unit M4, Section 4.2, using a p-value of 2.5%

### 4.3.4 Forecast modelling

The Vissim forecast matrices were developed from the WTM peak hour forecasts, with the WTM cordoned around the M4 Junction 17, providing a five-zone matrix to align with the Vissim zoning system.

The growth in WTM, has been mapped and profiled to the Vissim base demands to generate forecast flows across the Vissim network.

The 2018 survey data, which the Vissim model is primarily based on, was used to pivot the traffic growth from rather than the 2019 Vissim base matrix, as the SATURN model is a 2018 based model.

Signal timings within each forecast scenario have been optimised using LinSig, reflecting variations in demand at each point of the junction.

### 4.3.5 Model scenarios

The Do Minimum model has been coded with a committed scheme associated with the Chippenham Gateway development.

The forecast with scheme models have been used to test the predicted operational impacts of the M4 Junction 17 MRN scheme. The assessment undertaken provided feedback to the design team to produce an update on the original scheme specification. The updated scheme has been run through the WTM to understand if there is a predicted demand response prior to completing a final Vissim assignment.

## 4.4 Hybrid Model

### 4.4.1 Development of Hybrid Models

As described in Section 4.1 a ‘hybrid’ modelling approach has been developed to inform the economic appraisal, whereby the VISSIM model has been used to provide the most detailed representation of Junction 17 itself while the SATURN model represented the wider network, enabling rerouting of traffic between Junction 17 and alternative routes.

This approach has required a level of iteration between the two models as differences in journey times forecast in Vissim from those is SATURN will affect the choice of route taken for certain trips. That in turn will affect the demand flow across the junction and hence feed back to journey times.

In the first instance, forecast demands used in the Vissim Operational Model are reliant on inputs from SATURN, provided by WTM. Each model has initially been run using the same demand, but due to the different methods of representing flow, both in terms of model operation and profiling of that flow across the peak period, the forecast journey times from the two models were found to be inconsistent, with the Operational Model indicating significantly higher levels of delay in the Do Minimum scenario.

Within a local network such as has been used for the M4 Junction 17 Operational Model, Vissim is considered to provide the more accurate representation of travel behaviour but is limited by the inability to reassign traffic between Junction 17 and other routes on the wider network.

Therefore, travel times across the junction have been extracted from the Operational Model and time penalties have been applied to specific links within the WTM network to better align costs of travel across the junction with those from the Operational Model.

With these revised network costs, WTM has been re-run to assign traffic to the network. This resulted in flows across the junction being reduced in the Do Minimum scenario, as a proportion of trips choose to divert onto alternative routes to avoid delays.

The final stage of this iterative process has been to feed those revised trip numbers back into the Operational Model and reforecast journey times. This provided the more refined approach to assessing journey time impacts provided by Vissim, but with an element of the strategic rerouting capacity provided by SATURN.

This approach was discussed and agreed in principle with DfT in December 2021.

Additional detail of the approach and the reasons for its use are set out in Appendix A.

### 4.4.2 Use of Hybrid Modelling in Appraisal

The resultant outputs of this hybrid modelling approach were:

- A SATURN model which included an adjustment to better reflect journey times across Junction 17; and
- A Vissim model which had improved representation of traffic flows across the junction.

This provided good coverage of both the network in the direct vicinity of Junction 17 and of the wider network, with each model able to provide outputs which could be used in TUBA to capture user benefits. However, the area covered by the Operational Model was also included within WTM and so combining the results of such TUBA assessments would result in double counting of benefits. To ensure this double counting would not occur, a third model was prepared, using a cordon extracted from WTM which exactly replicated the section of network covered by the Operational Model.

An additional TUBA run performed using the cordoned SATURN model could therefore be used to directly cancel out the double counting effect from combining the benefits from the other two models.

The total TUBA benefits could therefore be calculated as:

Benefit = TUBA(VISSIM) + TUBA(SATURN Full Network) – TUBA(SATURN cordon)

Through this approach, the higher definition Operational Model informs the core of the benefit assessment in the area directly around Junction 17, while WTM is used to assess only the impacts on trips which reroute as a result of the scheme and the affects which these trips will have on other traffic.

A step-by-step process setting out how this approach has been conducted at a more disaggregate level, considering different scenarios, time periods and forecast years and considerations which have been made in identifying the most suitable approach are set out in Appendix A.

This hybrid modelling approach has been used only to inform the TUBA element of the economic assessment.

- **Safety Impacts** – Assessed through COBALT using only the full SATURN network, following the initial application of time penalties from VISSIM to identify re-routing. COBALT is not responsive to changes in journey times, reflecting only flow differences. Within this final iteration of the SATURN network, flow inputs are the same as those input to the VISSIM model.
- **Reliability** – Assessed using the Urban Roads approach from TAG using the full SATURN network only. Reliability impacts within this approach are calculated relative to the origin to destination distance of a journey and so would be misrepresented if measured based on the more restricted VISSIM or cordoned models.
- **Air quality, noise and greenhouse gas emissions -** similarly to the safety impacts these have been assessed primarily on the basis of changes in traffic flow on different links, with variations in speed over very short distances considered to have a significantly lower impact. Therefore, the full SATURN network has been used.
- **Distributional Impacts** – these benefits are directly related to the origin and destination of trips and so the VISSIM and cordoned SATURN model would not provide useful input to this element of the assessment. Therefore, these benefits have been derived using the full SATURN network.
- **Delays during construction** – impacts on users during the construction period will be divided between delays at Junction 17 itself and delays incurred as a result of re-routing. Ideally this element of the assessment would make use of the hybrid modelling approach but given the short period of works which has been represented it has not considered proportionate to do so. These disbenefits have therefore been captured through the full SATURN network.

# 5. Economic appraisal

## 5.1 Introduction

The purpose of the economic appraisal is to inform an overall Value for Money (VfM) assessment. The VfM Statement is included within the OBC Economic Case, along with key information relating to the economic appraisal. This section is intended to provide further supporting information and analysis.

The economic assessment compares the performance of the Do Something scenario with that of the Do Minimum. The economic assessment for this scheme involved estimating the following components;

- Scheme cost – defined as the total amount of money spent in constructing and maintaining the scheme. It includes preparation cost (planning and designing), land acquisition cost, construction costs, supervision and maintenance costs. Maintenance costs are the incremental value relative to the cost of maintaining the existing network.
- Scheme benefits – classified into:
  - Road user benefits – savings in travel time and vehicle operating costs derived using TUBA v 1.9.14 and File Economics v1.9.14 file details (Sensitivity Test: TAG Data Book v1.14 July 2020[2]). This included sensitivity tests of low/optimistic traffic growth scenarios.
  - Safety benefits – reduction in the number and/ or severity of accidents - derived using COBALT software version v2.1 (TAG Data Book November 2021, v1.17) economic parameters;
  - Construction and maintenance (dis)benefits – changes in travel time and vehicle operating costs during the construction and maintenance phase derived by modelling construction phases in SATURN;
  - Monetised environmental impacts, in line with TAG guidance;
  - Indirect tax revenue – due to change in the amount of fuel purchased and the associated impact to revenue from fuel duty as a result of the scheme derived from TUBA v 1.9.14 and File Economics v1.9.14 file details (Sensitivity Test: TAG Data Book v1.14 July 2020);
  - Journey time reliability benefits – from the reduction in variability in travel time in line with TAG guidance;
  - Wider economic benefits have been assessed qualitatively to outline the impacts of the scheme on contributing to improved performance of businesses.
  - The Social and Distributional Impacts (SDI) Appraisal was undertaken in accordance with requirements set out in Transport Appraisal Guidance (TAG) unit A4-1 and A4-2 published by the DfT.

The appraisal period of the scheme is 60 years, as recommended in TAG Unit A1.1.

Additional sensitivity testing has been carried out to better understand the level of uncertainty in the central forecasts of costs and benefits. These tests and how they have been evaluated are described in detail in section 5.11. They have included:

- A TUBA sensitivity test for the Core Scenario using TUBA v1.9.17 - December 2021, with Updated Economics File (TAG Data Book v1.18.0, May 2022);
- High and low demand growth forecasts;
- High and low scheme costs;
- Variations on values of times for business and non-business trips;
- High and low carbon values.

Additional qualitative sensitivity testing has been undertaken to consider potential impacts on performance under scenarios set out in the TAG Uncertainty Toolkit.

The results of the economic assessment has been presented in the following tables:

[2] Details on the use of TAG Databooks for different applications and the reasoning behind each are set out in section 5.3

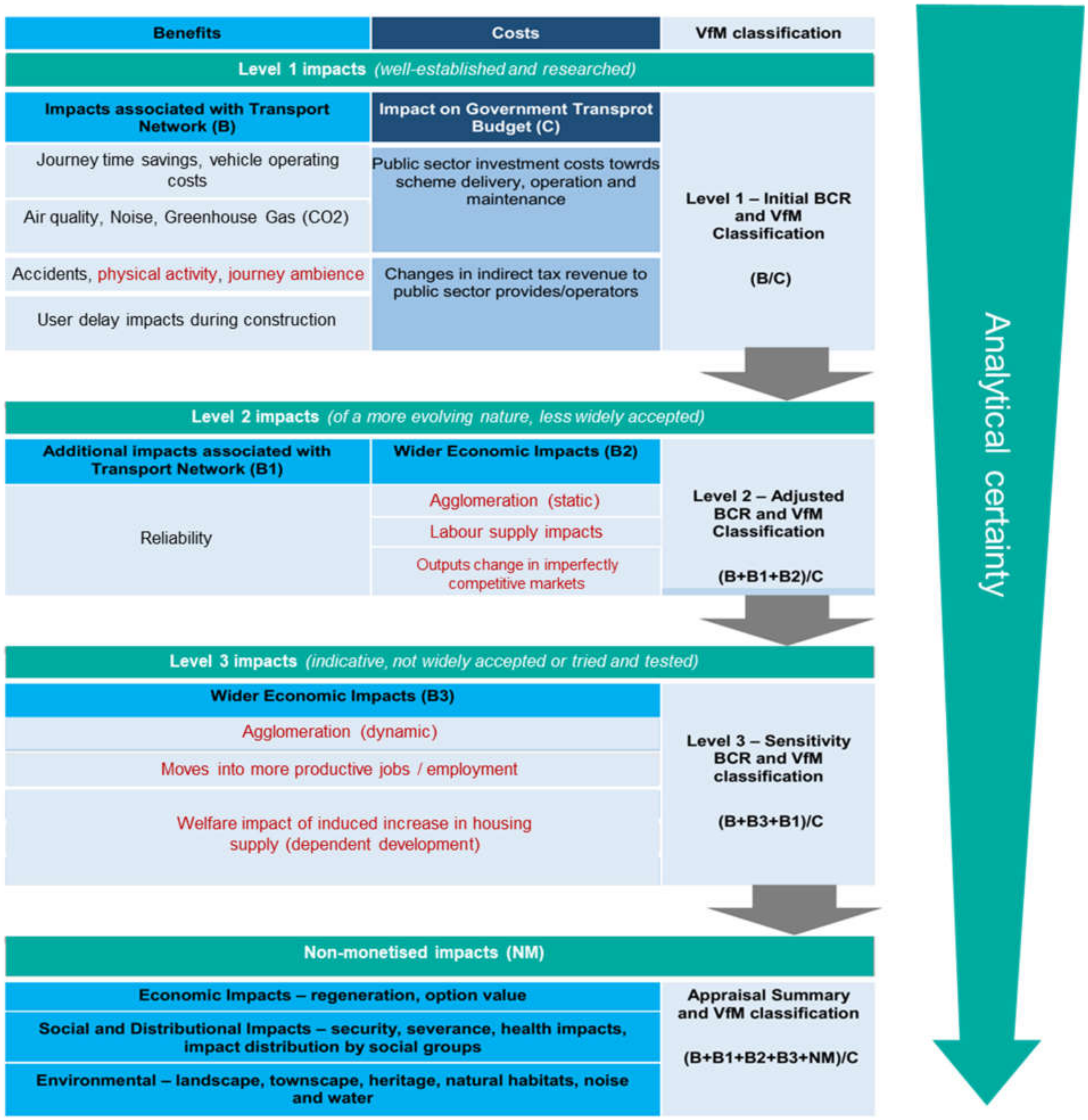
- Transport Economic Efficiency (TEE)- this lists out the user benefits apart from the reduction in accidents with the scheme and environmental benefits. It also includes private sector impacts;
- Public Accounts (PA)- relate to the costs faced by Government (either local or central) to implement the scheme. This includes investment costs, operating costs, revenue, developer and other contributions, and grant/subsidy payments, where relevant. It also indicates changes to indirect tax revenues to the government e.g. through fuel duty that results from the scheme;
- Analysis of Monetised Costs and Benefits (AMCB)- includes all monetised benefits and costs to set out the calculation of the BCR; and
- Appraisal Summary Table (AST)- provides an overview of the appraisal, considering impacts of all types in a single table, providing qualitative, quantitative and monetised assessments.

The total benefits has been compared with the total costs from the public accounts identified above, to determine the value for money of the scheme.

The TEE, PA and AMCB are presented in Appendix C of this document. The AST is in Chapter 10 of the Economic Dimension. This is followed in Chapter 11 by a Value for Money Statement, which draws together the full range of analysis, including monetised and non-monetised costs and benefits along with uncertainty analysis to present a VfM category for the scheme.

Figure 5-1 illustrates how the appraisal outputs are considered within the VfM assessment, following a tiered approach. There are certain impacts within the potential scope of economic assessment which are not considered directly attributable to the M4 Junction 17, or which it has not been considered proportionate to quantify given their lesser contribution to the overall value of the scheme. The impacts which have been monetised are listed in black. Other elements are considered in the non-monetised assessment in chapter 6 of this report.

**Figure 5-1 – Overview of the approach to value for money assessment**




*Note- includes all typical monetised and non-monetised impacts. Those in red are not monetised for the M4 Junction 17 scheme.*

The Level 1 impacts are well-established and those most commonly monetised within the appraisal; they inform an Initial BCR. All Level 1 impacts are monetised for the M4 Junction 17 scheme.

Level 2 impacts are considered evolving by DfT; they inform an Adjusted BCR. Reliability benefits have been assessed for the M4 Junction 17 scheme. Wider economic impacts have not been assessed qualitatively but not monetised.

Level 3 impacts are considered indicative by DfT; they inform a sensitivity BCR. Level 3 impacts, which involve land use change, have not been assessed.

This chapter focuses on the monetised impacts (Level 1 and 2). Non-monetised impacts are also considered within the overall VfM assessment. An overview of these is provided within chapter 6.

## 5.2 Appraisal tools and inputs

The economic appraisal of the M4 J17 Improvement scheme has been undertaken in line with DfT Transport Analysis Guidance (TAG). It uses industry recognised tools where appropriate. Where bespoke tools have been applied, these follow TAG principles and guidelines. A summary of the key appraisal tools / approach in relation to Level 1 and Level 2 impacts is provided in **Table 5-1**.

**Table 5-1 – Overview of Level 1 monetised impacts**

| Monetised impact | | Nature of impact | Primary tool(s) | Comments / notes on approach | Further information |
|---|---|---|---|---|---|
| **Highway user impacts:**<br>Travel-time benefits<br>Vehicle operating costs | Level 1 | Changes in journey times, average speeds and total vehicle kilometres<br>Business / commuting / other users | • Hybrid SATURN & VISSIM<br>• TUBA | Transport User Benefit Analysis (TUBA)[3] software v1.9.14 with Economics v1.9.14 file July 2020<br>(Sensitivity Test: TUBA v1.17 with TAG Data Book v1.18 August 2022).<br>Time cost and distance skims input from SATURN and VISSIM.<br>Full SATURN and cordoned SATURN. Cordoned SATURN outputs (around M4 J17) subtracted from full SATURN network outputs, with VISSIM outputs then added.<br>Limited masking of benefits applied to address model noise in the full SATURN network.<br>Annualisation factors used in the TUBA analysis are provided in section 5.2. | Economic Appraisal Report – Section 5.5 |
| **Collision impacts** | Level 1 | Change in collisions by severity and associated costs - 'with' and 'without' scheme. A function of traffic demand, distance travelled and changes in the risk or likelihood of an accident occurring. | • COBALT<br>(Cost and Benefit to Accidents – Light Touch) | COBALT, version 2.3 (published July 2022).<br>Inputs from SATURN – average annual daily traffic (AADT) and link classification.<br>Combined links and junction approach was adopted.<br>Default accident rates used for all links across the affected road network. | Economic Appraisal Report – Section 5.6 |

[3] TUBA is an industry-recognised software package, recommended by the DfT for the appraisal of highway and public transport schemes. TUBA provides a complete set of default economic parameters in its standard economics file, including values for variables such as values of time, vehicle operating cost data, tax rates and economic growth rates.

| Monetised impact | | Nature of impact | Primary tool(s) | Comments / notes on approach | Further information |
|---|---|---|---|---|---|
| **Impacts on indirect taxation revenue** | Level 1 | Incurred by transport users and providers, in the form of fuel duty and other user charges. Linked to changes in traffic demand and vehicle kilometres. | • Hybrid SATURN & VISSIM<br>• TUBA | Direct output from TUBA (approach as per highway user impacts) | Economic Appraisal Report – Section 5.5 |
| **Delays during construction** | Level 1 | User delays from disruption during construction works. | • SATURN<br>• TUBA | Indicative traffic management restrictions during construction defined and modelled in SATURN based on reduced speeds at the junction (single phase, 11 months duration).<br>Journey time impacts assessed through TUBA, with annualisation applied reflecting the duration. | Economic Appraisal Report – Section 5.7 |
| **Impacts on greenhouse gases** | Level 1 | Change in CO2e[4] emissions, associated with changes in vehicle kilometres and average speeds. | • DEFRA Emission Factors Toolkit v11.0<br>• NH air quality spreadsheet model v9 | The assessment has been based on Defra vehicle emission factor toolkit (EFT v11.0). AADT link data (flows and speeds) derived from SATURN model, with the study area covering the Area of Detailed Modelling (the traffic reliability area).<br>The change in CO2e emissions by link as a result of the scheme was calculated in the opening (2026) and future forecast (2036) years.<br>Emissions have been calculated for 24 hours a day, 365 days a year.<br>The Core assessment has used central values of CO2e emissions, with sensitivity testing performed for low and high values of carbon. | Economic Appraisal Report – Section 5.9 |
| **Air quality** | Level 1 | Changes in traffic levels / composition resulting from the scheme operation giving rise to changes in concentration of NOx and PM10. | • Damage costs approach<br>• NH air quality spreadsheet model v9 | A proportionate damage costs approach has been applied (in line with TAG Unit A3).<br>AADT link data derived from SATURN model, with the study area covering the Area of Detailed Modelling (the traffic reliability area).<br>The change in pollutant emissions by link as a result of the scheme was calculated in the opening (2026) and future forecast (2036) years. | Appraisal of Environment Impacts – Section 5.9 |

[4] Carbon dioxide equivalent

| Monetised impact | Nature of impact | | Primary tool(s) | Comments / notes on approach | Further information |
|---|---|---|---|---|---|
| **Noise** | Level 1 | Changes in traffic levels / speeds / composition resulting from the scheme operation giving rise to changes in noise levels. | • Noise model (NoiseMap v5.2)<br>• TAG Noise Workbook | Assessed in line with TAG Unit A3. Calculations undertaken based on DMRB LA111 and CRTN methodology.<br>AADT link data derived from SATURN model, with the study area defined based on traffic flow change criteria.<br>Short and long-term change in noise has been calculated at each of the receptors in the study area using a 2D noise model (local terrain is not reflected). | Appraisal of Environment Impacts – Section 5.9 |
| **Journey reliability** | Level 2 | More reliable journey times and greater resilience to network incidents. | • Bespoke spreadsheet tool | Assessed in line with TAG Unit A1.3, Section 6.3 (Reliability – urban roads) and based on the calculation of the standard deviation of journey times and distance for each O-D (origin-destination) pair. | Economic Appraisal Report – Section 5.8 |

## 5.3 Overarching appraisal assumptions

Key general assumptions and principles in relation to the appraisal are provided here. More specific and detailed assumptions in relation to the relevant parts of the assessment are provided through the remainder of this chapter.

### 5.3.1 TAG Databook

The TAG data book provides the primary reference source of standard modelling and appraisal values. At the time of model development to inform the economic appraisal, the prevailing version of TAG Databook was V1.14 (May 2020). To ensure consistency between modelling and appraisal this version of the TAG Databook forms the basis for the appraisal of benefits and costs which have been derived from the transport model and which make use of comparable data.

The transport model uses ‘pence per minute’ and ‘pence per kilometre’ values to assign trips and inform demand forecasting. These parameters use the same inputs from the TAG Databook as values of time and vehicle operating costs used in TUBA. This results in a direct correlation between calculations in TUBA and those in the transport model, making this use of consistency between the two a valuable methodology.

Sensitivity testing using the most recent TAG Databook at the time of writing this OBC (Databook v1.18, August 2022) has been performed to indicate the impacts of changes to underlying assumptions over this period on that group of benefits. The modelling itself has not been rerun to reflect these changes however.

Assessment of impacts which are not derived from the transport model have been based on Databook v1.18 throughout.

Other elements of the analysis, such as the COBALT safety assessment and the environmental analysis draw on inputs from the model, but do not have the same direct correlation in terms of parameters used. Therefore, it has been considered more appropriate to undertake these assessments using the most up to date parameters available.

The environmental assessments and scheme cost calculations have therefore been informed by TAG Databook v1.18 (August 2022). The safety assessment has been carried out based on Databook v1.17 (November 2021), as DfT were yet to release an update to the COBALT software to reflect the most recent changes to the TAG Databook. The assessment of reliability impacts draws directly on the TUBA assessment and so has used the same parameters.

A summary of these applications of the TAG Databook are set out in Table 5-2. Additional detail on the various approaches to assessment is provided later in this chapter.

**Table 5-2 – Applications of TAG Databooks**

| Year(s) | Assessment Approach | Databook |
|---|---|---|
| Scheme Costs | Spreadsheet-based | V1.18 |
| Time Savings | TUBA | V1.14 (sensitivity test with V1.18) |
| Vehicle Operating Costs | TUBA | V1.14 (sensitivity test with V1.18) |
| Indirect Tax | TUBA | V1.14 (sensitivity test with V1.18) |
| Safety | COBALT | V1.17 |
| Greenhouse Gases | DEFRA EFT | V1.18 |
| Air Quality | Damage costs approach | V1.18 |
| Noise | NoiseMap | V1.18 |
| Construction Impacts * | TUBA | V1.14 |
| Reliability * | TUBA-based approach | V1.14 |

*Construction and reliability impacts contribute a relatively small proportion of the total benefit and so it has not been considered proportionate to run the sensitivity test with the latest TAG Databook for these components.

### 5.3.2 Appraisal period

Impacts and costs arising from implementation of the scheme are monetised across a standard 60-year appraisal period in line with TAG Unit A1.1. The planned scheme opening year is 2026, hence the appraisal period runs from 2026 to 2085.

### 5.3.3 Annualisation

The appraisal considers impacts across all time periods from 07:00 to 19:00 for weekdays. Off peak and weekend impacts have not been modelled. Annualisation is of particular relevance to the TUBA assessment in order to expand modelled hours, and details of this are provided within section 5.5.3.

For other impacts captured in the economic assessment, benefits outside of the modelled periods have been represented through use of local traffic count data to convert flows from the modelled periods to Average AADT based on average proportions of flow during the off peak and weekend periods.

### 5.3.4 Discounting and price base

All benefits and costs have been assessed over a 60-year project lifetime and then discounted back to a common base year (2010). Discount rates of 3.5% have been applied to standard benefits and costs between 2010 and up to years 30 years from the current year (2022). A rate of 3.0% has been applied thereafter.

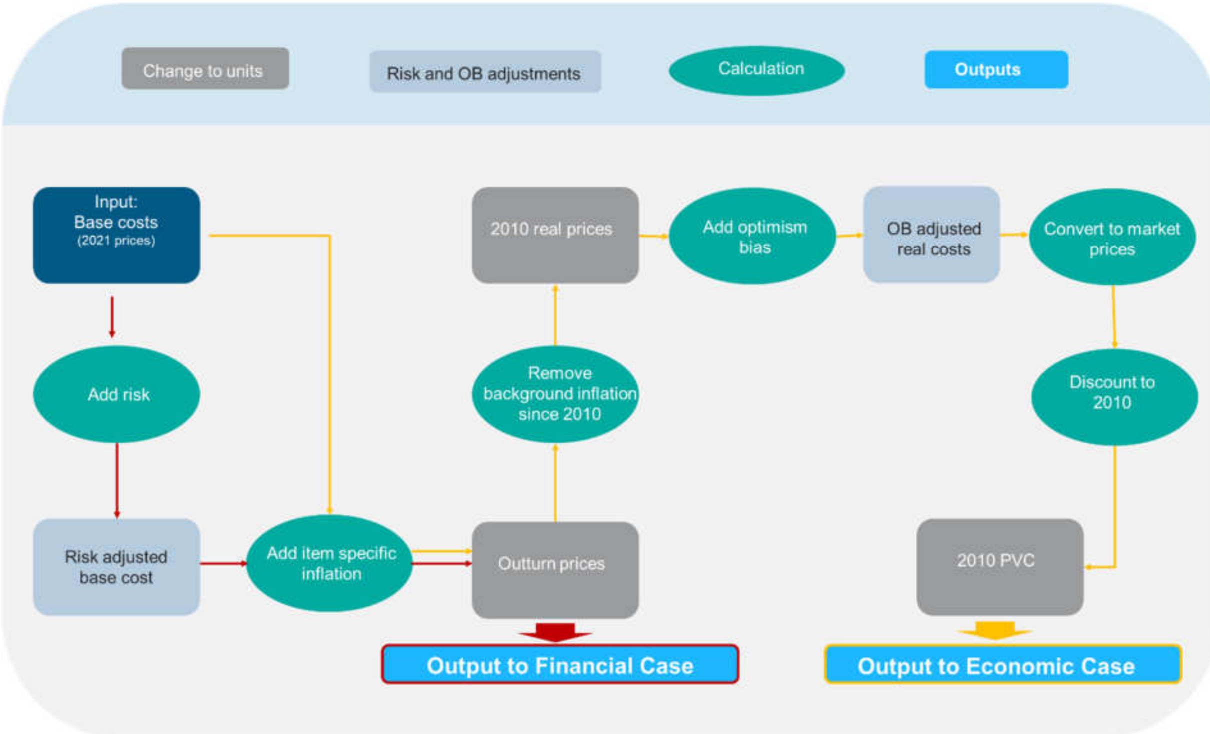
Discount rates for life and health-related impacts starting at 1.5% have been applied within the available appraisal tools as applicable, falling to 1.29% after 30 years from the current year. The price base is also 2010. All prices in the appraisal have been adjusted for inflation to be shown in 2010 prices. All benefits and costs are therefore shown in present values for a 2010 base year, at 2010 prices.

## 5.4 Scheme costs

This section discusses the treatment of those costs for appraisal. Estimation of the costs of transport schemes is important for decisions on scheme funding and is a crucial part of the scheme appraisal process. Unrealistic cost estimates that subsequently rise will adversely affect the robustness of the assessment of affordability and value for money of a scheme.

Figure 5-2 presents a flow diagram of the appraisal of costs, which follows the approach set out in TAG Unit A1.2 – Scheme Costs. The preparation of costs differs between the Economic and Financial Cases. The red arrows in the figure indicate the process to prepare costs for the Financial Case and blue arrows indicate the method used for the Economic Case.

**Figure 5-2 – Overview of the approach to cost appraisal**




Scheme capital costs, capital renewal costs and forecast annual maintenance costs have been estimated by Faithful & Gould using a 2021 (Q1) price base, profiled on a year by year basis, as factor prices. Table 5-3, Table 5-4, and Table 5-5 present the year by year cost estimates for the initial capital investment, future capital renewals, and regular maintenance profiles, respectively. The cost estimation parameters and assumptions, together with derivation of the projected expenditure profile are discussed in the Financial Case of the OBC.

**Table 5-3 – Investment cost profile (Q1 2021 prices, £ '000s)**

| Year | Construction | Preparation | Supervision | **Total** |
|---|---|---|---|---|
| 2022 | £0 | £775 | £0 | **£775** |
| 2023 | £0 | £1,162 | £0 | **£1,162** |
| 2024 | £5,655 | £194 | £180 | **£6,028** |
| 2025 | £10,367 | £0 | £330 | **£10,697** |
| 2026 | £0 | £0 | £0 | **£0** |
| **Total** | **£16,021** | **£2,130** | **£510** | **£18,661** |

**Table 5-4 – Capital renewal costs profile (Q1 2021 prices, £ '000s)**

| Year(s) | Capital renewal of infrastructure |
|---|---|
| 2035 | £2,407 |
| 2045 | £2,407 |
| 2055 | £5,215 |
| 2065 | £2,407 |
| 2075 | £2,407 |
| **Total over 60-years** | **£20,058** |

**Table 5-5 – Maintenance costs (Q1 2021 prices, £ '000s)**

| Year(s) | Maintenance costs |
|---|---|
| 2026-2085 | £2.2 p.a. |
| **Total over 60-years** | **£134** |

For the purposes of appraisal, the base costs in 2021 Q1 prices are converted to outturn costs using the BCIS Tender Price Index (TPI) or the Retail Price Index (RPI) from the TAG Databook. These values are then converted to 2010 real prices using the GDP Deflator. Table 5-6 outlines the inflation rates per cost type applied in this appraisal.

**Table 5-6 – Inflation indices**

| Category: | Construction, including capital renewals and maintenance, land, Risk, | Preparation, Supervision | Background inflation |
|---|---|---|---|
| Index: | TPI | RPI | GDP |
| 2022 | 8.05% | 10.27% | 4.05% |
| 2023 | 4.07% | 3.62% | 2.41% |
| 2024 | 3.58% | 2.38% | 1.85% |
| 2025 | 3.97% | 2.60% | 1.95% |
| 2026 | 3.75% | 2.73% | 2.00% |
| 2027 | 3.75% | 3.01% | 2.30% |
| 2028 | 3.75% | 3.00% | 2.30% |
| 2029 | 3.75% | 2.99% | 2.30% |
| 2030 | 3.75% | 2.98% | 2.30% |
| Beyond 10 years | 3.75% | 2.97% | 2.30% |

Table 5-7 summarises the base costs and the values at each step set out in Figure 5-2 to develop these values through to a Present Value of Cost (PVC) for economic appraisal.

### 5.4.1 Present value costs

The estimated base costs set out above have been converted to present value costs for economic appraisal using the steps set out in Figure 5-2. This involved the following adjustments and resulted in values at each step as set out in Table 5-7.

- Base costs are converted to outturn costs using the TPI and RPI inflation rates set out in Table 5-6.
- Outturn costs are rebased to 2010 real prices using the GDP deflator.
- Optimism bias of 23% is applied to capital costs in line with the recommended value for roads schemes at stage 2. An uplift of 41% has been applied to renewal and maintenance costs to reflect uncertainty over longer term cost forecasts.
- Optimism bias adjusted factor costs are converted to a market price unit of account using an indirect tax correction factor of 1.19.
- Values are discounted to 2010 Present Value Costs (PVC) in line with TAG guidance.

**Table 5-7 – M4 Junction 17 PVC calculation (£millions)**

| £ millions | Capital cost | Maintenance cost | Total cost |
|---|---|---|---|
| Base cost totals over 60-years (2021 Q1 prices) | 18.66 | 20.19 | 38.85 |
| Outturn costs | 22.69 | 123.67 | 146.35 |
| Rebased to 2010 real prices | 16.80 | 32.37 | 49.16 |
| Optimism bias contribution | 3.86 | 7.44 | 11.31 |
| Optimism bias adjusted cost | 20.66 | 39.81 | 60.47 |
| Uplifted to market prices | 24.58 | 47.38 | 71.96 |
| Discounted to 2010 values<br>**PVC (scheme costs)** | **14.97** | **6.87** | **21.84** |

The total PVC (inclusive of renewal and maintenance costs over a 60-year period) is £21,840,000. These costs form the basis of the Value for Money appraisals, discussed in the following sections.

## 5.5 User benefits (TUBA)

The quantification of the user benefits was undertaken using the DfT TUBA (Transport User Benefit Appraisal) software (version 1.9.14) using parameters from the DfT's TAG Databook version 1.14 (July 2020).

### 5.5.1 Overview of TUBA

TUBA is the industry standard tool (developed on behalf of the DfT) for the appraisal of transport impacts of highway and public transport schemes. It is of particular use where variable demand responses have been included in the transport modelling, as TUBA is based on the 'rule of half', which allows for explicit calculation of changes in demand between the 'Do Minimum' (without scheme) and 'Do Something' (with scheme) scenarios.

#### 5.5.1.1 Calculation of travel time changes

Travel time benefits are calculated using the 'rule of half' applied to the generalised time skims from the highway model. These are converted to vehicle hours and annualised for each modelled period, so that the annual time savings can be calculated for each modelled year.

Default economic assumptions have been applied, as contained in the TUBA software (v1.9.14) and based on guidance and values contained in the DfT's TAG Databook v1.14 July 2020.

#### 5.5.1.2 Calculation of vehicle operating cost changes

Vehicle operating costs (VOC) are calculated for both fuel and non-fuel elements, based on formulae set out in the DfT TAG Databook. The 'rule of half' formula is applied as for travel times, but with vehicle operating costs being based on distance travelled (vehicle-kilometres) and average vehicle speeds.

Default economic assumptions for fuel and non-fuel costs, duty and vehicle efficiency are those contained in the default TUBA economics file.

**The Calculation of Benefits: Consumer Surplus Theory**

The calculation of transport user benefits is based on the conventional consumer surplus theory. For the purposes of appraisal, use of the transport system is assumed to be the result of a balanced consideration of pros and cons by each individual decision-maker, subject to all the various constraints which exist.

Changes in the transport system give rise to changes in the perceived cost of personal travel and freight movement from origin to destination. This perceived cost is a broadly defined measure of the inconvenience or disutility to the user of moving between two points, and includes changes in:

- Travel time;
- User charges – fares, tariffs and tolls; and
- Vehicle operating costs met by the user.

Consumer surplus is defined as the benefit that a consumer enjoys, in excess of the perceived costs. In the simplest case, where time or money costs change, but demand stays the same, the total change in consumer surplus equals:

$$\text{change in cost} * \text{number of travellers} = (P^0 - P^1)*T$$

where $P^i$ is the perceived cost of travel (note that the superscript i is used to denote the scenario - 0 for Do Minimum, 1 for Do Something), and T is the number of travellers. This is commonly referred to as the fixed demand scenario – where the demand remains fixed in the 'Do Minimum' and 'Do Something' models.

Where, as is more usual, demand changes in response to the increase or decrease in travel costs, there is an additional impact on new or 'lost' travellers. With a relatively small change in costs, the convention is to attribute half of the change in costs to the trips lost or gained. The total change in consumer surplus in this scenario is represented by:

$$(\text{change in cost} * \text{do-minimum demand}) + (\text{half change in costs} * \text{change in demand})$$

$$= (P^0-P^1)T^0+½(P^0-P^1)(T^1-T^0)$$

$$= ½\,(T^0+T^1)(P^0-P^1)$$

This is referred to as the 'rule of a half' and is the recommended calculation to apply in variable demand scenarios, as has been used for this assessment.

### 5.5.2 Application of TUBA

As discussed in chapter 4, a 'hybrid' approach to modelling has been carried out, to enable detailed representation of the area immediately around M4 Junction 17 as well as a broader representation of the wider area to capture the more strategic impacts of the scheme.

This has involved development of three distinct models to represent the impacts of the M4 Junction 17 scheme and so in combination measure the economic impacts. These three models are:

- An Operational Model developed using Vissim, which was developed specifically for the M4 Junction 17 scheme. This provided the highest level of detail in representation of traffic flows across the junction, with flows profiled over time using 15-minute intervals. However, it had no representation of the wider network and included no capacity to enable traffic to change routes in response to cost changes generated by the scheme.

- A strategic SATURN model using WTM, providing a much wider network coverage, allowing for trips to reroute in response to cost changes. This model was based on average flows for each of the AM peak, PM peak and interpeak.
- A cordoned version of WTM, with scope defined to match that of the Operational Model.

The hybrid modelling process involved a series of steps to define these models and enable a level of interaction so that the advantages of each in providing most detailed performance of traffic at the junction and enabling forecasting of traffic rerouting could be brought together.

As a result of this process the SATURN networks included time penalties on approaches to the junction to better reflect levels of delay forecast in the Operational Model, while the Operational Model included a revised demand input from this adjusted version of the SATURN model. The cordoned SATURN model was extracted after all of these adjustments had been applied. Full details of the approach are set out in Appendix A.

The outcome of this approach is that three separate TUBA runs were required, the outputs of which would be combined to give an impact which covered both the immediate and wider areas. Each of these TUBA runs followed typical methodology, as is set out below, with the approach to annualisation being the only difference between how each was prepared.

### 5.5.3 Assumptions and parameters

TUBA uses the following outputs (‘skims’) from both the WTM and the Operational Model for each time period, modelled year (2026 and 2036) and user class for the Do Minimum and Do Something scenarios:

- Vehicle trips between each origin and destination;
- Journey distance between each origin and destination; and
- Travel time between each origin and destination.
- TUBA applies values of time, fuel and non-fuel costs from TAG to monetise the travel time and vehicle operating cost changes between the Do Minimum and Do Something scenarios.

#### 5.5.3.1 Annualisation

Annualisation is used to scale-up the ‘modelled hours’ benefits to annual benefits. The assessment has considered the weekday AM, Inter-peak and PM periods covering the hours of 07:00-19:00. The WTM is based on average hour flows for all time periods and therefore factoring benefits from a single hour up to a peak period is simply a case of factoring by 3 for the AM and PM peak, or by 6 for the interpeak.

The Operational Model does not provide any coverage of the interpeak but represents the full 3-hour periods from 07:00 to 10:00 and 16:00 to 19:00 using 15-minute intervals. Therefore, no conversion of benefits to capture daily values is required.

For all elements of the TUBA assessment benefits have been converted from daily to annual based on 253 working days per year. No assessment of off-peak, weekend or bank holiday benefits has been carried out in TUBA, as levels of congestion in the DM scenario will be substantially lower during most of these periods and time savings modelled during the AM peak, interpeak and PM periods will not provide an accurate representation of these benefits.

##### 5.5.3.1.1 Interpeak Benefits

As the VISSIM modelling prepared to test the operational performance of the junction doesn’t represent the interpeak period, an assessment of interpeak benefits has been considered drawing on a review of flow profiles across the day. This has established that the average flow rates across M4 Junction 17 during the interpeak period are largely comparable to the levels of flow during the final 15-minute interval of the AM peak and the first 15-minute interval of the PM peak. Therefore, the average of the impacts modelled during these two periods have been assumed to extend throughout the 6-hour interpeak period.

In both of these 15-minute intervals (09:45 to 10:00 and 16:00 to 16:15) Vissim forecasts a small disbenefit being generated by the scheme. This largely relates to trips from the A350 turning east onto the M4 which need to pass through an additional set of signals. As congestion on the junction is minimal at this time of day, this short delay of less than 1 minute per trip for that movement results in an overall disbenefit during the interpeak.

As is noted above, WTM does include coverage of the interpeak period. However, the hybrid approach to using Vissim and SATURN together to best capture local and strategic impacts means that it has not been possible to pass feedback from Vissim to SATURN for the interpeak period and as a result consistent do-minimum and do-something scenarios cannot be prepared in SATURN for the interpeak period.

Given the low level of journey time changes resulting from the scheme during the interpeak period at the junction itself, it is considered very unlikely that significant strategic re-routing would occur during this time and that any minor variations which should appear over the wider network are likely to be largely driven by low levels of noise in the model. Therefore, interpeak benefits have been based only on the results from the Vissim assessment.

Table 5-8 outlines the time slices and derivation of annualisation factors for all the time periods.

**Table 5-8 – Summary of appraisal annualisation assumptions**

| | AM peak average hour (0700-1000) | Inter-peak average hour (1000-1600) | PM peak average hour (1600-1900) |
|---|---|---|---|
| **Modelled Period to Peak Period** | | | |
| Operational Model | No factor required | [Average of 09:45 to 10:00 and 16:00 to 16:15] x 4 intervals per hour x 6 hours | No factor required |
| SATURN Cordon | 3 | N/A | 3 |
| SATURN Full | 3 | N/A | 3 |
| | | | |
| **Days per year** | | **253** | |

The above approach sets out annualisation has been performed for assessment of those benefits measured using TUBA. Alternative approaches have been used for other areas of assessment, depending on the period which TAG recommends assessing in each case.

Time periods represented by each area of monetised benefit and how these assessments have been developed based on the modelling, which represents traffic flows across 12 hours per weekday, are set out in Table 5-9.

**Table 5-9 – Annualisation of Benefits and Costs**

| Year(s) | Period Captured | Adaption from Modelled Traffic Flows |
|---|---|---|
| Scheme Costs | No Annualisation required | None |
| Time Savings | As set out above | As set out above |
| Vehicle Operating Costs | As set out above | As set out above |
| Indirect Tax | As set out above | As set out above |
| Safety | 24 hours per day, 365 days per year | 12hr AAWT[5] to 24hr AADT factors from Local Model Validation Report (LMVR) |
| Greenhouse Gases | 24 hours per day, 365 days per year | 12hr AAWT to 24hr AADT factors from Local Model Validation Report (LMVR) |
| Air Quality | 24 hours per day, 365 days per year | 12hr AAWT to 24hr AADT factors from Local Model Validation Report (LMVR) |
| Noise | 24 hours per day, weekdays | DMRB LA111 Method 3 to convert to daytime and night-time traffic |
| Construction Impacts | As set out above | As set out above |
| Reliability | As set out above | As set out above |

[5] Average annual weekday traffic

#### 5.5.3.2 User class and journey purpose

The WTM comprises five user classes. To enable TUBA to apply appropriate values of time and operating costs these have been disaggregated into seven user classes for economic appraisal. The modelled and adjusted user classes are shown in Table 5-10.

**Table 5-10 – Correspondence of user class to TUBA journey purpose**

| Modelled User Class | TUBA Trip Purpose | Factor |
|---|---|---|
| 1. Business | 1. Business | 1.00 |
| 2. Commuting | 2. Commuting | 1.00 |
| 3. Other | 3. Other | 1.00 |
| 4. LGV | 4. LGV Personal | 0.12 |
| 4. LGV | 5. LGV Freight | 0.88 |
| 5. HGV | 6. OGV1 | 0.40 |
| 5. HGV | 7. OGV2 | 0.60 |

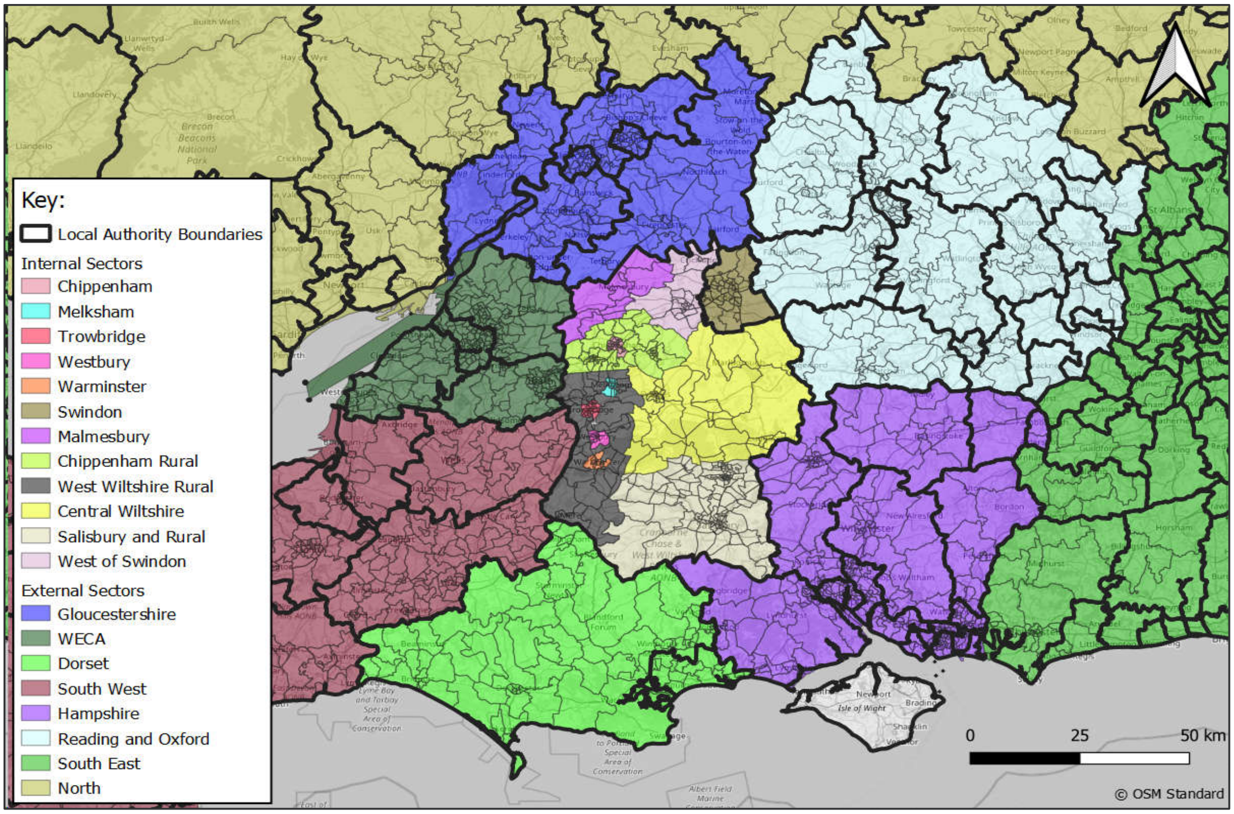
Note: LGV was disaggregated into LGV Personal and LGV Freight using TAG Databook's default proportional split (12% and 88% for LGV personal and LGV freight respectively).

#### 5.5.3.3 Sectoring system

Sector analysis provides an important check on the ability of the model to produce plausible forecasts of future-year travel demand; and can help give a better understanding of the journeys that are generating the greatest benefits or disbenefits. It may also show the extent to which model 'noise' is potentially having an impact on the results produced by TUBA. This is usually identified by counter-intuitive (dis)benefits for movements across the study area that would not be expected to be affected by the scheme (e.g. external-external movements that do not pass through or close to the scheme).

To assist with analysis, the transport model zones have been grouped into internal sectors, covering Wiltshire and Swindon, and external sectors representing the rest of the UK. Figure 5-3 shows the internal and external sectoring system, with key urban settlements along the A350 route marked out into individual sectors.

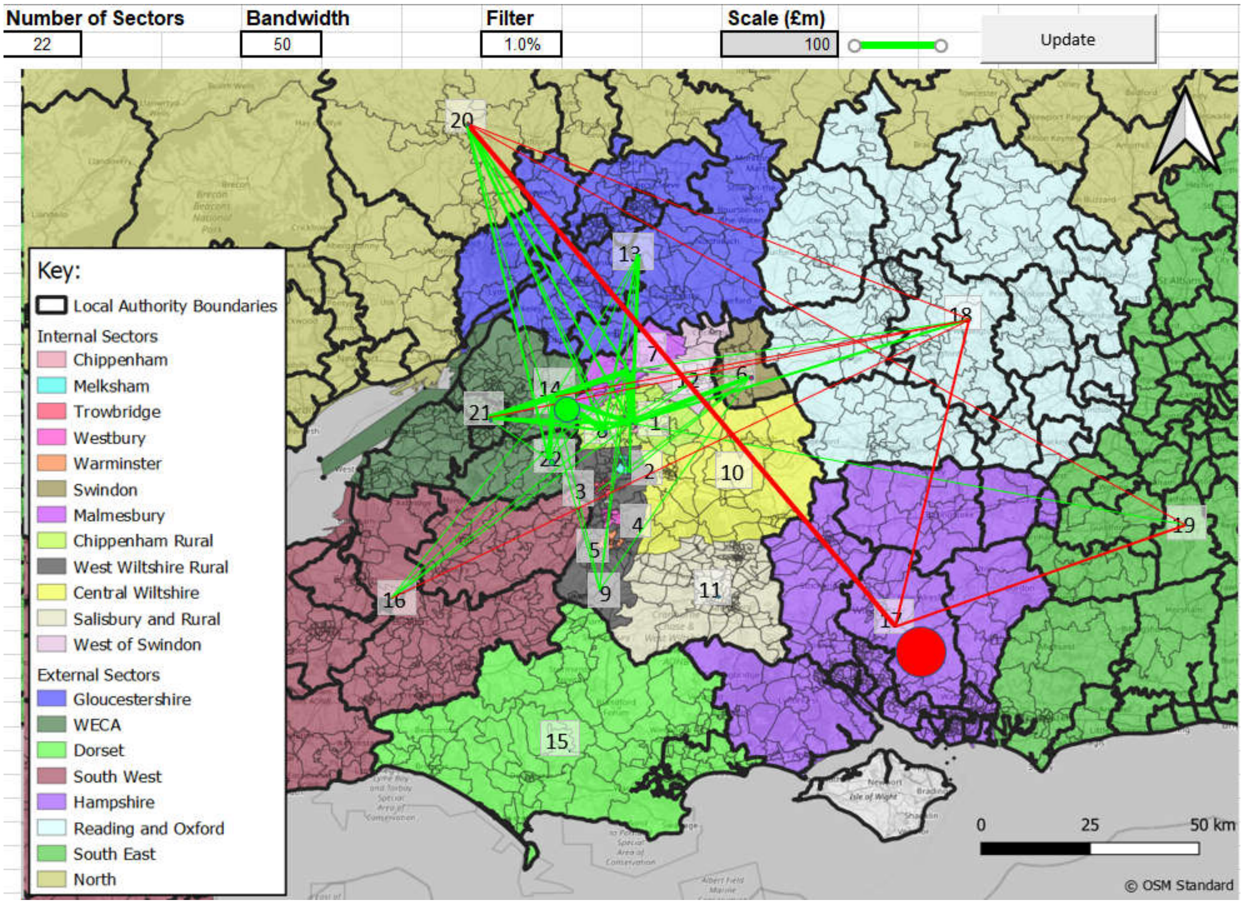
**Figure 5-3 – Sectoring system**




## 5.5.3.4 Masking

In order to minimise the effects of model 'noise', the highways model skims have been masked to screen out origin-destination movements which are considered unlikely to be affected by the M4 Junction 17 scheme. Figure 5-4 shows the sectored origin-destination movements which are forecast to generate the most significant benefits (green) and disbenefits (red). This indicates that the vast majority of benefits relate directly to the scheme, but an anomaly in Hampshire (sector 17) is identified which clearly is not related to the scheme. Therefore, benefits and disbenefits to and from Hampshire have been masked out no other masking has been required for the Core scenario.

**Figure 5-4 – Benefit Distribution**




## 5.5.4 User benefits – results and analysis

This section presents the results of the economic assessment for the core scenario. Sensitivity tests around this central forecast are set out in section 5.11. The results are based on the assumption that the scheme leads to changes in generalised travel costs and that this in turn leads to changes in the level of demand. The assessment therefore allows for induced demand and for the release of trips that, in the Do Minimum are suppressed due to prohibitive journey costs.

### 5.5.4.1 Headline user benefit outputs

**Table 5-11** summarises the TUBA outputs, which are presented as 2010 Present Value of Benefits (PVB).

**Table 5-11 – Present value of highway user benefits (£m)**

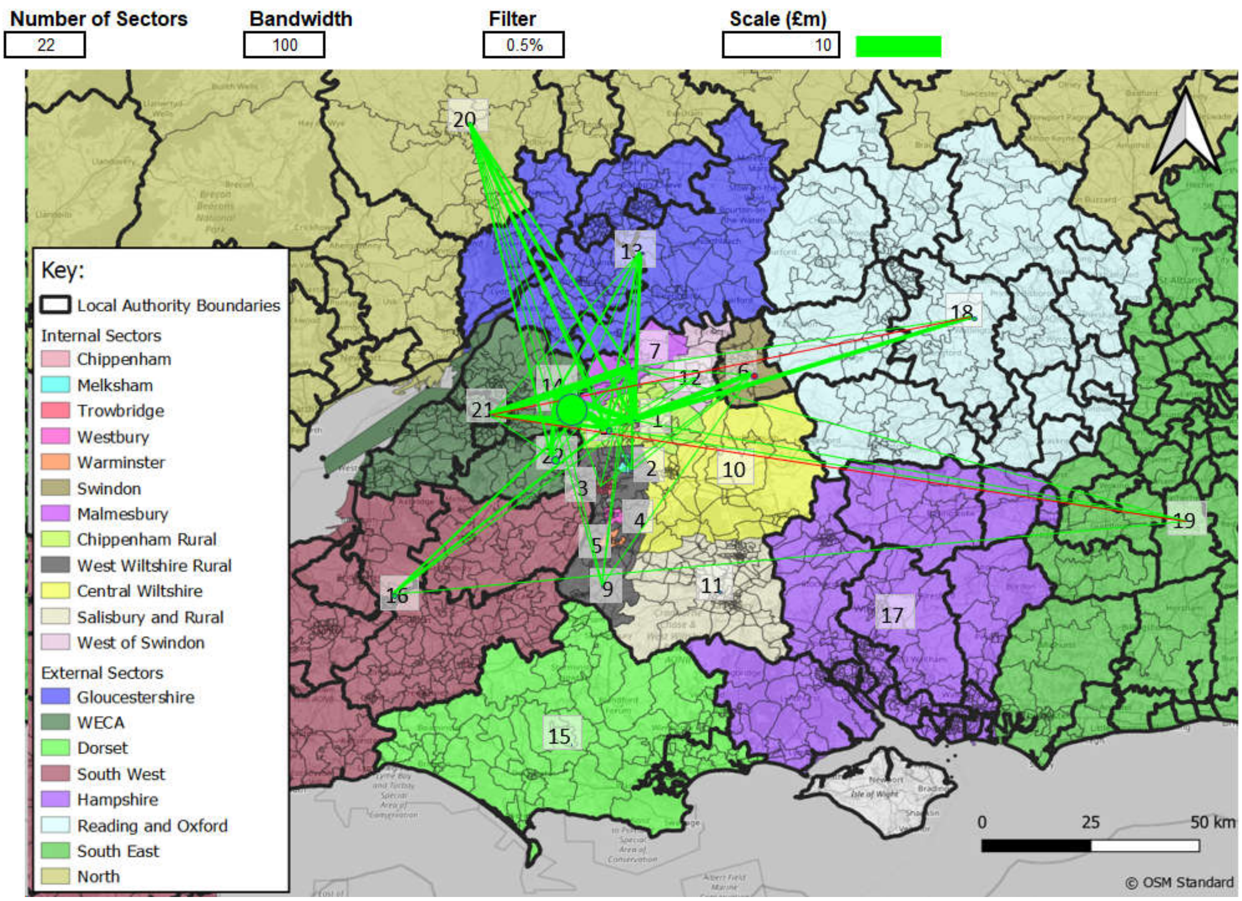
| TUBA benefits | Core |
|---|---|
| Travel time - business | 19.31 |
| Travel time - commuting | 17.60 |
| Travel time - other | 13.11 |
| Fuel operating costs | 3.00 |
| Non-fuel operating costs | 1.00 |
| Indirect taxation revenues | -0.63 |
| **Total** | **53.38** |

The PVBs in Table 5-11 comprise only transport user impacts calculated through TUBA. The two main contributing factors to user benefits are the travel time savings and vehicle operating cost savings. Vehicle operating costs benefits will result due to less time spent in traffic queues even though travel distances are forecast to increase. Indirect tax impact relate to changes in fuel and non-fuel operating costs, both of which are subject to higher rates of tax than average spend in the economy and so reducing these costs lead to a loss of revenue.

#### 5.5.4.2 Sectored assessment of TEE benefits

This section considers the sectoral distribution of travel time benefits as a check to gauge that the results are logical and in line with expectations. The distribution of benefits between sectors and across the broader geographic areas give a broad indication of the scheme's impacts. The sector analyses of the economic benefits of the scheme over the 60-year appraisal period are presented in Figure 5-5 and Table 5-12.

**Figure 5-5 – Distribution of Travel Time Benefits**




This indicates that the largest benefits calculated are for relatively short distance movements in the vicinity of Junction 17, particularly for movements on the north-south axis following the A350 and A429. This is followed by movements between Malmesbury and WECA (north and west of Junction 17 respectively) or Swindon and Chippenham (East and South of Junction 17). A range of longer distance movements passing through the scheme or surrounding area are also forecast to experience time savings.

Analysis shows that benefits are not constrained to movements directly through Junction 17 of the M4, but trips passing through Junction 16 and Junction 18 will also benefit, as the extra capacity at Junction 17 will reduce trip numbers using these alternative routes.

Some marginal disbenefits are forecast for trips using the M4, but not passing through these junctions, as additional traffic is able to access the M4 rather than using local roads. Due to the large number of trips using the M4 between WECA and the South-East or Reading and Oxford this disbenefit is represented in Figure 5-5, while many of the smaller local benefits resulting from reduced traffic on local roads are hidden to help focus on the most prominent impacts. Any sector-to-sector movement generating less than 0.5% of the total benefit has been hidden.

Table 5-12 presents this distribution of journey time benefits numerically.

Figures in Table 5-11 do not match exactly with those in Table 5-12. The spatial summary focuses on impacts across the whole modelled network and does not represent the more detailed analysis of Junction 17 based on Vissim modelling under the ‘Hybrid’ appraisal methodology. This is because the microsimulation modelling is not able to identify ultimate origins and destinations of trips.

Although these results may include some minor effects of model noise, overall, they broadly suggest that, once the component of model noise in Hampshire has been masked out, the sector-to-sector movements generating the majority of benefits are logical.

## Table 5-12 – Distribution of Travel Time Benefits (£000s, 2010 PVB)

| | | | Destinaiton | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 210 | 211 | **Total** |
| Origin | Chippenham | 100 | -136 | -38 | -42 | -7 | -4 | 2,376 | 2,217 | 374 | -43 | 306 | 24 | 565 | 1,046 | 3,035 | -2 | 691 | 0 | 1,832 | 686 | 1,076 | 1,830 | 94 | **15,882** |
| | Melksham | 101 | -278 | -23 | -3 | -2 | -2 | 579 | 376 | 261 | -31 | 246 | 31 | 80 | 254 | 376 | -1 | 7 | 0 | 166 | 55 | 282 | 201 | 71 | **2,644** |
| | Trowbridge | 102 | -348 | -56 | -2 | -2 | -3 | 620 | 209 | 192 | -322 | 201 | 15 | 61 | 138 | 210 | 0 | 21 | 0 | 147 | 34 | 222 | 141 | 25 | **1,505** |
| | Westbury | 103 | -56 | -13 | -5 | 0 | -2 | 153 | 53 | 37 | -48 | 30 | 6 | 26 | 53 | 43 | -1 | 2 | 0 | 17 | 11 | 71 | 21 | 9 | **408** |
| | Warminster | 104 | -21 | -7 | -4 | -6 | 0 | 82 | 38 | 23 | -28 | 16 | 10 | 10 | 25 | 22 | 0 | 0 | 0 | 7 | 5 | 47 | 12 | -5 | **227** |
| | Swindon | 105 | 22 | -5 | -3 | -1 | 0 | -880 | -2 | 31 | -5 | -64 | -1 | -100 | 55 | -478 | -1 | -46 | 0 | -153 | -38 | -28 | -363 | -83 | **-2,141** |
| | Malmesbury | 106 | 1,834 | 234 | 160 | 35 | 18 | 750 | 49 | 488 | 183 | 140 | 18 | 45 | 161 | 3,016 | 22 | 1,057 | 0 | 815 | 460 | 1,062 | 2,982 | 389 | **13,918** |
| | Chippenham Rural | 107 | -54 | 53 | 51 | 5 | 2 | 1,285 | 533 | 821 | 41 | 282 | 26 | 378 | 738 | 3,258 | 4 | 981 | 0 | 1,067 | 479 | 1,474 | 1,470 | 336 | **13,230** |
| | West Wiltshire Rural | 108 | -278 | -59 | 48 | -8 | -6 | 652 | 270 | 168 | -172 | 181 | 23 | 140 | 359 | 404 | -2 | 27 | 0 | 336 | 149 | 381 | 217 | 160 | **2,989** |
| | Central Wiltshire | 109 | 3 | 5 | 19 | 2 | 1 | 432 | 37 | 84 | -1 | 265 | 6 | 95 | 80 | 160 | 0 | 20 | 0 | 126 | 36 | 118 | 80 | 27 | **1,594** |
| | Salisbury and Rural | 110 | -4 | -5 | -4 | -5 | -3 | 26 | 22 | 1 | -28 | 19 | 247 | 7 | 12 | 46 | 10 | -5 | 0 | 12 | 78 | 75 | 29 | -6 | **526** |
| | West of Swindon | 111 | 145 | 11 | 17 | 9 | 6 | 270 | 53 | 120 | 35 | 14 | 2 | 100 | 75 | 526 | 9 | 216 | 0 | 39 | 8 | 173 | 305 | 14 | **2,145** |
| | Gloucestershire | 200 | 884 | 270 | 144 | 60 | 63 | -37 | -115 | 348 | 327 | 24 | 4 | -21 | -414 | 863 | 40 | 159 | 0 | -108 | -117 | 173 | 241 | 224 | **3,012** |
| | WECA | 201 | -3 | -1 | -9 | 0 | 9 | 308 | 204 | 305 | -1 | 47 | 13 | 67 | 494 | 3,462 | 17 | 170 | 0 | 388 | 201 | 388 | 532 | 222 | **6,814** |
| | Dorset | 202 | -16 | -6 | -5 | -6 | -4 | 21 | 37 | 9 | -24 | 11 | 95 | 0 | 53 | 68 | -85 | -338 | 0 | -31 | -23 | 82 | 6 | -13 | **-169** |
| | South West | 203 | -69 | -15 | -13 | -1 | 4 | 165 | 42 | 26 | -70 | 44 | 5 | 32 | 118 | 301 | 6 | 389 | 0 | -109 | 348 | 234 | 82 | -9 | **1,510** |
| | Hampshire | 204 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | Oxford & Reading | 205 | 34 | 9 | 15 | 6 | 8 | 33 | 34 | 23 | 12 | -6 | -2 | -8 | -29 | -588 | -51 | -245 | 0 | -475 | -72 | 89 | -503 | -110 | **-1,827** |
| | South East | 206 | 2 | -2 | -1 | -1 | 0 | 9 | 16 | 2 | -7 | -3 | 3 | -9 | -11 | -473 | -102 | -98 | 0 | 33 | -2 | -214 | -458 | -89 | **-1,405** |
| | North | 207 | 446 | 221 | 209 | 98 | 46 | -81 | -48 | 123 | 301 | -24 | -12 | -16 | -42 | 118 | -46 | 6 | 0 | -452 | -252 | -221 | -76 | 84 | **383** |
| | Bristol | 210 | -27 | -16 | -22 | 1 | 2 | 4 | 44 | 63 | -1 | -4 | 6 | -4 | 128 | 88 | 1 | 68 | 0 | -25 | -21 | 80 | 139 | -20 | **483** |
| | Bath | 211 | -304 | -45 | -48 | 14 | 12 | 290 | 222 | -144 | -28 | 66 | 9 | 88 | 535 | 1,919 | 4 | 251 | 0 | 428 | 356 | 911 | 654 | 863 | **6,053** |
| | **Total** | | **1,775** | **512** | **503** | **190** | **148** | **7,057** | **4,292** | **3,355** | **90** | **1,792** | **528** | **1,538** | **3,828** | **16,375** | **-176** | **3,333** | **0** | **4,058** | **2,380** | **6,475** | **7,543** | **2,185** | 67,782 |

A similar analysis of the distribution of benefit for turning movements directly across Junction 17 based on the Vissim modelling is set out in Table 5-13 and Table 5-14. These tables show benefits which have not been monetised but are indicative of the number of hours of benefit generated in each peak period in the 2036 forecast year.

These indicate that the largest benefits in the AM peak are generated by trips travelling northbound from the A350 and either turning west onto the M4 or continuing north on the A429.

In the PM peak period, the largest benefits are forecast to be experienced by trips travelling along the M4 from the east and turning south onto the A350.

**Table 5-13 – Distribution of Travel Time Savings at M4 Junction 17, (hours of benefit per AM peak period, 2036)**

| | M4 West | A429 North | M4 East | B4122 | A350 South |
|---|---|---|---|---|---|
| **M4 West** | - | - 4 | - 1 | - 5 | - 4 |
| **A429 North** | 21 | - | 14 | 7 | 24 |
| **M4 East** | 1 | - 1 | - | - 0 | 1 |
| **B4122** | 35 | 27 | 48 | - | 20 |
| **A350 South** | 114 | 78 | - 12 | - 3 | - |

**Table 5-14 – Distribution of Travel Time Savings at M4 Junction 17, (hours of benefit per PM peak period, 2036)**

| | M4 West | A429 North | M4 East | B4122 | A350 South |
|---|---|---|---|---|---|
| **M4 West** | - | - 1 | - 1 | - 4 | - 5 |
| **A429 North** | 6 | - | 2 | 2 | 6 |
| **M4 East** | - 0 | 12 | - | 8 | 75 |
| **B4122** | 8 | 7 | 15 | - | 20 |
| **A350 South** | 36 | 23 | - 11 | - 2 | - |

### 5.5.4.3 Profile of benefits over the 60-year appraisal period

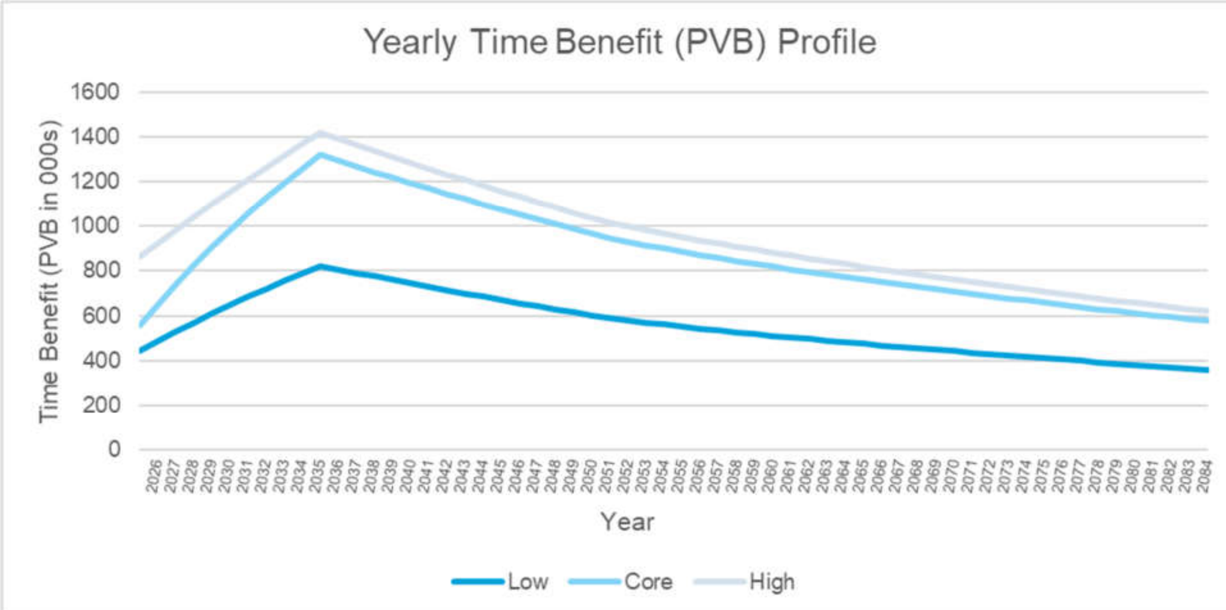
Figure 5-6 shows the profiles of PVB across the 60-year project lifetime for each option.  It can be observed that a period of considerable growth in benefits is forest to occur between 2026 and 2036, as levels of congestion in the Do Minimum scenario are exacerbated by growing levels of traffic.

Beyond 2036 no further growth in trip numbers has been assumed and so the number of vehicle-hours saved is assumed to remain constant. This results in a decline in annual benefits as the rate of discounting is higher than the rate of real-terms value of time growth.

This suggests that the calculated benefits are conservative, as forecasts of demand in the region beyond 2036 indicate continued levels of growth in traffic. However, these contain higher levels of uncertainty and so have not been used to inform the appraisal.

Benefit profiles over the appraisal period are also illustrated for the low and high demand growth scenarios, which are discussed in detail in section 5.11.

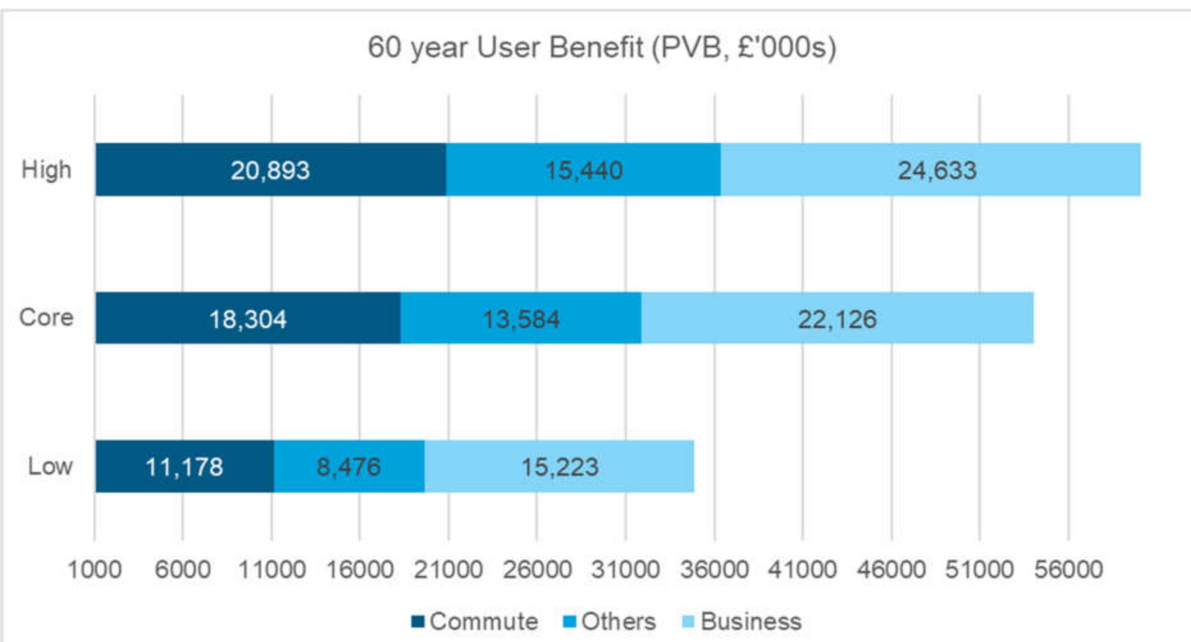
**Figure 5-6 – Sixty-year profile of time benefits (PVB,000s)**




### 5.5.4.4 Benefits by journey purpose

Consideration of the user economic benefits by journey purpose is presented in Figure 5-7. This generally shows a similar split of benefits between business, commuting and 'other' journey purposes across all scenarios. Approximately 40%-44% of benefits are attributed to business users, who have the highest value of time. Approximately 32%-34% of benefits are attributed to commuter trips and around 24%-25% to 'other' trips.

**Figure 5-7 – User benefits by journey purpose (PVB)**



#### 5.5.4.5 Monetised travel time benefits by time saving

Travel time benefits have been analysed in terms of the scale of journey time change. Due to constraints with the analysis of outputs, this is based on the unmasked TUBA outputs. It is therefore indicative but considered to be generally representative of masked benefits in relation to patterns observed.

Table 5-15 presents a breakdown of the monetised travel time benefits, showing the net benefits by different scales of journey time change (decrease or increase) for each scenario. This is based upon the TUBA assessment. This analysis indicates that net travel time benefits mostly fall into the 2 to 5 minute journey time change bands. There is a significant net benefit from journeys saving less than 2 minutes per trip with a far smaller net benefit associated with journey time changes in excess of 5 minutes.

This distribution of benefits by scale of time saving is considered to align well with the expected impacts of the junction improvement, as delays will be reduced for a high number of trips but only specific movements across the junction at the busiest times of day are forecast to experience delays greater than 5 minutes per trip and even in these cases most of the affected trips will choose alternative routes if no improvement to Junction 17 is made.

**Table 5-15 – TUBA monetised net time benefits by time saving (£000s, 2010 prices, discounted to 2010)**

| Scenario | Size of journey time change +/- | | |
|---|---|---|---|
| | 0 to 2 mins | 2 to 5 mins | > 5 mins |
| Core | 19,013 | 31,498 | 3,057 |

### 5.5.5 Checking and assurance

The analysis of the outputs from TUBA indicates that the results are generally logical and in line with expectations. In line with guidance and best practice, further checks have also been undertaken on the raw output files from TUBA, including a review of the warning messages which are automatically generated by the software.

The details of the checks are provided in Appendix D, with explanations provided in relation to the main types of warnings. TUBA output files in their original format are to be provided to DfT directly (Appendix E).

## 5.6 Safety impacts (COBALT)

The accident benefits assessment was undertaken using the DfT's Cost Benefit Analysis – Light Touch (COBALT) spreadsheet model, in accordance with TAG guidance. COBALT software version v 2.1 has been used with economic parameters file based on TAG Data Book November 2021, v1.17.

The COBALT assessment provides an analysis of the likely impact of a highway scheme on the number and severity of accidents, including a monetised impact for inclusion in the BCR and Value for Money assessment.

COBALT forecasts the number of accidents on each road link for the Do Minimum and Do Something scenarios over the 60-year appraisal period, based on the product of the accident rate, the road length and the forecast annual traffic flow. Relationships and data contained in COBALT take account of changes in accident and casualty rates over time.

The "link and junction combined" approach has been adopted, which is the standard approach for developing a COBALT assessment from data extracted from strategic models with COBALT default accident rates (based on national average rates per million vehicle-kilometres) applied.

24-hour (AADT) flows for all links in the study area for the Base, Do Minimum and the Do Something scenarios have been derived from the modelled hours using calculated expansion factors established for the WTM, set out in the LMVR. Link details, including link length, speed limit and link type, have also been determined from the WTM.

The following sections discuss the inputs required, and the results of the accident analysis for the M4 Junction 17 scheme using COBALT software are discussed in detail in the subsequent sections.

### 5.6.1 Approach

The assessment of safety benefits using COBALT has focussed on the full SATURN network modelling and has not considered either the Vissim model or the cordoned SATURN model. The benefits of the Vissim model for assessment of journey time savings are not applicable to COBALT assessment, so use of the additional models is not required.

The network changes introduced by the Junction 17 scheme are not well suited to representation in COBALT, which focusses either on links or standard forms of junctions. Junction 17 does not fall well into either of these categories. It is too large and complex a junction to fit within the junction categories supported by COBALT. While it could be represented as a series of smaller junctions this wouldn't reflect the complexities of traffic changing lanes as it passes around the circulatory and would be unable to represent merging of traffic.

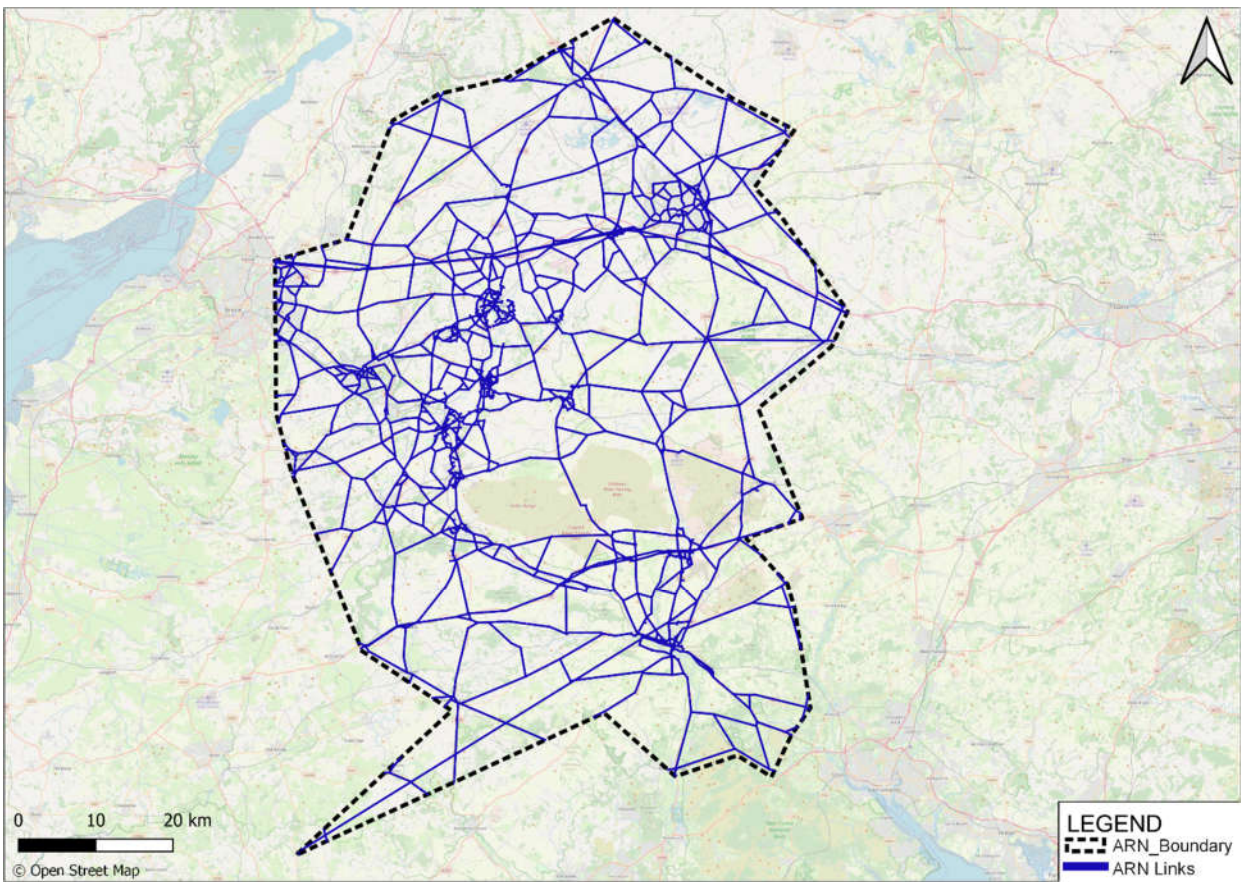
Therefore, the safety assessment has been focussed primarily on impacts of strategic rerouting which will be generated by the scheme, with larger flows on the M4, A350 and A429, and reduced flows on circulatory and diagonal movements. This change in patterns of travel means that larger volumes of traffic will use the safer parts of the network, in particular the sections of the MRN which include central reserve barriers, but also this traffic may travel longer distances by following perpendicular links via Junction 17, rather than following a more direct route using local roads.

To represent the changes made by the scheme in the SATURN model various links around Junction 17 are added or removed, enabling widening and realignment to be applied. These variations are represented in the COBALT assessment but impacts are expected to be limited due to the short length of these links.

### 5.6.2 COBALT study area

The geographic extent of the COBALT assessment covers the area presented in Figure 5-8. This area covers the 'Affected Road Network' (ARN) which is based on the Area of Detailed Modelling, as set out in the LMVR.

**Figure 5-8 – COBALT study area**




### 5.6.3 Results

By comparing the Do-Minimum scenario to the Do-Something scenario, COBALT utilises the link information, accident rates and traffic flows to calculate the number of accidents and casualties saved by the scheme. The casualties are categorised as either fatal, serious or slight and each has a different monetised benefit associated with it. Table 5-16 summarises the accidents and Table 5-17 summarises casualties, with and without the scheme.

**Table 5-16 – Accident summary**

| COBALT summary | COBALT assessment |
|---|---|
| | Core |
| Total Without-Scheme Accidents | 84,843 |
| Total With-Scheme Accidents | 84,772 |
| Total Accidents saved by Scheme | 70.8 |

**Table 5-17 – Casualty summary by accident type**

| COBALT summary | Casualty type | COBALT assessment |
|---|---|---|
| | | Core |
| Total Without-Scheme Casualties | Fatal | 1,150 |
| | Serious | 11,446 |
| | Slight | 106,989 |
| Total With-Scheme Casualties | Fatal | 1,150 |
| | Serious | 11,439 |
| | Slight | 106,912 |
| Total Casualties saved by Scheme | Fatal | -0.3 |
| | Serious | 7.8 |
| | Slight | 77.0 |

COBALT then converts the change in accidents and casualties to an overall monetised benefit or disbenefit for each link. This includes costs related to damage-only accidents, which are additional to those set out above. Table 5-18 presents the monetised impacts of the scheme for the core and sensitivity assessments, over a 60-year appraisal period.

**Table 5-18 – COBALT Monetised impacts (2010 PVB, £m)**

| COBALT summary | COBALT monetised assessment (£m) |
|---|---|
| | Core |
| Total Without-Scheme Casualties | 3,755 |
| Total With-Scheme Casualties | 3,753 |
| Total Casualties saved by Scheme | 2.22 |

Overall accident benefits for the Core scenario are calculated as £2.22 million. Under the Core assessment, benefits are derived from a predicted reduction in total collisions with the scheme. The benefits from a reduction in slight and serious collisions more than to offset a slight increase in predicted fatal collisions. Due to the relocation of traffic caused by the scheme, a greater proportion of travel will be made using the safer M4 and A350, rather than using local roads.

The use of default accident rates on the M4 Junction 17 under the combined link and junction approach is considered to result in a conservative outcome for the Core assessment. This is because it does not reflect the additional safety benefits of the scheme which will be achieved through completing the signalisation of the junction which will reduce risk of collisions. Neither does the monetised assessment reflect safety benefits of the measures taken to divert cyclists away from Junction 17, providing a quiet route to cross the M4 corridor.

## 5.7 Construction and maintenance impacts

### 5.7.1 Scope of impacts

Transport users incur additional costs when the transport network is undergoing construction and/or maintenance works. There are four typical costs associated with these works: delay (value of time), vehicle operating costs, carbon emissions and accidents.

Construction impacts have been assessed in the WTM SATURN model, with outputs run through TUBA to generate the monetised impact.

Traffic management requirements during the construction period have not yet been developed, so a high-level approach to modelling impacts during this period has been prepared. It has been assumed that works can be carried out with no closures to any parts of the network and no lane closures, but that narrowed lanes during works will result in reduced speeds. Modelling has been set out to restrict speeds to 20mph on the circulatory and 30mph on the access/egress links. This has been prepared in WTM to enable re-routing impacts of the delays to be captured.

These restrictions are planned to be in place for 11 months up to the date of scheme opening. This has been reflected in the annualisation factors applied in the TUBA assessment.

### 5.7.2 Assessment

This element of the assessment has been performed using only the SATURN full network model and so interpeak disbenefits have been included directly from this modelling, in addition to AM and PM peak benefits, rather than following the approaches described in Appendix A.

The construction disbenefit has then been estimated by undertaking a TUBA assessment for the period of construction.

No change to delays during periods of future maintenance have been assumed. The additional lanes will increase the level of maintenance required, as set out in the assessment of scheme costs, but these will also provide additional capacity, so reducing delays while these works take place.

### 5.7.3 Results

The construction delay impacts are presented in Table 5-19.

**Table 5-19 – Present Value of indirect construction impacts (Core scenario)**

| Impact | Construction Delays (£m) |
|---|---:|
| Time benefits | -0.50 |
| Fuel vehicle operating costs | 0.05 |
| Non-fuel vehicle operating costs | 0.01 |
| Indirect taxation revenues | -0.03 |
| Greenhouse gases | 0.01 |
| **All** | **-0.47** |

All values are in 2010 prices and values

The impact of the construction period on user benefits is -£0.47m. These disbenefits are associated with journey time delays, as traffic management will require temporary reassignment of carriageway space for the works to take place.

## 5.8 Journey time reliability

Journey time reliability refers to the extent that transport users experience unpredictable travel time variations as a result of recurring congestion at the same period each day (day-to-day variability) or incidents and non-recurring events.  This excludes predictable variation relating to varying levels of demand by time of day, day of week, and seasonal effects. The scheme aims to improve the journey time reliability for both longer and shorter distance trips.

The reliability impacts of the scheme are assessed using the "urban roads" method set out in TAG Unit A1.3 for the existing A350, A429, the M4 Junction 17 and local roads.

While Junction 17 is not in an urban area, the guidance is based on assessment of impacts on journeys where alternative route options are available, with a particular focus on the network enabling diversions to avoid incidents which might otherwise result in unexpected levels of delay. Much of the benefit generated by the Junction 17 scheme does correlate well to this definition in that it enables increased flow across the junction, much of which would otherwise use alternative routes around Junction 17 or connect with the M4 elsewhere.

### 5.8.1 Urban roads method

This approach represents the variability of journey times through changes in the standard deviation of journey time, and is estimated using the formula:

$$\Delta\sigma_{ij} = 0.0018\left(t_{ij2}^{2.02} - t_{ij1}^{2.02}\right)d_{ij}^{-1.41}$$

Where:

$\Delta\sigma_{ij}$ is the change in the standard deviation of journey time from i to j (seconds);

$t_{ij1}$ and $t_{ij2}$ are the journey times, before and after the change, from i to j (seconds); and

$d_{ij}$ is the distance from i to j (km).

The reliability benefit for every movement within the study area is then calculated using the formula:

$$Benefit = -\frac{1}{2}\sum_{ij}\Delta\sigma_{ij} * \left(T_{ij}^{0} + T_{ij}^{1}\right) * Reliability\ Ratio * \ Value\ of\ Time$$

where:

$T_{ij}^{0}$ and $T_{ij}^{1}$ are the number of trips before and after the change respectively; and

the Reliability Ratio is assumed to be 0.4 for cars and 0.6 for goods vehicles (the value of one minute of standard deviation is related to one minute of average travel time, i.e. for car travel this means that one minute of standard deviation has the same value as 0.4 minutes of average travel time[6].

All economic and scheme-specific parameters used for the calculation of the reliability impacts (such as values of time, annualisation factors, user class definition, appraisal period, etc) are consistent with the TUBA assessment of the scheme.

The value of time for business purpose car trips has been calculated using the varying values of time by distance method, as in the TUBA assessment of the scheme. The extents of the study area have also been masked as in the TUBA assessment.

With reference to the urban roads reliability calculation formula summarised above because the standard deviations of journey times take into account the changes in journey times per origin-destination distance, the reliability benefits can be disproportionately affected by journey time changes on short-distance trips, while potentially damping the reliability impacts calculated on long-distance trips. Although the effects of short-distance trips generally do not have any significant impact on the conventional user benefits assessed in TUBA, they can result in unrealistic reliability impacts when using the urban roads reliability calculation formula. It has therefore been considered appropriate to reduce the effect of those movements on reliability, by filtering out trips with distance less than 0.5 kilometre.

As set out above, the Urban Roads approach to assessment of journey time reliability is based on changes in distance and time between the origin and destination of a journey. Neither the Vissim model or the SATURN cordoned model reflect true origins and destinations, instead focussing on network performance over a relatively small number of links in a constrained area. Therefore, the Urban Roads method would not be applicable to either of these models, and so it has been applied only to the full network SATURN model.

[6] Sourced from MyRIAD v1.3 (Motorway Reliability Incidents And Delays User Manual)

### 5.8.2 Results

The reliability impact of the scheme is calculated as a benefit of £2.64m over the appraisal period. Table 5-20 summarises the reliability benefits disaggregated by user class; and Table 5-21 summarises the reliability benefits by journey purpose.

**Table 5-20 – Reliability benefits, by user class (£m, 2010 prices, discounted to 2010)**

| User Class | Reliability benefit – PVB (£m) |
|---|---|
| Car Business | 0.25 |
| Car Commute | 0.83 |
| Car Other | 0.85 |
| LGV Other | 0.03 |
| LGV Business | 0.51 |
| OGV1 Business | 0.10 |
| OGV2 Business | 0.07 |
| **TOTAL** | 2.64 |

**Table 5-21 – Present Value of reliability benefits (Core Scenario)**

| Journey purpose | Reliability benefit – PVB (£m) |
|---|---|
| Business | 0.93 |
| Commuting | 0.83 |
| Other | 0.88 |
| **TOTAL** | 2.64 |

All monetised values in 2010 prices discounted to 2010.

The masked reliability benefits of £2.64m amount to around 5% of masked TUBA journey time benefits of £50.0m.

## 5.9 Monetised environmental impacts

Impacts relating to greenhouse gases, air quality and noise have been monetised. An overview of the key methodology, assumptions and outputs is provided below. The relevant TAG worksheets are included in the Environment Report (Appendix D).

The assessment of environmental benefits has been carried out based on outputs from the full SATURN network model only, with no contribution from the Vissim or cordoned SATURN network. The primary environmental impacts of the scheme have been considered to be the effect on strategic rerouting of traffic which is captured only through this model. The reasons for excluding impacts which may be represented by the other more localised models are set out in section 0 of Appendix A.

### 5.9.1 Greenhouse gases

#### 5.9.1.1 Methodology and assumptions

Changes in greenhouse gas emissions were assessed following the guidance presented in TAG Unit A3 section 4. The traffic data and emissions data prepared for the air quality study area (discussed below) were also used to calculate total emissions of CO2e with and without the scheme. The national highways air quality spreadsheet model v9, based on Defra vehicle emission factor toolkit (EFT v11.0) was used to calculate regional emissions.

The change in CO2e emissions as a result of the scheme was calculated in the opening (2026) and forecast (2036) years. It was assumed that emissions of CO2e would change incrementally between these two years and would remain unchanged post 2036 for the remainder of the 60 year appraisal period.

#### 5.9.1.2 Monetised impacts – key outputs

An increase in CO2e of approximately 34,000 tonnes is predicted over the 60-year period in the Core scenario (Table 5-22). This produces a PVB of -£2.5m.

**Table 5-22 – Present Value of greenhouse gas impacts (2010 prices)**

| Greenhouse gas impacts | Core |
|---|---|
| Change in CO2e: non- traded (tonnes, 60 years) | 33,843 |
| Change in CO2e: traded (tonnes, 60 years) | 557 |
| PVB (£m) - total | -2.5 |

All entries are present values discounted to 2010, in 2010 prices

The predicted increase in emissions is considered to be associated with an increase in total vehicle kilometres. This results from a combination of trips following slightly less direct routes and the reduced congestion leading to a small increase in total trip numbers.

The assessment does not take into account potential for carbon off-setting measures (such as tree planting as part of the scheme).

### 5.9.2 Noise impacts

#### 5.9.2.1 Methodology and assumption

Traffic data (AADT) was derived from the WTM for the scheme opening year 2026 and design year 2036 for both 'With Scheme' and 'Without Scheme' scenarios. Operational noise predictions were undertaken in line with DMRB LA 111, using a 3D noise model of the scheme built in Noisemap® v5.2 software. The road traffic noise calculations were undertaken in accordance with the modified CRTN methodology set out in DMRB LA 111 Appendix A2, assuming soft-ground topography and a bituminous road surface for all roads.

The assessment included traffic links within the Traffic Reliability Area (TRA), with a study area as defined within DMRB LA111.

No specific mitigation (e.g. noise barriers) were reflected within the noise modelling and the assessment could therefore be considered to provide a conservative assessment.

Using the outputs from the noise modelling the TAG Noise Workbook was completed using the current guidance and tools as at August 2022, with reference to:

TAG Unit A3 Environmental Impact Appraisal, Section 2 Noise (May 2022); and

TAG Noise Workbook (May 2022) – Incorporating changes in appraisal accounting from TAG Unit A3; updated to reflect TAG Databook v1.18.

#### 5.9.2.2 Monetised impacts – key outputs

The change in noise impacts has been calculated as a net benefit of £0.23m, representing an overall reduction in noise impacts from the scheme (Table 5-23).

**Table 5-23 – Present Value of noise impacts (Core scenario)**

| Noise impact | PVB (£m) |
|---|---|
| Sleep disturbance | 0.11 |
| Amenity | 0.08 |
| Acute myocardial infarction (AMI) | 0.02 |
| Stroke | 0.01 |
| Dementia | 0.00 |
| **Total** | **0.23** |

All monetised values in 2010 prices discounted to 2010; Numbers do not add due to rounding

The largest benefits are due to reduced sleep disturbance and positive impacts on amenity.

The positive noise benefits are driven by the impact of the junction improvement drawing traffic away from properties in surrounding villages and onto the Strategic Road Network.

There is an overall net reduction in households experiencing noise disturbance.

## 5.9.3 Air quality impacts

### 5.9.3.1 Methodology and assumptions

Impacts from changes in nitrous oxide (NOx) and particulate matter (PM10) concentrations are valued. The assessment is line with the following guidance:

- TAG Unit A3 Environmental Impact Appraisal (May 2022).
- TAG Local Air Quality Assessment Workbook (May 2019).
- TAG Air Quality Valuation Workbook (May 2022).

Given that the Scheme is expected to have minimal impact on existing traffic conditions, a proportionate approach was taken which included an examination of local air quality constraints within 200 m of the Scheme extent in line with the Design Manual for Roads and Bridges (DMRB) LA105 Air Quality and a quantitative appraisal following the damage costs approach in accordance with TAG Unit A3 Chapter 3.

Forecast changes in traffic flows and speeds have been taken from the WTM, based on the opening year (2026) and a forecast year of 2036. This traffic has been factored up to cover 24hrs a day and 365 days a year. The study area included the traffic links within the Affected Road Network (ARN). The assessment uses the Department for Environment, Farming and Rural Affairs (DEFRA) Emissions Factor Toolkit (EFT v11).

No specific mitigation has been reflected and the assessment could therefore be considered to provide a conservative assessment.

- The TAG Air Quality Valuation Workbook has been used to derive the monetised values.

### 5.9.3.2 Monetised impacts – key outputs

The overall monetised air quality impact for the Core scenario is assessed as -£0.3m (Table 5-24). The 'central value' of air quality impacts has been incorporated into the overall VfM assessment.

**Table 5-24 – Present Value of air quality impacts (Core scenario)**

| Air quality impact | Absolute change (tonnes) | Central value - PVB (£m) |
|---|---|---|
| Change in PM10 concentrations | +8 | -0.2 |
| Change in NOx concentrations | +18 | -0.1 |
| Total PVB | | **-0.3** |

All monetised values in 2010 prices discounted to 2010

The air quality disbenefits are driven by an increase in the assessment score for NOx and PM10 concentrations over the 60-year appraisal period, due to an increase in concentrations at the majority of receptors.

## 5.10 Benefit Cost Ratio

The scheme cost (PVC) and the various monetised impacts assessed (PVB) inform the Benefit Cost Ratio (BCR). This is discussed within the OBC Economic Dimension, in terms of the overall Value for Money assessment. Table 5-25 provides a summary of the Initial BCR and Adjusted BCR based upon the information and analysis relating to monetised impacts presented within this chapter.

The **Initial BCR for the Core scenario is 2.4,** associated with a Net Present Value (NPV)[7] of £30.8m. With Level 2 monetised impacts included, the **Adjusted BCR is 2.5**, associated with a NPV of £33.5m.

This represents the central forecast of scheme performance, but it includes a range of uncertainties in both the benefits and the costs of the scheme. Therefore, a range of alternative scenarios have been developed to inform the consideration of uncertainty and sensitivity in relation to the appraisal. These are set out in section 5.11.

[7] NPV is equal to the difference between the PVB and PVC

**Table 5-25 – Summary of Benefit Cost Ratio (all scenarios)**

| Impact / measure | PV (£m) |
|---|---|
| Highway user time benefits | 50.0 |
| Vehicle operating costs | 4.0 |
| Indirect tax revenues | -0.6 |
| Greenhouse gases | -2.5 |
| Construction impacts | -0.5 |
| Accidents | 2.2 |
| Noise | 0.2 |
| Air Quality | -0.3 |
| **PVB (Level 1 impacts)** | 52.6 |
| Present Value of Costs (PVC) | 21.8 |
| Net Present Value (NPV) | 30.8 |
| **Initial BCR** | 2.4 |
| Reliability | 2.6 |
| **PVB (Level 1 and 2 impacts)** | 55.3 |
| Present Value of Costs (PVC) | 21.8 |
| Net Present Value (NPV) | 33.5 |
| **Adjusted BCR** | 2.5 |

It is noted that there are some apparent inconsistencies in some of these outputs, as the TUBA assessment indicates a small reduction in fuel consumption producing a vehicle operating cost benefit, while the EFT assessment indicates a small increase in fuel consumption, leading to adverse greenhouse gas and air quality benefits. Both tools follow TAG methodology, but it is applied in different ways:

TUBA assesses benefits to users, by applying the 'rule of a half' calculation, whereas the environmental assessment considers cost to society. These methods are largely comparable, but in cases where trip numbers change between the DM and DS scenario they will result in a discrepancy. This is because the TUBA method only reflects the growth in economic value generated, which is less than the full cost of the new trips.

Of more significances in this case though, since the number of trips generated is low, is the fact that TUBA considers origin-destination movements while EFT considers variations by model link. The link-based method provides a greater level of accuracy when calculating fuel consumption, as trips are made at varying speeds rather than at a constant average speed. However, this link-based approach cannot be translated into a calculation of user benefits as a single trip may follow different routes in the DM and DS scenarios and TUBA relies on inputs in the form of time and distance matrices.

Furthermore, the scope of movements considered by these two assessments differs slightly, with the environmental assessment having considered only the area of detailed modelling, while the TUBA assessment has considered movements across the whole modelled network, with masking of benefits applied where considered appropriate.

These small variations are therefore considered to be reasonable within the context of the overall assessment and as both contribute a relatively low proportion of the total PVB sensitivity testing has not been judged to be proportionate.

## 5.11 Sensitivity tests

Uncertainty and sensitivity within the appraisal and overall VfM assessment is covered within the OBC Economic Case, Section 3.14. This section includes details of some of the components which have informed that.

### 5.11.1 Demand sensitivity

The alternative scenarios detailed within this chapter include demand-side scenario tests which consider uncertainty in relation to national trends such as economic and traffic growth and local land use and development:

- Low growth scenario
- High growth scenario

Details of how these scenarios have been assessed and the variation to benefits are set out Appendix A. Figure 5-6 illustrates how benefits develop over time in these low and high growth scenarios relative to the Core scenario and Figure 5-7 shows how the breakdown of benefits by journey purpose compare between these scenarios.

**Table 5-26 – Summary of demand-side alternative scenarios**

| Measure | Core | Low Growth | High Growth |
|---|---|---|---|
| Scheme cost (PVC) | £21.8 | £21.8 | £21.8 |
| PVB – level 1 and 2 impacts | £55.3 | £36.9 | £62.6 |
| Adjusted BCR | 2.53 | 1.69 | 2.87 |

Based on these demand-side scenarios, the Adjusted BCR has a range between 1.69 and 2.87. The outcomes indicate that the scheme BCR is slightly more sensitive to low growth conditions than it is to high growth conditions.

### 5.11.2 Cost sensitivity

The central forecast of scheme costs includes an optimism bias uplift of 23% on investment costs in line with TAG A1.2 guidance for a road scheme at this stage of development. This 23% is a mean value generated from a large sample of past schemes which have produced a distribution of cost uplifts by the time construction has been completed. To test this range a P20 and P80 value from this optimism bias range have been tested. Based on the data provided by DfT the P20 uplift is 2% and the P80 uplift is 54%.

This sensitivity test considers only the investment costs for the scheme. Maintenance and renewals over the operational period are assumed to remain unchanged from the central forecast.

**Table 5-27 – Summary of cost sensitivity**

| Measure | Core 23% OB | P20 cost 2% OB | P80 cost 54% OB |
|---|---|---|---|
| Capital Investment | £16.8 | £16.8 | £16.8 |
| Scheme cost (PVC) | £21.8 | £18.1 | £27.3 |
| PVB – level 1 and 2 impacts | £55.3 | £55.3 | £55.3 |
| Adjusted BCR | 2.53 | 3.05 | 2.02 |

The outcome indicates that the scheme BCR is more sensitive to a reduction in scheme cost. It should be noted that the core assessment includes optimism bias applied at 23%.

### 5.11.3 Values of time sensitivity

As a significant proportion of the scheme benefits are related to travel time benefits it is appropriate to consider uncertainty and sensitivity in relation to the values of time assumed. The core assessment uses default assumptions as per TAG Databook v1.14. The sensitivity test follows guidelines set out in TAG A1.3 to assess the impact of higher and lower values of time. TAG recommends that work time savings and non-work time savings are treated separately with a range of +/-25% applied to the values of business and commuting time and +/-60% applied to values of time for other trip purposes. This range represents a 95% confidence interval based on the studies which have informed the TAG forecasts of values of time. A summary of how this affects the forecast benefits is set out in Table 5-28.

**Table 5-28 – Summary of values of time sensitivity**

| Measure | Core | Work | | Non-work | |
|---|---|---|---|---|---|
| | | +25% business user benefits | -25% business user benefits | +25% commuter / +60% other | -25% commuter / -60% other |
| Travel time benefits - business | 19.3 | 24.1 | 14.5 | 19.3 | 19.3 |
| Travel time benefits - commuting | 17.6 | 17.6 | 17.6 | 22.0 | 13.2 |
| Travel time benefits - other | 13.1 | 13.1 | 13.1 | 21.0 | 5.2 |
| Total travel time benefits | 50.0 | 54.8 | 45.2 | 62.3 | 37.8 |
| | | | | | |
| PVB – level 1 and 2 impacts | 55.3 | 60.1 | 50.5 | 67.6 | 43.0 |
| Scheme cost (PVC) | 21.8 | 21.8 | 21.8 | 21.8 | 21.8 |
| Adjusted BCR | 2.5 | 2.7 | 2.3 | 3.1 | 2.0 |

The outcomes of the sensitivity test indicate an overall range of BCR from 2.0 to 3.1. The scheme BCR is most sensitive to changes in non-work values of time.

### 5.11.4 TAG Parameters Sensitivity

The Core assessment has been carried out using TUBA's default parameters file which aligns with DfT's TAG Databook 1.14. This set of economic parameters is consistent with those used in development of the transport model, providing direct correspondence of values which have determined trip rates and route choice with those used to calculate economic benefits.

A sensitivity test has been applied using the latest TAG Databook (v1.18) to demonstrate the impact of applying latest parameters such as values of time, fuel consumption and carbon values. This update has been applied only to the benefits captured through TUBA and has not involved any update to the transport model itself.

**Table 5-29 – Summary of TAG Parameters Sensitivity**

| | TAG Databook v1.14 | TAG Databook v1.18 |
|---|---|---|
| Measure | NPV £m | NPV £m |
| Scheme benefits (PVB) | 55.3 | 58.0 |
| Scheme cost (PVC) | 21.8 | 21.8 |
| Adjusted BCR | 2.5 | 2.7 |

The outcome of the indicative carbon value sensitivity test indicates a small change (increase) in the scheme BCR compared to the core assessment.

### 5.11.5 Greenhouse gases (carbon values) sensitivity

DfT's TAG Databook provides unit values of carbon emissions which have been applied through TUBA. These values have been forecast in the Databook with Central, Low and High rates of growth over time. The Core results have been reported based on central carbon values, and sensitivity tests using low and high values have been reported. This sensitivity test has been performed using the most recent TAG Databook for low, central and high values. (Table 5-30).

The 'central' value of carbon emissions from TAG Databook v1.18 is £167.3 per tonne of CO2e (2010, in 2010 prices). The 'high' value is £250.9 per tonne of CO2e and the 'low' value is £83.6 per tonne of CO2e.

**Table 5-30 – Summary of greenhouse gases (carbon value) sensitivity - indicative**

| | Central carbon value | High carbon value | Low carbon value |
|---|---|---|---|
| Measure | NPV £m | NPV £m | NPV £m |
| Greenhouse gases | -2.5 | -3.7 | -1.2 |
| | | | |
| Scheme cost (PVC) | 21.8 | 21.8 | 21.8 |
| PVB – level 1 and 2 impacts | 55.3 | 56.5 | 54.1 |
| Adjusted BCR | 2.53 | 2.59 | 2.48 |

The outcome of the indicative carbon value sensitivity test indicates a small variation either side of the BCR compared to the core assessment.

# 6. Non-monetised impacts

## 6.1 Introduction

Prior to the monetised assessments set out above being undertaken a review was carried out to understand what impacts the M4 Junction 17 scheme was expected to generate, the extent to which each of these would contribute to the total value generated and the complexity of assessment in each case.

As has been demonstrated above, the primary impact of the scheme was expected to be on generating time savings for users, particularly as levels of demand increase as is forecast over future years.

These time savings lead to a range of additional impacts, both on users of the junction and other stakeholders with an interest in the transport network and how it contributes to the surrounding area. Certain elements of these impacts could be monetised relatively easily and others are required for assessment to ensure that there are not unintended adverse impacts. Other benefit groups however, such as social and distributional impacts are better suited to qualitative assessment, as are certain elements of environmental assessment.

Wider economic impacts have been identified as an important contributor to the overall value of the scheme, but given the level of complexity of assessment and the scale of additional value they are anticipated to add relative to other monetised benefits a qualitative assessment has been considered appropriate at this stage of business case development.

## 6.2 Wider Economic Impacts

TAG defines Wider Economic Impacts as a set of impacts, which are additional to conventional transport economic impacts, that can arise when the economy is not functioning efficiently. As a result, additional benefits (or disbenefits) will arise as the impact of transport improvements is transmitted into the wider economy.

These impacts include productivity gains resulting from improvements in how well businesses are connected to each other as well as potential employees, and benefits arising from structural changes as businesses and households relocate.

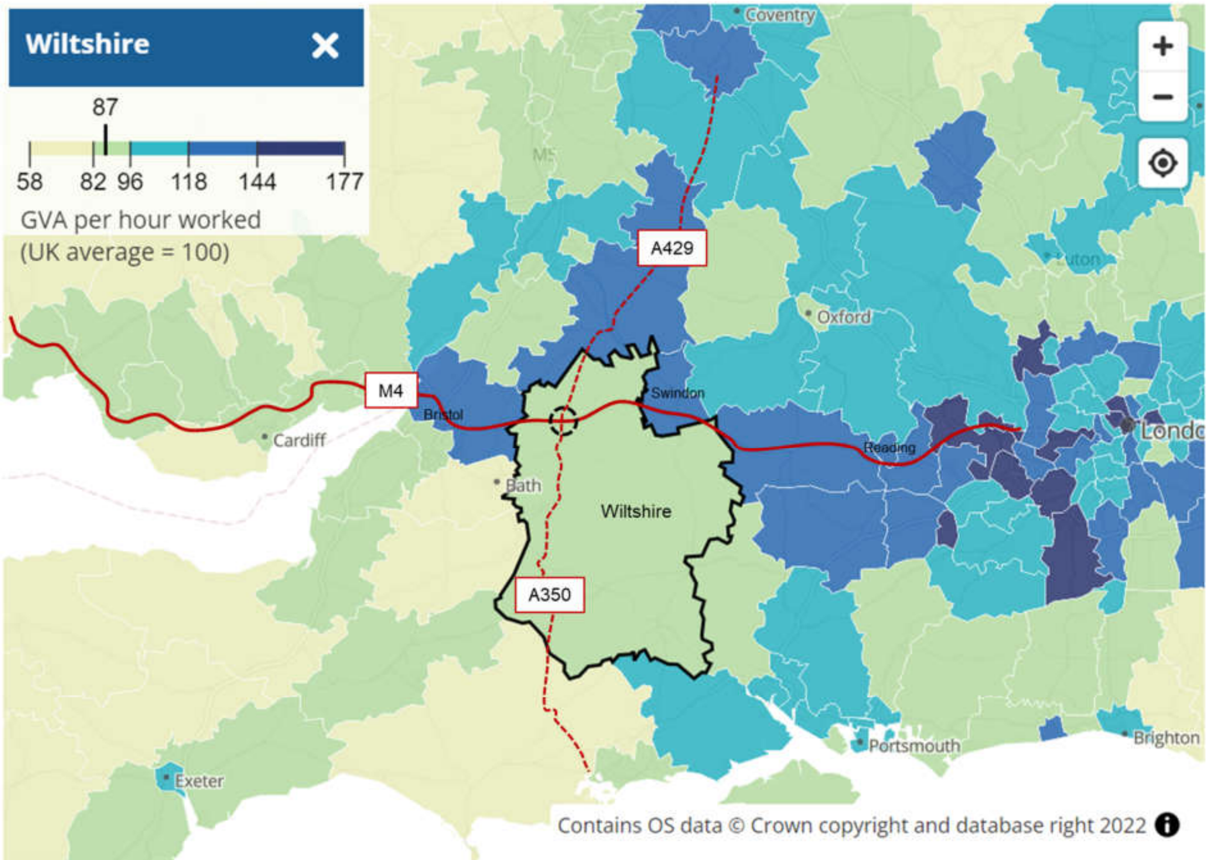
These are not captured in the conventional economic appraisal based on journey time savings and so need to be captured separately using a defined set of calculations drawing on travel cost and trip matrices and additional economic data and parameters.

The M4 Junction 17 scheme is expected to generate positive wider economic impacts, by reducing journey times for business trips, freight and commuters. This will bring down costs to businesses enabling increased competitiveness, greater agglomeration impacts and provide access to a wider labour market enabling increased productivity. Individuals will also benefit from access to jobs which are better paid or more suited to their individual requirements.

A key challenge for the Western Gateway region is closing the productivity gaps affecting parts of the region, including Wiltshire. Figure 6-1 illustrates this through mapping a GVA index, and highlights the significance of the M4 Junction 17 scheme for maintaining high quality strategic connections between Wiltshire (particularly the west Wiltshire towns) and surrounding areas of higher productivity.

**Figure 6-1 – Subregional Productivity**

**Britain grouped by ITL1 region and country, smoothed, 2019, UK=100**




**Office for National Statistics – subregional productivity**

Faster and more reliable journey times resulting from the scheme (compared to the ‘Do Minimum’) will support enhanced connectivity between Wiltshire and key economic centres, including surrounding Functional Urban Regions[8] such as Swindon, Bristol and Bournemouth / Poole on the south coast, and those farther afield with primary access via the M4, such as the Thames Valley area, Heathrow and London.

The scheme is expected to drive agglomeration-based productivity improvements for Wiltshire and the wider Western Gateway region in particular; serving to effectively bring workers and employment opportunities closer together. Workers would have access to a greater range of employment opportunities, whilst employers would have greater access to a more diverse pool of labour (and a greater range of skills). As a result, an associated increase in economic activity would be expected, accompanied by higher levels of output per worker.

These beneficial impacts for the area are particularly relevant when considered in the context of the broader improvement strategy for the corridor, but the M4 Junction 17 scheme is a key component and will prevent the junction becoming a bottleneck and thus a constraint to realising the full wider benefits of other investment in the A350 corridor. As a point of reference, the Western Gateway connectivity study[9] estimated potential total agglomeration benefits of approximately £350 million (over 60 years) associated with enhancement to the A350 corridor as a whole.

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[8] Functional Urban Regions (FUR) comprising a core and a surrounding hinterland, are defined areas of concentrated economic activity and are identified within TAG (e.g. A2.4) as areas more likely to be associated with agglomeration benefits.

[9] Western Gateway STB Economic Connectivity Study (WSP, 2019) - https://westerngatewaystb.org.uk/wp-content/uploads/2020/08/wg-reb-appendix-a-Economic-Connectivity-Study.pdf

The ongoing Wiltshire Local Plan Review identifies a requirement of approximately 24,000 new homes within the A350 corridor between 2016 to 2036, with a need to identify new site allocations to deliver approximately 10,000 of these. Chippenham has been identified as a key growth area; its convenient access to the M4 (via Junction 17) is a particular strength in terms of attractiveness in the housing market.

The appraisal of the M4 Junction 17 scheme demonstrates its effectiveness in catering for planned and future growth and the associated additional traffic demands.

Facilitating new local housing sites would generate economic benefit for the area through Land Value Gain. At a full corridor-wide level, the Western Gateway connectivity study estimated potential Land Value Gain of £156 million associated with enhancement of the A350. The benefit directly attributable to the M4 Junction 17 scheme would be substantially lower than this.

There is tangible evidence to demonstrate that wider economic impacts of unlocking greater demand potential on the A350 corridor will be realised. However, these are expected to contribute a relatively low proportion of the total value of the scheme's impacts. In addition, since these in part relate to the interaction between M4 Junction 17 and complementary investments along the A350 there would be a high level of complexity involved with assessing these impacts. It has therefore not been considered proportionate to monetise them at this stage.

## 6.3 Non-monetised environmental impacts

The assessment of non-monetised environmental impacts follows TAG Unit A3 and applies the qualitative environmental capital approach[10]:

- Step 1 – consider potential impacts and the area of impact
- Step 2 – identify key environmental resources with potential to be impacted by the scheme and identify their features
- Step 3 – for each resource, define the scale, significance, and value
- Step 4 – estimate the magnitude of impact and provide an assessment score for each feature.
- Step 5 – derive an overall assessment using a seven-point scale (large adverse to large beneficial)

This approach is common for each environmental topic, with specific considerations taken into account for each in line with TAG.

The proposed scheme will facilitate the upgrade of the junction along with widening of approaches. The majority of the proposed scheme area is within existing highway boundaries. However, there are small pockets of land which will require land easement, which will require agreement with landowners.

The presence of a Site of Special Scientific Interest (SSSI) has informed the design of the scheme, and the potential impacts of the scheme on the SSSI will continue to be monitored.

High-level assessments of environmental impacts which have not been monetised above have been undertaken to provide a qualitative assessment of the likely environmental effects from the proposed development.

Monetised assessments have also been made of local air quality, noise impacts and greenhouse gas emissions based on the transport model forecasts for changes in vehicle flows resulting from the scheme.

Qualitative assessments have been performed for the impacts of the scheme on landscape, historic environment, biodiversity and water environment. While there are certain impacts within this range which have potential to result in moderate to large adverse effects, mitigation measures have been identified which can be put in place to bring these ratings down to no worse than a slight adverse impact.

Table 6-1 provides a summary of the assessment scores and the subsequent sections consider each impact in turn.

[10] The environmental capital approach was developed by the statutory environmental bodies Natural England (formerly the Countryside Agency and English Nature), English Heritage and the Environment Agency in co-operation with DfT

**Table 6-1 – Non-monetised environmental impacts summary**

| Non-monetised impact - Environment | | Qualitative assessment score |
|---|---|---|
| Landscape | It is assumed that the proposed scheme will have a slight adverse impact on the landscape due to the vegetation removal required and throughout the construction phase. Impacts will be reduced once mitigation and enhancement measures have been established. | Slight adverse |
| Townscape | Due to the location of the scheme, no impact is assumed on townscape. | N/a – not assessed |
| Historic environment | No permanent adverse impacts on heritage assets in the vicinity of the junction have been identified. Works will be confined to the existing junction and roads where any archaeological remains have already been identified by survey works or truncated/disturbed by previous construction activity. The operation of the scheme would not result in adverse impacts on the settings of any designated heritage assets. | Neutral |
| Biodiversity | Loss of a small area of non-priority habitat which has low biodiversity and earth heritage value, but has potential for protected species. The poor quality of this habitat means that the loss of the habitat would give a 'Neutral' score. However, it is also possible that future surveys may identify populations of protected species, which could change the receptor value to 'Medium' or 'High'. As long as appropriate mitigation is provided, this would still result in an overall score of 'Slight adverse'. | Slight adverse |
| Water environment | The scheme will result in an increase in impermeable road area. This could potentially impact the water quality of Rodbourne Brook, Sutton Benger Brook and other watercourses and/or the underlying aquifer's water quality. There is also potential for the increase in impermeable road area to cause an increase in flood risk as a result of an increase in surface water runoff. Sustainable drainage measures that attenuate runoff volumes could be implemented to mitigate this. | Neutral |

## 6.4 Non-monetised social impacts

### 6.4.1 Approach

Non-monetised social impacts have been assessed qualitatively, in line with TAG A4.1, using a seven-point scale (large beneficial to large adverse).

The Social and Distributional Impacts Report (WC_M4J17-ATK-GEB-XX-RP-TB-000006 – main OBC Appendix B10) provides full details of the methodology and outputs.

### 6.4.2 Key outcomes

The results of the social impacts appraisal are summarised in Table 6-2. The assessment scores have been included in the AST.

**Table 6-2 – Non-monetised social impacts summary**

| Indicator | Key impacts - qualitative statements | Overall assessment |
|---|---|---|
| Physical activity | The scheme plans to provide new signage for cyclists to follow that runs west of the junction. The demand for active journeys crossing the M4 J17 is currently low. The improved signage for cycling the quieter local route may redirect more cyclists away from M4 Junction 17. The local routes around the scheme are used by local cycling groups, particularly at weekends, however, there are no survey counts or evidence of numbers. The improved cycling signage may encourage some uptake in localised, leisure cycling trips. Generally, given the nature of proposal, it is not expected that the scheme or the new cycle signage will have a noticeable impact on active travel. The overall impact on physical activity was therefore assessed as neutral. | Neutral |
| Security | The appraisal has resulted in a neutral assessment for most security indicators. The overall assessment for security is therefore considered to be neutral. It should be noted that the landscape/lighting improvements are assumed to positively impact the level of security for transport users to some extent. Care should be taken when considering the result of this assessment because the level of data available affecting security are limited at this stage. | Neutral |
| Severance | There are more road links with a reduction in traffic flow, a number of which are in areas with communities and settlements close by. It is expected there will be greater pedestrian activity movement in these locations compared to pedestrian movements across the M4 Junction where traffic is expected to worsen.<br>Based on the above assessment, the overall assessment on severance is considered to be slight beneficial. | Slight beneficial |
| Journey quality | The junction improvements are expected to improve traveller care factors, resulting in a better user experience for pedestrians and cyclist, although the number of these users at the junction are low.<br>The scheme is not expected to have a significant impact on travellers' views as the junction.<br>The scheme aims to reduce congestion at the M4 Junction 17 and provide more reliable and quicker journey times. As a consequence, a significant reduction in driver frustration is expected as a result of the scheme and reduced traveller stress. | Slight beneficial |
| Option and non-use value | As the M4 Junction 17 scheme includes no changes to any public transport routes or services provided in the area, no significant impacts are associated with the valuation of option values and non-use values. Therefore, no further appraisal is required for this social indicator. | No assessment required |
| Accessibility | Journey time improvements and traffic relief are expected to bring user benefits and, consequently, to change the cost of travel. It should be noted that within the net outcome of user benefits, some people may experience disbenefits, for example through longer journey times.<br>The scheme is not considered to have any impact on access by rail or bus transport<br>Improving the existing safety levels at the M4 Junction 17 is one of the main scheme objectives. To make the corridor safer and more resilient would help to deliver desired strategic and local outcomes.<br>The improvements at M4 Junction 17 would lead to wider travel horizons for residents of some nearby areas, providing faster and more reliable journey times through the junction and on the A350 to access leisure, employment, and education opportunities. | Slight beneficial |

| | | |
|---|---|---|
| Personal affordability | A reduction in congestion is expected to improve fuel efficiency for some users. There is not expected to be any significant increase in other costs including cycling, public parking, or road user charges as a result of this scheme.<br>Overall, slight beneficial impacts are anticipated for personal affordability for commuters and other non-business users. | Slight beneficial |
| Collisions | The M4 Junction 17 scheme is expected to reduce collision rates marginally. However, the overall reduction represents a very small proportion of the total number of collisions across the study area. The collision impacts have been scored as neutral. | Neutral |

## 6.5 Distributional impacts

### 6.5.1 Approach

A distributional impacts appraisal has been carried out to understand the transport impacts of the scheme and their effects in relation to individual social groups.

The Social and Distributional Impacts Report (WC_M4J17-ATK-GEB-XX-RP-TB-000006– main OBC Appendix B10) provides full details of the methodology and outputs.

The appraisal has been conducted in line with the three-stage process defined in TAG A4.2:

- Step 1: Screening – determining the relevance of impacts in relation to the scheme;
- Step 2: Assessment – defining the social groups and amenities affected within the scheme impact area; and
- Step 3: Appraisal – core analysis of the impacts to derive appraisal scores.

Impacts on security and accessibility were screened out as part of Step 1. A full appraisal (Steps 2 and 3) has been undertaken for user benefits, air quality, noise, severance, personal affordability and accidents.

### 6.5.2 Key outcomes

The results of the distributional impacts appraisal are summarised in Table 6-3. The assessment scores have been included in the AST.

**Table 6-3 – Distributional impacts summary**

| Indicator | Key impacts - qualitative statements | Overall assessment |
|---|---|---|
| **User Benefits** | User benefits impacts favour the least deprived income quintiles as large beneficial versus slight beneficial for the most income deprived quintiles. However, all income quintiles are appraised as beneficial. | Moderate beneficial |
| **Air Quality** | A slight adverse assessment was outlined for children as there are more links with increases than decreases for PM10 and NOx levels in areas with the 20% highest proportions of children. Income quintiles 4 and 5 (less deprived) are assessed as slight to moderate adverse impact. | Slight adverse |
| **Noise** | Noise impacts favour the least deprived income quintiles (slight to moderate beneficial), with neutral impacts for other quintiles.<br>Since there are more properties with decreased noise levels in proximity to schools within the noise impact area, the impact has been assessed as slight beneficial. The population of elderly residents and daytime population of children is greater than national average - therefore, impacts on both of these vulnerable groups are assessed as slight beneficial. | Slight beneficial |
| **Severance** | Forecast changes in the distribution of traffic flows resulting from the scheme leads to an assessment of a slight beneficial impact for older people and a slight adverse impact for children. Disabled residents and no car households were appraised as neutral due to the minimal presence of these vulnerable groups in the study area. | Neutral |
| **Accidents** | Slightly more links are forecast to experience an increase in collision rates than those experiencing a decrease. However, detailed analysis of existing collision data demonstrates that collisions involving the vulnerable groups are generally not significantly different between the affected links and are minimal compared to the wider impact area. Therefore, the impacts on the majority of vulnerable groups is assessed as neutral. | Neutral |
| **Personal affordability** | Assessed impacts mostly favour residents in income quintile 1, 2, 3 and 5, with a slight adverse impact appraised for income quintile 4.<br>Therefore, the impact is mainly beneficial, but is distributed relatively unevenly. | Slight beneficial |

# 7. Value for Money Assessment

The Economic Dimension for the M4 Junction 17 OBC seeks to establish the extent to which the scheme provides good value for money in relation to impacts on public accounts by improving transport economic efficiency for all users.

The economic assessment compares the monetised costs and benefits of the proposed scheme (the Do Something) against the alternative without scheme scenario (the Do Minimum).

The costs of the scheme used in the assessment comprise the scheme construction costs plus maintenance and renewal costs. These costs are described in detail in Section 5.4.

The benefits of the scheme have been assessed both in monetised form and through qualitative methods, as appropriate to the various components of benefit. The monetised benefits have been calculated from a number of sources, drawing on inputs from the traffic modelling and various other datasets. These assessments have included:

- User benefits during normal operation (savings relating to travel times and vehicle operating costs and impacts on indirect revenues) have been assessed using TUBA;
- User disbenefits during construction have also been assessed using TUBA;
- Accident savings have been forecast using COBALT;
- Environmental impacts on greenhouse gas emissions, air quality and noise have been assessed using DEFRA's Emission Factors Toolkit (EFT) and Noisemap®; and
- Reliability impacts have been assessed based on TAG A1.3 guidance.

Qualitative assessments have been undertaken to assess benefits related to:

- Wider economic impacts;
- Social and distributional impacts; and
- Further environmental impacts.

An initial Benefit Cost Ratio (BCR) has been calculated over the 60-year appraisal period that excludes the outputs of the journey time reliability assessment, with an adjusted BCR also reported that includes these impacts.

All benefits and costs were calculated in monetary terms and expressed as present values (PV) in 2010 prices, discounted to 2010.This enables direct economic comparison with other schemes which may have very different timescales.

The scheme is forecast to produce user benefits of £55.3m (PV) over the 60-year appraisal period.

These benefits are generated by travel time savings of £50.0m and vehicle operating cost benefits of £4.0m due to the proposed scheme generating reductions in congestion which requires less fuel to be consumed and lowers wear and tear on vehicles. Safety benefits of £2.2m are forecast due to increased use of safer roads, while noise benefits of £0.2m have been calculated because of traffic moving away from populated areas.

Disbenefits of the scheme include a £2.5m increase in greenhouse gas emissions and £0.3m increase in particle emissions resulting in adverse impacts on air quality as a result of increased fuel consumption. Indirect tax losses of £0.6m have been calculated relating to expenditure on vehicle operating costs and approximately a £0.5 disbenefit is forecasted as a result of traffic management during the construction period.

A reliability benefit of £2.6m has been forecast, resulting from reduced congestion, which has been included only in the adjusted BCR.

It is noted that there are some small apparent inconsistencies in some of these outputs relating to findings on fuel consumption, which have been discussed in section 5.10 and are considered to be justified.

The total scheme costs inclusive of construction and maintenance are £21.8m (PV).

With consideration of the positive and negative user benefits and non-user benefits the initial BCR is 2.4 which represents 'High' Value for Money (VfM)[11] based on the monetised elements of the assessment. Inclusion of journey time reliability benefits gives an adjusted BCR of 2.5.

The scheme is forecast to generate wider economic impacts, but they are anticipated to be modest in scale as a result of the characteristics of the scheme and its impacts on travel costs and the economic characteristics of the study area. Given the limited anticipated scale of the impacts, it was not considered proportionate to monetise the agglomeration and labour market impacts at this stage.

Further non-monetised benefits have been captured including social and distributional benefits and additional environmental benefits. These non-monetised impacts have all contributed to the assessment of value for money of the scheme.

In addition to all of these assessments which have considered the most likely outcomes, various sensitivity tests have been undertaken. These have included scenario modelling to reflect high and low demand, high and low cost, high and low value of time and high and low carbon price scenarios. A cumulative risk assessment has been prepared considering the level of uncertainty in the benefits and costs of the scheme and how this will combine to affect uncertainty in the BCR.

Switching values have also been considered to identify the scale of change in benefits or costs required to result in a change in VfM category from the central forecast of 'High' VfM.

These uncertainties have indicated that, while there is little probability of variations to circumstances resulting in the VfM category rising to 'Very High', it is possible that it could fall to 'Medium', for instance if future levels of traffic growth are substantially lower than forecast, or if value of time growth in the future has been significantly over-estimated. Therefore, the final assessment of VfM for the M4 Junction 17 scheme has been rated as 'Medium to High'

[11] According to the DfT Value for Money Framework https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/918479/value-for-money-framework.pdf

# Appendices

# Appendix A. Economic Appraisal Approach

## Purpose of this Appendix

This appendix provides a detailed explanation of the approach taken to analysis of transport user benefits based on DfT's TUBA software, expanding on the details provided in the Economic Dimension. Due to the nature of the scheme and the modelling packages available a bespoke approach has been applied to enable a reliable assessment of impacts both directly around M4 Junction 17 (M4J17) and those in the wider region which will be affected by improvements to this junction on the Strategic Road Network (SRN). This approach was discussed and agreed in principle with DfT in December 2021.

Details are provided below of the reasons why it has been considered necessary to develop a bespoke approach in the case of this economic appraisal, the method which has been used and the approach taken to identifying this preferred method.

## Background

In 2021 strategic modelling of the M4J17 scheme was undertaken using the SATURN-based Wiltshire Transport Model (WTM), with the intention of informing the economic appraisal. This modelling was based on an average peak period level of flow.

In parallel to this, a VISSIM model was developed as an operational model to enable testing and ensure sufficient capacity would be provided to meet the demand requirement up until at least the design year for the scheme.

These two models had different purposes and a range of different specifications related to the scope and level of detail of each in the M4J17 area, so an exact match between the two would not be expected. However, both models were intended to provide forecasts of the future performance of the junction and so would be expected to provide a degree of consistency.

Having reviewed the levels of delay which each model was forecasting would occur, the level of divergence was found to be significant enough as to cast considerable doubt over the findings of the economic analysis which had been informed by SATURN. In particular, the VISSIM modelling, which had undergone highly detailed validation across M4 Junction 17, was indicating high levels of delay in the 2036 DM scenario, much of which would be relieved by the proposed scheme. The SATURN modelling however showed little delay in either DM or DS scenarios.

A review was therefore undertaken of the specifications and the outputs of the two models to better understand why this large difference was occurring.

## Model Comparison

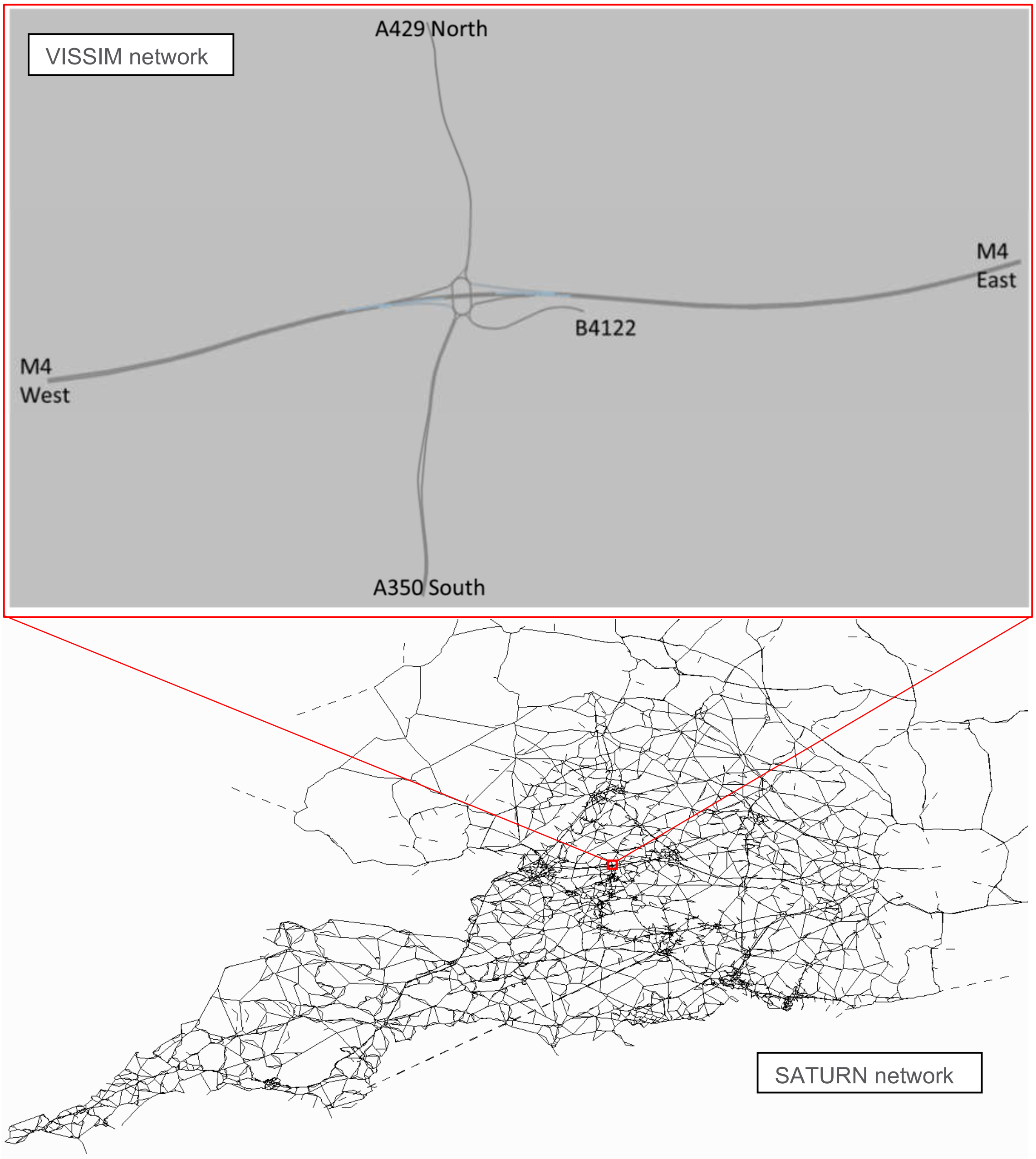
### Model Specifications

An initial review of the SATURN and VISSIM models focussed on how each had been defined in terms of scope. This review identified the following variations:

**Table A-1 - Model Variations**

| | SATURN | VISSIM |
|---|---|---|
| Scope of Network | See Figure A-1 | |
| Time period represented | Peak periods based on average flow over 3 hours.<br>Interpeak based on average over 6 hours. | Peak periods based on 15-minute intervals over 3-hour periods. The split of flow between these intervals was consistent with base year profiling of flows. No interpeak modelling was used. |
| Forecast years | 2024, 2036 and 2051 | 2036 |

**Figure A-1 - Model Layouts**




### Model Structure and Limitations

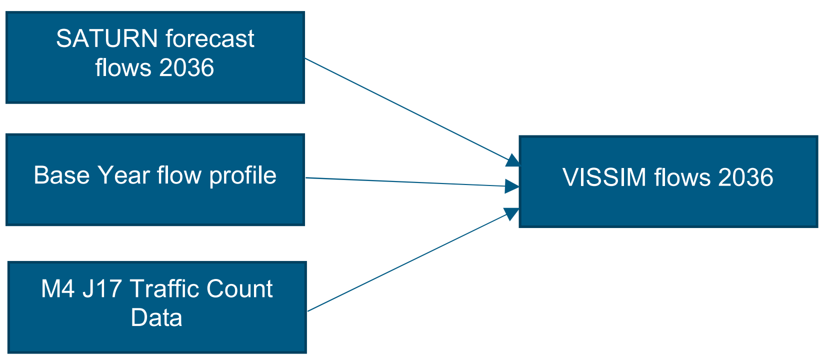
In addition to these variations in specifications and scope of the models the two modelling packages themselves have been designed for different purposes and have different strengths and advantages in representing traffic behaviour and forecasting future performance. A summary of these differences is set out in Table A-2.

**Table A-2 - Advantages and Limitations of Modelling Approaches for Application to Economic Appraisal**

| Modelling Platform | Advantages | Limitations |
|---|---|---|
| SATURN approach | • Technically more recognised approach, with representation of complete journeys.<br>• Able to capture strategic rerouting. | • Complexity of interaction of traffic from different arms of the junction is not so well represented in SATURN.<br>• Poor representation of the variation in flows across peak periods, due to use of average peak period.<br>• Potential for model noise in the outskirts of the modelled area to distort benefits. |
| VISSIM approach | • More suited to representation of detailed junction interactions.<br>• Retains a degree of consistency with operational assessment. | • Less conventional approach to appraisal for a strategic network improvement[12].<br>• Limited ability to capture potentially significant re-routing impacts, or knock-on impacts on other parts of the network.<br>• Re-routing could complicate the rule of a half calculation.<br>• Not fully developed for appraisal. Additional work required to add to existing modelling. |

Based on these assumptions Figure A-2 illustrates how trip numbers and profiles have been developed. This process has been applied for AM and PM peak periods and for the DM and DS scenarios.

**Figure A-2 – VISSIM Flow Forecasts**




## Modelling Assumptions

As well as the variations in model scope and structure, certain key assumptions were identified as including differences between the two models.

**Table A-3 – Variations in Assumptions**

| | SATURN | VISSIM |
|---|---|---|
| Demand at M4J17 | Demand is identified at a zonal level and so flows across M4J17 are determined by the levels of | Demand is initially informed by the SATURN base year model, but uses flows adjusted to better |

[12] Though less conventional it is not without precedent, as the M25 J28 Full Business Case has been developed based on VISSIM modelling, informed by SATURN demand inputs.

| | SATURN | VISSIM |
|---|---|---|
| | delay on different routes which may make the route through M4J17 more or less attractive. This is a dynamic allocation of demand which responds to variations in journey times across the network and so the flow in the DS scenario can vary from the DM scenario. | reflect count data at a site in the proximity of M4J17. Flows are fixed in each of the DM and DS scenarios and cannot respond to changes in journey times. |
| Signal Optimisation | Signals optimised for forecast demand levels at M4J17. | As an operational model, initially signal timings had been optimised in the DS scenario only. To provide a more representative forecast of impacts of the proposed scheme, to compare against those forecast in SATURN, the signal timings in the DM scenario were also optimised. |
| Do Minimum Network | Excludes any variations from the existing layout which are considered to be dependent on the M4J17 scheme. | Included certain network upgrades which would only occur with the M4J17 scheme. |

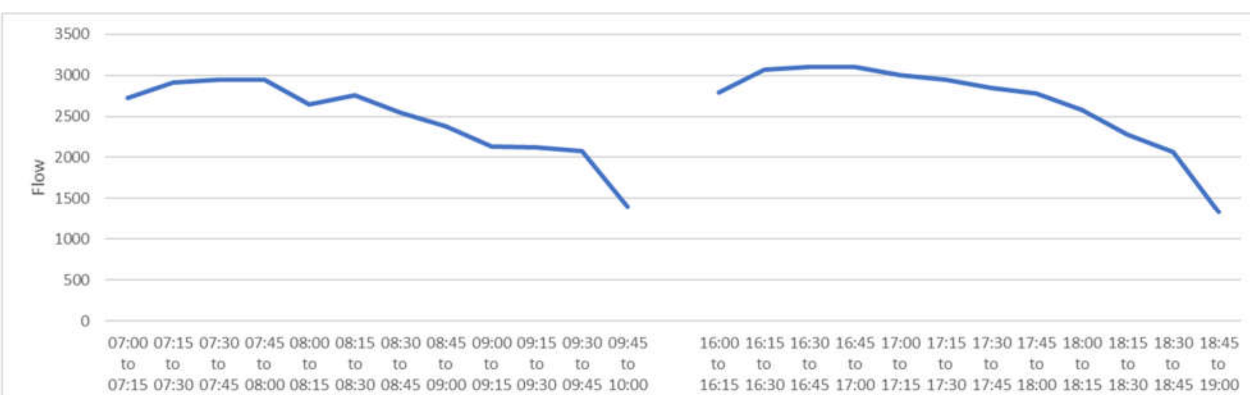
## Outcome of Comparison

The stages of review set out above highlighted a number of substantial differences between the models, some of which had the potential to lead to the large difference in forecast performance of the junction which had been observed. The key contributors were identified as:

### Flow profiling

Traffic flows during the peak periods showed a high level of variation, with the last hour of both the AM peak period and the PM peak period having substantially fewer trips across M4J17 than during the earlier hours as illustrated in Figure A-3.

**Figure A-3 – Flow Profiles – Base Year**




The high levels of early flow in VISSIM result in queues at the junction starting to build up early in simulation period and levels of flow later on are constrained by the longer journey times created by these queues. It is only towards the latter part of the modelled periods that the flows become sufficiently low for the queues to disperse. The result of this is that forecast delays in the DM scenario are much more pronounced in VISSIM in the earlier hours of each period, but with low delays in the latter hours.

SATURN assumes a smooth flow profile over the 3-hour peak periods, with the result that the average flow is significantly lower than the busiest part of the peak period. Because of this traffic does not experience long delays and long queues do not form in the way forecast by VISSIM.

This suggests that a peak-hour model in SATURN would have provided a better representation of benefit than the peak-period model, but this would have lost the ability to forecast benefits during the periods with lower flows.

### Strategic Re-routing

The inability of VISSIM to redirect traffic onto other routes based on variations in journey time across M4J17 between different scenarios is one of the key limitations of the software for use in economic appraisal. Combined with other variations between SATURN and VISSIM model structures and assumptions this limitation was resulting in over-estimates of flow across the junction in future forecast years in the DM scenario.

Due to the lack of flow profiling in SATURN described above, levels of forecast delay at M4J17 were being under-represented. This meant that traffic flow being assigned to the network on routes passing through the junction was higher than would have been the case if journey time were more accurately represented.

These high flows in the DM scenario were passed to VISSIM, and with its more accurate flow profiling over the peak period this resulted in high levels of forecast delay. However, VISSIM has no capacity to reassign traffic to alternative routes and so these high delays remained in the final outputs.

In addition to trips choosing to either travel via M4J17 or via an alternative route, for a number of more strategic trips and even for some local trips going to or from the area immediately south of the junction, there are a number of alternative routes through M4J17 which can be followed dependent upon which incurs the least delay. Because trips in VISSIM are locked into a particular entry and exit point on the network (as illustrated in Figure A-1) even this relatively localised rerouting cannot be captured.

### Scope of Network

While the SATURN modelling experiences certain limitations in capturing benefits for movements across M4J17 itself, it is the only means for capturing the impacts of any rerouting on other sections of the network.

Reductions in congestion at the junction forecast to be generated as a result of the proposed scheme will reduce the volume of traffic diverting to use alternative routes, with M4 J16 and M4 J18 and the section of local network used to access these points on the SRN particularly affected. Increased traffic on local roads accessing J17 will also have negative impacts on other traffic which is using the same parts of the network but not benefiting from improvements at J17.

These strategic impacts are entirely excluded from the VISSIM modelling, but can be captured by SATURN if the level of rerouting is well represented.

### Other Factors

The other factors which have been discussed above all contribute to variations between SATURN and VISSIM outputs, but are of less significance in their contribution to the appraisal.

The exclusion of the interpeak period from VISSIM will have limited impact, as delays forecast in SATURN in the DM scenario during the interpeak are much lower than those in the peak periods. Therefore benefits will be substantially smaller and make up only a fraction of the total.

The VISSIM modelling, originally developed to consider only 2036 has been extended to also include 2024 to give a more consistent contribution to the economic appraisal, details of which are set out in the following section. Forecasts for 2051 are inherently less certain than those of less distant forecast years and so the exclusion of growth beyond 2036 has been considered appropriate.

The potential for model noise within SATURN has been examined and outputs filtered accordingly to minimise any distortion to outputs.

### Response to Comparison of Models

The outcome of this analysis was to conclude that neither the existing SATURN or VISSIM model in isolation were well suited to the economic assessment of the M4J17 scheme impacts. SATURN alone resulted in under-representation of delays in the DM scenario due to its peak period representation of demand. For the same reason VISSIM was limited by using demand outputs from SATURN which under-estimated the scale of diversion of traffic away from the junction. VISSIM was also unable to represent any of the impacts of delays causing traffic to reroute, either for the wider network or for the junction itself based on any variance to delay between the VISSIM and SATURN forecasts.

It was therefore determined that an alternative approach would be required which made better use of the advantage of each of the two models.

## Resolution of Model Disparity

This section sets out details of the bespoke process put in place to enable an improved assessment of economic benefits of the scheme, drawing on both SATURN and VISSIM components of the modelling.

### Model Refinement and Limitations

With awareness of the modelling limitations set out above, each element of the modelling and related appraisal was refined and developed from its initial state to overcome these so far as possible. The aim of this refinement was to ideally find a resolution whereby one or other of the models could be developed to an extent that it could provide reliable analysis for input to the economic appraisal, but if that were considered not to be feasible then to find an alternative approach.

#### Refinement of SATURN Assessment

As part of the initial appraisal process based on SATURN, measures have been taken to mitigate the described weaknesses so far as is possible. A benefit masking process has been developed to minimise the potential impacts of model noise, providing improved confidence that the captured benefits are directly related to the network changes introduced as part of the proposed scheme.

However, to improve the representation of the variation in flows across the peak period would require significant reconstruction, calibration and validation of the model. The limitations on the ability of the software to represent highly detailed interactions across the junction cannot be resolved while using this software alone.

#### Refinement of VISSIM Assessment

The VISSIM modelling would provide a solution to both of the key remaining limitations of the SATURN modelling use in appraisal, relating to detail of flow profiles and traffic interactions. Flow input to VISSIM is introduced at 15-minute intervals throughout the 3-hour peak periods, based on recorded flow patterns, while the software is designed specifically for detailed representation of interacting flows of traffic at a localised level.

A refinement of the VISSIM modelling was therefore developed to replicate conditions in the SATURN model, in terms of do-minimum network provision and demand to exclude those elements which had been considered dependent on the scheme.

The model was extended to use a forecast year of 2024 as well as 2036 and the network represented in VISSIM was aligned as closely as possible to existing links in the SATURN network to enable direct transfer of information between the two and to allow outputs to be generated from the two models without double counting or exclusions.

#### Limitations of VISSIM Assessment

From a technical perspective, the key challenge relating to use of VISSIM for the economic appraisal is the exclusion of the wider network, meaning that only a short section of each trip is captured, rather than measuring impacts on origin to destination movements. This causes certain complications which are detailed below:

- Changes in journey times across the junction between DM and DS scenarios will result in a proportion of traffic diverting, so that it passes through the section of the network represented by VISSIM in either the DM or DS scenarios, but not in both. VISSIM alone will not capture these impacts, due to the limited scope and would interpret this as a change in trip numbers (i.e. trips being generated or supressed) rather than a change in route.

As benefits are calculated using the rule of a half, this may result in a distortion to the calculation of user benefits. E.g. if a trip diverts around Junction 17 in DM to avoid delays, but passes through Junction 17 in DS the calculation of benefit should be measured as:

GJT benefit = 0.5 x (DM demand + DS demand) x (DM time – DS time)

Where:

DM demand = 1 and DS demand = 1

as for simplicity this example is focussed on a single trip

DM time = DM time around Junction 17

DS time = DS time through Junction 17

However, if using only VISSIM, the inputs to this calculation (for diverted trips) would be:

DM demand = 0

DS demand = 1

Therefore only half of the time saving across the junction would be recorded as a benefit.

- Such variations in flow in the DS scenario would result in changes to the forecast journey times.
- Just as flows through Junction 17 would be affected by changes to journey times between DM and DS scenarios, flows across the wider strategic network would also change. This will affect journey times outside of the VISSIM network and result in (dis)benefits for traffic which are entirely outside the scope of VISSIM.

The scheme is most likely to result in an increase in flow through the junction, as delays are mitigated. However, the difference in journey time across the junction between DM and DS scenarios is likely to be greater than the actual difference between DM and DS journey times for a given trip, as the DM diversion route would only be used if it were quicker than the DM time through the junction. This is illustrated in Figure **A-4**.

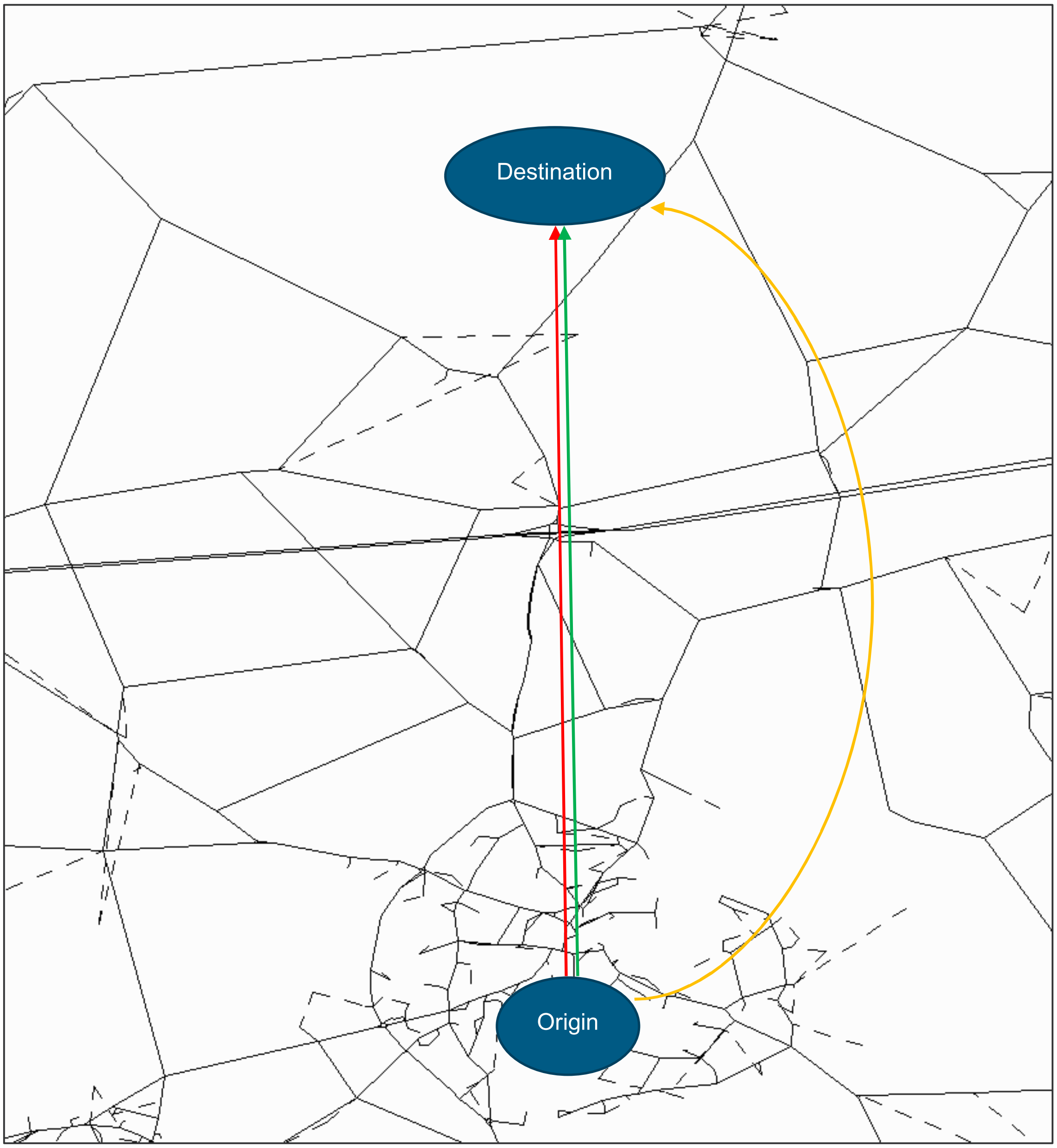
For a trip between the indicated origin and destination, the lines indicate the following:

- Red = DM journey via Junction 17
- Orange = DM journey not via Junction 17
- Green = DS journey via Junction 17

In the DM scenario, if the diversion around Junction 17 gives the faster journey time then the majority of trips will follow the orange route. If the scheme reduces congestion at Junction 17 so that it becomes quicker to follow this route rather than the diversion, then the benefit per trip will be the difference between the orange route in DM and the green route in DS. This difference will be less than that between the red route in DM and the green route in DS, which is what VISSIM would measure.

Therefore, this difference in application of the rule of a half between SATURN and VISSIM would be expected to result in an over-estimate of benefits if based on VISSIM alone.

**Figure** A-4 **- Application of the Rule of a Half in VISSIM**




## Hybrid Modelling

As neither the SATURN modelling nor VISSIM modelling alone could be developed in such a way as to provide robust assessment of user benefits, an alternative hybrid method, making use of information from both models has been considered most reliable.

The 'Hybrid' method which has been devised draws on VISSIM's ability to accurately reflect the performance of traffic as it passes across M4 Junction 17 and its detailed time profile of flows, while building in SATURN's ability to represent rerouting options across the wider network and the effects of this rerouting on other traffic.

In order to provide the most robust assessment based on a combination of the two models, a level of interaction between them is required. For this to operate effectively it has been necessary that the models were developed to be as consistent as possible.

In terms of network representation, the models already had a high level of consistency, in that the full VISSIM network was reflected by existing links in the SATURN model. The key difference effecting traffic behaviour was the scale of delay for trips entering Junction 17 in the DM scenario, with entries from the A350 (south) and A429 (north) most affected.

As had been established by the earlier use VISSIM in its role as an operational model, the DS scenario showed much more limited delays up the design year and was therefore more consistent with the SATURN model. Further analysis was therefore focussed on the DM scenario and finding a method to achieve a level of consistency between SATURN and VISSIM in this case.

### Interaction between Models

To better reflect the performance of M4J17 in the DM scenario with respect to traffic entering the junction from the more congested A350 and A429 arms a series of tests were undertaken. The aim of these was to understand how increasing delays would affect travel behaviour and route choices. These tests involved introducing a time penalty to the relevant arms in the SATURN model to represent the additional expected delay, based on the VISSIM outputs.

At the upper end of this scale, the delays forecast by the existing VISSIM model were applied, while at the lower end of the scale no additional delay was applied. Incremental steps between these two points were also modelled to evaluate the extent of rerouting caused as delays increase.

The VISSIM model for the 2036 AM peak with no rerouting applied had forecast delays of around 15-minutes for trips entering M417 from the A429 or the A350. Tests in SATURN were conducted applying delays to these arms of 2, 5, 10 and 15 minutes. Table A-4 indicates the scale of diversion away from M417 resulting from each of these tests.

**Table A-4 - Testing of Scale of Diversion at M4 J17**

| Additional delay applied at A350 and A429 | Reduction in flow at A350 | Reduction in flow at A429 |
|---|---|---|
| 0 minutes | 0% | 0% |
| 2 minutes | 8% | 15% |
| 5 minutes | 56% | 61% |
| 10 minutes | 75% | 80% |
| 15 minutes | 93% | 94% |

These results indicate the most significant shift in behaviour of traffic occurs between the 2 minute and 5-minute delay points. As further delay is added, more traffic continues to divert away from the junction, but the rate of diversion slows. The equilibrium point, at which traffic diverting away from the junction will result in reductions to delay, which in turn will lead to lower levels of diversion, appears very likely therefore to occur at around the 5-minute delay level.

Further examination of these iterative tests indicated that a proportion of traffic diverting away from the A350 as a result of the added delays was choosing to use the B4122 entry to M417 instead. Similarly to the A350 and A429, this route displays very little delay in SATURN, but is somewhat more congested in VISSIM, though to a lesser extent than the other arms. To balance this effect of diversion from the A350 to the B4122, a further test was performed in SATURN in which, in addition to the 5-minute delays added to the A350 and A429 a 3-minute delay was applied to the B4122. This resulted in flows on the B4122 being comparable to those forecast with no additional delays applied, effectively balancing the impact of the 5-minute delay added to the A350.

While this is substantially lower than the 15-minute delay observed in VISSIM, analysis of the surrounding network and of behaviour of traffic in SATURN where re-routing around M4J17 was an available option, showed that certain minor roads would provide a limited level of spare capacity, while other longer distance routes would provide options for a proportion of the traffic to avoid M4J17 if delays did become excessive. Further analysis on this point is set out in Section 0.

## Limitations of Interaction

Based on the findings above, the ideal solution would be to follow the iterative process employed by SATURN to reroute traffic, identify the impact on journey times of all routes, reroute traffic again and continue to repeat this process until equilibrium is reached. However, there is no means to enable VISSIM and SATURN to directly communicate to enable such a process. Therefore, any such transfer of information requires manual extraction of data from one model and input to the other. That model then needs to be run and the same process repeated to feed data back to the first model.

This is a very time-consuming process making it impractical to follow this ideal solution. An alternative method was therefore required to approximate the same outcome.

## Hybrid Model Process

Based on the analysis above the following process for preparation of modelling inputs to the economic appraisal and calculation of user benefits was developed. The process is illustrated in Figure A-5. As has been described, levels of delay in the DS scenario for both VISSIM and SATURN were very low with a good level of consistency between the models and so this process has focussed on refining the DM scenario in both VISSIM and SATURN to achieve a similar level of consistency.

**Modelling Process**

1. Forecast Trips Modelled in Demand Model

2. Trips Assigned to Strategic Network in SATURN. Forecast flows are passed from SATURN to VISSIM and assigned to network – at this stage no rerouting will be possible in VISSIM.
   Outputs from the DS SATURN scenario were extracted to inform a TUBA assessment.

3. Trip data across M4J17 is extracted from DM and DS SATURN models to feed into VISSIM.
   Outputs from the DS VISSIM scenario were extracted to inform a TUBA assessment.

4. The DS SATURN model was used to generate a cordoned version of itself, excluding all of the network outside of the area represented by VISSIM.
   Outputs from the DS SATURN cordoned scenario were extracted to inform a TUBA assessment.

5. Delay forecast at Junction 17 in VISSIM (step 3) is passed to SATURN in the form of delay added on key links (as adjustments to step 4). This informs a range of delay scenarios modelled in SATURN with VISSIM delay forecasts providing the upper limit. Based on the analysis set out in section 0 this range of delay inputs was set as 3 minutes, 4 minutes and 5 minutes added to the A350 and A429 links.

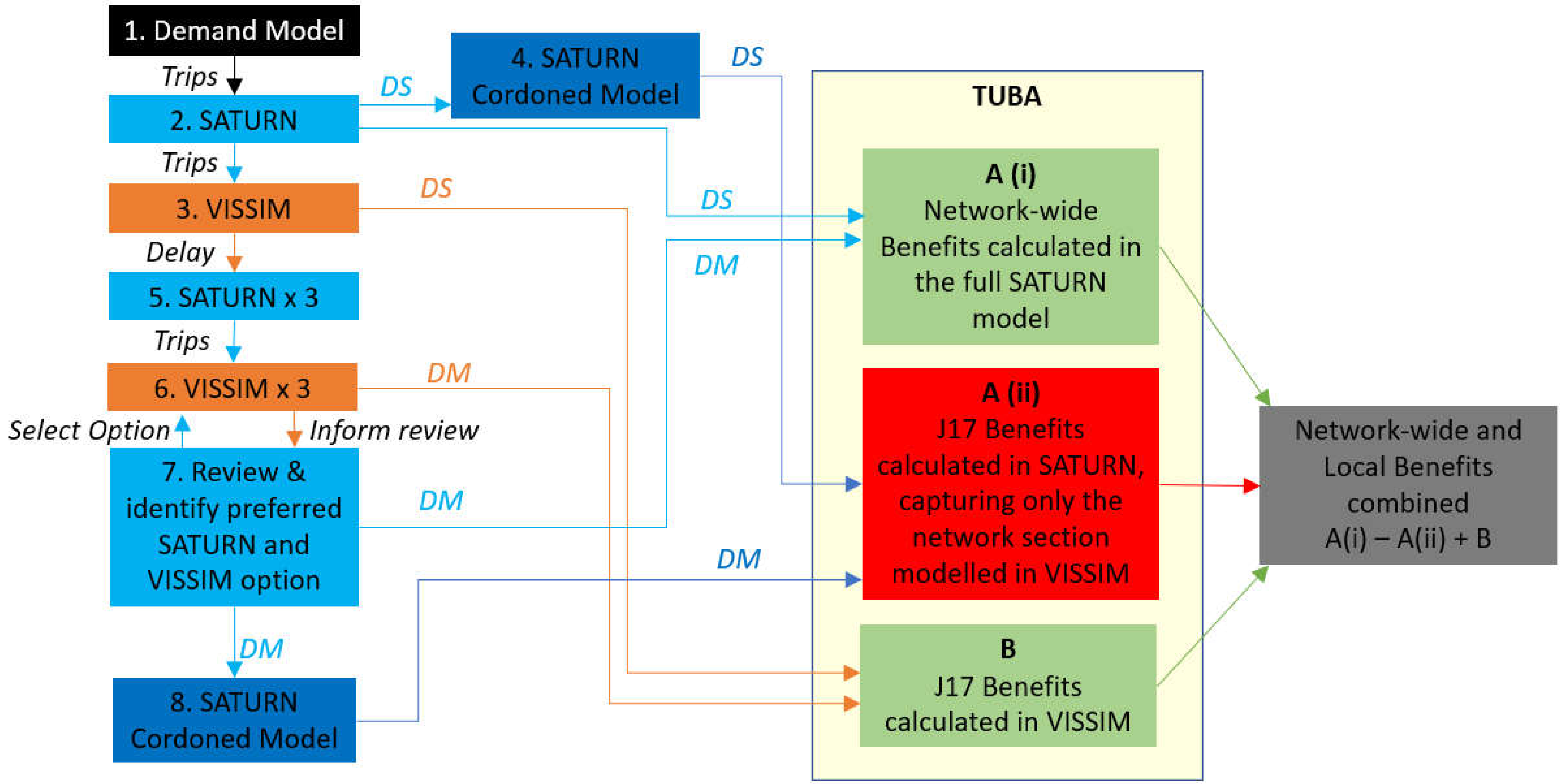
6. Demand from the three delay scenarios modelled in SATURN was fed back into the DM VISSM model and re-assigned, generating three VISSIM scenarios with no delays added to the A350 or A429 links, but with traffic across M4J17 reflecting the impacts of these delays having been added to the SATURN network.

7. A review was undertaken of these delay scenarios to identify which of the SATURN and VISSIM models were considered the most representative and confirm that the selected models indicated comparable performance (as summarised in 0). If this were found not to be the case for any of the modelled options, then it would be necessary to return to Step 5 and extend the range of delay scenarios. Details of this review are set out below.
   Outputs from the DM SATURN scenario (Step 5) were extracted to inform a TUBA assessment.
   Outputs from the DM VISSIM scenario (Step 6) were extracted to inform a separate TUBA assessment.

8. The DM SATURN model was used to generate a cordoned version of itself, excluding all of the network outside of the area represented by VISSIM.
   Outputs from the DM SATURN cordoned scenario were extracted to inform a TUBA assessment.

Further details of elements of this process are described below. This first focusses on Step 7, the process whereby the range of delay scenarios was manually reviewed to identify the best fit. An explanation is then provided of how the various components were brought together to generate a meaningful and robust economic appraisal.

**Figure A-5 - Hybrid Appraisal Process**



## Review of Delay Scenarios

As described above, Step 5 of the Hybrid process involved modelling of 3 scenarios in SATURN with delays added to the A350 and A429 arms of M4J17, with increments of 3, 4 and 5 minutes, to reflect the higher level of forecast delay output by VISSIM. As it was not possible to go through a large number of iterations of this feedback loop to establish convergence in the traditional sense, a manual review of this limited number of scenarios was undertaken to identify which returned the most likely outcome which would be achieved if further iterations were to be performed.

This analysis involved consideration of the impacts of the added delays on both trip numbers and journey time delays across the junction, with both AM and PM peaks considered for the 2036 forecast year.

Set out below are charts illustrating peak hour flows and average journey times across M4J17 considering the extent of the network represented in VISSIM. As journey times are origin-destination based, an average time has been taken for movements from each origin to all possible destinations, weighted according to the number of vehicles making each trip.

**Figure A-6 – Peak Hour Flow Variation - AM Peak**

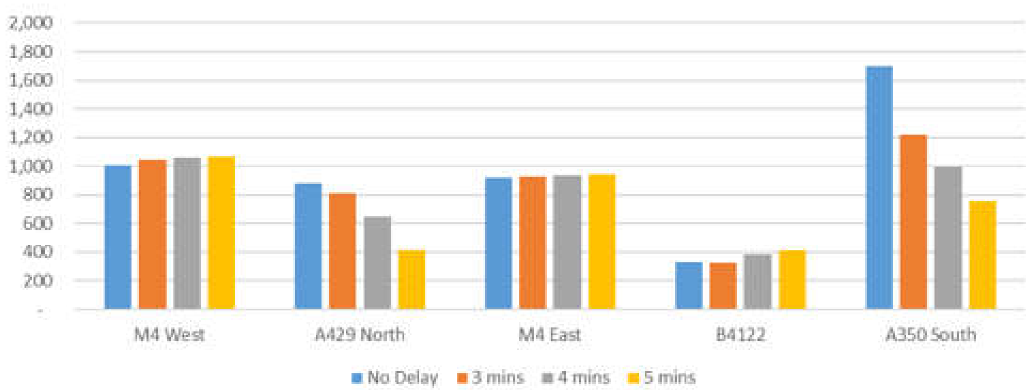



**Figure A-7 – Peak Hour Flow Variation - PM Peak**

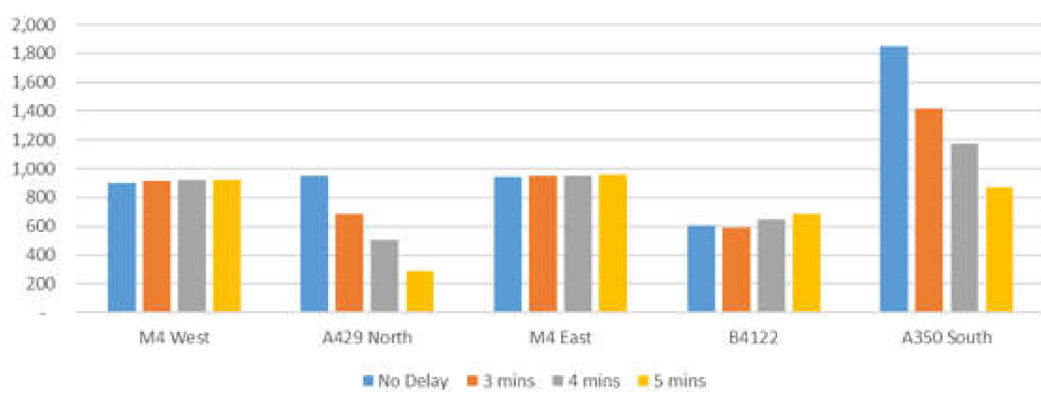
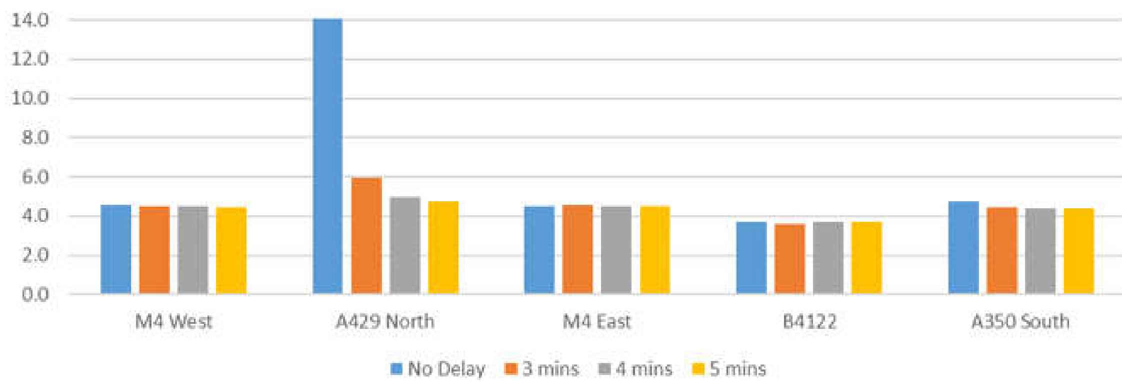



Figure A-6 and Figure A-7, indicating impacts on flows across M4J17, demonstrate that the added delays have significant impacts on the levels of flow entering the junction from the relevant arms, but that this has very limited impact on volumes of traffic entering the junction from other directions. The introduction of a 5-minute delay at the A350 results in a drop in traffic flow of around 80%, with a fairly linear pattern in change with 3 minute or 4-minute delays applied.

On the A429 arm reductions in flow resulting from introduced delay are proportionally of a similar scale, but with fewer trips making this movement in the original model with no delay applied.

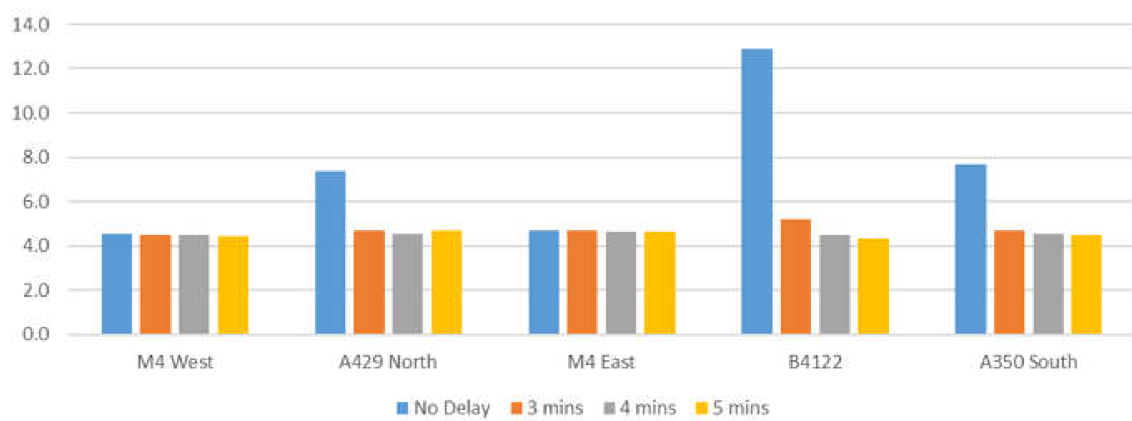
Figure A-8 and Figure A-9 show how these changes in flows translate into forecasts of journey times across the junction when modelled in VISSIM. These show that, in the AM peak the large reduction in flow from the A350 resulting in the addition of delays on this link in SATURN result in very limited variations in journey time. Delays are slightly reduced as a result of the reduced flow, but little delay existing on this arm in the AM peak initially. The A429 arm by contrast shows a high level of delay in the original modelling, but that this is quickly dispersed by even the low levels of diversion of traffic, as introduced by the 3 minutes delay in SATURN. Flow variations resulting from the addition of further delays in SATURN have a very limited impact on journey times in VISSIM.

**Figure A-8 – Journey Time[13] - AM Peak**




In the PM peak the more significant impacts on journey times relate to the southern arms of the A350 and B4122. These also show a pattern of flow changes resulting from a 3-minute delay in SATURN contributing the vast majority of the impacts on journey times in VISSIM, with further diversion away from M4J17 having limited impacts.

**Figure A-9 – Journey Time - PM Peak**




The outcome of this analysis was that the impacts on journey times in VISSIM give a very clear indication that the diversion resulting from addition of a 3-minute delay in the SATURN model and the impact this has on journey times in VISSIM will represent the highest level of consistency between the two models.

As was indicated in Table A-4, the impact of a 2-minute delay is relatively marginal in terms of flow change and so has not been further considered.

The scenario based on 3-minute delays added to the A350 and A429 arms in SATURN has therefore been progressed, both for its use in direct economic assessment of strategic network and for determining the flows used in the VISSIM model.

This analysis was undertaken for 2036 only with a proportionate approach being taken for the 2024 forecast year of assuming a similar level of variation between SATURN and VISSIM models would exist. The same adjustments have therefore been applied.

[13] Weighted average time by origin

### Appraisal Process

The Hybrid appraisal process, as set out in Section 0, results in the production of a range of outputs to inform TUBA assessments based on both SATURN and VISSIM modelling. These outputs contributed to three separate TUBA assessment which have been used together to provide a detailed assessment of the economic impacts of the M4J17 scheme. These scenarios are:

A. The selected SATURN scenario from Step 5, based on review at Step 7. This was used to inform two TUBA assessments:
   i. Based on the entire SATURN network; and
   ii. Based on only the M417 section of the network, as represented in VISSIM, by applying a cordon around this area in the SATURN model (Step 8).
B. The selected VISSIM model from Step 6, identified from the review in Step 7, was used to inform a further TUBA assessment to capture in detail the benefits for movements across M4J17.

Item B forms the core of the economic assessment, as this provides the most detailed representation of the changes to M4J17 itself.

Impacts across the remainder of the network, including any impacts of rerouting to or from Junction 17 are captured based on the SATURN modelling, with the cordoned SATURN model used to avoid any double counting which would result from the overlap with the VISSIM model:

Strategic and Rerouting Benefit (excluding Junction 17) = A(i) – A(ii)

Therefore, the total benefit is measured as:

Total Benefit = B + A(i) – A(ii)

This process is set out in Figure A-5.

## Application of Hybrid Approach

While the TUBA assessment is primarily based on the combination of three models as described above, with the cordoned SATURN model used to remove any double counting of benefits between the other two, the SATURN cordon and Vissim models don't represent exactly the same network areas, due to the lengths of link in the existing SATURN model.

For calculation of time benefits this doesn't affect outputs, as the journey times on the network sections which are represented in the SATURN cordon, but not in Vissim are essentially free flow times and don't change between DM and DS scenarios, so no extra benefit is calculated. This is because the journey time benefit is calculated using the Rule-of-a-Half (ROH) as:

$$0.5 \times (V0 + V1) \times (C0 - C1)$$

Where C is cost (in this case time), V is vehicle trips, 0 is DM and 1 is DS.

Because C0 and C1 are identical on these sections which differ between the models the extra benefit from those extra or extended links is zero, regardless of any changes in trip numbers.

However, some elements of benefit, including greenhouse gases, indirect tax and some vehicle operating costs are calculated as:

$$V0 \times C0 - V1 \times C1$$

So even though the cost per trip is almost identical between DM and DS, the higher level of demand across the junction in DS results in a large disbenefit in both the Vissim and SATURN cordon networks. However, the difference in extent of the models means that this calculated disbenefit does not cancel out between the two.

Flows (V0 and V1) in the Vissim and SATURN networks are the same, with V1 a little higher than V0 as the scheme enables more traffic to pass through Junction 17, but the cost components are somewhat different. Changes to certain elements of cost will occur between C0 and C1 due to variations in speed, but user benefits related to changes in fuel consumption are calculated using the ROH, so will not be affected by the difference in external link lengths. Meanwhile non-fuel benefits are based only on journey distance and in each model the distances are fixed between DM and DS scenarios.

Therefore, these operating costs can be calculated as:

SATURN operating cost = V0 x C(SAT) – V1 x C(SAT)

Vissim operating cost = V0 x C(Vis) – V1 x C(Vis)

These calculation methods will apply to the following benefit groups, while all other impacts assessed through TUBA are measured using the ROH:

- Non-fuel benefits for non-business trips,
- Indirect tax revenues; and
- Greenhouse gas emissions

A review of the changes in flow between DM and DS shows the largest change on the approaches to J17 from the A350 and A429. Increases in flow on the M4 are lower, but will also have a significant impact because of the scale of difference in the lengths of these links in the two models:
Distances

**Table A-5 – Distance Variations Between Models**

| Route | Vissim | SATURN Cordon |
|---|---|---|
| M4 West to M4 East | 7.12km | 22.28km |
| A350 to A429 | 3.96km | 6.00km |

Therefore, for each additional trip forecast to pass from the A350 to A429 as a result of the scheme, rather than following a route outside the scope of these models, the SATURN cordon model will calculate the extra[14] cost of fuel consumption as being that needed to travel 6km, while the Vissim model will calculate the cost of the same trip travelling only 4km. If the extent of the two models were exactly aligned there would be almost no cost differential between the two.

The impacts of changing routes affecting operating costs of this kind are adequately captured within the full SATURN network and so for any elements of benefits calculated not using the ROH the benefits have been based only on the TUBA run performed for the full SATURN network, rather than combining the outputs of the three separate models.

## Impacts of the Hybrid Approach

Having developed this hybrid approach to assessment a review was undertaken to validate the forecast impacts relative to the alternative modelling approaches of either SATURN or Vissim in isolation.
As set out in section 0 the outputs of the Vissim modelling with rerouting of demand having been applied through SATURN indicated variations in forecast journey times across the junction of between 4 minutes for uncongested routes and 14 minutes when high levels of congestion occurred. The application of time penalties resulting in journey times, inclusive of time penalties, of no more than 9 minutes.

By comparison, the Vissim model in isolation had indicated delays of up to 40 minutes in the most extreme case, because of the wide differential in performance of the junction between SATURN and Vissim. SATURN, using the average peak period demand forecasts did not forecast any significant delays, as traffic levels when averaged across the peak period are not sufficient to create congestion. This also resulted in very low levels of diversion away from the junction.

[14] Extra in the context of the scope of these models. The actual change in cost will be captured within the full SATURN network which includes the cost on both the route through J17 in the DS scenario and the alternative route used in the DM scenario.

When the resultant demand across the junction was time profiled in Vissim, the result of no diversion occurring was to create excessive levels of congestion through the high-peak period, which Vissim was unable to divert onto other routes.

The headline benefits from these different methods of analysis were that SATURN in isolation forecast journey time benefits of around £4m (2010 PV) for the scheme while Vissim in isolation forecast benefits of over £140m. The equivalent output from the Hybrid approach of £50m, represents a much more feasible impact than either, based on analysis of how the three approaches affect journey times between the DM and DS scenarios, as set out above.

This total from the Hybrid method is comprised of £30m from the Vissim modelling of the area immediately around the junction and £20m from the SATURN modelling[15] capturing the impacts of trips rerouting across the network, including those which choose to use Junction 17 in the DS scenario but would otherwise have followed an alternative route.

## Sensitivity Testing

High and Low growth scenarios have been assessed to provide an indication of the sensitivity of the scheme to the uncertainty in future travel demand.

Additional sensitivity testing has been carried out to understand potential impacts for varying assumptions, parameters and future performance. These tests have included:

- An update to TAG parameters – the Core assessment has been carried out using TUBA's default parameters file which aligns with DfT's TAG Databook 1.14. This set of economic parameters is consistent with those used in development of the transport model, providing direct correspondence of values which have determined trip rates and route choice with those used to calculate economic benefits.

  A sensitivity test has been applied using the latest TAG Databook (v1.18) to demonstrate the impact of applying latest parameters such as values of time, fuel consumption and carbon values. This update has been applied only to the benefits captured through TUBA and has not involved any update to the transport model itself.

### High and Low Growth

Due to the high level of complexity of the Hybrid method set out above and the time required to generate outputs in this way the High and Low Growth scenarios have followed a somewhat more proportionate approach, while ensuring that a reasonable level of comparability is retained. The High Growth scenario has been modelled in SATURN following the usual methodology as set out in TAG Unit M4. This model has not been progressed through the Hybrid method of assessment using VISSM and SATURN in parallel, as this would require a full repetition of the process outlined earlier in this appendix.

Instead, a detailed review has been undertaken of the performance of the High Growth model relative to the Core scenario, examining benefits from TUBA, flows across the network as a whole and flows across Junction 17.

This review has highlighted the following variations in performance arising as a result of the application of High Growth:

- Total trips across the network increase by 5.8% in 2026 and by 9.2% in 2036 compared to Core levels.
- Trips across Junction 17 increase by 4.6% in 2026 and by 6.7% in 2036 compared to Core levels
- The Core scenario shows 16.4% growth from 2026 to 2036 while the High Growth scenario shows an 18.7% increase in trips over the same period.

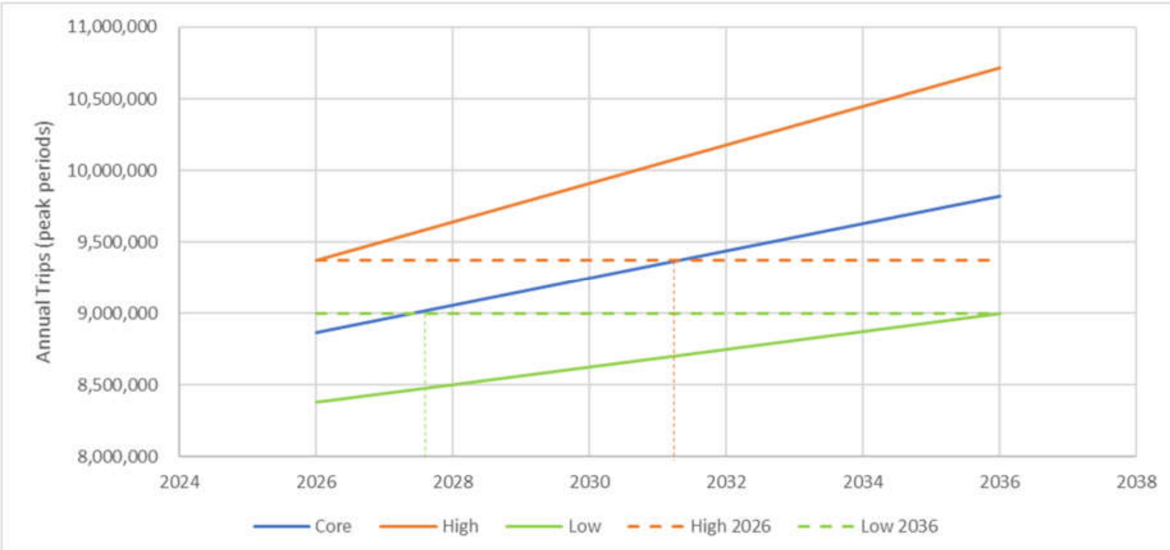
The low growth scenario has not been modelled in SATURN, but given that the approach to modelling of low and high growth scenarios set out in TAG Unit M4 is to use symmetrical levels of growth either side of the core a similar assumption for flows across the junction has been made, deriving flows for the Low Growth scenario based on those of the Core and High Growth scenarios.

Based on these rates of growth over time and the relatively faster increase in trip numbers in the High Growth scenario and slower rate in the Low Growth scenario, this would indicate that the High Growth

[15] The benefit related to the full SATURN network minus the benefit from the cordoned SATURN network, to avoid double counting of Vissim benefits.

scenario in the 2026 forecast year will be comparable in demand on the network to the Core scenario at around 2031, as shown in Figure A-10. Similarly, the Low Growth scenario in 2036 will have comparable flows to the Core scenario at around 2028.

**Figure A-10 – Core, High and Low Growth Traffic Flows at Junction 17**




Benefits of the High Growth scenario in 2026 and of the Low Growth scenario in 2036 at the Junction 17 localised area, may therefore be inferred by interpolation between forecast years of the Core growth scenario forecasts based on Vissim.

In 2036 the benefits generated during the High Growth scenario cannot be directly interpolated from the Core scenario, as flows are high than both Core scenario forecast years. The same is true of the Low Growth scenario in 2026, as flows are lower than any point represented in the Core scenario.

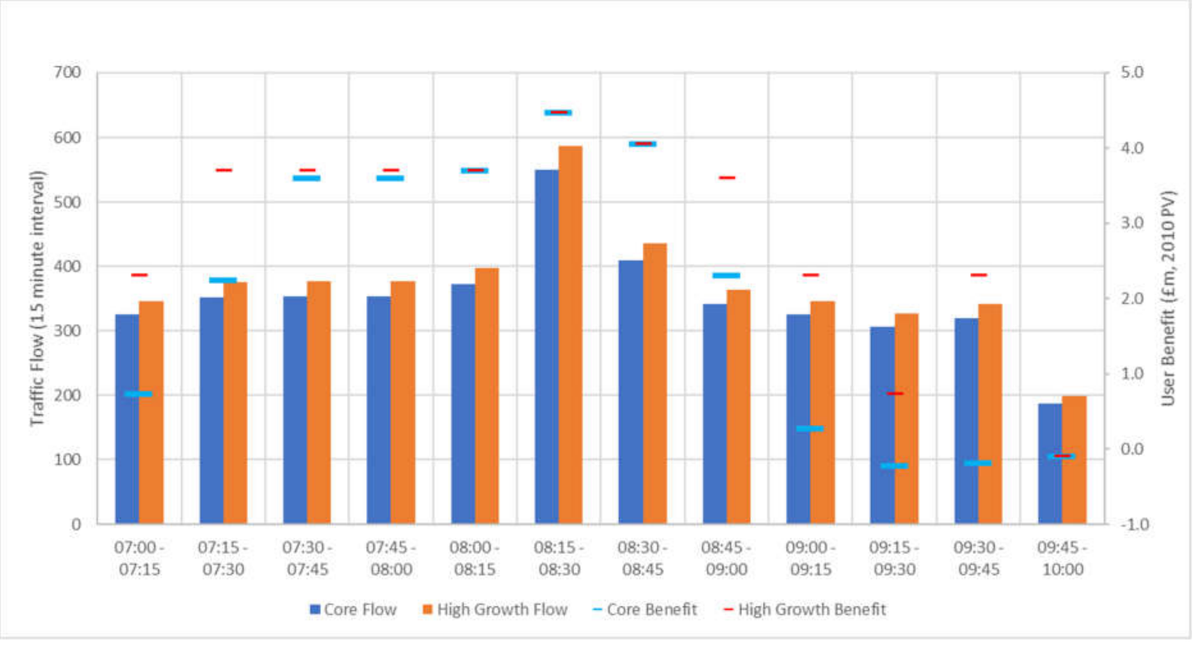
Instead, a review of VISSIM data has been carried out to consider flow levels at 15-minute intervals, to identify representative levels of journey time benefits, where less busy periods across the 3-hour peak period in the High Growth scenario may be well represented by less busy time periods from the Core scenario.

The flow in the High Growth scenario for each 15-minute interval has been matched to an equivalent or higher flow in the Core Growth scenario, taking the most representative interval in each case. Where an exact match is not found the closest match which will not return an over-estimate has been used. The user benefits for those comparable intervals have then been assigned to the High Growth scenario.

As indicated in Figure A-11 all time periods except for 08:15 to 08:30 have datapoints where High Growth flow levels can be matched with comparable flows from the Core growth scenario. This means that user benefits for those periods can be determined with relatively high confidence based on the existing modelling.

The rate of flow at 08:15 to 08:30 in the High Growth scenario is greater than the flow rate in the Core Growth scenario at any time in the AM Peak. Therefore, benefits have conservatively been assumed to be equal to those in the Core scenario for the same time of day.

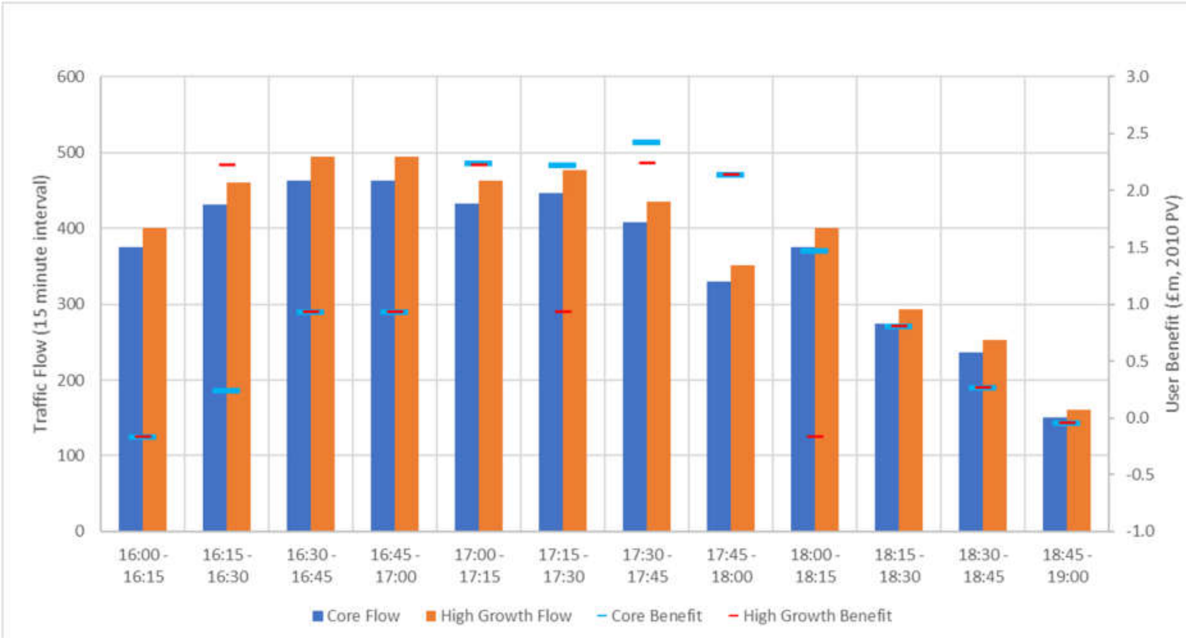
**Figure A-11 – Traffic Flow and User Benefit – High Growth Scenario 2036 Benefits Determined by Core Scenario Modelling – AM Peak**




A similar process has been applied to the PM peak period. In this case 3 time intervals, 16:30 to 16:45, 16:45 to 17:00 and 17:15 to 17:30, all show higher levels of flow in the High Growth scenario than any Core growth time interval. Therefore benefits at these times have been set equal to those generated during the busiest of the Core Growth intervals.

Although these busiest periods of the PM peak have lower flows than certain times in the AM peak, the distribution of flow by direction differs substantially between the AM and PM peak periods, and so it has not been considered appropriate to derive PM peak benefits from the AM peak modelling.

**Figure A-12 – Traffic Flow and User Benefit – High Growth Scenario 2036 Benefits Determined by Core Scenario Modelling – PM Peak**




A similar approach to representing benefits of the Low Growth scenario has been taken, with benefits matched to the 15-minute interval from the Core scenario which best replicates Low Growth flows. Details of this analysis are set out in Figure A-13 and Figure A-14.

**Figure A-13 – Traffic Flow and User Benefit – Low Growth Scenario 2026 Benefits Determined by Core Scenario Modelling – AM Peak**

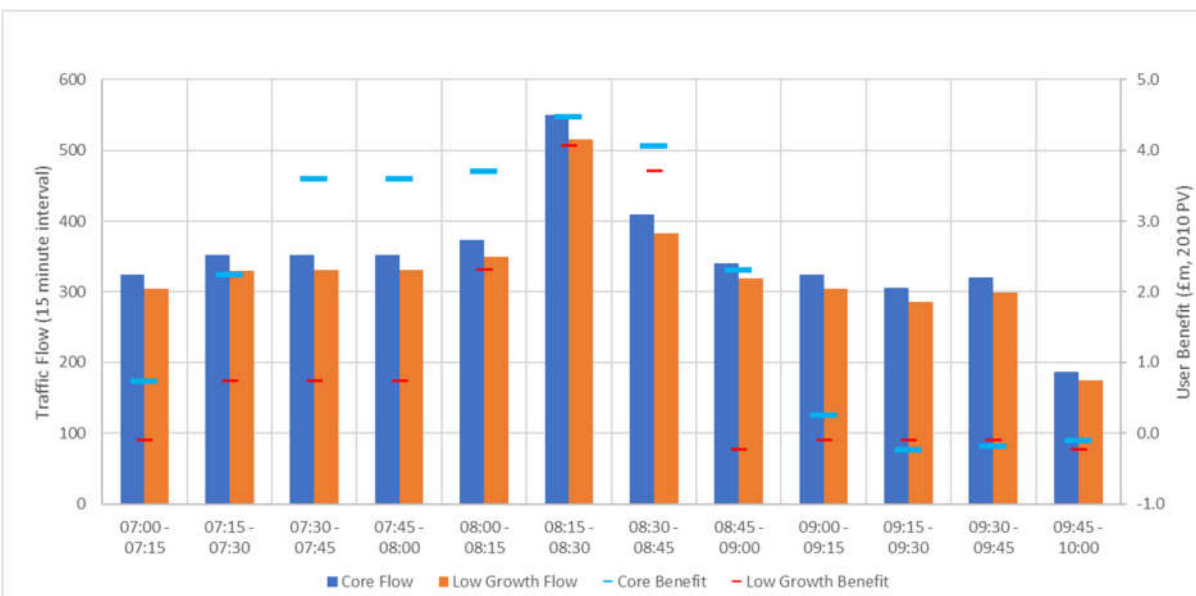
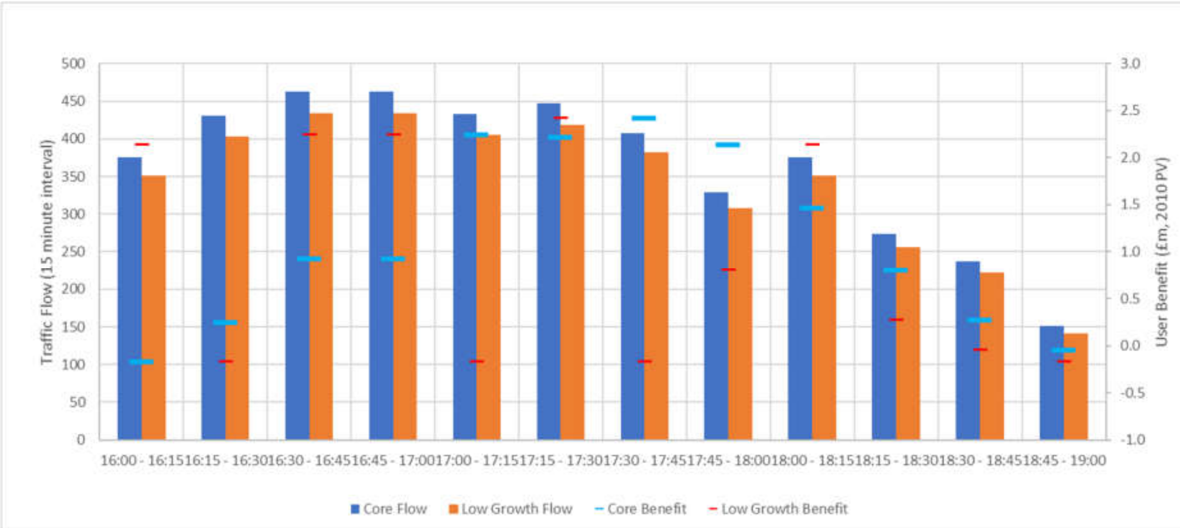


**Figure A-14 – Traffic Flow and User Benefit – Low Growth Scenario 2026 Benefits Determined by Core Scenario Modelling – PM Peak**




The result of this approach indicates a 23.4% increase in user benefits generated across the scope of the Vissim network in the 2036 forecast year under the High Growth scenario, relative to the Core Growth scenario. In the Low Growth scenario, a reduction in benefits of 39.5% compared to the Core 2026 scenario is forecast.

The above analysis has focussed on benefits generated by the scheme in Low and High Growth scenarios in the direct vicinity of Junction 17. Further analysis has been carried out of how the High Growth modelling indicates performance would be affected over the wider network.

Table A-6 provides a summary of annual user benefits forecast based on the network-wide SATURN modelling, disaggregated by forecast year and time period, comparing TUBA runs performed using the Core scenario modelling against those using the High Growth scenario.

Considering the impact of High Growth on user benefits across the wider network, modelled in SATURN, impacts become somewhat less clear. The High Growth scenario in 2026 showed a level of benefit which would be expected based on the growth in flow levels relative to the 2026 and 2036 Core scenario models. However, by 2036 the additional growth resulted in a considerable amount of instability in the model. Congestion in the larger towns and cities in particular such as Bath and Swindon started to show signs of large delays, with outputs of the model becoming highly sensitive and generating significant amounts of model noise which distorted the calculation of user benefits across the wider area. While it was possible to apply masking to results from TUBA to filter out elements of benefit and disbenefit which were clearly not related to the M4 Junction 17 scheme, remaining patterns of benefits suggest that changes in delays between DM and DS scenarios which were not related to the scheme were still being captured and contributing significantly to the benefit totals.

Table A-6 sets out the breakdown of user time benefits derived from the full SATURN network in the Core and High Growth scenarios, disaggregated by forecast year and time period. This shows a high level of consistency in 2026, but by 2036 High Growth benefits have reduced compared the Core scenario. A review of the spatial distribution of benefits across these scenarios indicated that this change is not related to the M4 Junction 17 scheme but is largely related to movements to and from Bath, which are not in locations which suggest masking would be appropriate, but neither do they appear to be scheme related.

**Table A-6 – User Benefits by Time Period and Forecast Year – Core and High Growth (£m, 2010 PV)**

| Year | Time Period | Core Growth | High Growth |
|---|---|---|---|
| 2026 | AM | £0.7m | £0.7m |
| | PM | £0.6m | £0.6m |
| 2036 | AM | £0.9m | £0.8m |
| | PM | £0.8m | £0.6m |

This sort of model noise can often occur when high rates of future growth in traffic are applied to already congested sections of network with no addition of capacity.

While a Low Growth scenario would not be expected to encounter similar issues relating to flows exceeding capacity, the SATURN modelling has only covered Core and High Growth scenarios, with Low Growth traffic and benefits being derived from the relationship between these. As the High Growth performance over the wider network has not been considered to be reliable as an indicator of scheme impacts, neither can it contribute to a Low Growth forecast over this wider area.

Therefore, the economic assessment of the High Growth and Low Growth scenarios has focussed on the impact across the scope of the VISSIM network around M4 Junction 17 itself, so as to avoid potential distortions which may affect the wider network where no network alterations have been applied.

# Appendix B. Application of Revised Modelling and Appraisal Approach

Review of the existing modelling has been undertaken to establish what will be the most appropriate and proportionate approach to preparation of the assessment described above. The following areas have been considered.

## Forecast Years

Forecast years which had been developed for the two models included:

- Opening year of 2024 (SATURN & VISSIM)
- Design year of 2036 (SATURN & VISSIM)
- Horizon year of 2051 (SATURN only)

VISSIM has not been tested for 2051 and the additional growth in traffic is likely to lead to more extreme delay scenarios, with sensitivity of performance of the scheme to the ability of traffic to divert becoming a greater factor in the assessment of performance. A conservative and proportionate approach has therefore been taken to assess the benefits up until the 2036 forecast year and assume no further growth in user benefits beyond that point.

## Do Minimum and Do Something Scenarios

The purpose of the approach set out in Figure A-3 is to bring together the much higher levels of delay forecast by VISSIM and the rerouting forecast by SATURN in a single system which provides an equilibrium between the two elements. The determining factor which established the requirement for such a process was the large difference in delays forecast by the two models.

However, this large difference in delays is apparent only in the Do Minimum VISSIM model. Even at the busiest times the Do Something network can comfortably support the levels of forecast demand provided by SATURN, without using the above process of rerouting demand. This supports the original purpose of the VISSIM operational modelling, which was to ensure that the proposed design would be sufficient for the forecast traffic growth up to the design year.

With only minimal (positive and negative) differences in delay in the Do Minimum scenario between the SATURN and VISSIM models, passing the delays in VISSIM back to SATURN would have only a marginal effect on rerouting.

Therefore, it has not be considered proportionate to follow the process above for modelling of the Do Minimum scenarios. These scenarios have instead been based on Step 2 SATURN modelling and Step 3 VISSIM modelling for the purpose of appraisal.

The input to the appraisal for the Do Something scenarios, where the delay variations between the two models is much more significant are based on Step 4 SATURN modelling and Step 6 VISSIM modelling as described above.

## Time Periods

SATURN modelling has been developed for the average AM and PM peak periods and an average interpeak period, while VISSIM has considered only the AM and PM peaks. Analysis of the interpeak flows has shown that traffic levels remain at a largely consistent level between the end of the AM peak and the start of the PM peak.

Therefore, the interpeak period has not undergone additional modelling in VISSIM, but will draw on the outputs of the final 15 minute period of the AM peak period and the first 15 minute period of the PM peak period from the Step 6 VISSIM models.

Unlike VISSIM, the SATURN outputs are not able to isolate changes in performance by 15-minute intervals, so this approach cannot be taken to capture benefits over the wider network. It is likely, based on modelling undertaken so far, that delays in the interpeak scenario will be low and benefits small. Therefore, similarly to the modelling of Do Minimum scenarios discussed above, Stage 2 SATURN models will be used to inform the wider network element of the interpeak period analysis.

Figure 3-1 provides additional detail of how the modelled scenarios and time periods will flow through the appraisal process.

## Sensitivity Testing

High and Low growth scenarios have been assessed to provide an indication of the sensitivity of the scheme to the uncertainty in future travel demand. For these scenarios it has not been considered proportionate to undertake the highly detailed assessment set out above for each of these scenarios as well.

Modelling for the high growth scenario has been developed in SATURN. This has used the same adjustments through application of time penalties to the entries to the gyratory in the DM scenario as have been used in the Core growth DM scenario. These have been applied to ensure that the effects of the variation between Vissim and SATURN modelling on causing traffic to divert away from the junction are replicated.

Due to the lower detail represented in the modelling of Junction 17 in SATURN this approach is considered to be less precise in terms of absolute performance but provided a suitable indicator of how variable performance of the junction may be.

Having performed this test and analysed the results it has been identified that the modelling did not provide a suitably reliable representation of the high growth scenario. Details of how this has been resolved are set out in section A.5 of Appendix A. That section also clarifies the treatment of the Low Growth scenario.

## Delays During Construction

The approach to assessing the impacts of delays during the construction period has been determined according to the level of detail currently available for traffic management plans.

The traffic management will be determined by the contractor and therefore at this stage only relatively high-level assumptions can be made. The main factors in the traffic management which are likely to influence the level of disruption for users are:

- Carriageway closures (single or dual lane);
- Works undertaken during peak periods; and
- Duration of works.

At the current stage of scheme design it is considered that lane closures will not be required and only narrowing of lanes resulting in reduced speeds on the circulatory and approach arms will be required.

The impact of such traffic management is likely to result in an element of rerouting of traffic away from the junction during peak hours. It has therefore been considered most appropriate that the assessment of impacts be undertaken using the SATURN model.

For reasons of proportionality, a combined SATURN and VISSIM approach has not been undertaken at this stage, due to lack of certainty of the traffic management measures themselves. Once these measures have been determined by the contractor the method of assessment of these impacts at FBC should be proportionate to the costs to the users.

These impacts have been modelled using the opening year DM model in SATURN.

## Summary

As has been set out, it has been identified following initial assessment that certain limitations exist in the process of capturing economic impacts of the M4 Junction 17 scheme under the originally proposed method, resulting in a low level of accuracy. An alternative method, drawing on both Vissim modelling to capture changes in delays across the junction itself and SATURN modelling for more strategic impacts relating to diversion of traffic, has been developed to provide a more refined measure of these two types of impacts of the scheme, with interaction between the two models used to establish a feedback relationship between the elements.

While this approach is expected to significantly increase accuracy in representation of the user benefits the methodology goes beyond standard approaches set out in guidance. Therefore, additional detailed review of the findings has been undertaken to ensure results are both plausible and consistent across scenario tests.

Due to the complexity of the proposed assessment method, a proportionate approach has been proposed for its application. The core elements of assessment have undergone the most precise modelling, while those generating lesser impacts and those for which detailed specifications are yet to be developed, have been based on a simplified and more conventional modelling approach.

# Appendix C. Economic appraisal tables

The following standard DfT tables are presented:

- Transport Economic Efficiency (TEE) (C.1.)
- Public Accounts (PA) (C.2.)
- Analysis of Monetised Costs and Benefits (AMCB) (C.3.)

These tables are also provided in their original (Excel) file format, as appendices to the main OBC document TEE: (WC_M4J17-ATK-GEB-XX-SH-TB-000002).

PA: (WC_M4J17-ATK-GEB-XX-SH-TB-000003)

AMCB: (WC_M4J17-ATK-GEB-XX-SH-TB-000001)

These tables are in a standard format provided within TAG and so do not include reliability benefits or calculations up to the Adjusted BCR.

# Transport Economic Efficiency table

**Economic Efficiency of the Transport System (TEE)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Non-business: Commuting** | **ALL MODES** | | **ROAD** | | **BUS and COACH** | **RAIL** | | **OTHER** |
| ***User benefits*** | **TOTAL** | | **Private Cars and LGVs** | | **Passengers** | **Passengers** | | |
| Travel time | 17604 | | 17604 | | | | | |
| Vehicle operating costs | 700 | | 700 | | | | | |
| User charges | 0 | | 0 | | | | | |
| During Construction & Maintenance | -71 | | -71 | | | | | |
| **NET NON-BUSINESS BENEFITS: COMMUTING** | 18,233 | *(1a)* | 18233 | | | | | |
| **Non-business: Other** | **ALL MODES** | | **ROAD** | | **BUS and COACH** | **RAIL** | | **OTHER** |
| ***User benefits*** | **TOTAL** | | **Private Cars and LGVs** | | **Passengers** | **Passengers** | | |
| Travel time | 13,109 | | 13109 | | | | | |
| Vehicle operating costs | 476 | | 476 | | | | | |
| User charges | 0 | | 0 | | | | | |
| During Construction & Maintenance | -67 | | -67 | | | | | |
| **NET NON-BUSINESS BENEFITS: OTHER** | 13,517 | *(1b)* | 13517 | | | | | |
| **Business** | | | | | | | | |
| ***User benefits*** | | | **Goods Vehicles** | **Business Cars & LGVs** | **Passengers** | **Freight** | **Passengers** | |
| Travel time | 19,307 | | 10003 | 9304 | | | | |
| Vehicle operating costs | 2,819 | | 2067 | 751 | | | | |
| User charges | | | | | | | | |
| During Construction & Maintenance | -308 | | -152 | -156 | | | | |
| **Subtotal** | 21,818 | *(2)* | 11919 | 9899 | | | | |
| ***Private sector provider impacts*** | | | | | | **Freight** | **Passengers** | |
| Revenue | 0 | | | | | | | |
| Operating costs | 0 | | | | | | | |
| Investment costs | 0 | | | | | | | |
| Grant/subsidy | 0 | | | | | | | |
| **Subtotal** | 0 | *(3)* | | | | | | |
| ***Other business impacts*** | | | | | | | | |
| Developer contributions | 0 | *(4)* | | | | | | |
| **NET BUSINESS IMPACT** | 21,818 | *(5) = (2) + (3) + (4)* | | | | | | |
| **TOTAL** | | | | | | | | |
| Present Value of Transport Economic Efficiency Benefits (TEE) | 53,569 | *(6) = (1a) + (1b) + (5)* | | | | | | |

Notes: Benefits appear as positive numbers, while costs appear as negative numbers.
All entries are discounted present values, in 2010 prices and values

# Public Accounts table

## Public Accounts (PA) Table

| | ALL MODES TOTAL | | ROAD INFRASTRUCTURE | BUS and COACH | RAIL | OTHER |
|---|---|---|---|---|---|---|
| **Local Government Funding** | | | | | | |
| Revenue | | | | | | |
| Operating Costs | 6,868 | | | | | |
| Investment Costs | | | | | | |
| Developer and Other Contributions | | | | | | |
| Grant/Subsidy Payments | | | | | | |
| NET IMPACT | 6,868 | *(7)* | | | | |
| **Central Government Funding: Transport** | | | | | | |
| Revenue | | | | | | |
| Operating costs | | | | | | |
| Investment Costs | 14,968 | | 14968 | | | |
| Developer and Other Contributions | | | | | | |
| Grant/Subsidy Payments | | | | | | |
| NET IMPACT | 14,968 | *(8)* | 14,968 | | | |
| **Central Government Funding: Non-Transport** | | | | | | |
| Indirect Tax Revenues | 658 | *(9)* | -658 | 0 | 0 | 0 |
| **TOTALS** | | | | | | |
| **Broad Transport Budget** | 21,836 | *(10) = (7) + (8)* | | | | |
| **Wider Public Finances** | 658 | *(11) = (9)* | | | | |

Notes: Costs appear as positive numbers, while revenues and 'Developer and Other Contributions' appear as negative numbers.

All entries are discounted present values in 2010 prices and values.

# Analysis of Monetised Costs and Benefits table

## Analysis of Monetised Costs and Benefits

| | | |
|---|---|---|
| Noise | 227 | *(12)* |
| Local Air Quality | -257 | *(13)* |
| Greenhouse Gases | -2,452 | *(14)* |
| Journey Quality | 0 | *(15)* |
| Physical Activity | | *(16)* |
| Accidents | 2,219 | *(17)* |
| Economic Efficiency: Consumer Users (Commuting) | 18,233 | *(1a)* |
| Economic Efficiency: Consumer Users (Other) | 13,517 | *(1b)* |
| Economic Efficiency: Business Users and Providers | 21,818 | *(5)* |
| Wider Public Finances (Indirect Taxation Revenues) | -658 | *- (11) - sign changed from PA table, as PA table represents costs, not benefits* |
| Present Value of Benefits (see notes) (PVB) | 52,649 | *(PVB) = (12) + (13) + (14) + (15) + (16) + (17) + (1a) + (1b) + (5) - (11)* |
| Broad Transport Budget | 21,836 | *(10)* |
| Present Value of Costs (see notes) (PVC) | 21,836 | *(PVC) = (10)* |
| OVERALL IMPACTS | | |
| **Net Present Value (NPV)** | 30,813 | NPV=PVB-PVC |
| **Benefit to Cost Ratio (BCR)** | 2.41 | BCR=PVB/PVC |

Note : This table includes costs and benefits which are regularly or occasionally presented in monetised form in transport appraisals, together with some where monetisation is in prospect. There may also be other significant costs and benefits, some of which cannot be presented in monetised form. Where this is the case, the analysis presented above does NOT provide a good measure of value for money and should not be used as the sole basis for decisions.

# Appendix D. TUBA Output Checks

All scenarios assessed in TUBA have had output files reviewed to check warning messages for any possible indications of problems.

Due to the large scale of the modelling which has informed the appraisal a high number of warnings have been output. While these warnings can indicate problems in the modelling which has informed the appraisal that is not necessarily the case and many warnings for such models will be generated simply as a result of travel times and distances being above a set threshold, to help users identify erroneous data when using much smaller modelled areas.

Therefore, a proportionate approach has been taken to checking these warnings, focussing on areas which are more likely to suggest distortion to outputs. A high-level record of the review undertaken for the Core Scenario is set out below.

In addition to reviewing the warnings in the TUBA output files, a range of manual checks have been undertaken, looking at breakdowns of outputs spatially, by trip purpose, time period, submode, forecast year and various combinations of the above, to help identify any possible anomalies in the results.

Annualised total trip matrix numbers that were fed as an input to TUBA have also been cross checked for different peak periods, user classes and forecast years by deriving them independently from SATURN matrices and comparing them to TUBA outputs. All comparisons showed the results to be internally consistent.

Warnings on the Core Scenario TUBA output file, such as the ratio of DM to DS travel distance or travel time being outside the defined range, were investigated. The number of warnings of each type and explanations of investigations are summarised in Table D-1, which considers the TUBA assessment of the full SATURN network and Table D-2 which sets out a similar analysis based on the TUBA assessment of the Vissim network.

**Table D-1 – TUBA Warnings for Core Scenario (SATURN Full Model)**

| TUBA Warning | Number of types of warning | Comment |
|---|---|---|
| Ratio of DM to DS travel time lower than limit | None | |
| Ratio of DM to DS travel time higher than limit | 108 | All relate to very low absolute changes |
| Ratio of DM to DS travel distance lower than limit | 189 | All relate to either very low absolute changes or very low trip numbers and so will have marginal impacts on benefits |
| Ratio of DM to DS travel distance higher than limit | 39 | All relate to either very low absolute changes or very low trip numbers and so will have marginal impacts on benefits |
| DM speeds less than limit | 18,135 | All relate to very short distance movement and can be attributed to properties of centroid connectors which are consistent between DM and DS |
| DM speeds greater than limit | 1,998,286 | All speeds are only very marginally above limit |
| DS speeds less than limit | 18,031 | All relate to very short distance movement and can be attributed to properties of centroid connectors which are consistent between DM and DS |
| DS speeds greater than limit | 2,050,658 | All speeds are only very marginally above limit |

| TUBA Warning | Number of types of warning | Comment |
|---|---|---|
| DM trips greater than limit | 35 | Warnings relate to few OD pairs where DM trips exceeds the maximum limit of 100,000 trips/hr as specified in TUBA. These are big external zones. For example, zone 50002 represents the whole of Scotland. |
| DS trips greater than limit | 35 | Warnings relate to few OD pairs where DS trips exceeds the maximum limit of 100,000 trips/hr as specified in TUBA. These are big external zones. For example, zone 50002 represents the whole of Scotland. |
| DM time greater than limit | 2,218 | Warnings relate to few DM trips where travel time exceeds the maximum limit of 10 hrs as specified in TUBA. The WTM is a very big model covering the entirety of GB, so trips greater than 10 hours are realistic. Trips from Scotland to Cornwall could take longer than 10 hours. |
| DS time greater than limit | 2,214 | Warnings relate to few DS trips where travel time exceeds the maximum limit of 10 hrs as specified in TUBA. The WTM is a very big model covering the entirety of GB, so trips greater than 10 hours are realistic. Trips from Scotland to Cornwall could take longer than 10 hours. |
| Possible introduction of new mode one of DM and DS time is zero, but not both | None | |
| Possible introduction of new mode one of DM and DS distance is zero, but not both | 56 | Warnings relate to OD pairs in which either DM or DS (but not both) distance is zero. In all cases these relate to very small differences in distance between the DM and DS (up to 3 metres). These will have no impact on calculated benefits. |

**Table D-2 – TUBA Warnings for Core Scenario (Vissim Model)**

| TUBA Warning | Number of types of warning | Comment |
|---|---|---|
| Ratio of DM to DS travel time lower than limit | None | |
| Ratio of DM to DS travel time higher than limit | 824 | Due to the very short nature of trips in Vissim it is not unreasonable for these large proportional changes to occur. All times have been reviewed in detail externally to sense check benefits. |
| Ratio of DM to DS travel distance lower than limit | None | |
| Ratio of DM to DS travel distance higher than limit | None | |
| DM speeds less than limit | 21 | All speeds are only very marginally below the limit. This is not unexpected as the Vissim modelling represents a large portion of trips being on the congested section of network. |
| DM speeds greater than limit | 192 | All speeds are only very marginally above the limit and relate to M4 through movements. |
| DS speeds less than limit | None | |
| DS speeds greater than limit | 192 | All speeds are only very marginally above the limit and relate to M4 through movements. |
| DM trips greater than limit | None | |
| DS trips greater than limit | None | |
| DM time greater than limit | None | |
| DS time greater than limit | None | |
| Possible introduction of new mode one of DM and DS time is zero, but not both | 33 | All warnings relate only to OGVs where trip numbers are so small for specific movements that they have been rounded down to zero and so no time skim is generated.<br>Due to the very low number of trips this will not distort benefits. |
| Possible introduction of new mode one of DM and DS distance is zero, but not both | 33 | All warnings relate only to OGVs where trip numbers are so small for specific movements that they have been rounded down to zero and so no distance skim is generated.<br>Due to the very low number of trips this will not distort benefits. |

**Table D-3 – TUBA Warnings for Core Scenario (SATURN Cordon Model)**

| TUBA Warning | Number of types of warning | Comment |
|---|---|---|
| Ratio of DM to DS travel time lower than limit | None | |
| Ratio of DM to DS travel time higher than limit | 423 | Due to the very short nature of trips in the cordoned SATURN model it is not unreasonable for these large proportional changes to occur. All times have been reviewed in detail externally to sense check benefits. |
| Ratio of DM to DS travel distance lower than limit | None | |
| Ratio of DM to DS travel distance higher than limit | None | |
| DM speeds less than limit | None | |
| DM speeds greater than limit | 30 | All speeds are only very marginally above the limit and relate to M4 through movements. |
| DS speeds less than limit | None | |
| DS speeds greater than limit | 44 | All speeds are only very marginally above the limit and relate to M4 through movements. |
| DM trips greater than limit | None | |
| DS trips greater than limit | None | |
| DM time greater than limit | None | |
| DS time greater than limit | None | |
| Possible introduction of new mode one of DM and DS time is zero, but not both | None | |
| Possible introduction of new mode one of DM and DS distance is zero, but not both | None | |

# Appendix E. TUBA output files

TUBA output files in their original format will be provided to DfT directly.

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