

WP 1-143 - Evaluation of Scheme Forecasting Phase 2

Final Report

14 March 2017

Version 1.3

Document Control

Document Title	WP 1-143 - Evaluation of Scheme Forecasting Phase 2 Report
Owner	Andrew Currall
Distribution	Highways England, AECOM, Arup
Document Status	Complete

Revision History

Version	Date	Description	Author
0.3	24 Jan 2017	Initial Draft	Stefanos Psarras
1.0	16 Feb 2017	For internal review	Stefanos Psarras
1.1	13 Mar 2017	Fully Reviewed	Andrew Currall
1.2	15 Mar 2017	Paragraph numbers inserted	Andrew Currall
1.3	21 Mar 2017	Review by Russell Martin	Andrew Currall

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Table of Contents

0.	Executive Summary	5
0.1.	Background	5
0.2.	Research Scope and Applicability	5
0.3.	Study Conclusions	5
1.	Introduction.....	7
1.1.	Background	7
1.2.	Terminology.....	7
1.3.	Research Phases	8
2.	Selection of Models.....	9
2.1.	Requirements	9
2.2.	Approach	10
2.3.	Motorway Schemes	10
2.4.	A-Road Schemes	11
2.5.	Selected Motorway Scheme.....	12
2.6.	Selected A-Road Scheme	13
3.	Modelling Methodology	15
3.1.	Elasticity Model.....	15
3.2.	Fixed Demand	17
3.3.	M25 Modelling Approach.....	17
3.4.	A46 Modelling Approach	20
3.5.	Contingency Scheme Methodology.....	22
3.6.	Accidents Appraisal.....	29
4.	A-Road (A46) Scheme Results	30
4.1.	Elasticity Model Calibration	30
4.2.	Traffic Demand Impacts	31
4.3.	Cost-Benefit Analysis	54
4.4.	Summary of Findings.....	66
5.	Motorway (M25) Scheme Results	66
5.1.	Elasticity Model Calibration	66
5.2.	Traffic Demand Impacts	67
5.3.	Summary of Findings.....	91
6.	Study Conclusions	92
6.1.	Schemes and Models Chosen	92
6.2.	Model Form	92

6.3. Scale of Benefits..... 93

6.4. Benefits by Type..... 94

6.5. Contingency Scheme Methodology..... 95

6.6. Previous Research 96

6.7. Sensitivity Testing..... 97

6.8. Hybrid Approaches 97

6.9. Recommendations..... 98

APPENDICES 100

APPENDIX 1 – Long List of Potential Schemes/ Models 100

0. Executive Summary

0.1. Background

- 0.1.1.1. Highways England commissioned Atkins, Arup and AECOM to conduct research into the benefits of, and need for, full variable demand models (VDMs) in transport modelling for highway scheme appraisal. VDMs were compared with alternative approaches of fixed demand, elasticity models and an approach adopted by the Highways Agency for “contingency” schemes, involving a small modelled area with an elasticity model.
- 0.1.1.2. Two existing transport schemes and associated models were used for the research, the A46 Newark-Widmerpool Scheme and Model, and the M25 J16-23 Widening scheme and associated M25 Model, both of which originally used a full variable demand model for appraisal. Alternative forecasting approaches were constructed in these models and the schemes re-appraised to assess the impacts.
- 0.1.1.3. A number of sensitivity tests where various aspects of the modelling were changed were carried out to understand the effect these might have on appraisal.

0.2. Research Scope and Applicability

- 0.2.1.1. As only two models/schemes were studied, the conclusions of this research cannot be absolutely confidently assumed to be applicable in all cases. There were many differences between the two models; despite this almost all of the study conclusions were supported by both. However, they both represented capacity improvement (widening) schemes. It may be that some considerations for bypass or missing link schemes are different.
- 0.2.1.2. Where overlap exists, and for all key conclusions, the conclusions of the research carried out here are consistent with previous Department for Transport research carried out by AECOM and Mott MacDonald in 2006, Use of Elasticity Models to Model Variable Demand.
- 0.2.1.3. This research has not explored the extent to which ranking of similar options would be affected by use of different forecasting approaches; only the benefits for a single scheme option were studied in each case. The 2006 DfT study did include some consideration of option ranking.

0.3. Study Conclusions

- 0.3.1.1. Overall it appears that use of “fixed demand”, where forecast travel demand is derived using land-use data and global assumptions, but no network or travel cost information or adjustment related to a new scheme, significantly overstates scheme benefits, and is thus not generally advised or suitable. If the ‘Without-Scheme’ demand is derived using a full VDM, using the same demand, without adjusting for the scheme effects, for the ‘With-Scheme’ model is likely to produce appropriate time benefits, but most other benefits (fuel, accidents, carbon, noise, etc.) will remain substantially in error.
- 0.3.1.2. ‘Own-cost’ elasticity models, where a simple function is applied to the cost changes for each zone-to-zone movement to adjust the demand, if properly calibrated, tend to slightly understate scheme benefits relative to a VDM, but

the discrepancy is much smaller than that occurring with a fixed approach. Most of the discrepancy relates to the derivation of a 'Without-Scheme' model; use of a VDM to derive the 'Without-Scheme' and an elasticity model pivoting from this to create the 'With-Scheme' demand, where this would be significantly easier and less costly, appears appropriate.

- 0.3.1.3. An appraisal made using an elasticity model will almost certainly return benefits of a broadly appropriate scale; for testing whether a scheme makes broad economic sense (PCF1: option identification), an elasticity model is certainly adequate (that is, no worse than a VDM).
- 0.3.1.4. There may still be case for using a VDM to rank very similar schemes or finalise a business case for a larger scheme towards the end of the assessment process (for example, PCF3: scheme development). Should POPE research conclude that an elasticity approach was notably biased downwards (as seems probable), caution should be exercised in using a method with a known bias, even a small one, as this could lead to under-investment in transport infrastructure.
- 0.3.1.5. The Contingency Scheme methodology has some notable weaknesses; however we consider it probably superior to a Fixed Demand Model, even one with a larger complete network. Given the potential weaknesses and problems that can arise, it is unlikely to be worthwhile to cordon a scheme model out of a larger one for appraisal unless considerable savings in model run times can be thus made or convergence is otherwise impossible to achieve. It may well, however, be proportionate to construct (with care) a small cordon model rather than one with a wider scope if no suitable larger model exists.
- 0.3.1.6. It is very important to include in any demand modelling (whether VDM or elasticity) the effect of changing perceived fuel costs over time, in accordance with current DfT WebTAG advice. Failing to do this is likely to severely understate benefits.
- 0.3.1.7. The most important part of a VDM is the distribution (attraction choice) model; time period choice and even mode choice are significantly less critical. Time period choice in most contexts has negligible impact on appraisal results.

1. Introduction

1.1. Background

- 1.1.1.1. In 2014, Highways England commissioned Atkins and AECOM to conduct research into the benefits of, and need for, full variable demand models (VDMs) in transport modelling for highway scheme appraisal. VDMs were compared with alternative approaches of fixed demand, elasticity models and an approach adopted by the Highways Agency for “contingency” schemes, involving a small modelled area with an elasticity model.
- 1.1.1.2. This work completed and was reported in March 2015. Following on from this, Highways England has requested some follow-up research from Arup and AECOM to investigate the sensitivity of the conclusions to a number of variables as well as to consider some hybrid forecasting approaches using a VDM for the creation of a “without scheme” case only.
- 1.1.1.3. The original 2014-15 research was reported in Task 372: Evaluation of Scheme Forecasting: Final Report. Following on from the 2016-17 study, this is a combined report covering both phases of the research projects, structured as follows:
- Chapter 2 outlines the selection of suitable schemes and associated models for the study, and describes the models selected- the A46 and M25 models;
 - Chapter 3 explains how the models used in this study were set up and outlines assumptions and methodology adopted for modelling and appraisal;
 - Chapter 4 provides the results of modelling and appraisal for the A46 (A-Road) scheme;
 - Chapter 5 provides the results of modelling and appraisal for the M25 (Motorway) scheme; and
 - Chapter 6 contains the study conclusions.
- 1.1.1.4. Two existing transport schemes and associated models were used for the research, as outlined in Chapter 2.

1.2. Terminology

- 1.2.1.1. This document discusses the modelling scenarios using various modelling terms which may not have the same meaning to all readers; for clarity these are defined below:
- The **‘Base’** model refers to the base year transport model (representing 2004 in both the A46 and M25 cases), which has been validated against observed data in that year and is used as a starting point for forecasting.
 - The **‘Reference’** model is a future-year forecast of demand representing changes in population, employment and car-ownership over the ‘Base’ (such as those derived from the National Trip-End Model, NTEM). It does not include any demand-model effects, and as such does not take into account the effect of changes in travel times and costs of transport on demand. A ‘Reference’ assignment is one that has been carried out on the future transport network, including forecast changes in transport

infrastructure, but the demand has not responded to these changes except in terms of route-choice.

- The **'Without Scheme'** model is a forecast of a most likely future scenario without the transport scheme under appraisal. In general, it does include the impact of changes in travel times and cost of transport on demand.
- The **'With Scheme'** model is a forecast of a most likely future scenario with the transport scheme under appraisal in place. The input assumptions are identical to the 'Without Scheme' model except for the inclusion of the appraised scheme.
- The **'Variable Demand Model'** (or VDM) is a full hierarchical logit model as outlined in WebTAG and as used in the original appraisal for each scheme.
- The **'Fixed Demand'** model is an assignment model identical to that used for the VDM, but with no cost-dependant demand response.
- The **'Elasticity Model'** is a simple power elasticity model, with one power parameter, also using the assignment model as used in the original VDM.
- The **'Contingency Model'** is an elasticity model based on the 'Contingency Scheme' modelling methodology. This model uses a smaller network, cordoned out of the network used for the other three models, discussed in full in Section 3.5.

1.3. Research Phases

1.3.1.1. The original 2014-15 research studied the two models and four forecasting approaches for each:

- A full variable demand model, as used in the original scheme appraisal.
- An 'own-cost' elasticity model.
- A 'fixed demand' approach with no transport-cost-dependant demand model.
- The 'contingency scheme' approach, discussed in section 3.5.

1.3.1.2. TUBA user benefits and carbon emissions were extracted. Accident benefits were not calculated.

1.3.1.3. The more recent 2016-17 research calculated accident benefits for the original four forecasting approaches. Two additional forecasting methods were considered in both models:

- A full variable demand model to calculate the 'Without Scheme' model, with the same (fixed) demand then used for the 'With Scheme' model: the VDM/Fixed hybrid approach.
- A full variable demand model to calculate the 'Without Scheme' model, with an own-cost elasticity model pivoting from the 'Without Scheme' used for the 'With Scheme' model: the VDM/Elasticity hybrid approach.

1.3.1.4. Five sensitivity tests around existing forecast approaches were also carried out, in one model each:

- A VDM without time period choice.
- A VDM with varying fuel and economic parameters over time.
- A VDM with varying fuel and economic parameters over time in the demand model only.

- An exponential form of own-cost elasticity model.
- A contingency scheme model with realistic access/egress distances.

1.3.1.5. These are discussed in more detail in sections 3.4.1 and 3.3.2.

2. Selection of Models

2.1. Requirements

2.1.1.1. It was necessary to select two schemes with associated models suitable for the research. Some scheme characteristics were essential to the work, as follows:

- The schemes had to be Highways England schemes, concerned with improving the trunk road network, to ensure applicability to Highways England's work.
- The schemes had to be of reasonable size to enable modelling in a traditional transport model, and must represent genuine changes to the road network or capacity; resurfacing work, for example, would not have been suitable.
- The schemes had to have been modelled using a full hierarchical variable demand model, comprising at a minimum a full distribution (destination/attraction choice) model. Developing a new variable demand model would have been too costly and time consuming for this work programme.
- An appraisal, including user benefit analysis, had to have been carried out using model outputs.
- The modelling and appraisal work, including all relevant computer files, needed to be available to the project team.

2.1.1.2. Other characteristics of the schemes were desirable, and formed part of the criteria to select the best schemes, as follows:

- Ideally the schemes would have opened, and a Post-Opening Project Evaluation (POPE) been carried out on them to assess the accuracy of the original appraisal. At least one scheme was required to have a POPE; it was preferred if both did, but not essential.
- Subject to this, schemes modelled and appraised more recently were preferred, as the methodologies and parameters were likely to align more closely with current advice.
- The two schemes selected were preferred to be as different as possible within the scope. For example, it was preferred that one be a motorway and one an A-road, and that the schemes were not in the same part of the UK.
- Larger schemes were preferred, as the results of the study are more likely to be used to inform modelling approaches for larger schemes; for very small schemes modelling may not be cost-effective anyway.
- Well converged models were preferred, as poor convergence will result in stochastic "noise" in appraisal results that may be hard to disentangle from the differences in modelling approaches to be tested.

- Schemes with unusual travel demand considerations in their vicinity were undesirable, as all traditional demand modelling approaches would be hard to apply well, and the conclusions may not be generally applicable. For example, roads carrying unusually high levels of freight traffic, or primarily serving single large attractors such as ports or airports, would not have been desirable.
- Models and software packages familiar to the project team were preferred over those less familiar.
- “Tiered” model structures such as those where variable demand modelling was done in a more strategic parent model while assignments and costs from a more local model were used in appraisal would have been more awkward to work with; it was preferred to avoid these if possible.

2.2. Approach

- 2.2.1.1. The selection of two schemes/models proceeded as follows.
- 2.2.1.2. During the inception meeting on 29th July 2014, it was agreed that one of the four recent M25 widening/hard-shoulder running schemes (J5-7, J16-23, J23-27 and J27-30) should be included. These schemes were modelled using the M25 Model, which the AECOM project team is familiar with, having developed the demand model and highway demand matrices. Other aspects of the schemes are also desirable; they are relatively recent, in-draft POPEs are available for the two schemes that have opened, convergence is known to be appropriate and they are of reasonable size.
- 2.2.1.3. A long-list of 97 other Highways England schemes, for which POPEs either exist or are planned, was provided to the project team. The full long-list can be found as Appendix A.
- 2.2.1.4. All schemes without variable demand models were discarded, as were all motorway schemes (the M25 having been chosen already) and some other schemes due to size, location, model convergence or age. Most schemes with no POPE were also discarded, except for two schemes known to the project team to be otherwise promising.
- 2.2.1.5. After discarding, the list comprised eight schemes, which became an A-road shortlist. A motorway shortlist of the four M25 schemes was also prepared.
- 2.2.1.6. Available documentation for each of the shortlist schemes was obtained and studied to inform a decision on the best schemes. When an initial selection had been made, enquiries were made regarding the availability of the models and appraisal methodology before this decision was finalised.

2.3. Motorway Schemes

- 2.3.1.1. The four M25 schemes are summarised below with details of various relevant factors. All four schemes were modelled and appraised by Hyder using the M25 Model. The POPE information was correct at the end of 2014 when the selection was undertaken.

Table 2-1: Motorway Scheme Shortlist

Scheme	Appraisal Year	Opening Year	Type	Other Notes
M25 Junction 5-7 (S2)	2011	2014	Hard-Shoulder Running	No POPE available
M25 Junction 16-23 (S1)	2007	2012	Widening	Close to Heathrow
M25 Junction 23-27 (S5)	2012	2014 (est)	Hard-Shoulder Running	Not yet open
M25 Junction 27-30 (S4)	2007	2012	Widening	Close to Dartford

2.3.1.2. Given the preference for a scheme with POPE, the two 2012 opening year schemes were preferred. Following discussions with Hyder, the Junction 16-23 scheme was selected on the grounds that the economic appraisal was less problematic, with little, if any, masking of economic benefits required during the appraisal of the scheme.

2.4. A-Road Schemes

2.4.1.1. The eight A-road schemes are summarised below:

Table 2-2: A-Road Scheme Shortlist

Scheme	Appraisal Year	Opening Year	Local Model	Higher Tier VDM Model
A419 Blunsdon Bypass	2005	2008	Swindon Area Traffic Model	None
A419 Commonhead Junction	2005	2007	Swindon Area Traffic Model	None
A421 Bedford to M1 Improvement	2007	2010	Bedford DC model.	London to South Midlands Multi-Modal Model (LSM)
A45/A46 Tollbar Improvement	2003	2017 (est)	A45/A46 Tollbar End traffic model	Unknown
A3 Hindhead Improvement	2005	2012	A3 Hindhead Traffic Model	None
A46 Newark - Widmerpool Improvement	2007	2012	A46 Newark - Widmerpool Improvement Model	DIADEM
M1-A5 Link (Dunstable Northern Bypass)	2010	2017 (est)	A5-M1 Local Area Model	East of England Regional Model (EERM)
A21 Tonbridge to Pembury Improvement	2010	2017 (est)	A21 Tonbridge to Pembury traffic model	Scheme Unknown

2.4.1.2. From the eight shortlisted schemes **A46 Newark to Widmerpool Improvement** was identified as the most suitable for the following reasons:

- the scheme has been modelled using a full variable demand model within DIADEM;
- the report shows that the convergence criteria have been met in the forecast year; and
- detailed economic analysis has been undertaken using TUBA.

2.4.1.3. Consultation of the model documentation for the schemes **A419 Blunsdon Bypass, A419 Commonhead Junction** and **A3 Hindhead Improvement** revealed that contrary to the long-list table suggestion, these schemes do not

include a full variable demand model; they are actually elasticity models. They were thus excluded from consideration.

2.4.1.4. The **A45/A46 Tollbar Improvement, M1-A5 Link (Dunstable Northern Bypass)** and **A21 Tonbridge to Pembury Improvement** are not expected to open until 2017. Therefore these schemes are less desirable, as no POPE data will be available in the lifetime of this project.

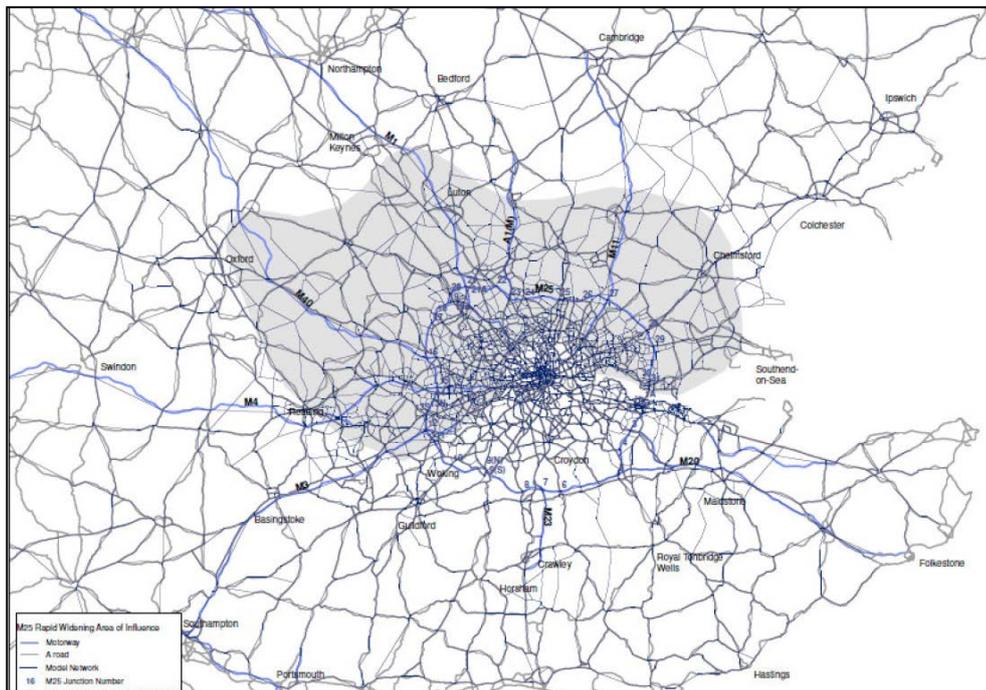
2.4.1.5. The local area model developed for the scheme **A421 Bedford to M1 Improvement** incorporates variable demand modelling from the strategic multimodal model. Although this does not preclude its use, the tiered structure would make recreating the model runs results and understanding the outcomes of the variable demand for this scheme more difficult.

2.5. Selected Motorway Scheme

2.5.1.1. The M25 Junction 16-23 scheme forecasting model integrates a SATURN highway assignment and a variable demand model implemented in Emme.

2.5.1.2. The highway assignment model was developed in SATURN v10.6 with 971 zones, with detailed zone structure within the south-east of England. The model represents three time periods: AM peak, PM peak and an average inter-peak hour.

Figure 2-1: Network Plot - M25 Junction 16-23 Scheme Forecasting Model



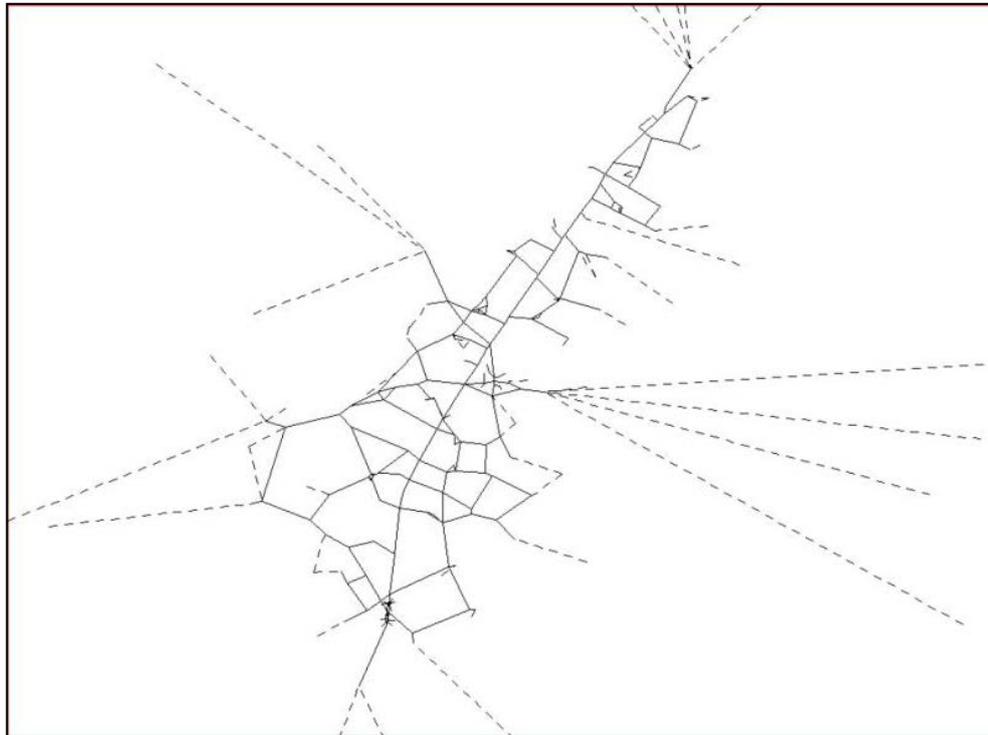
2.5.1.3. The M25 Model uses a bespoke variable demand model implemented using Emme software and the Emme macro language. This has seven demand segments, similar to the SATURN models' five (car commuting, car business, car other, LGV, HGV) but with the car other and car business user classes split into "home-based" and "non-home-based".

- 2.5.1.4. Trip frequency, mode choice, macro time period choice, and trip distribution choice models are used. Trip frequency was applied only to “other” and “commuting” car trips.
- 2.5.1.5. Variable demand is applied to freight travel as well as car. Only the time period choice and trip distribution models were used for freight; there is no freight mode choice or trip frequency.
- 2.5.1.6. Generalised costs were calculated using SATURN time and distance skims, but without using the SATURN ppm/ppk weights. Instead, weights were recalculated based on matrix-level origin-destination speed. Weights varied by model year based on changes in vehicle occupancy, fuel price, value of time and fuel efficiency.
- 2.5.1.7. Cost-damping was applied to the generalised costs, meaning that cost changes for long-distance trips were ‘damped’; reduced by a factor related to the distance. The effect of this is to leave the demand model sensitivity to cost to be somewhere between a pure absolute cost difference (un-damped costs in a VDM), and a pure cost ratio (an elasticity model). This is in contrast to the A46 VDM, which used ‘undamped’ costs.
- 2.5.1.8. The existing VDM was calibrated to produce an elasticity of vehicle distance to fuel cost of -0.26, using a 10% fuel cost decrease sensitivity test. This is in contrast to current guidance, which is to model an increase; however since the change is fairly small the effect should have been very similar.
- 2.5.1.9. The economic analysis was carried out using TUBA v1.7a.

2.6. Selected A-Road Scheme

- 2.6.1.1. The model suite developed for the A46 Newark to Widmerpool scheme includes a highway assignment model developed in SATURN (v10.6.17) with 65 zones. The SATURN model represents four time periods, AM peak, PM peak, an average inter-peak and an average off-peak (night). It models three user classes: light vehicles (car and LGV), OGV1 and OGV2.

Figure 2-2: Network Plot - A46 Newark to Widmerpool Forecasting Model



- 2.6.1.2. The model uses a variable demand model implemented in DIADEM v2.1. This has nine demand segments, with the SATURN “light” user class split into five car and two LGV segments; car by purpose (commuting, business and other) and home-basis, and LGV by personal and business.
- 2.6.1.3. Trip frequency, macro time period choice, and trip distribution choice models were used in DIADEM. No mode choice was modelled. Trip frequency was applied only to “other” purpose car trips. Time period choice was applied only to “other” and “business” purposes; i.e. not to commuting trips.
- 2.6.1.4. Variable demand was not applied for HGV demand (segmented into OGV1 and OGV2). It was, however, applied to LGV demand.
- 2.6.1.5. Generalised costs used in DIADEM were derived directly from SATURN with ppm and ppk weights for time and distance used. A consequence of this is that, since these weights did not vary in SATURN by model year, changes in user perception of vehicle operating costs (e.g. due to changes in fuel prices, values of time, or fuel efficiency) were not taken account of in the demand model.
- 2.6.1.6. Cost-damping, or the reduction in sensitivity to absolute cost changes for longer trips, was not used in the generalised costs for the A46 Model. This is in contrast to the M25 Model.
- 2.6.1.7. The VDM was calibrated to produce an elasticity of car vehicle distance to fuel cost of -0.30, using a 10% fuel cost sensitivity test. The calibration returned extremely low sensitivity for commuting (home-based work) trips, probably because these are doubly-constrained in the distribution model, consistent with WebTAG.
- 2.6.1.8. The economic analysis was carried out using TUBA v1.7a.

3. Modelling Methodology

3.1. Elasticity Model

3.1.1.1. WebTAG Unit M2, Appendix A, provides a brief overview of elasticity models:

“Where an elasticity model is appropriate the functional form and parameter values need to be selected. The simplest functional form - an ‘own cost’ elasticity model - assumes that changes in the demand for travel between two points can be adequately estimated purely by a function of the change in costs between the two places.”

3.1.1.2. The cost change can take a number of forms, the most common of which are the power and exponential forms, both covered in unit M2 Appendix A. They are both discussed here, as both were used in the research.

3.1.2. Power Function

3.1.2.1. A key property of the power function is that it assumes that a proportionate change in trips is related to a proportionate change in cost. For most applications WebTAG suggests the power function:

$$T_{ij} = T_{ij}^0 (C_{ij} / C_{ij}^0)^\beta$$

Where:

- T_{ij} final demand matrix after applying the elasticity function;
- T_{ij}^0 original demand matrix;
- C_{ij} new cost as a result of a scenario, scheme or policy input;
- C_{ij}^0 original cost; and
- β (cost) elasticity parameter.

3.1.2.2. A suitable set of power parameters were calibrated to the target car vehicle distance fuel cost elasticity of -0.30 overall (as recommended in WebTAG M2, A.1.15), across all trip purposes, with variation by purpose. WebTAG recommends the power formulation largely because it relates most simply to the concept of a (fuel-cost or journey time) elasticity and will return elasticities broadly equal for all journey lengths. Like the exponential function, the power function is “base-independent”; that is, it will return the same results whether a scenario is calculated directly from a ‘Base’ model or via an intermediate scenario (such as a ‘Do Minimum’).

3.1.3. Exponential Function

3.1.3.1. An alternative form of elasticity model makes use of an exponential function very similar to that used by logit variable demand models.

$$T_{ij} = T_{ij}^0 * \exp(\beta (C_{ij} - C_{ij}^0))$$

- 3.1.3.2. Unlike the power function, which is based on proportional cost changes, this function is based on absolute cost differences. This means that it will tend to exhibit larger elasticities for longer trips.
- 3.1.3.3. Although one might expect on this basis the exponential function to return results more similar to those of a VDM, we have previously found this not to be the case. Most VDMs in practice include some form of “cost-damping” to reduce the sensitivity of long-distance movements, meaning that their sensitivity is related to somewhere between absolute and relative differences, so a pure absolute difference may not be as close as expected.

3.1.4. Pivoting Mechanism

- 3.1.4.1. Elasticity models use cost changes to estimate changes in trip patterns. WebTAG M2 A.1.8 discusses two possible pivoting approaches:
- pivot from ‘Base’ costs, with ‘Reference’ future demand matrices; and
 - pivot from ‘Without Scheme’ demand and costs in the same year.
- 3.1.4.2. As the object of this research was primarily to consider the use of an elasticity model for the entire scheme forecasting procedure, we initially adopted the first approach, pivot from base, so that the Elasticity Model is used to derive the ‘Without Scheme’/‘Do-Minimum’ demand as well as the scheme demand.
- 3.1.4.3. Characteristically, in the elasticity functions discussed above:
- Cij - forecast scenario generalised cost
- Cij0 - base year generalised cost
- 3.1.4.4. The second option, pivot ‘With Scheme’ scenarios from the corresponding ‘Without Scheme’, was used both for the Contingency Scheme models, discussed in Section 3.5, and the VDM/Elasticity combined approach, discussed in 3.4.1.

3.1.5. Calibration

- 3.1.5.1. An iterative process was used in both A46 and M25 to calibrate the Elasticity Model parameters. The model was run after each adjustment and the elasticity values were calculated using the arc elasticity formulation:
- $$\text{Fuel Cost Elasticity} = \ln(\text{veh_kms}^1 / \text{veh_kms}^0) / \ln(1+x)$$
- Where:
- x = percentage of fuel increase
- veh_kms⁰ - Base Year vehicle km travelled
- veh_kms¹ - Base Year vehicle km travelled after fuel increase
- 3.1.5.2. Adjustment to the coefficient β in the power elasticity model formulation (see Section 3.1.2) was iteratively made and the fuel cost elasticity re-calculated as above, until the target fuel cost elasticity is achieved.
- 3.1.5.3. The same coefficient was used for the without scheme and with scheme tests, and for the VDM/elasticity model combined approach. The exponential elasticity model was of course calibrated separately from the power model. The contingency scheme approach used different elasticities, calibrated previously

as part of the specification of the contingency approach for M6 modelling; this is discussed in 3.5.19.

3.2. Fixed Demand

3.2.1.1. In the fixed demand approach, demand is independent of cost, and the trip matrix is adjusted using trip-ends and global adjustments only. In particular, the demand matrices for the 'Without Scheme' and 'With Scheme' models are the same.

3.2.1.2. Fixed demand models require adjustment to the initial 'Reference' demand matrices for the effect of transport cost changes (primarily perceived fuel prices) over time. The approach used was derived from advice in WebTAG M4, §7.4.13, and involves applying two factors: one for growth in income and one for change in fuel cost. The fixed demand matrix was estimated using the following function:

Fixed Demand = 'Reference' Demand * Income adjustment factor* Fuel adjustment factor

Table 3-1: Fuel Price and Income Adjustment Factors (WebTAG Databook Table M 4.2.1), as of November 2015

Year	Income adjustment factor	Fuel cost adjustment factor
2016	1.005	1.011
2017	1.008	1.015
2018	1.011	1.019
2019	1.013	1.024
2020	1.016	1.029
2021	1.019	1.034
2022	1.021	1.04
2023	1.023	1.046
2024	1.026	1.052
2025	1.028	1.057
2026	1.031	1.061
2027	1.034	1.065
2028	1.036	1.069
2029	1.039	1.072
2030	1.042	1.075
2031	1.045	1.076

3.3. M25 Modelling Approach

3.3.1.1. The M25 Junction 16-23 scheme variable demand model (the North of Thames Demand Model, or NoTDM) was primarily implemented using Emme transport planning software.

3.3.2. Tests Carried Out

- 3.3.2.1. A number of TUBA appraisals were carried out for the M25, as follows:
1. A re-run of the previous final appraisal for the scheme. This reproduced the same results as reported.
 2. A run as 1, with more stringent convergence parameters for the highway assignment. This produced very similar results.
 3. An elasticity model, where the demand for both the without scheme and with scheme was estimated from the reference demand using a power elasticity model.
 4. A fixed demand model, where forecast demand was estimated as described in section 3.2 and the same demand used for the without scheme and with scheme cases.
 5. A VDM/fixed hybrid model, where the without scheme case was as in 2, but the with scheme case used the same demand matrix as the without scheme.
 6. A VDM/elasticity hybrid model, where the without scheme case was as in 2, but an elasticity model was used, pivoting from the without scheme scenario, to adjust demand to create a with scheme matrix.
 7. A “contingency scheme” model, as described in 3.5.
 8. A “contingency scheme” model with full trip lengths, where entry/exit links were adjusted to represent reasonable average trip lengths, instead of very short/zero length access roads.
- 3.3.2.2. Note that the variable demand model itself for the M25 was not re-run at any point in the research; outputs from the original modelling were used.

3.3.3. Reference Demand

- 3.3.3.1. Within NoTDM the future year highway ‘Reference’ demand has been derived by applying purpose-specific trip-end growth factors using a matrix balancing procedure. These ‘Reference’ demand matrices are exclusive of the direct effect of changing costs of travel, which are applied by the variable demand model. The ‘Reference’ demand matrix development process was implemented using Emme macros. These matrices were used as the input for all the models described above.
- 3.3.3.2. The demand matrices are segmented by the following trip purposes:
- home-based work (HBW);
 - home-based employers’ business (HBEB);
 - home-based other (HBO);
 - non-home-based employers’ business (NHBEB);
 - non-home-based other (NHBO);
 - heavy goods vehicles (HGV); and
 - light goods vehicles (LGV).

3.3.4. Supply Model

- 3.3.4.1. Within NoTDM a simplified highway assignment model, based on the SATURN network model, is implemented in Emme and calibrated to reflect the SATURN Highway network to derive costs for the choice models. This approach was introduced for the original model development to reduce run

times to a practical level. The highway generalised cost matrices were derived from the NoTDM internal supply model, which assigns four user classes; HGV, LGV, car non-work and car work.

- 3.3.4.2. Implementing a similar approach for the Elasticity Model would have provided complete consistency between the VDM and the corresponding elasticity model and make assessing the key behavioural differences between the two approaches easier. However, SATURN software is likely to be the tool of choice for elasticity models.
- 3.3.4.3. Consequently, conclusions based on a more usual elasticity model approach implemented entirely within SATURN were considered to have more practical value, so this was adopted as the appropriate methodology. It should be noted that this does imply an inconsistency in the calculation of generalised costs between the VDM and elasticity models.

3.3.5. Elasticity Model

- 3.3.5.1. Elasticity models were developed using the power elasticity formulations, applied via an elastic assignment procedure within the SATURN software. The SATURN model uses the following user classes:
 - home-based work car;
 - employers' business car;
 - other car;
 - heavy goods vehicles (HGV); and
 - light goods vehicles (LGV).
- 3.3.5.2. The models were applied for the car user classes. No elasticity sensitivity was modelled for freight. The VDM does contain choice models for freight, but these are more limited than the car models; there are no trip-frequency or mode-choice responses, for example.
- 3.3.5.3. It was necessary to calculate new ppm and ppk parameters for the forecast elasticity models based on the variable demand model economic inputs. The existing M25 Model did not vary ppm/ppk over time, although it did take account of changes in fuel costs and incomes through variable demand model parameters. Because our Elasticity Model was applied directly in SATURN, in order to similarly account for these changes in the Elasticity Model, variation in the ppm and ppk had to be introduced. This necessitated another minor inconsistency between the VDM and elasticity models.
- 3.3.5.4. Current WebTAG guidance recommends varying ppm and ppk parameters over time for assignment, so a modern model would probably have this variation anyway in both assignment and demand modelling.

3.3.6. Fixed Demand

- 3.3.6.1. The fixed demand matrices were created following the approach outlined in Section 3.2, based on the 'Reference' demand.

3.3.7. Appraisal

- 3.3.7.1. Appraisal for the M25 scheme was carried out using TUBA. The same setup, TUBA version, scheme files and economics file were used for the Elasticity and Fixed Demand models.
- 3.3.7.2. TUBA was run for seven user classes:
- home-based work car;
 - employers' business car;
 - other car;
 - light goods vehicles-personal use (LGV);
 - light goods vehicles-work use (LGV);
 - other goods vehicles 1 (OGV1), i.e. rigid vehicles with 2 or 3 axles (PCUs); and
 - other goods vehicles 2 (OGV2), i.e. rigid vehicles with 4 or more axles, and articulated vehicles (PCUs).
- 3.3.7.3. These user classes involve two splits to assignment user classes (LGV into personal and business, and OGV into OGV1 and OGV2). These are both applied in the TUBA scheme files themselves, and the same splits were adopted for all demand model variants.

3.4. A46 Modelling Approach

3.4.1. Tests Carried Out

- 3.4.1.1. A number of TUBA appraisals were carried out for the A46, as follows:
1. A re-run of the previous final appraisal for the scheme. This reproduced the same results as reported.
 2. A re-run of the variable demand models as well as the appraisal itself for the original approach. This produced very similar results to 1, but not identical.
 3. A power elasticity model, where the demand for both the without scheme and with scheme was estimated from the reference demand using a power elasticity model.
 4. A fixed demand model, where forecast demand was estimated as described in section 3.2 and the same demand used for the without scheme and with scheme cases.
 5. A VDM/fixed hybrid model, where the without scheme case was as in 2, but the with scheme used the same demand matrix as the without scheme.
 6. A VDM/elasticity hybrid model, where the without scheme case was as in 2, but an elasticity model was used, pivoting from the without scheme, to adjust demand to create a with scheme matrix.
 7. A "contingency scheme" model, as described in 3.5.
 8. An exponential formulation elasticity model, otherwise similar to 3.
 9. A model as 2, but with no time period choice in the variable demand models.
 10. A model as 2, but with ppm and ppk parameters (values of time and vehicle operating cost) varying over time in line with current WebTAG guidance in both the variable demand and assignment models. The original modelling used fixed ppm/ppk parameters throughout.

11. A model as 10, but with ppm/ppk parameters fixed to the base in the saturn assignment model only, varying over time in calculation of costs for demand modelling.

3.4.2. Reference Demand

3.4.2.1. Within the A46 variable demand model future year 'Reference' demand matrices were developed by applying NTEM6-based trip rates to the 2004 observed matrix. These factors were applied using a Furness procedure within SATURN. These 'Reference' demand matrices were adopted for the Elasticity Model without alteration. The 'Reference' demand is segmented by the following trip purposes, identically to the VDM structure:

- home-based work (HBW);
- home-based employers' business (HBEB);
- home-based other (HBO);
- non-home-based employers' business (NHBE);
- non-home-based other (NHBO);
- light goods vehicles-personal use (LGV);
- light goods vehicles-work use (LGV);
- other goods vehicles 1 (OGV1), i.e. rigid vehicles with 2 or 3 axles (PCU); and
- other goods vehicles 2 (OGV2), i.e. rigid vehicles with 4 or more axles, and articulated vehicles (PCU).

3.4.2.2. These were aggregated to the assignment model level (light vehicles, OGV1, OGV2) for use in the Elasticity Model.

3.4.3. Supply Model

3.4.3.1. The model suite includes a SATURN highway assignment model with 2004 'Base' network. The model assignment was undertaken using three user classes; Car/LGV, OGV1 and OGV2. The SATURN model represents four time periods, AM peak, PM peak, inter-peak and off-peak. The SATURN highway assignment model was linked with the VDM and used to derive costs for the choice models within VDM.

3.4.4. Elasticity Model

3.4.4.1. The elasticity models were implemented using the options available within SATURN, rather than using DIADEM. Elasticity models were developed for the car assignment user class (UC1) using the application of power and exponential elasticity formulations, applied via an elastic assignment procedure within the SATURN software, and pivoting from the 'Base' (2004) model.

3.4.4.2. No elasticity model was run for the OGV user classes. This is consistent with the VDM model, which also did not apply to freight travel.

3.4.4.3. The hybrid model where a VDM was used to derive the 'Without Scheme' but an elasticity model was applied to calculate the 'With Scheme' (Test 6 listed above) was of course pivoted from the 'Without Scheme' model. However, the same power parameter was used as in the full elasticity test.

3.4.5. Fixed Demand

3.4.5.1. The variable demand model in DIADEM took account of changes in traffic congestion over time through differences between future and 'Base' generalised cost. However, it did not take account of changes in perceptions of fuel or other operating costs for highway travel, as the ppm and ppk parameters in SATURN were not varied over time. Consequently, it would not be appropriate to take account of this in the Fixed Demand Model, as this would be inconsistent with both the VDM and elasticity modelling approach. Accordingly, the fixed demand matrices used were the 'Reference' demand unaltered, and this was used in both the 'Do Minimum' and scheme models.

3.4.6. Appraisal

3.4.6.1. Appraisal for the A46 scheme was carried out using TUBA. The same setup, TUBA version, scheme file and economics file were used for the elasticity and fixed demand models.

3.4.6.2. TUBA was run for seven user classes (the same segmentation as the M25 Model, although both the assignment and demand models use different segmentation):

- home-based work car;
- employers' business car;
- other car;
- light goods vehicles-personal use (LGV);
- light goods vehicles-work use (LGV);
- other goods vehicles 1 (OGV1), i.e. rigid vehicles with 2 or 3 axles (PCU); and
- other goods vehicles 2 (OGV2), i.e. rigid vehicles with 4 or more axles, and articulated vehicles (PCU).

3.4.6.3. To recreate these seven user classes from the Elasticity Model results (which will be at the SATURN assignment user class level), it was necessary to split SATURN user class 1. This was done proportionally by O-D movement and time period using the 'Reference' demand.

3.5. Contingency Scheme Methodology

3.5.1. Contingency Scheme Approach

3.5.1.1. The contingency scheme methodology is described in full in *Major Projects Scenario Planning Schemes: Traffic Modelling and Economic Assessment*, by Highways England. Its application in practice, including the elasticities derived from the large parent model, is discussed in more detail in *TN07: Application of Forecast Elasticities*, by URS for Highways England.

3.5.1.2. A minimal network model is constructed, covering the scheme, access and egress links, upstream and downstream links to one trunk road junction, and

any key parallel roads. This will not include any significant external network, and will not represent the full range of trip lengths in detail.

- 3.5.1.3. Demand data are prepared using a combination of Trafficmaster origin-destination data and Automatic Number-Plate Recognition (ANPR) surveys. No roadside interview data are used.
- 3.5.1.4. Two sets of power elasticity models are then run. The 'Without Scheme' models are pivoted from the 'Reference' (TEMPro-growthed) demand, and the 'Base' model costs. The 'With Scheme' models are then pivoted from the 'Without Scheme' models. Different elasticities apply to the 'Reference'-future model and the 'Without Scheme' to 'With Scheme' model.
- 3.5.1.5. The elasticity impact includes both congestion effects, and, in the 'Reference'-future case, economic changes (in fuel prices, fuel efficiency and values of time) in accordance with WebTAG.
- 3.5.1.6. The contingency scheme elasticities were derived by running the M6 J16-19 scheme through a full variable demand model and calculating outturn elasticities. These were then run through an elasticity model to check the demand responses were similar. They are thus probably more suitable for schemes more like the M6 scheme (in terms of surrounding road context and scheme scope) than those significantly different from it.

3.5.2. Application for this Study

- 3.5.2.1. Two existing models/schemes with full variable demand models were used: the **A46 Newark to Widmerpool**, and the **M25 J16-23**. Our goal was to adapt these to a methodology as close as reasonably possible to the contingency scheme methodology, but otherwise consistent with the variable demand models used to appraise the schemes originally.
- 3.5.2.2. To this end, we "cordoned" the networks used for these schemes. The A46 Model was not much larger than the contingency approach would imply in the first place, although it did represent a full range of trip lengths through long (up to 100km) centroid connectors, which were removed by the cordoning. The M25 Model, on the other hand, covered the whole UK, and most of the south-east of England in considerable detail, so the cordoning produced a much smaller model.
- 3.5.2.3. The demand matrices for the models were not redeveloped using Trafficmaster and ANPR data. This would not have been achievable within project timescales and budget. Instead, the existing demand matrices for the two models were cordoned along with the networks.
- 3.5.2.4. The cordoned and un-cordoned networks are illustrated below for both M25 and A46 Models.

Figure 3-1: Network Plot - A46 Cordoned Network

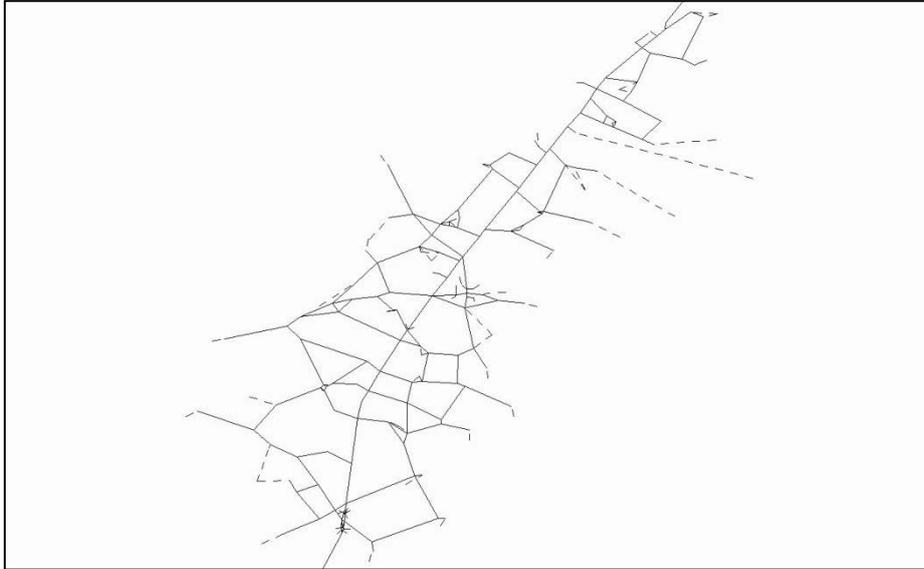


Figure 3-2: Network Plot - A46 Original Network

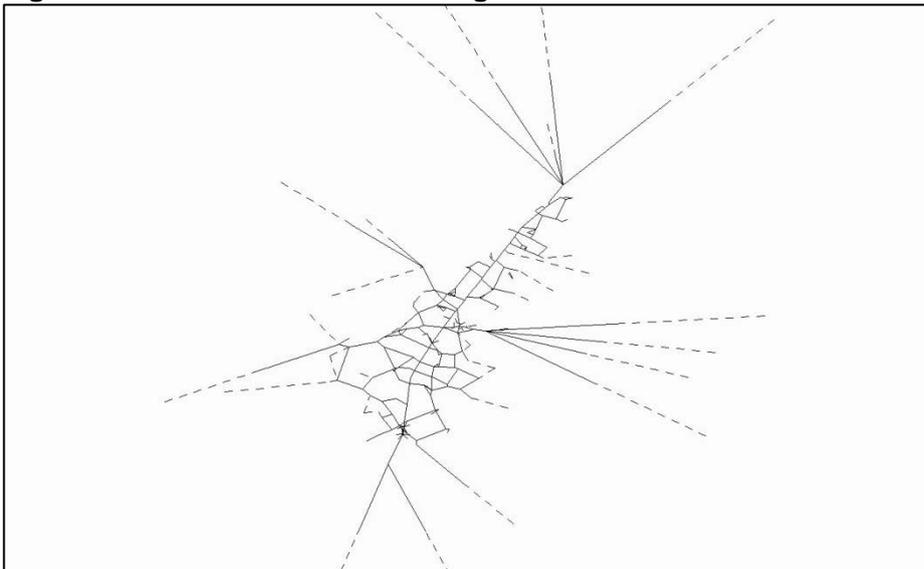
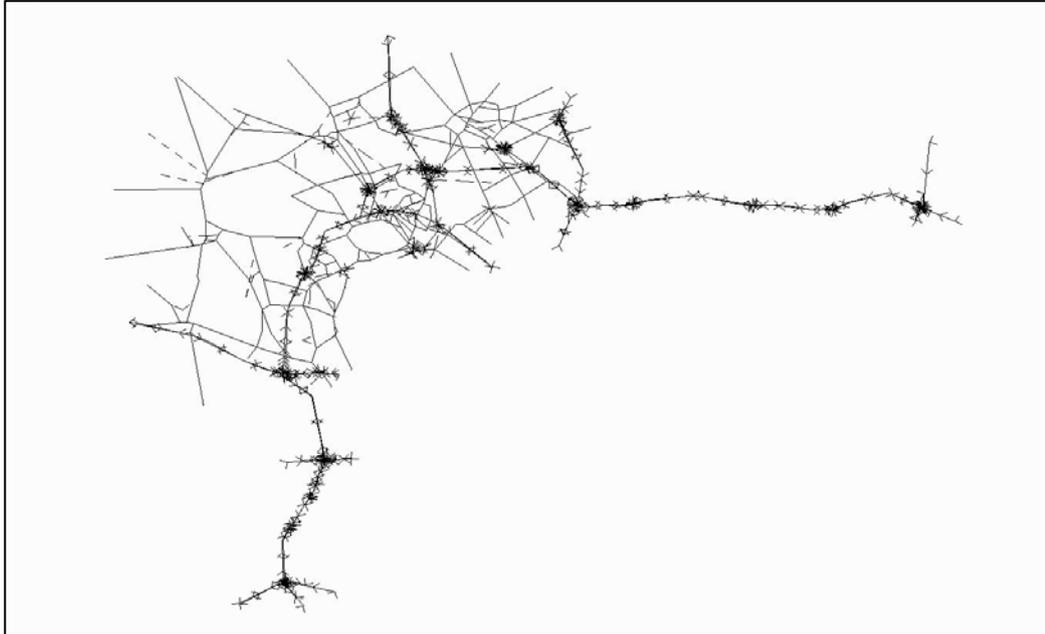
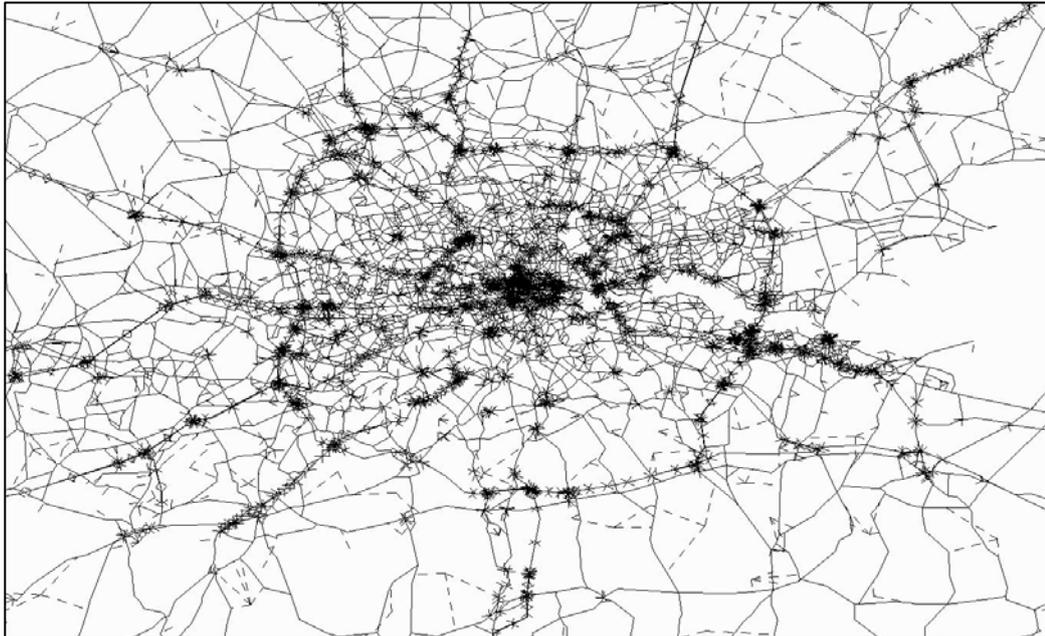


Figure 3-3: Network Plot – M25 Cordoned Network**Figure 3-4: Network Plot – M25 Surrounding Original Network**

3.5.2.5. The models were then converted to the split of user classes required by the contingency scheme methodology; that is Car Local, Car Strategic, Light Goods Vehicles and Heavy Goods Vehicles. This involved both aggregating and disaggregating the existing user classes. The A46 light vehicles user class was split into LGV and Car using Regional Traffic Forecasts (RTF) for trunk roads in the East of England. In both models, the car local/strategic split was achieved by allocating all trips with either or both trip-ends inside the cordon to local, and all external-external trips to strategic.

- 3.5.2.6. The A46 off-peak model was discarded (no night-time model was used for the contingency schemes) and three model years only were selected from each model for appraisal.
- 3.5.2.7. For the A46, these were 2012, 2027 and 2041. For the M25, they were 2012, 2021 and 2030. In the M25 case, this is not consistent with the other contingency schemes, but there is no 2041 model for the M25 and while there is a 2027 model, it was discarded by Hyder due to strange results being observed.
- 3.5.2.8. Finally, for the A46 Model, variable ppm/ppk values over time were estimated (these had been fixed in the original modelling) using the WebTAG data available in 2007.

3.5.3. Key Differences from 'Elasticity Model'

- 3.5.3.1. In Phase 1 of the research (discussed in Section 3.1), a simple elasticity model was developed. The Contingency Model also uses an elasticity formulation, but differs in a number of ways from this Phase 1 Elasticity Model, as follows, in approximate order of decreasing significance:
- The Contingency Model uses a cordoned network. This is the key difference and key feature of the contingency approach; use of a tight cordoned network covering only the scheme and immediate surroundings rather than a wider model area.
 - The A46 Contingency Model includes the effect of changes in fuel price and values of time on demand. None of the other A46 models (VDM, elasticity model, fixed demand model) include this effect. All M25 models include it, however.
 - The Contingency Models use elasticities that differ both by the local/strategic nature of car trips and for the 'Reference' to 'Without Scheme' effect versus the 'Without Scheme' to 'With Scheme' effect. In addition, a response for Heavy Goods Vehicles is modelled; this is intended to reflect strategic rerouteing (outside the scope of the cordoned network) rather than a change in trip patterns. The Elasticity Model uses only a single elasticity, and does not model a freight response.
 - The Contingency Models use only three model years, and user classes are split into only car, LGV and HGV. They also model only three time periods: AM Peak, Inter-peak and PM Peak; the original A46 Model had a night-time Off-Peak as well, but the M25 Model was consistent with the contingency approach to periods.

3.5.4. Elasticity Parameters Used

- 3.5.4.1. The sensitivity (power) parameters for the contingency scheme elasticity models are presented in Table 3-2, below, as derived by URS for the M6 Model using a full variable demand model. They differ both between local and strategic traffic ("strategic" here means with both trip-ends external to the model), and between the 'Reference' to 'Without Scheme' effect and the 'Without Scheme' to 'With Scheme' effect.
- 3.5.4.2. There is no elasticity response for Light Goods Vehicles. The elasticity response for Heavy Goods Vehicles is intended to reflect strategic rerouteing that would be captured at an assignment level in a larger-scale model, but

which cannot be so captured in the cordoned model. It does not, therefore, represent an actual redistribution or trip-frequency effect.

- 3.5.4.3. Such an actual demand response for HGVs would itself be quite possible in practice, but little evidence is available for the scale of effect and it is common not to model it.
- 3.5.4.4. The values in Table 3-2 can be compared with the value of -1.698 (see Section 4.1.7) calibrated for the un-cordoned Elasticity Model. It will be noted that the strategic car values are of a similar order, but a little lower than -1.698. The HGV values are much lower, since these are intended to represent fewer demand responses, and the car local response to the scheme was also calibrated lower; the latter may be because short trips experience large proportional changes in cost but small absolute ones, leading to smaller responses to given proportional cost changes.

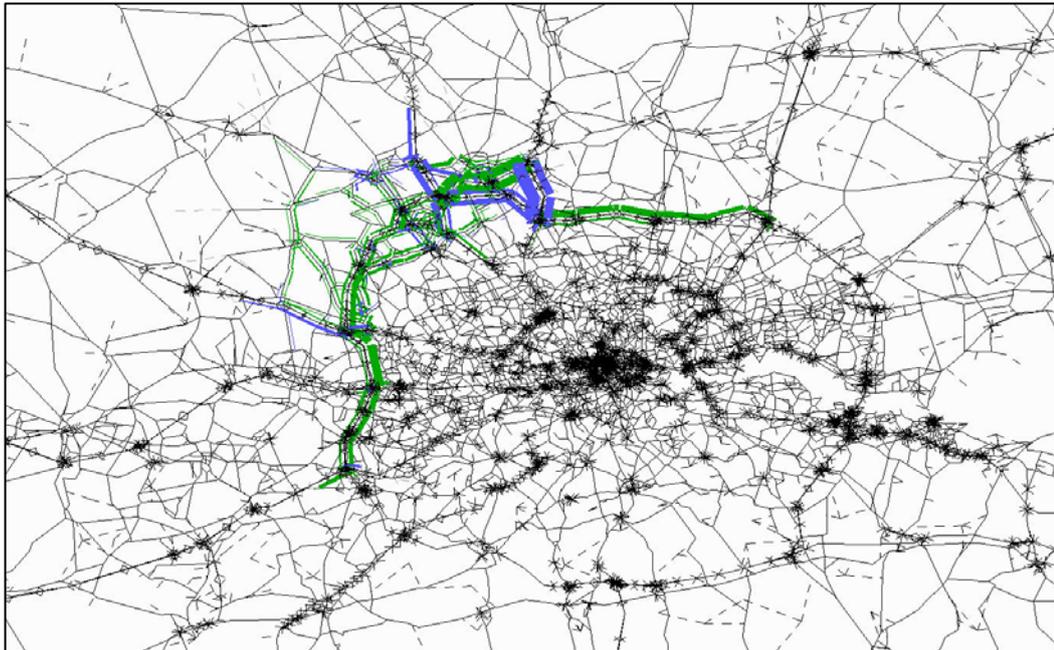
Table 3-2: Sensitivity (Power) Values used for both Contingency Models.

Scenario	User Class		Power
Reference to 'Without Scheme'	Car	All	-1.44
	HGV	Strategic	-0.19
'Without Scheme' to 'With Scheme'	Car	Local	-0.30
		Strategic	-1.29
	HGV	Strategic	-0.65

3.5.5. Effect of Cordoning on Flows

- 3.5.5.1. The cordoned A46 'Base' and 'Reference' models reproduced the traffic flows in the un-cordoned model almost exactly (within a few vehicles per hour). However, the cordoning of the more complex M25 Model did not precisely reproduce flows. The differences in the base year are illustrated below.

Figure 3-5: M25 Cordoned Base (2004) vs Original Base Model, Actual Flows



- 3.5.5.2. The cordoned model shows a general increase along the scheme when compared with the original, with flows of around 200 PCUs/hr on the outskirts of the scheme. This is proportionally small (around 4%), since the flow on the M25 is around 5,000 PCUs/hr, but is unfortunately not negligible in comparison with the scheme flow changes.
- 3.5.5.3. There are no significant flow differences on the cordoned model connector links; the differences appear to relate to re-routing and junction simulation and capacities.

3.5.6. Access and Egress Distances and Times

- 3.5.6.1. Initial assessment of the contingency scheme methodology revealed a weakness in the approach in calculating benefits based strongly on changes in vehicle kilometres, such as carbon emissions, tax impact, and non-business non-fuel benefits. Because the contingency scheme models are cordoned, and don't have realistically long access/egress distances, a lot of affected vehicle kilometres are essentially "missing" from the model. Benefits such as these are therefore generally underestimated.
- 3.5.6.2. One desired outcome of the second phase of the research was to consider how these might be reinstated and consider the effect that doing so would have on the conclusions. Accordingly, a process was developed to calculate average access distances and times to the cordon crossing points in the un-cordoned model, by crossing point, and apply these distances and times to the connector zones in the cordoned model.
- 3.5.6.3. Because access and egress distances and times does not affect network routing, it was considered suitable to apply these distance and times at a matrix level to the distance and time skims used for TUBA assessment, rather than editing the model networks. This of course means that the power elasticity

model ratios used to calculate induced traffic do not include the increased times and distances, which is desirable because the elasticities for the contingency scheme models were calculated for a “cordoned” model and are thus not necessarily applicable to one with full trip lengths.

- 3.5.6.4. This approach, while sound, might be hard to apply fully in practical contexts as it depends on the existence of a good ‘parent’ model containing all access/egress links. Strategic access/egress links might be infilled using a parent model such as the Highways England Regional Models, while more local crossing links might have to be estimated by the developer with reference to zone and land-use maps.

3.6. Accidents Appraisal

- 3.6.1.1. The original research conducted in 2015 considered only TUBA software benefits. A desire to study the effect of demand forecasting approaches on accident benefits, which can often be a non-negligible part of an appraisal, has led to some further work looking at accidents.
- 3.6.1.2. For neither the A46 nor the M25 models were we able to obtain the original accident appraisal. Furthermore, the M25 model essentially didn’t originally report any accident benefits (it found benefits to be negligible) and the M25 POPE didn’t report accident benefits either (it concluded that changes were not statistically significant).
- 3.6.1.3. Consequently no attempt was made to reproduce the original accident appraisal; new analysis was carried out using the COBALT software (previous accident appraisal would have used COBA). These results are therefore not comparable with the original appraisal. In order to allow results to be presented consistently, however, we have converted the accident benefits from 2010 prices as COBALT reports, to 2002 prices as were used in all the existing appraisal for both models.
- 3.6.1.4. An analysis was carried out using “combined” link and junction data in COBALT. No local accident rates were used; COBA default accident rates were applied throughout.
- 3.6.1.5. Average Annual Daily Traffic (AADT) was calculated as follows for each link:

$$\text{A46: AADT (24hr)} = 1.105 * ((2.63 * \text{AM peak}) + (7.35 * \text{Inter-peak}) + (2.01 * \text{PM peak}))$$

$$\text{M25: AADT (24hr)} = 1.1 * ((2.86 * \text{AM peak}) + (6.50 * \text{Inter-peak}) + (2.40 * \text{PM peak}))$$

- 3.6.1.6. The A46 expression was taken directly from the original accident appraisal for the A46. The M25 one is a simplification of a process used to calculate AADTs for air quality assessment in the original work; the distinction between motorway and strategic roads and between light and heavy vehicles has been removed using appropriate averages.
- 3.6.1.7. Accident benefits were calculated for the four original approaches (VDM, Elasticity Model, Fixed Demand and Contingency Scheme). Accident benefits were not calculated for sensitivity test approaches that were assessed in the 2016 work.

4. A-Road (A46) Scheme Results

4.1. Elasticity Model Calibration

- 4.1.1.1. The Elasticity Model sensitivities were calibrated for this work using the base year (2004) A46 Models. The value of distance in SATURN (ppk) was increased to reflect a 10% increase in fuel prices (see below), and the sensitivity of the response calculated. The sensitivity was adjusted to reflect WebTAG guidance about appropriate fuel cost elasticities (-0.30). A similar approach would have been used in the original model development to calibrate the variable demand model.
- 4.1.1.2. No demand response was calibrated for HGV travel.
- 4.1.1.3. A 10% car fuel cost increase was modelled by adjusting the ppk parameters in SATURN. Because the ppk parameters include both fuel and non-fuel operating costs, and because the user class includes both car and LGV vehicle types, the resulting increase to the ppk parameters is less than 10%. The appropriate increase has been calculated using the original derivation of ppk parameters for the A46 Model to determine the split into fuel and non-fuel cost; the LGV proportion has been approximated using the WebTAG databook.
- 4.1.1.4. The ppk parameters were adjusted separately by time period, as slightly different values are used for each in the A46 Model.
- 4.1.1.5. Note that this calibration applied to the 'full' Elasticity Model only (Power and Exponential variants). The Contingency Model also used elasticities, but applied sensitivity parameters taken from the URS report (see Section 3.5.19).
- 4.1.1.6. Because the first user class in the A46 Model contains both LGV and car, a 13.8% LGV proportion (derived from the WebTAG databook) has been assumed in applying a 10% increase in car fuel cost. Consequently the calibration target for the whole user class is $-0.30 * (1-0.138)$, or -0.26. Overall the model produces a response of this sensitivity at both a network and a matrix level. The OGV1 and OGV2 cross-elasticities are very small, as no fuel cost change is modelled for freight.

4.1.2. Power Elasticity Model

- 4.1.2.1. A value for the sensitivity (β -value) of the power elasticity function of -1.69806 was calibrated. This is a dimensionless quantity. This was applied to the light vehicles (cars and LGV) user class only. The model sensitivity was assessed using arc elasticities of fuel cost to vehicle distance as advised in WebTAG M2 §6.4, calculated using both matrix and network statistics. The elasticities obtained are shown below.

Table 4-1: Fuel Cost Elasticities, A46 Model, Matrix-Level, Internal Origins, Power Elasticity Model

	Light Vehicles	OGV1	OGV2
AM	-0.26	0.07	0.03
IP	-0.23	-0.01	-0.01
PM	-0.27	0.04	0.01
OP	-0.29	-0.00	-0.00
24hr	-0.26	0.02	0.00

Table 4-2: Fuel Cost Elasticities, A46 Model, Network-Level, Internal Links, Power Elasticity Model

	Light Vehicles	OGV1	OGV2
AM	-0.24	-0.00	-0.00
IP	-0.22	-0.00	-0.00
PM	-0.29	-0.01	-0.01
OP	-0.29	-0.00	-0.00
24hr	-0.26	-0.00	-0.00

4.1.3. Exponential Elasticity Model

4.1.3.1. A value for the sensitivity (β -value) of the exponential elasticity function of -0.000403 s⁻¹ was calibrated. This was applied to the light vehicles (cars and LGV) user class only. The model sensitivity was assessed using arc elasticities of fuel cost to vehicle distance as advised in WebTAG M2 §6.4, calculated using both matrix and network statistics. The elasticities obtained are shown below.

Table 4-3: Fuel Cost Elasticities, A46 Model, Matrix-Level, Internal Origins, Exponential Elasticity Model

	Light Vehicles	OGV1	OGV2
AM	-0.27	0.06	0.04
IP	-0.25	0.00	-0.01
PM	-0.26	0.04	0.01
OP	-0.27	0.00	0.00
24hr	-0.26	0.02	0.01

Table 4-4: Fuel Cost Elasticities, A46 Model, Network-Level, Internal Links, Exponential Elasticity Model

	Light Vehicles	OGV1	OGV2
AM	-0.27	-0.00	-0.00
IP	-0.31	-0.01	-0.00
PM	-0.23	-0.00	-0.00
OP	-0.34	-0.00	-0.00
24hr	-0.30	-0.00	-0.00

4.2. Traffic Demand Impacts

4.2.1. Trips

4.2.1.1. The effect of the VDM and Elasticity Model on trip totals in the 'Without Scheme' and 'With Scheme' forecasting models is shown in the table below for the final model year of 2041. Figures are in passenger car units (PCUs). Trip totals for all models have been included, for comparison with the Contingency Model which contains a different set of user classes.

Table 4-5: Trip Total Impacts of A46 Demand Models, 2041, PCUs

		UFM Matrices Comparison-Demand in PCUs								
		VDM Model		Elasticity Model		Exponential Elasticity Model		VDM Elasticity Hybrid		
		Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	
User Class	Base Year	Reference								
	AM, 2004		AM, 2041							
Car/ LGV	10,088	13,818	-750 (-5%)	718 (5%)	-1,545 (-11%)	1,805 (15%)	-1,556 (-11%)	1,490 (12%)	2,223 (17%)	
OGV1	592	728	0	0	0	0	0	0	0	
OGV2	674	1,224	0	0	0	0	0	0	0	
Total	11,354	15,769	-750 (-5%)	718 (5%)	-1,545 (-11%)	1,805 (15%)	-1,556 (-11%)	1,490 (12%)	2,223 (17%)	
	IP, 2004		IP, 2041							
Car/ LGV	6,870	10,044	213 (2%)	117 (1%)	-694 (-7%)	815 (9%)	-632 (-6%)	800 (8%)	1,287 (13%)	
OGV1	548	672	0	0	0	0	0	0	0	
OGV2	639	1,159	0	0	0	0	0	0	0	
Total	8,057	11,875	213 (2%)	117 (1%)	-694 (-7%)	815 (9%)	-632 (-6%)	800 (8%)	1,287 (13%)	
	PM, 2004		PM, 2041							
Car/ LGV	12,184	16,956	-1,204 (-7%)	557 (4%)	-1,896 (-11%)	1,298 (9%)	-1,996 (-12%)	1,276 (9%)	1,589 (10%)	
OGV1	294	356	0	0	0	0	0	0	0	
OGV2	451	810	0	0	0	0	0	0	0	
Total	12,929	18,121	-1,204 (-7%)	557 (4%)	-1,896 (-11%)	1,298 (9%)	-1,996 (-12%)	1,276 (9%)	1,589 (10%)	
	OP, 2004		OP, 2041							
Car/ LGV	1,950	2,696	346 (13%)	-123 (-4%)	-8 (0%)	119 (4%)	-5 (0%)	105 (4%)	227 (8%)	
OGV1	156	188	0	0	0	0	0	0	0	
OGV2	181	325	0	0	0	0	0	0	0	
Total	2,287	3,209	346 (13%)	-123 (-4%)	-8 (0%)	119 (4%)	-5 (0%)	105 (4%)	227 (8%)	

- 4.2.1.2. The 2041 'Reference' demand, generated from National Trip-End Model forecasts of population and employment, is higher than the 2004 base, as expected. It should be noted that for the A46 Modelling, the 'Reference' demand was also used for the fixed demand appraisal.
- 4.2.1.3. Freight demand is fixed across all the VDM and Elasticity Model tests.
- 4.2.1.4. The VDM demand in the 'Without Scheme' case is overall slightly lower than the 'Reference' scenario, indicating that congestion is suppressing trips. However, because the model contains time period choice, the inter-peak and off-peak trips are in fact higher than the 'Reference', as demand is shifted out of the peaks (which are more congested) into the less congested off-peak periods.
- 4.2.1.5. When the scheme is included, demand increases in the VDM model, as expected. Again, the off-peak exhibits a reverse-effect, as the scheme moves trips back into the peaks through time period choice, resulting from the decongestion effect of the scheme in the peaks.
- 4.2.1.6. The Elasticity Model changes are of the same overall sign, but exhibit greater sensitivity; both the effect of the 'Without Scheme' model on the 'Reference' and the impact of the scheme itself are significantly larger, by more than a factor of two. This is because the VDM and Elasticity Model are calibrated to exhibit similar sensitivities of traffic response. In the VDM the increase or decrease in traffic is achieved partly through trip lengthening or shortening via the trip distribution model. In the Elasticity Model this is not possible and all changes in traffic must be achieved through changes in trip totals. This leaves the Elasticity Model showing a larger impact on trips.
- 4.2.1.7. Furthermore, it should be noted that the time period effects in the VDM do not occur in the Elasticity Model; consequently trips reduce between 'Reference' to 'Without Scheme' in all periods, and rise from 'Without Scheme' to 'With Scheme' in all periods. This means, for example, that all changes in trips in the off-peak are of the opposite sign to those in the VDM.
- 4.2.1.8. The Exponential and Power Elasticity models show very similar trip change effects. The hybrid VDM/Elasticity approach exhibits scheme changes of a similar level to the full Elasticity Models; however the changes are generally larger. This may be because there is slightly more capacity available in the VDM 'Without Scheme' case than in the Elasticity model one, and thus more scope for trip increases.

Table 4-6: Trip Total Impacts of A46 Demand Models, 2041, PCUs, Sensitivity Tests

	UFM Matrices Comparison-Demand in PCUs							
	VDM Model ¹		VDM No Time Period Choice		VDM fuel change		VDM fuel change demand only	
	Reference to Without Scheme	Reference to Without Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme
User Class	AM, 2041							
Car/ LGV	-399 (-3%)	594 (4%)	-198 (-1%)	308 (2%)	557 (4%)	706 (5%)	525 (4%)	586 (4%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-399 (-3%)	594 (4%)	-198 (-1%)	308 (2%)	557 (4%)	706 (5%)	525 (4%)	586 (4%)
User Class	IP, 2041							
Car/ LGV	-155 (-2%)	246 (2%)	-184 (-2%)	281 (3%)	711 (7%)	403 (4%)	961 (10%)	652 (6%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-155 (-2%)	246 (2%)	-184 (-2%)	281 (3%)	711 (7%)	403 (4%)	961 (10%)	652 (6%)
User Class	PM, 2041							
Car/ LGV	-629 (-4%)	506 (3%)	-357 (-2%)	404 (2%)	805 (5%)	833 (5%)	292 (2%)	722 (4%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-629 (-4%)	506 (3%)	-357 (-2%)	404 (2%)	805 (5%)	833 (5%)	292 (2%)	722 (4%)
User Class	OP, 2041							
Car/ LGV	116 (4%)	-55 (-2%)	-1 (0%)	30 (1%)	445 (16%)	-31 (-1%)	559 (21%)	-74 (-2%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	116 (4%)	-55 (-2%)	-1 (0%)	30 (1%)	445 (16%)	-31 (-1%)	559 (21%)	-74 (-2%)

¹ The VDM Model used for comparison here had to be rerun using different version of SATURN and DIADEM and so shows different trip total changes. While these are unfortunately not very close to the original VDM, the overall pattern is similar and subsequent analysis (e.g. TUBA benefits) matches very well indeed (within a few %).

- 4.2.1.9. The no time period choice VDM has similar sort of trip impacts to the full one, but the effects of disabling time period choice are clear, in that the off-peak changes are now the same sign as the peak period, instead of the opposite sign. Furthermore the peak period impacts are slightly smaller, while the interpeak effect is larger, as expected.
- 4.2.1.10. The two VDMs with fuel cost changes over time are similar to each other, but very different from the original VDM. They exhibit large growth in trips over time, rather than suppression, because perceived fuel cost are reduced. The scheme growth is larger, because the congestion relief is bigger, because the 'Without Scheme' case has significantly more traffic.
- 4.2.1.11. The trip changes from the Contingency Model are shown below.

Table 4-7: Trip Total Impacts, A46 Demand Contingency Model, 2041, PCUs

	UFM Matrices Comparison-Demand in PCUs			
			Contingency Model	
	Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme
User Class	AM, 2004	AM 2041		
Car Local	5,067	6,364	-390 (-6%)	282 (5%)
Car Strategic	3,640	4,896	247 (5%)	902 (18%)
LGV	1,357	2,492	0	0
HGV	1,264	1,945	21 (0%)	77 (4%)
Total	11,328	15,697	-122 (-1%)	1210,261 (8%)

User Class	IP, 2004	IP 2041		
Car Local	3,562	4,747	246 (5%)	111 (2%)
Car Strategic	2,375	3,466	347 (10%)	627 (16%)
LGV	925	1,818	0	0
HGV	1,185	1,828	34 (2%)	56 (3%)
Total	8,047	11,859	627 (5%)	794 (6%)

User Class	PM, 2004	PM 2041		
Car Local	6,673	8,482	-417 (-5%)	222 (3%)
Car Strategic	3,853	5,327	221 (4%)	979 (18%)
LGV	1,640	3,056	0	0
HGV	745	1,163	6 (1%)	68 (6%)
Total	12,911	18,028	-190 (-1%)	1,269 (7%)

- 4.2.1.12. The 'Base' and 'Reference' Contingency Models have very similar trip totals to the original Elasticity Model; this is as expected since very little network was cordoned off the model and very few trips will have been lost.
- 4.2.1.13. The effect of the demand modelling between 'Reference' and 'Without Scheme' models is quite different in the Contingency Model; with the inter-peak increasing and the peaks experiencing slight suppression. In the original

Elasticity Model, all three periods experience significant suppression. This difference is due to the inclusion of fuel cost impacts in the Contingency Model; these tend to increase demand as cars become more fuel efficient over time.

4.2.1.14. On the other hand, the effect of the demand models between 'Without Scheme' and 'With Scheme' is quite similar, with both Contingency and Elasticity Models increasing demand and by similar levels. The Contingency Model tends to induce slightly fewer trips; this is logical since the elasticity sensitivities are slightly lower.

4.2.2. Vehicle Distance

4.2.2.1. The consistency of the traffic impact can be illustrated more clearly by examining total trip distance (in terms of PCU kilometres) instead of total trips. Trip totals can be quite misleading, especially when considering variable demand models, because most of the VDM impact is typically redistribution of trips rather than generation or suppression. Trip distance impacts are shown below.

Table 4-8: Trip Distance Impacts of A46 Demand Models, 2041, PCU Km

		UFM Matrices Comparison-Demand in PCUs							
		VDM Model		Elasticity Model		Exponential Elasticity Model		VDM Elasticity Hybrid	
		Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Without Scheme to With Scheme	
User Class	Base Year	Reference							
	AM, 2004		AM, 2041						
Car/ LGV	484,206	689,486	-57,272 (-8%)	72,605 (11%)	-47,721 (-7%)	70,336 (11%)	-43,391 (-6%)	92,929 (14%)	67,218 (10%)
OGV1	32,423	40,703	0	0	0	0	0	0	0
OGV2	42,686	78,936	0	0	0	0	0	0	0
Total	559,315	809,125	-57,272 (-8%)	72,605 (11%)	-47,721 (-7%)	70,336 (11%)	-43,391 (-6%)	92,929 (14%)	67,218 (10%)
	IP, 2004		IP, 2041						
Car/ LGV	330,111	507,305	61 (0%)	37,858 (7%)	-22,322 (-4%)	37,956 (8%)	-27,053 (-5%)	56,050 (12%)	39,584 (8%)
OGV1	27,055	33,820	0	0	0	0	0	0	0
OGV2	37,849	70,140	0	0	0	0	0	0	0
Total	395,015	611,265	61 (0%)	37,858 (7%)	-22,322 (-4%)	37,956 (8%)	-27,053 (-5%)	56,050 (12%)	39,584 (8%)
	PM, 2004		PM, 2041						
Car/ LGV	534,173	776,963	-68,036 (-9%)	77,552 (11%)	-53,922 (-7%)	63,165 (9%)	-55,126 (-7%)	94,862 (13%)	64,905 (9%)
OGV1	15,904	19,701	0	0	0	0	0	0	0
OGV2	29,015	53,512	0	0	0	0	0	0	0
Total	579,092	850,176	-68,036 (-9%)	77,552 (11%)	-53,922 (-7%)	63,165 (9%)	-55,126 (-7%)	94,862 (13%)	64,905 (9%)
	OP, 2004		OP, 2041						
Car/ LGV	93,646	135,756	16,846 (12%)	-3,575 (-2%)	-295 (0%)	6,300 (5%)	-364 (0%)	9,087 (7%)	6,655 (5%)
OGV1	7,678	9,512	0	0	0	0	0	0	0
OGV2	10,740	19,795	0	0	0	0	0	0	0
Total	112,064	165,063	16,846 (12%)	-3,575 (-2%)	-295 (0%)	6,300 (5%)	-364 (0%)	9,087 (7%)	6,655 (5%)

- 4.2.2.2. In the peaks, the sensitivity of the Elasticity Model and VDM are much closer in terms of total distance travelled than they are in terms of trips, and the Elasticity Model is now slightly less sensitive than the VDM.
- 4.2.2.3. The difference is much more marked in the inter-peak and off-peak, where the Elasticity Model exhibits small suppression from the 'Reference' and the VDM exhibits a small increase in the inter-peak and a large increase in the off-peak. This is again a product of time-period choice: the VDM redistributes peak demand into the inter-peak and off-peak. This does not occur in the Elasticity Model. Time period choice also explains why the VDM now appears slightly more sensitive than the Elasticity Model in the peaks (albeit not much): the time period choice impact is additional; it does not significantly affect the fuel cost calibration as the fuel cost adjustment is applied in all periods.
- 4.2.2.4. The exponential elasticity is very similar to the power in the over-time effect, as expected since the two are calibrated to a similar overall sensitivity. However it is notably more sensitive in its scheme impact. This is because the scheme primarily benefits relatively long trips, and the exponential elasticity model is based on absolute cost differences, which will be larger for long trips.
- 4.2.2.5. The hybrid model is very similar in its scheme effect to the pure elasticity model. The only difference between them is the level of demand in the starting point 'Without scheme' case.

Table 4-9: Trip Distance Impacts of A46 Demand Models, 2041, PCU Km, Sensitivity Tests

UFM Matrices Comparison-Demand in PCUs								
User Class	VDM Model ²		VDM No Time Period Choice		VDM fuel change		VDM fuel change demand only	
	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme
AM, 2041								
Car/ LGV	-30,226 (-4%)	65,774 (10%)	-20,935 (-3%)	51,689 (8%)	137,965 (20%)	87,239 (11%)	139,059 (20%)	73,233 (9%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-30,226 (-4%)	65,774 (10%)	-20,935 (-3%)	51,689 (8%)	137,965 (20%)	87,239 (11%)	139,059 (20%)	73,233 (9%)
IP, 2041								
Car/ LGV	-15,562 (-3%)	40,808 (8%)	-16,082 (-3%)	42,026 (9%)	171,115 (34%)	71,286 (11%)	211,865 (42%)	107,118 (15%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-15,562 (-3%)	40,808 (8%)	-16,082 (-3%)	42,026 (9%)	171,115 (34%)	71,286 (11%)	211,865 (42%)	107,118 (15%)
PM, 2041								
Car/ LGV	-37,936 (-5%)	68,427 (9%)	-24,812 (-3%)	60,129 (8%)	236,683 (30%)	109,579 (11%)	176,372 (23%)	96,416 (10%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	-37,936 (-5%)	68,427 (9%)	-24,812 (-3%)	60,129 (8%)	236,683 (30%)	109,579	176,372 (23%)	96,416 (10%)
OP, 2041								
Car/ LGV	6,381 (5%)	-489 (0%)	47 (0%)	4,636 (3%)	62,805 (46%)	4,368 (2%)	79,379 (58%)	-1,032 (0%)
OGV1	0	0	0	0	0	0	0	0
OGV2	0	0	0	0	0	0	0	0
Total	6,381 (5%)	-489 (0%)	47 (0%)	4,636 (3%)	62,805 (46%)	4,368 (2%)	79,379 (58%)	-1,032 (0%)

² The VDM Model used for comparison here had to be rerun using different version of SATURN and DIADEM and so shows different trip total changes. While these are unfortunately not very close to the original VDM, the overall pattern is similar and subsequent analysis (e.g. TUBA benefits) matches very well indeed (within a few %).

4.2.2.6. The VDM without time period choice demonstrates similar vehicle distance impacts to its trip ones; it tends to be less sensitive in the peaks, but more sensitive in the interpeak and offpeak. The tests with fuel changes over time again demonstrate much larger impacts, with the over-time effect being substantial growth, rather than suppression, and the scheme impacts being larger. They are not very different from each other.

4.2.2.7. The Contingency Model figures are shown in a separate table below.

Table 4-10: Trip Distance Impacts of A46 Contingency Models, 2041, PCU Km

	UFM Matrices Comparison-Distance in Vkm			
	Base Model		Contingency Model	
	Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme
User Class	AM, 2004	AM 2041		
Car Local	53,131	67,222	-3,377(-5%)	4,694 (7%)
Car Strategic	66,556	89,852	2,107(2%)	27,366 (30%)
LGV	18,615	34,702	0	0
HGV	21,584	34,028	267 (1%)	1,737 (5%)
Total	159,886	225,804	-1,003 (0%)	33,797 (15%)

User Class	IP, 2004	IP 2041		
Car Local	34,872	47,249	1,786 (4%)	2,136 (4%)
Car Strategic	42,919	63,170	4,819 (8%)	17,701 (26%)
LGV	12,094	24,383	0	0
HGV	18,010	28,654	355 (1%)	1,074 (4%)
Total	107,895	163,456	6,960 (4%)	20,911 (12%)

User Class	PM, 2004	PM 2041		
Car Local	62,286	79,908	-1,635 (-2%)	3,649 (5%)
Car Strategic	69,510	96,567	2,258 (2%)	28,684 (29%)
LGV	20,483	38,955	0	0
HGV	12,669	20,319	107 (1%)	1,026 (5%)
Total	164,948	235,749	730 (0%)	33,359 (14%)

4.2.2.8. In contrast to the trip totals, the Contingency Model trip kilometres are much smaller than those of the other models. This is because the long strategic connector links have been removed. The impact of the 'Without Scheme' and 'With Scheme' models follows a similar pattern to the trips; the absolute differences are lower for the same reason that the 'Base' and 'Reference' totals are.

4.2.3. Network Flows

4.2.3.1. The effect of the demand models on the 'Reference' demand assignment is shown graphically below for the 2041 inter-peak, for both the variable demand and elasticity models. Blue bars represent reduction in flow; green bars increase in flow. Bar width is proportional to size of change.

Figure 4-1: A46, 2041, Interpeak, 'Without Scheme' Minus Reference, VDM

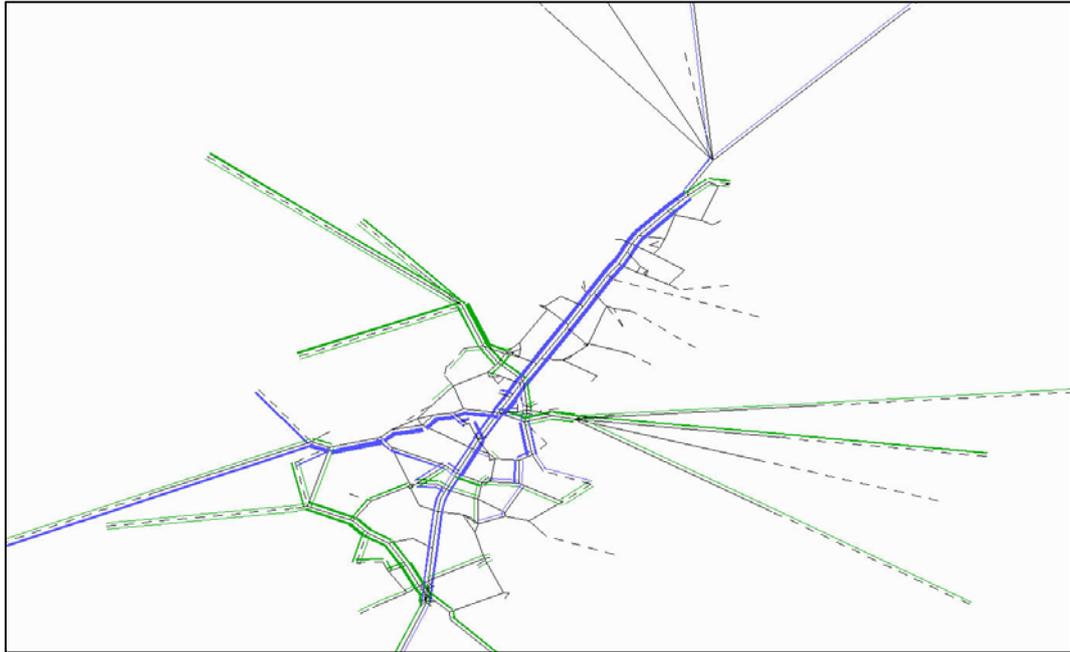
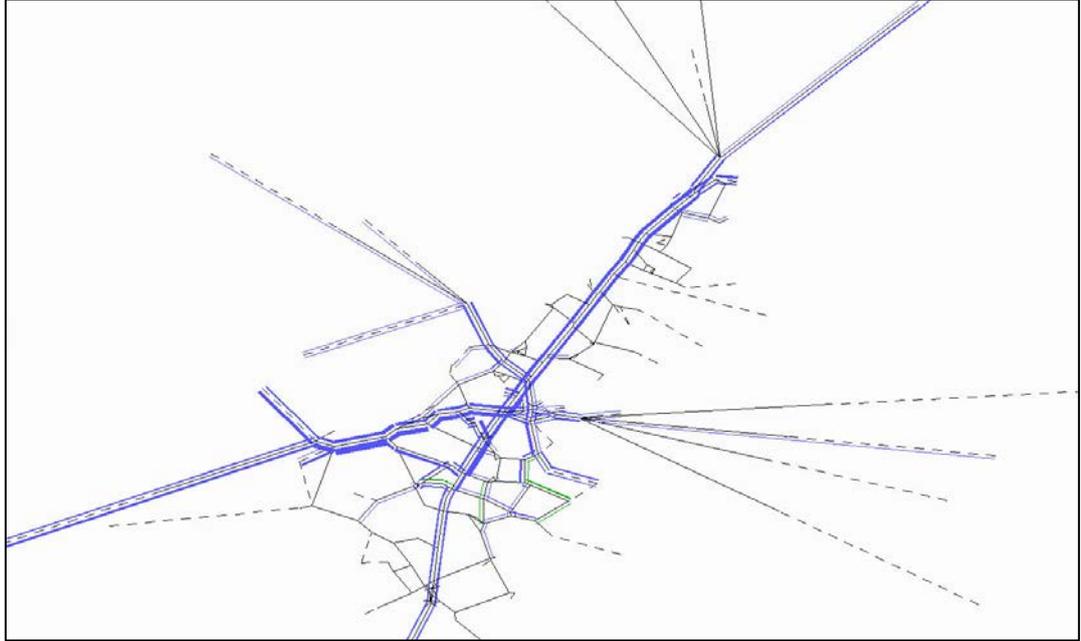


Figure 4-2: A46, 2041, Interpeak, 'Without Scheme' Minus Reference, Elasticity Model



4.2.3.2. Although both demand models suppress strategic traffic along the A46 and the A52, the Elasticity Model tends to suppress all traffic, while the VDM actually increases shorter, more local trips. This is consistent with the evidence above; the VDM redistributes demand from longer to shorter trips thus increasing demand for more local movements; the Elasticity Model is not capable of doing this. The impact of the scheme itself is shown graphically below for the 2041 inter-peak.

Figure 4-3: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, VDM

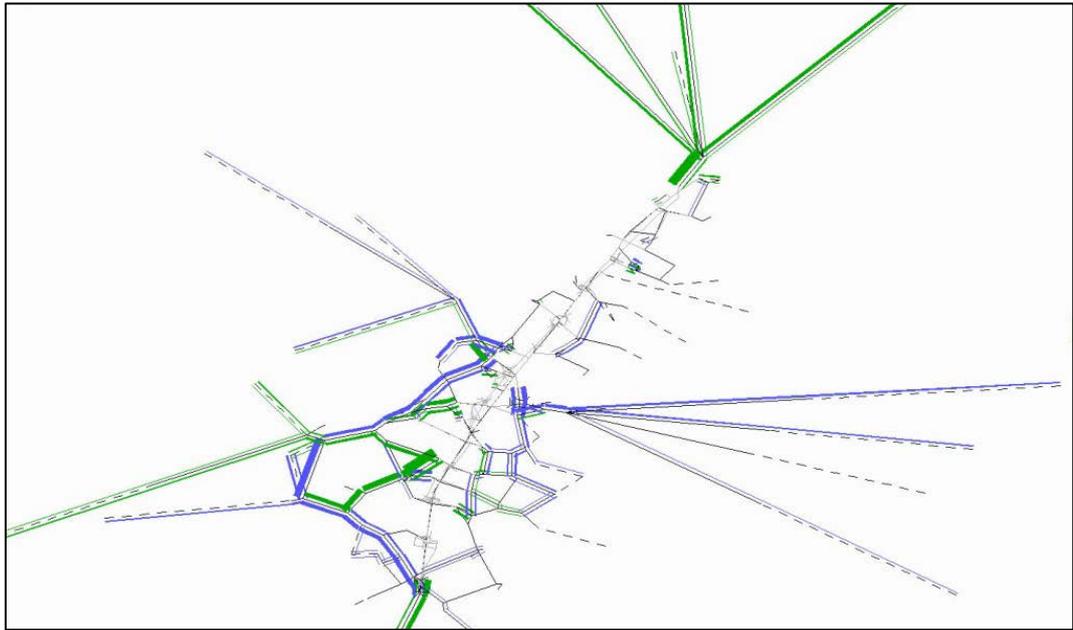


Figure 4-4: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, Elasticity Model

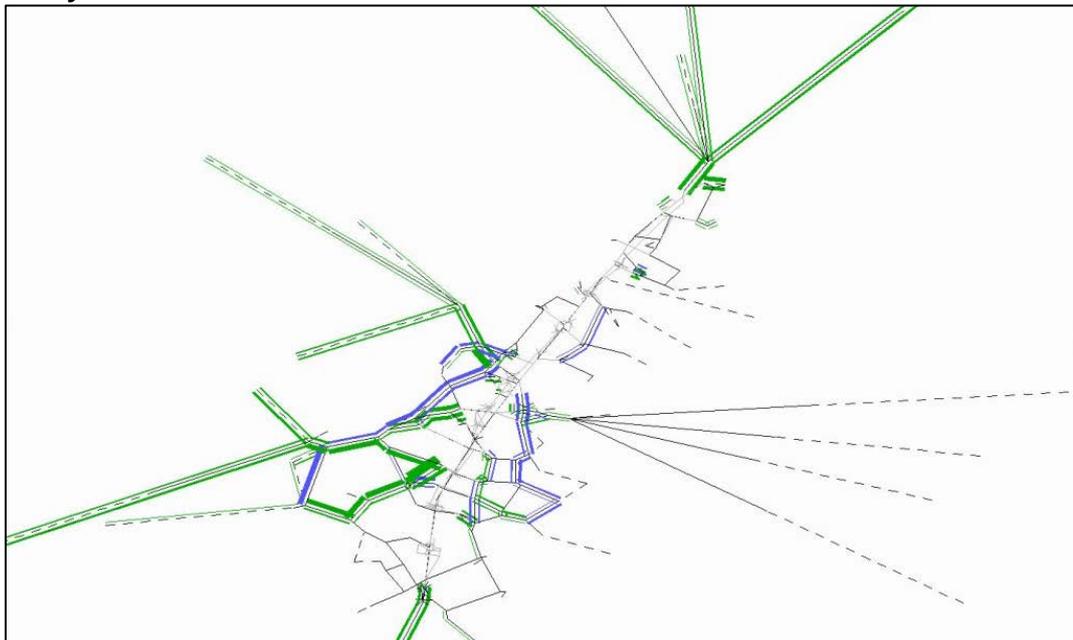
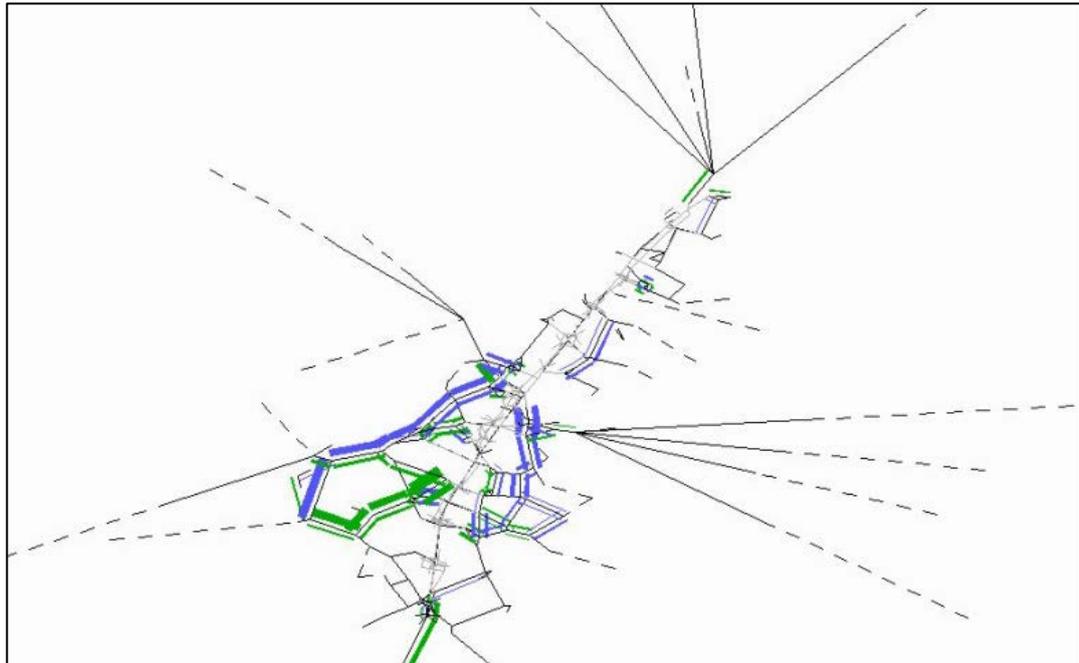


Figure 4-5: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, Fixed Demand



- 4.2.3.3. The effect on the A46 itself is not shown, as the network was recoded along the route, leaving the model nodes/links no longer in correspondence.
- 4.2.3.4. The VDM and Elasticity Model have a similar impact for the most part, certainly on strategic traffic (note the increase in flow at either end of the scheme). However, analogous to the above, the VDM has a greater tendency to suppress traffic on some routes. There is some suppression evident in the Elasticity Model, as re-routeing is modelled; however trip redistribution is not. The fixed demand model shows some re-routeing from parallel routes and other local re-routeing but as expected has no strategic impact.
- 4.2.3.5. Flow differences for the Contingency Model are shown below. The 'Reference' to 'Without Scheme' effect is quite different to that of the other models; this is again due to the inclusion of fuel cost effects in the demand modelling, which causes traffic to increase rather than decrease (compare with Figure 4-1 and Figure 4-2). However, the effect of the scheme itself is comparable with the other models.

Figure 4-6: A46, 2041, Inter-peak, 'Without Scheme' Minus Reference, Contingency Model

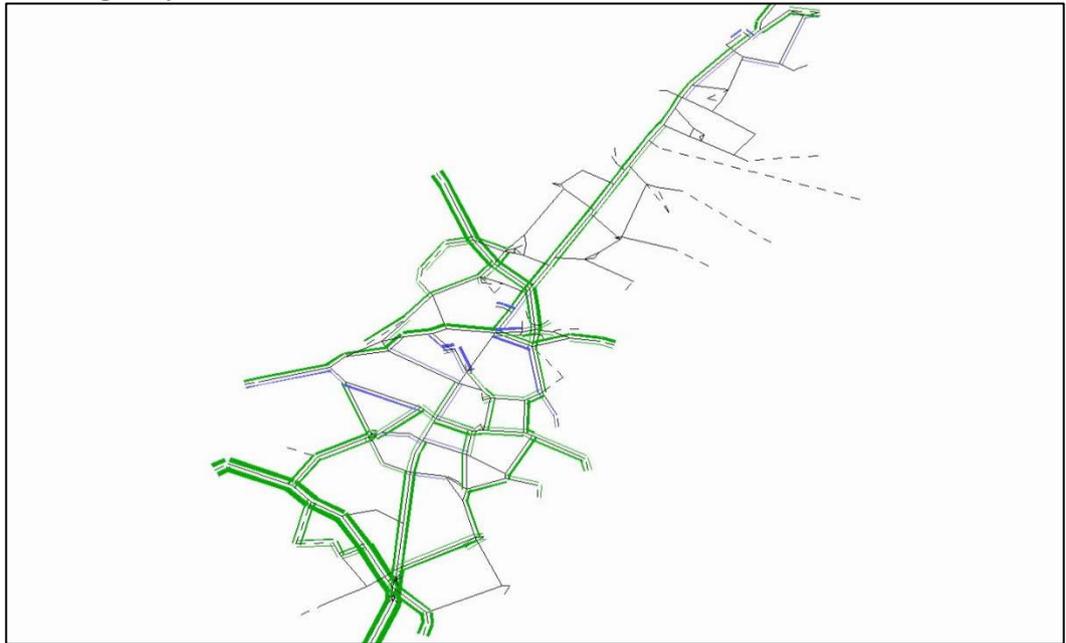
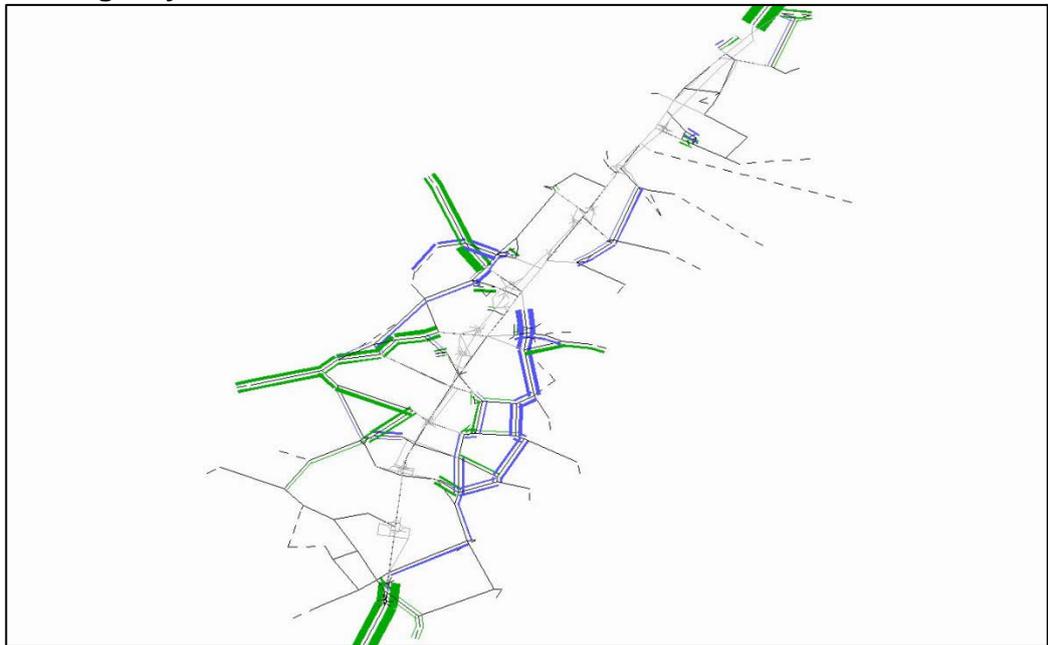


Figure 4-7: A46, 2041, Inter-peak, 'Without Scheme' Minus Reference, Contingency Model



4.2.3.6. Some plots for selected sensitivity tests are shown below. The fuel cost change VDMs show much larger growth over time, but the effect of the scheme model is not visibly much changed. The other tests are all visibly very similar to the original VDM, Elasticity or Fixed Demand assessments.

Figure 4-8: A46, 2041, Inter-peak, 'Without Scheme' Minus Reference, Exponential Elasticity Model

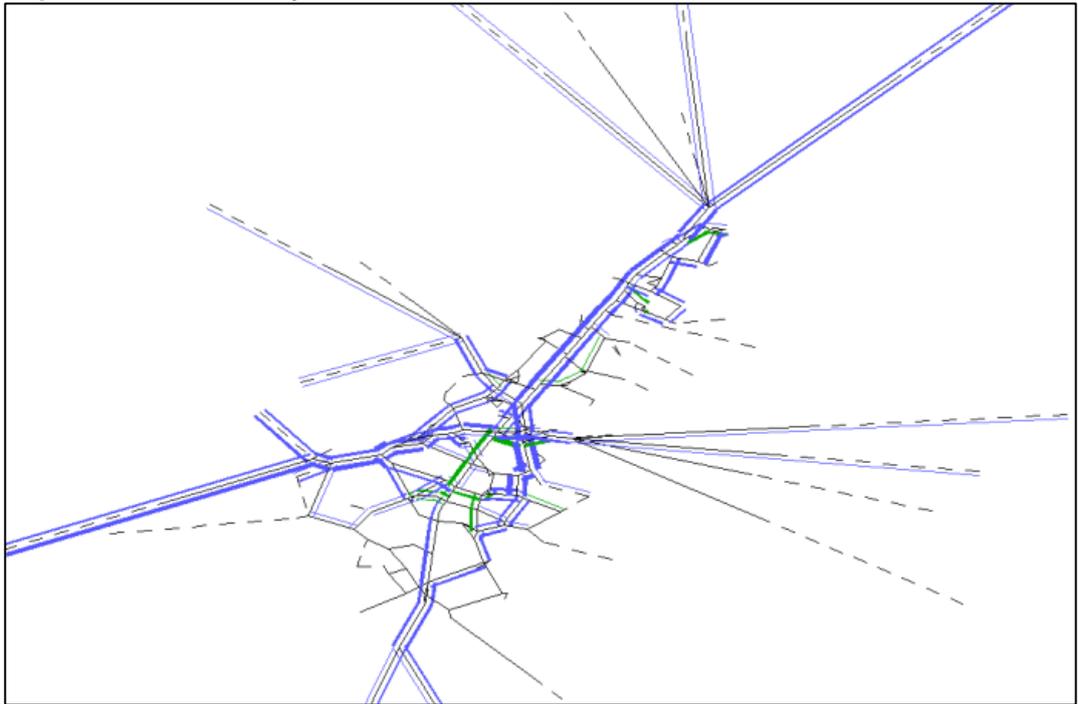


Figure 4-9: A46, 2041, Inter-peak, 'Without Scheme' Minus Reference, VDM No Time Period Choice

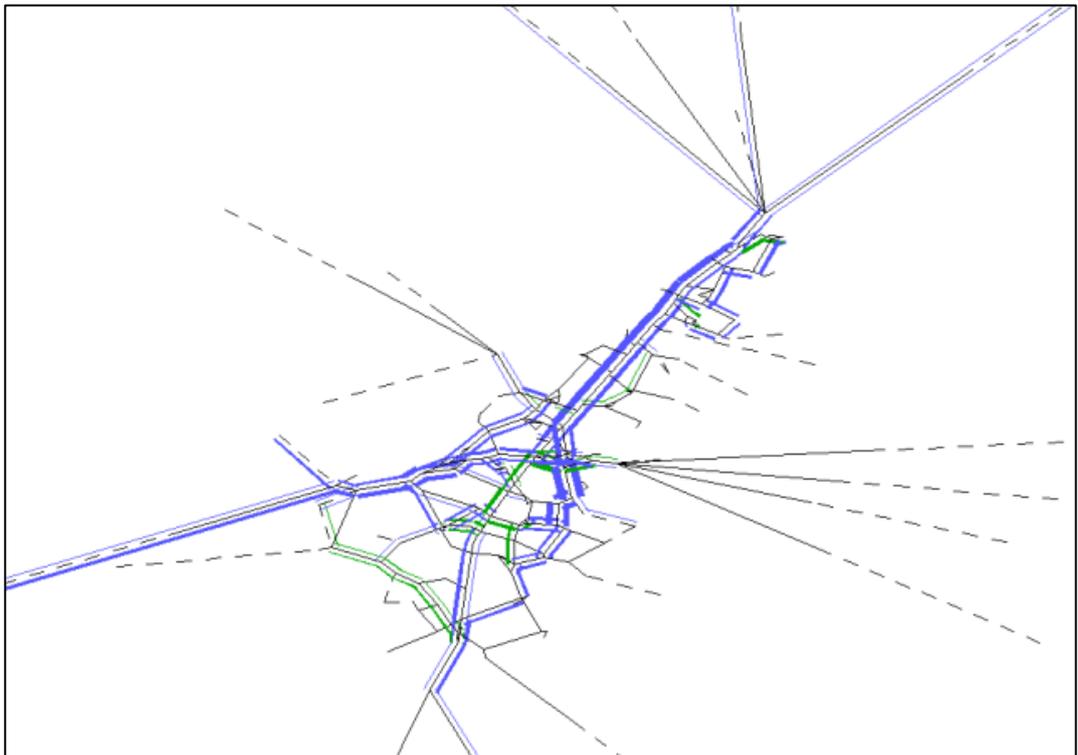


Figure 4-10: A46, 2041, Inter-peak, 'Without Scheme' Minus Reference, VDM Fuel Change

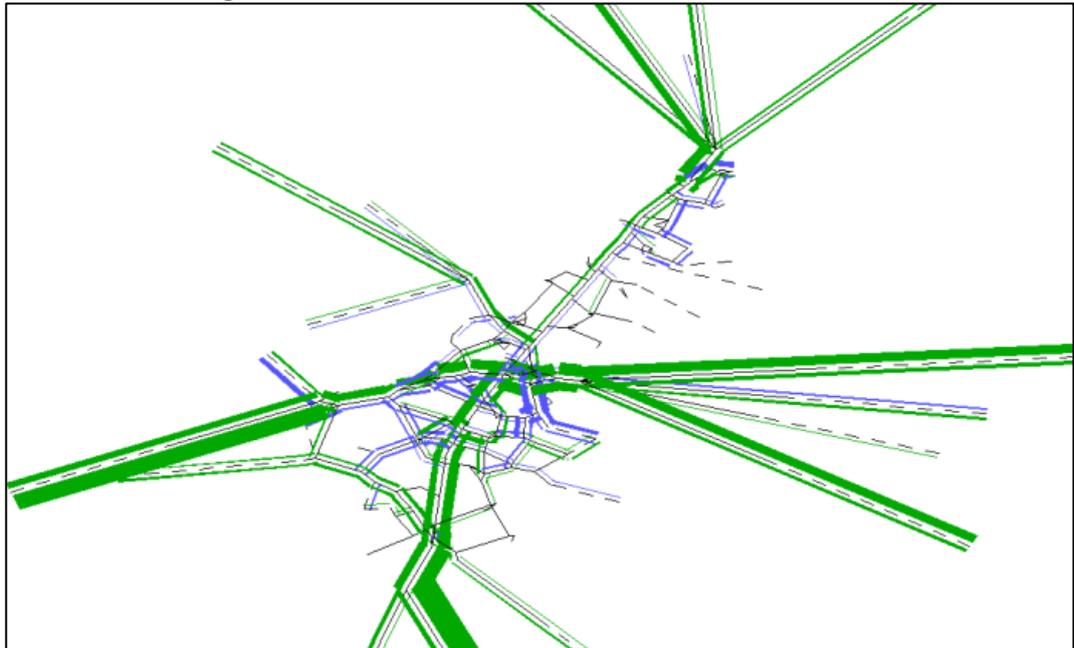


Figure 4-11: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, Exponential Elasticity Model

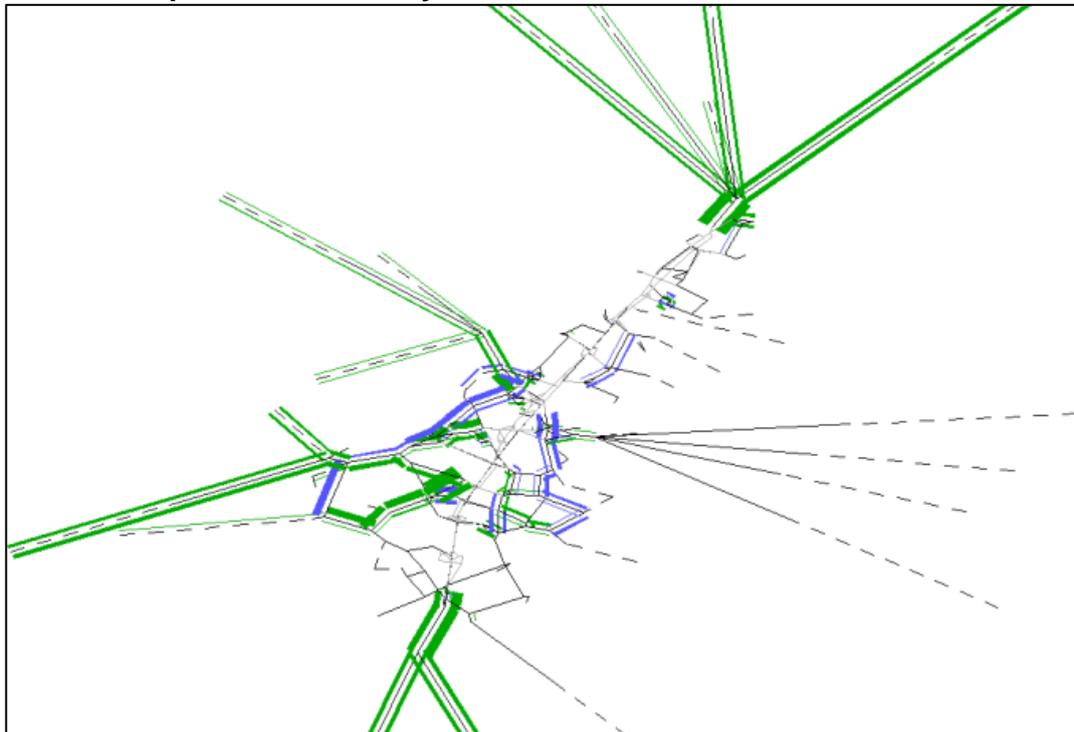


Figure 4-12: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, VDM Fixed Hybrid

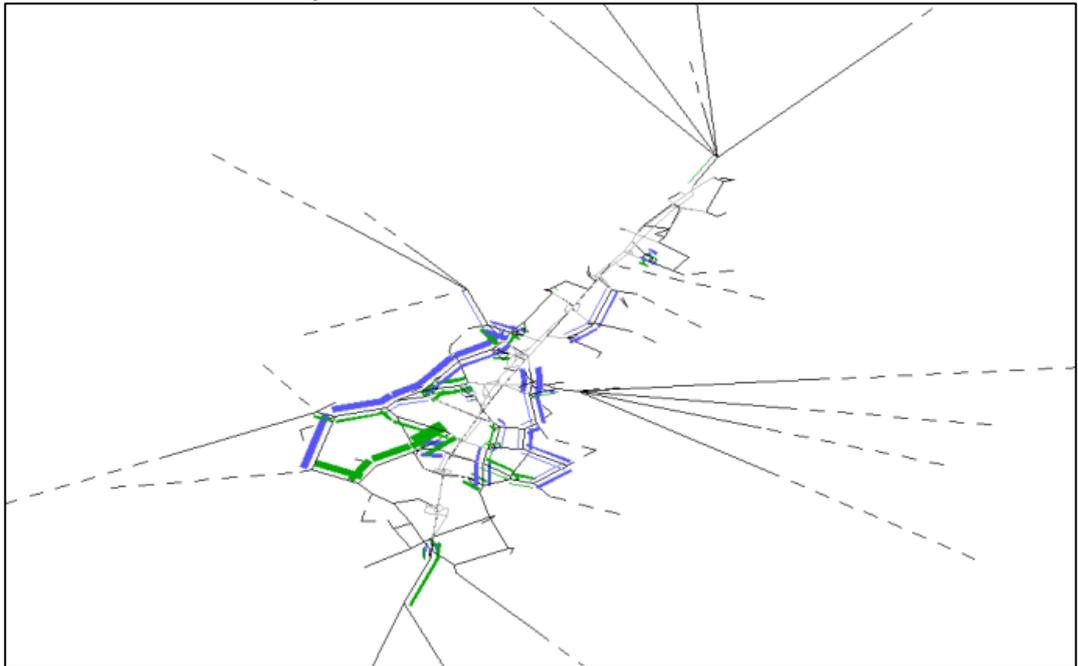


Figure 4-13: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, VDM Elasticity Hybrid

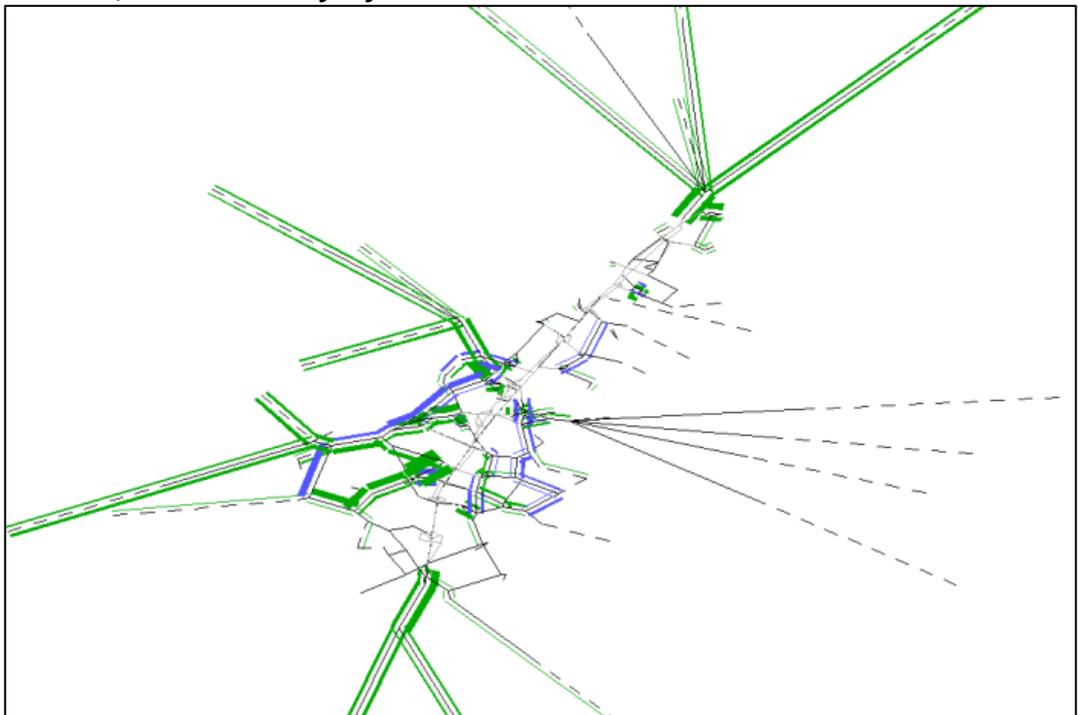


Figure 4-14: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, VDM No Time Period Choice

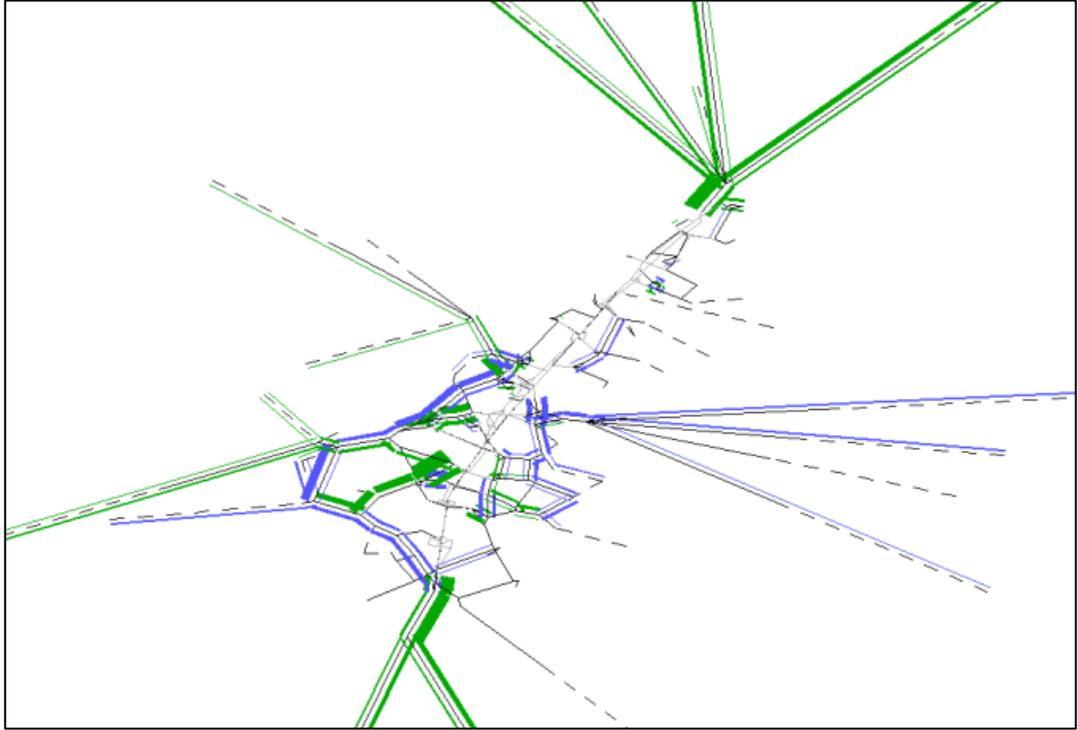
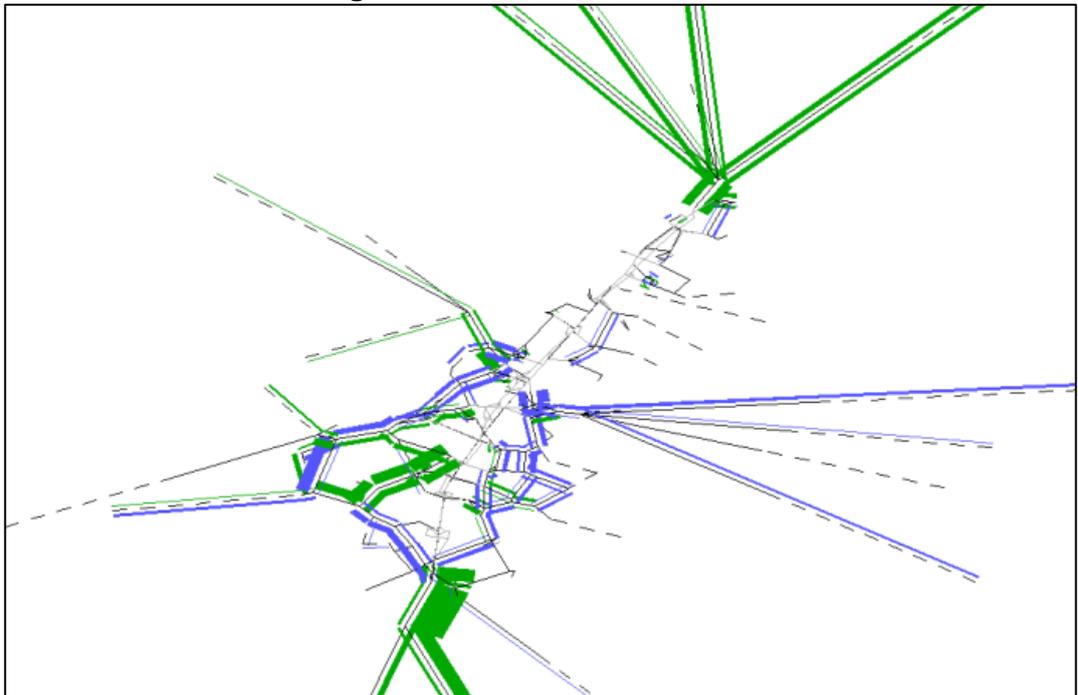


Figure 4-15: A46, 2041, Inter-peak, With Scheme Minus Without Scheme, VDM Fuel Change



4.2.4. Scheme Flows

4.2.4.1. Flows have been extracted for a link in the middle of the scheme for all four models plus the 'Base' and 'Reference' models. As the network for the 'With Scheme' scenario is different, the 'With Scheme' link is not identical to the 'Without Scheme', however, it represents the same section of road with no junction layout changes immediately surrounding it.

4.2.4.2. The 'Base' and 'Reference' flows for the Contingency Model are slightly different from the un-cordoned 'Reference' models used for the other three models; however the differences are very minimal (<1%) so they are not shown separately.

Table 4-11: A46, 2041 AM, Flows and Flow Changes

Model	Southbound		Northbound	
	Flow	Flow Change	Flow	Flow Change
Base Year	1,205		1,220	
Reference	1,487		1,280	
Elasticity Without	1,434		1,321	
Elasticity With	1,942	508	2,008	687
Fixed Demand Without	1,487		1,280	
Fixed Demand With	1,765	278	1,748	468
VDM Without	1,374		1,189	
VDM With	1,957	582	2,073	884
VDM Without, Re-run*	1,415		1,289	
VDM With, Re-run	1,986	571	2,247	958
VDM No TP Choice Without	1,417		1,280	
VDM No TP Choice With	1,933	516	2,227	947
VDM Fuel Change Without	1,478		1,357	
VDM Fuel Change With	2,214	736	2,578	1,221
VDM Fuel Change Demand Only Without	1,458		1,342	
VDM Fuel Change Demand Only With	2,188	730	2,546	1,204
Exponential Elasticity Without	1,420		1,319	
Exponential Elasticity With	1,998	578	2,097	777
VDM Fixed Hybrid With	1,639	224	1,581	291
VDM Elasticity Hybrid With	1,894	479	1,937	648
Contingency Without	1,496		1,292	
Contingency With	2,154	658	2,122	830

* The Re-run VDM is comparable with the sensitivity tests below it. The original one is as was run for the original appraisal; we were unable to reproduce this exactly.

Table 4-12: A46, 2041 Inter-peak, Flows and Flow Changes

Model	Southbound		Northbound	
	Flow	Flow Change	Flow	Flow Change
Base Year	865		823	
Reference	1,237		1,185	
Elasticity Without	1,244		1,170	
Elasticity With	1,489	246	1,417	247
Fixed Demand Without	1,237		1,185	
Fixed Demand With	1,354	117	1,263	78
VDM Without	1,223		1,138	
VDM With	1,509	286	1,668	531
VDM Without, Re-run	1,219		1,105	
VDM With, Re-run	1,505	289	1,597	492
VDM No TP Choice Without	1,221		1,104	
VDM No TP Choice With	1,509	287	1,593	489
VDM Fuel Change Without	1,269		1,265	
VDM Fuel Change With	1,906	637	1,925	660
VDM Fuel Change Demand Only Without	1,273		1,273	
VDM Fuel Change Demand Only With	1,972	699	2,018	745
Exponential Elasticity Without	1,228		1,136	
Exponential Elasticity With	1,518	289	1,431	294
VDM Fixed Hybrid With	1,252	33	1,152	47
VDM Elasticity Hybrid With	1,470	251	1,380	275
Contingency Without	1,260		1,234	
Contingency With	1,673	413	1,566	331

Table 4-13: A46, 2041 PM, Flows and Flow Changes

Model	Southbound		Northbound	
	Flow	Flow Change	Flow	Flow Change
Base Year	1,022		1,257	
Reference	1,250		1,353	
Elasticity Without	1,304		1,370	
Elasticity With	1,598	294	2,075	705
Fixed Demand Without	1,250		1,353	
Fixed Demand With	1,483	233	1,711	357
VDM Without	1,172		1,320	
VDM With	1,650	478	2,260	940
VDM Without, Re-run	1,005		1,314	
VDM With, Re-run	1,659	654	2,360	1,047
VDM No TP Choice Without	1,022		1,314	
VDM No TP Choice With	1,659	636	2,353	1,039
VDM Fuel Change Without	1,229		1,380	
VDM Fuel Change With	1,806	577	2,714	1,334
VDM Fuel Change Demand Only Without	1,174		1,377	
VDM Fuel Change Demand Only With	1,791	617	2,663	1,286
Exponential Elasticity Without	982		1,364	
Exponential Elasticity With	1,590	608	2,088	724
VDM Fixed Hybrid With	1,317	311	1,554	240
VDM Elasticity Hybrid With	1,519	513	1,969	656
Contingency Without	1,320		1,381	
Contingency With	1,661	342	2,212	831

- 4.2.4.3. The VDM produces higher overall increases in flow along the scheme than the Elasticity Model, although the two demonstrate broadly comparable scales of increase.
- 4.2.4.4. The fixed demand model produces substantially smaller increases in flow, as expected, since it does not induce traffic.
- 4.2.4.5. The Contingency Model is generally similar to the Elasticity Model, with no significant differences. Generally it produces slightly higher scheme impacts, but not greatly so.
- 4.2.4.6. There are a few noteworthy observations to be made regarding the sensitivity tests.
- 4.2.4.7. The tests with fuel cost changes exhibit much higher flows. The difference is most notable in the 'With Scheme'. This is because in the 'Without Scheme' case saturn is preventing some of the demand flows from getting through junctions as the existing links are often at capacity.
- 4.2.4.8. The VDM/Fixed hybrid has broadly similar but slightly smaller flow changes compared to the fully fixed demand assessment, but a lower absolute flow as it starts from a lower base and thus experiences a smaller cost change. Similarly, the VDM/Elasticity hybrid has similar changes to the full Elasticity Model; it is

notable that the changes are generally more like the Elasticity Model than they are like the VDM.

4.2.4.9. The VDM without time period choice is not materially different from the full VDM.

4.2.5. Demand Impact by Distance

4.2.5.1. It is interesting to consider the effect of the forms of demand model on trips by distance band. This is plotted below, both for the 'Reference' to 'Without Scheme' effect and for the 'Without Scheme' to 'With Scheme'.

Figure 4-16: A46, 2041, Inter-peak, Demand Changes by Trip Length, 'Reference' to 'Without Scheme'

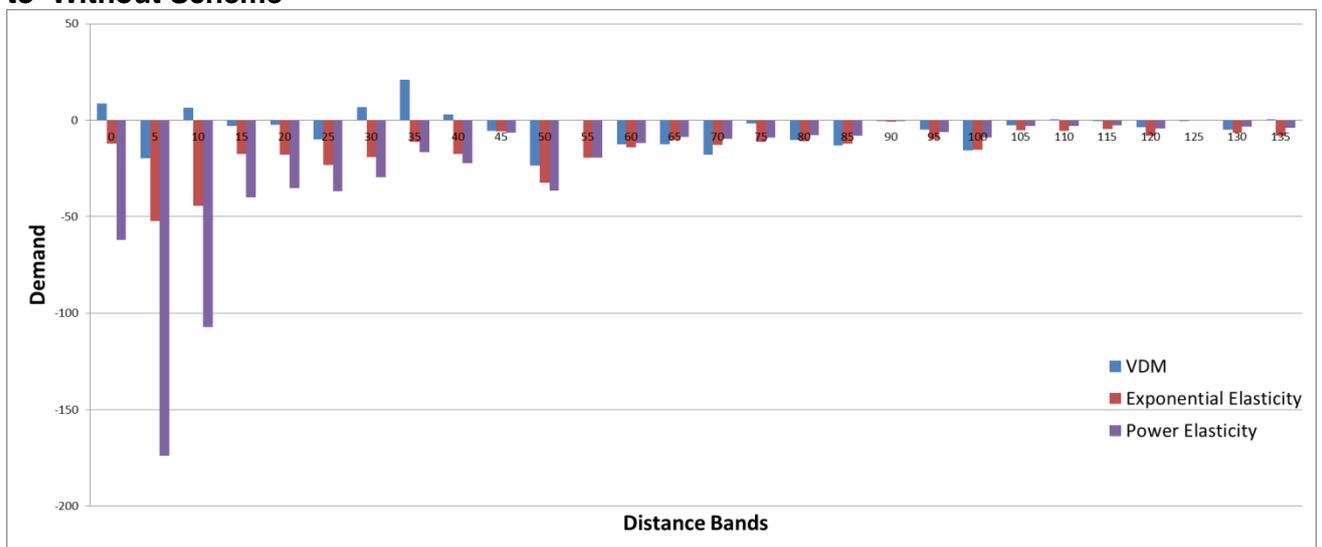
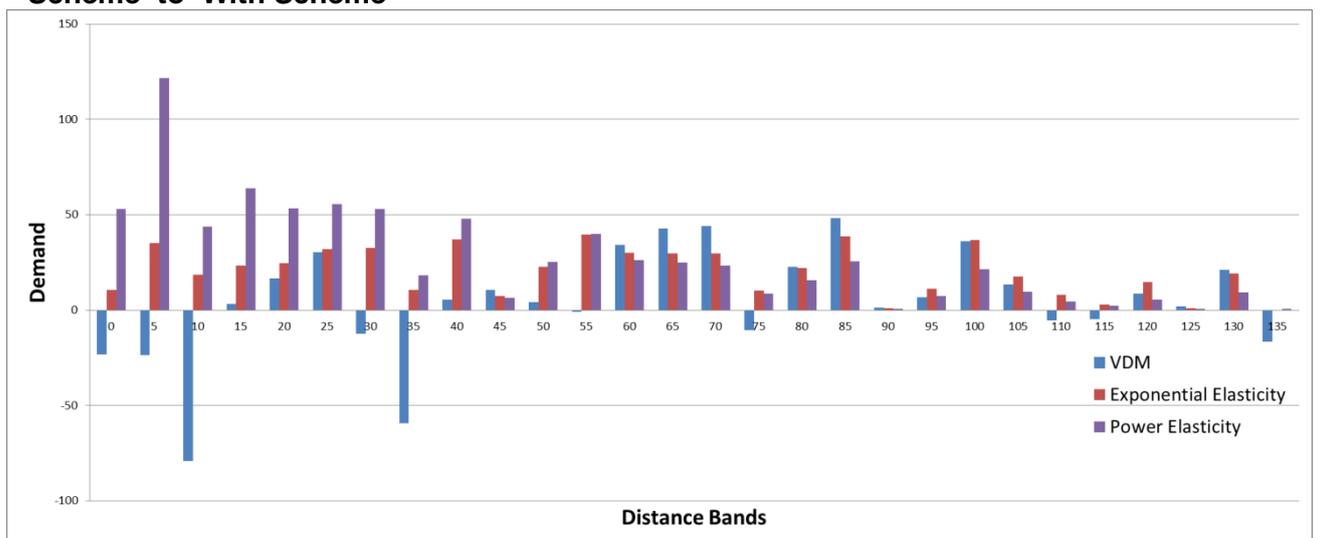


Figure 4-17: A46, 2041, Inter-peak, Demand Changes by Trip Length, 'Without Scheme' to 'With Scheme'



- 4.2.5.2. The broad pattern of the changes by method is similar across the two plots, although the changes are in opposite directions and the VDM impacts are relatively larger in the second plot.
- 4.2.5.3. The Power Elasticity Model affects (suppresses in the 'Without Scheme'; increases in the 'With Scheme') all trips in a similar proportional way; trips at each band change broadly proportionally to their initial level, meaning that the shortest bands, which have a lot of trips in, experience large absolute changes. The VDM, by contrast, has a large impact on long-distance trips, much larger than the Power Elasticity Model, but an opposite impact (increase in the 'Without Scheme'; suppression in the 'With Scheme') on the shortest trips.
- 4.2.5.4. This is due both to the redistributive effect of the VDM (which allows the shortest trips to change in the opposite direction to the general effect), and the use of absolute cost changes in a VDM in contrast to the cost ratios in use in the Elasticity Model. The latter means that long trips, which experience a large absolute cost change, but a proportional cost change broadly similar to all trips, are affected more strongly in the VDM.
- 4.2.5.5. The Exponential Elasticity Model lies somewhere between the other two. Like the VDM, it has larger proportional effects at long distances with much smaller effects at short distances. Like the Power Elasticity, it exhibits changes of consistent sign, without the opposite impact on short trips. This is because the Exponential Elasticity shares the VDM's use of absolute cost changes, but not its redistribution model.
- 4.2.5.6. There are a few counter-direction impacts at longer distance bands in the VDM case. These relate to specific origin-destination movements that happen to have that distance; for example, in the second plot, they will be movements running perpendicular to (and thus not benefiting from), the scheme.

4.3. Cost-Benefit Analysis

4.3.1. Scheme Journey Time Savings

- 4.3.1.1. Scheme journey times were calculated by summing the journey times for each link and turn along the route for each model with both scenarios.
- 4.3.1.2. The 'Base' and 'Reference' journey times for the Contingency Model are noticeably different from the un-cordoned equivalent times used for the other three models. Therefore, they are shown separately.

Table 4-14: A46, 2041 AM, Scheme Journey Time Savings, Minutes

Model	Southbound		Northbound	
	Time	Saving	Time	Saving
Base Year	33.5		35.2	
Reference	46.1		53.2	
Elasticity Without	43.4		48.7	
Elasticity With	20.2	-23.2	23.6	-25.1
Fixed Demand Without	46.1		53.2	
Fixed Demand With	19.9	-26.2	20.5	-32.7
VDM Without	39.6		42.3	
VDM With	20.7	-19.0	22.3	-20.1
VDM Without, Re-run	40.1		42.7	
VDM With, Re-run	20.2	-19.9	23.4	-19.3
VDM No TP Choice Without	40.6		42.9	
VDM No TP Choice With	20.1	-20.5	23.2	-19.7
VDM Fuel Change Without	45.7		46.5	
VDM Fuel Change With	26.0	-19.7	27.8	-18.7
VDM Fuel Change Demand Only Without	45.6		46.5	
VDM Fuel Change Demand Only With	25.6	-20.0	27.5	-19.0
Exponential Elasticity Without	40.0		41.7	
Exponential Elasticity With	20.4	-19.7	23.0	-18.8
VDM Fixed Hybrid With	19.7	-20.4	19.3	-23.3
VDM Elasticity Hybrid With	20.2	-20.0	21.1	-21.5
Contingency Base Year	33.5		35.4	
Contingency Reference	46.4		51.0	
Contingency Without	47.6		50.6	
Contingency With	24.4	-23.2	27.1	-23.5

Table 4-15: A46, 2041 IP, Scheme Journey Time Savings, Minutes

Model	Southbound		Northbound	
	Time	Saving	Time	Saving
Base Year	29.3		28.9	
Reference	36.9		35.9	
Elasticity Without	34.6		33.3	
Elasticity With	19.9	-14.7	19.0	-14.2
Fixed Demand Without	36.9		35.9	
Fixed Demand With	19.7	-17.1	19.0	-16.9
VDM Without	35.2		33.6	
VDM With	19.9	-15.3	19.1	-14.5
VDM Without, Re-run	34.3		33.0	
VDM With, Re-run	19.9	-14.5	19.1	-13.9
VDM No TP Choice Without	34.3		33.0	
VDM No TP Choice With	19.9	-14.4	19.1	-13.9
VDM Fuel Change Without	41.0		36.9	
VDM Fuel Change With	20.9	-20.1	21.5	-15.4
VDM Fuel Change Demand Only Without	42.2		37.8	
VDM Fuel Change Demand Only With	21.7	-20.5	22.5	-15.4
Exponential Elasticity Without	34.3		31.2	
Exponential Elasticity With	20.0	-14.2	19.0	-12.2
VDM Fixed Hybrid With	19.6	-14.7	19.0	-14.1
VDM Elasticity Hybrid With	19.9	-14.4	19.0	-14.0
Contingency Base Year	29.2		28.9	
Contingency Reference	36.8		34.2	
Contingency Without	37.1		36.3	
Contingency With	20.5	-16.6	19.1	-17.2

Table 4-16: A46, 2041 PM, Scheme Journey Time Savings, Minutes

Model	Southbound		Northbound	
	Time	Saving	Time	Saving
Base Year	31.2		37.9	
Reference	43.6		54.4	
Elasticity Without	38.5		52.0	
Elasticity With	21.2	-17.4	19.8	-32.1
Fixed Demand Without	43.6		54.4	
Fixed Demand With	20.5	-23.1	19.5	-34.9
VDM Without	36.4		43.5	
VDM With	20.8	-15.6	21.1	-22.4
VDM Without, Re-run	39.5		44.8	
VDM With, Re-run	20.9	-18.6	21.7	-23.1
VDM No TP Choice Without	40.1		45.1	
VDM No TP Choice With	20.9	-19.2	21.6	-23.5
VDM Fuel Change Without	45.2		49.2	
VDM Fuel Change With	24.0	-21.2	27.7	-21.4
VDM Fuel Change Demand Only Without	44.1		48.4	
VDM Fuel Change Demand Only With	23.1	-21.0	26.4	-21.9
Exponential Elasticity Without	39.9		43.8	
Exponential Elasticity With	22.0	-17.9	20.1	-23.7
VDM Fixed Hybrid With	20.1	-19.4	19.3	-25.5
VDM Elasticity Hybrid With	21.0	-18.4	19.7	-25.1
Contingency Base Year	32.3		38.0	
Contingency Reference	44.5		52.2	
Contingency Without	43.4		55.5	
Contingency With	24.5	-18.9	25.2	-30.3

4.3.1.3. As expected, the Fixed Demand Model savings are greatest. It should be noted that this is more due to high travel times in the ‘Without Scheme’ case than low times in the ‘With Scheme’ (although the latter is also true). **The Fixed Demand Model fails to suppress forecast traffic in the future sufficiently to keep it within the constraints of the network, resulting in very high travel times.**

4.3.1.4. The VDM and elasticity models are generally closer. However, the VDM forecasts lower journey time savings for all three time periods in both directions, more so northbound. This too is more related to the Elasticity Model returning higher travel times in the ‘Without Scheme’ (if anything it actually forecasts lower travel times than the VDM in the ‘With Scheme’). This may be because the VDM has more ability, such as via time-period choice, to allocate trips away from high congestion than the Elasticity Model.

4.3.1.5. The (cordoned) Contingency Model does not perfectly reproduce the un-cordoned model in the ‘Base’ or ‘Reference’ cases, although it is quite close. It tends to produce notably higher delays than the Elasticity Model in forecasting; closer to the order of the Fixed Demand Model; this is primarily due to the inclusion of fuel cost effects in forecasting, meaning that it induces demand over the ‘Reference’ rather than suppressing it, like the other models.

- 4.3.1.6. However the journey time savings between 'Without Scheme' and 'With Scheme' in the Contingency Model are closer to the original Elasticity Model and significantly lower than the Fixed Demand Model.
- 4.3.1.7. The VDMs with fuel changes exhibit much higher delays in both cases than the other models, as expected due to the additional traffic.

4.3.2. Accidents

- 4.3.2.1. Accident benefits have been calculated for each approach using COBA, as follows.

Table 4-17: A46, Accident Benefits, 60y, Forecasting Approach, 2002 Prices

	Cost (£m)			Accidents		
	With	Without	Benefit	With	Without	Benefit
VDM	293	396	103	5849	7678	1830
Elasticity	293	391	99	5815	7596	1781
Fixed	285	404	119	5674	7858	2184
Contingency	307	412	105	6124	8018	1894

- 4.3.2.2. For comparison, the original appraisal found accident benefits of £114m, which is close to the VDM benefit found here, reassuringly.
- 4.3.2.3. **All approaches return accident benefits of a similar order**, in fact. This is perhaps not surprising. Where a highway scheme returns accident benefits at all, these will usually relate primarily to improved safety of the new road compared to the existing one. As assumptions relating to this do not vary with forecasting approach, the main driver of the accident benefit will be the level of flow on the new scheme, and while this does vary by forecasting approach, it doesn't vary by more than 10-20% or so (see Table 4-11).
- 4.3.2.4. It is, however, notable that the **fixed demand approach returns higher benefit than the others**. This is despite the fact that it actually has the lowest flow on the scheme and that by a fairly large margin. This is because, counterbalancing the improved safety of the new road, the scheme will induce extra trips and traffic, and more traffic means more accidents. In the other three models, this effect acts to reduce the scheme accident benefit. In the fixed demand case, there is no induced traffic, so the full improved safety benefit is realised.

4.3.3. User and Provider Benefits

- 4.3.3.1. The scheme benefits derived from TUBA using inputs from each of the three modelling approaches as well as the Contingency Scheme are summarised below. The Elasticity Model and Fixed Demand Model results have been calculated as part of this work, while the VDM results have been extracted from TUBA output files derived in the original forecasting and appraisal work. These VDM results were reproduced using the original TUBA input files.
- 4.3.3.2. The accident benefits quoted below are from the new COBALT analysis above; not the original appraisal. Accordingly, the PVB, PVC and BCR for the VDM are not quite the same as the original appraisal.

4.3.3.3. The conclusions from the POPE (Post-Opening Project Evaluation) review of the scheme following its completion are also included. It should be noted that the published Economic Appraisal Report quotes as the appraisal results, very slightly (about 0.5%) different benefit values from those quoted under “VDM” above (the figures above are from our re-run of the VDM appraisal using VDM outputs). This discrepancy is sufficiently small to not affect conclusions.

Table 4-18: A46 Scheme, TUBA Benefits, 60 Year Appraisal, 2002 Prices, £m

Benefit	VDM	Elasticity	Fixed Demand	Contingency	POPE
Time	1,150	1,036	1,254	918	601
Vehicle Operating Costs	-240	-217	-108	-43	-131
Indirect Tax	197	210	87	93	109
Carbon	-35	-38	-16	-12	-17
Accidents*	124	119	143	127	50
Present Value of Benefits (PVB)	1196	1110	1360	1083	612
Present Value of Costs (PVC)	244	244	244	244	265
Benefit Cost Ratio (BCR)	4.9	4.5	5.6	4.4	2.3

4.3.3.4. It will be noted that the POPE study concluded that all the benefits were overstated by roughly a factor of two. There are a number of reasons for this, discussed at length in the POPE, but the recession and consequent lower levels of traffic growth and road investment is a major factor.

4.3.3.5. This finding makes it hard to judge which of the modelling methods is the most accurate, as they are in a sense all ‘wrong’. However, it does illustrate that **in this instance, uncertainty in forecasting is of a considerably larger scale than the differences between the four methods**, with both alternative methods returning PVBs within 15% of the VDM, while the POPE benefit is estimated at about 50% lower (it should be noted that even the POPE benefits are an estimate, albeit with better observed data than the forecasting models).

4.3.3.6. As has been found in previous studies, here the **Fixed Demand Model benefits are generally larger than the VDM, while the Elasticity Model benefits are smaller**. This is a common, but not inevitable finding.

4.3.3.7. Elasticity models tend to forecast the benefits on the scheme fairly well (assuming they are well calibrated), but fail to fully capture decongestion benefits elsewhere as they don’t take account of trip redistribution and consequent traffic reductions on other routes, as compared with a VDM. It is worth noting that the Elasticity Model actually forecasts larger travel time savings on the scheme route (see Table 4-14 to Table 4-16) than the VDM.

4.3.3.8. Fixed demand models might be expected to overstate benefits because they tend to understate delay in the ‘With Scheme’ case, due to a lack of induced traffic and thus large time savings, which will not materialise in practice as additional traffic moves in to fill the available capacity. While this is true to an extent, we have observed that in actuality, the high benefit in the Fixed Demand Model case tends to be much more strongly related to high delay in the ‘Without Scheme’ case than low delay in the ‘With Scheme’ case.

- 4.3.3.9. **Because fixed demand models do not suppress traffic, they tend to demonstrate very large delay on unimproved scheme roads.** A scheme will generally have been identified due to an existing capacity problem. Applying growth from a trip-end model is likely to make this problem worse, thus generating very high delay in the 'Without Scheme' model. In a VDM or elasticity model, this high delay will suppress traffic, mitigating the problem somewhat, but in a fixed demand model the delay remains. In the 'With Scheme' case the delay largely disappears, resulting in high benefit in the fixed demand case.
- 4.3.3.10. It will also be noted that fixed demand benefits for tax, carbon, and operating cost are much lower than (around half) the values in the variable demand and elasticity models. This is because tax and carbon benefits come primarily from increased fuel usage derived from increased traffic, which does not occur in a fixed demand case. Non-business, non-fuel operating costs are also derived primarily from a simple increase in demand. This issue is discussed in more detail under the M25 Model results.
- 4.3.3.11. **The Contingency Model returns time benefits very similar to the Elasticity Model (and thus VDM).** However its other benefits are significantly lower. This is because the Contingency Model does not fully represent the complete length of trips using the scheme, and therefore omits much induced traffic and thus fuel and emissions impacts. The scale of this problem in practice would depend upon how tightly the model was defined around the scheme and how the lengths of connecting links were defined.
- 4.3.3.12. Benefits for the sensitivity tests are shown below.

Table 4-19: A46 Scheme, TUBA Benefits, 60 Year Appraisal, 2002 Prices, £m

Benefit	VDM	VDM Re-run	VDM No TP Choice	VDM Fuel Change	VDM Fuel Change Demand Only	VDM Fixed Hybrid	VDM Elasticity Hybrid	Exponential Elasticity
Time	1,150	1,091	1,105	1,513	1,533	1,000	1,124	1,030
Vehicle Operating Costs	-240	-235	-238	-357	-388	-115	-211	-267
Indirect Tax	197	207	217	306	341	88	213	275
Carbon	-35	-37	-39	-57	-65	-16	-38	-49
Present Value of Benefits (PVB) ³	1,070	1,027	1,045	1,404	1,420	958	1,088	989
Present Value of Costs (PVC)	244	244	244	244	244	244	244	244
Benefit Cost Ratio (BCR)	4.4	4.2	4.2	5.6	5.7	3.9	4.4	4.0

³ No accidents are included

- 4.3.3.13. It can be noted that despite significant differences in trip and vehicle kilometre changes, the re-run of the VDM returns benefits almost identical to the original. The VDM without time period choice is also not materially different.
- 4.3.3.14. The results for the VDMs with fuel cost changes over time are very different from the core VDM, albeit very similar to each other. All benefits are substantially higher, simply due to higher traffic levels. This illustrates that **assumptions about changes in travel costs over time can have a large effect on the case for transport schemes.**
- 4.3.3.15. The hybrid models, where a VDM is used to derive the 'Without Scheme' case, but the 'With Scheme' demand is based on a simpler method, both behave reasonably well. The Fixed version has broadly appropriate time benefits (much closer to the VDM than the fully Fixed model), but it continues to produce tax, carbon and operating cost benefits substantially at variance with the demand models, as the fully Fixed model does because it fails to induce traffic. The Elasticity hybrid, by contrast, is highly consistent with the VDM for all benefits; slightly more so than the full Elasticity Model.
- 4.3.3.16. The exponential elasticity returns higher tax, carbon and operating cost benefits than the other models; it apparently induces "too much" traffic. The time benefits are very comparable, however. **The exponential elasticity does not appear better than; indeed appears slightly worse than; the power elasticity at reproducing the VDM.**
- 4.3.3.17. More detailed benefit results are shown below for all tests.

Table 4-20: A46 Scheme, User Benefits, 60 Year Appraisal, 2002 Prices, £m

	Vehicle Type	VDM	Elasticity	Fixed Demand	Contingency	VDM	VDM No TP Choice	VDM Fuel Change	VDM Fuel Change Demand Only	VDM Fixed Hybrid	VDM Elasticity Hybrid	Exponential Elasticity
Time	Business Car	469	416	503	349	441	446	576	582	408	470	415
	Non Business Car	416	382	452	313	402	406	613	624	355	405	379
	LGV	172	151	182	123	160	163	212	215	145	164	151
	HGV	94	86	117	132	88	90	112	112	93	85	84
Fuel	Business Car	-16	-15	-14	-2	-16	-16	-20	-21	-15	-14	-15
	Non Business Car	-69	-64	-61	-6	-68	-67	-104	-106	-61	-59	-66
	LGV	-38	-35	-33	-2	-36	-36	-50	-51	-33	-33	-35
	HGV	-37	-37	-36	-28	-36	-36	-41	-40	-37	-35	-36
Non-fuel	Business Car	11	10	11	9	10	10	13	13	9	11	9
	Non Business Car	-107	-91	0	-42	-104	-109	-171	-197	0	-96	-137
	LGV	-2	-2	3	1	-3	-3	-6	-7	3	-2	-4
	HGV	19	17	23	27	18	18	22	22	19	17	17

- 4.3.3.18. The Fixed Demand Model returns benefits similar to (though generally slightly larger than) the other two models for time and fuel benefits, and for business and OGV non-fuel. However it returns very much less non-fuel non-business benefit. The former set is calculated using rule-of-half, and is thus based on the travel speed and distance changes induced by the scheme, which are similar across the models.
- 4.3.3.19. However, the non-fuel non-business benefit is calculated by simply subtracting total maintenance cost in the 'Without Scheme' case from cost in the 'With Scheme' case, and is thus highly dependent on changes in the level of demand, which do not exist in the fixed demand model. The appraisal assumption in TUBA is that non-business users do not perceive non-fuel operating costs as they depend on journey distance and that their decisions are thus independent of them.
- 4.3.3.20. The Contingency Model returns broadly similar time benefits. It benefits car and LGV somewhat less, but partially compensates for this by higher HGV benefit. It behaves very like the Fixed Demand Model for non-fuel benefits, deriving the business impact correctly, but understating non-business (albeit not as much as fixed demand). The Contingency Model does induce traffic, of course, but because it lacks representation of the full length of strategic trips, it does not fully capture the effect of these induced trips on fuel usage, as noted above.
- 4.3.3.21. The most interesting effect is the substantially lower car and LGV fuel impacts in the Contingency Model scheme. From investigation, this is also related to the removal of the long connecting links that represent full trip lengths in the un-cordoned model. These were coded with notably higher speeds than the scheme itself and are considerably longer than the scheme.
- 4.3.3.22. Because TUBA calculates fuel consumption based on end-to-end average journey speeds, in the un-cordoned models it thus derived, from the scheme, an increase in speed for a journey that was already quite fast (due to the long fast connector links). This leads to an increase in fuel consumption and notable disbenefit.
- 4.3.3.23. In the cordoned (Contingency Model) network, on the other hand, the increase in speed from building the scheme is from a much lower 'Without Scheme' speed. As this is close to optimum fuel-consumption speed anyway, and fuel consumption curves are quite flat close to the optimum, this does not have a significant effect on fuel consumption, leading to little benefit.
- 4.3.3.24. The curious point about this difference is that here, the Contingency Model, with its smaller network area, is probably closer to reality (although likely still not correct). In practice relieving congestion will almost always reduce fuel consumption and emissions per vehicle kilometre (it may not do so overall once induced traffic has been accounted for, but this does not affect user fuel consumption benefits), so the TUBA results for the un-cordoned models should be regarded as unlikely, and an artefact of the use of matrix-level speeds to derive differences in fuel consumption.
- 4.3.4. **The use of average journey speeds to calculate fuel consumption and emissions, while reasonable for absolute totals, has significant potential problems in calculating differences or benefits induced by a speed-change;** it can easily, as probably here, return values of the wrong sign. Unfortunately, use of link by link speeds is not correct either, as the underlying

fuel consumption research is related to drive cycles rather than instantaneous speeds.

4.3.5. Time Benefits by Sector Movement

- 4.3.5.1. The user time benefits, which, here as in many appraisal contexts, tend to dominate the overall benefit, have been extracted by sector movement. “Internal” here refers to model zones within the modelled area (within a short distance of the A46 scheme).
- 4.3.5.2. This demonstrates that the strategic impacts are very similar across the three forecasting methods. It is in the more local internal movements that the elasticity and fixed demand models under and over-estimate benefits respectively. In the case of the Elasticity Model, as noted earlier, this is due to its failure to fully capture decongestion benefits elsewhere.
- 4.3.5.3. In the case of the Fixed Demand Model, this appears to be related to high delays for access to and from the A46 evident in the ‘Without Scheme’ case, because it does not suppress traffic over time due to congestion. Both of the other forecasting models generated lower ‘Without Scheme’ traffic and access delays and thus have less scope to generate additional benefit.
- 4.3.5.4. As noted previously, the VDM and elasticity models did not take account of falling perceived fuel costs over time. Had they done so, they would have suppressed traffic in the ‘Without Scheme’ case less, possibly to the point where congestion effects and fuel cost effects broadly cancelled each other out. So it cannot necessarily be concluded that the fixed demand results are ‘wrong’, although if they do represent a better forecast this is somewhat fortuitous.

Table 4-21: A46, Time Benefits by Sector Movement, 60 Yr, 2002 Prices, £m

Sector Movement	VDM	Elasticity	Fixed Demand	Contingency
Strategic Along Scheme	228	213	220	338
Other Strategic (E-E)	278	268	289	127
External-Internal (and I-E)	473	404	529	305
Internal-Internal	171	151	216	148
Total	1150	1036	1254	918

4.3.6. Convergence and Stability of Impacts

- 4.3.6.1. All of the A46 ‘With Scheme’ elasticity models were run a second time with an additional iteration of assignment in each loop to gauge the impact of demand model convergence on the results. The resulting TUBA benefits varied by less than 0.1% from the original assessment, indicating that the models are extremely well converged.
- 4.3.6.2. In a small “cordon” model of this type, with few links and zones and no external network, this sort of convergence is likely to be frequently achievable. In larger and broader models, such as the M25 Model, convergence in appraisal is a significantly larger problem.

4.4. Summary of Findings

1. Uncertainty in forecasting is of a considerably larger scale than the differences between the four methods.
1. Fixed Demand Model benefits are generally larger than the VDM, while the Elasticity Model benefits are smaller
2. The Fixed Demand Model fails to suppress forecast traffic in the future sufficiently to keep it within the constraints of the network, resulting in very high travel times.
2. Assumptions about changes in travel costs over time can have a large effect on the case for transport schemes.
3. The Contingency Model does not fully represent the complete length of trips using the scheme, and therefore omits much induced traffic and thus fuel and emissions impacts
3. All approaches return accident benefits of a similar order; fixed demand approach returns higher benefit than the others.
4. The exponential elasticity does not appear better than; indeed appears slightly worse than; the power elasticity at reproducing the VDM

5. Motorway (M25) Scheme Results

5.1. Elasticity Model Calibration

- 5.1.1.1. The Elasticity Model sensitivity was calibrated for this study using the base year (2004) models. The value of distance in SATURN (ppk) was increased to reflect a 10% increase in fuel prices, and the sensitivity of the response calculated. The sensitivity was adjusted to reflect WebTAG guidance relating to appropriate fuel cost elasticities (between -0.25 and -0.30, due to the London/strategic context). A similar approach was used to calibrate the variable demand model for the original appraisal. No response was calibrated for freight travel. A 10% car fuel cost increase was modelled by adjusting the ppk parameters in SATURN; the ppk parameters represent both fuel and non-fuel cost, so, as with the A46 Model, the ppk adjustment was less than 10%.
- 5.1.1.2. A value for the sensitivity (β -value) of the power elasticity of -1.69806 was derived, the same elasticity as used for the A46 Model; on the basis that this produced suitable elasticities it was decided to use the same sensitivity for both models. The Elasticity Model was applied to the car user classes only. The model sensitivity was assessed using arc elasticities of fuel cost to vehicle distance, as advised in WebTAG M2 §6.4. The elasticities obtained are shown below. "Internal" here refers to the entire M25 Model area, covering all of Greater London, the M25 and surrounding area. This is the area for which the M25 Model is reasonably detailed.

Table 5-1: Fuel Cost Elasticities, M25 Model, Matrix-Level, Internal Origins

	Business	Commute	Other	LGV	HGV	All Car
AM	-0.03	-0.39	-0.34	0.00	0.00	-0.30
IP	-0.10	-0.48	-0.29	0.00	0.00	-0.25
PM	-0.05	-0.42	-0.26	0.00	0.00	-0.29
12hr	-0.07	-0.45	-0.29	0.00	0.00	-0.27

Table 5-2: Fuel Cost Elasticities, M25 Model, Network-Level, Internal Links

	Business	Commute	Other	All Car
AM	-0.03	-0.41	-0.35	-0.30
IP	-0.11	-0.50	-0.31	-0.27
PM	-0.04	-0.43	-0.27	-0.29
12hr	-0.08	-0.46	-0.31	-0.28

5.2. Traffic Demand Impacts

5.2.1. Trips

5.2.1.1. The effects of the VDM and elasticity model on trip totals are shown in the table below for the final model year 2030. Figures are in passenger car units (PCUs).

5.2.1.2. The 2030 'Reference' demand, generated from National Trip-End Model forecasts of population and employment, is higher than the 2004 base, as expected.

Table 5-3: M25, 2030, Impact of Demand Models on Trip Totals, PCUs

Demand Matrices Comparison-Demand in PCUs							
		VDM Model		Elasticity Model		VDM Elasticity Hybrid	
Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Without Scheme to With Scheme	
User Class	AM, 2004	AM, 2030					
Car Business	517,176	607,186	-9,611 (-2%)	827 (0%)	-19,344 (-3%)	169 (0%)	-93 (0%)
Car Commute	3,104,270	4,120,173	-46,135 (-1%)	3,279 (0%)	32,111 (1%)	63 (0%)	-219 (0%)
Car Other	2,521,041	3,077,139	15,305 (0%)	4,959 (0%)	-3,081 (0%)	127 (0%)	-590 (0%)
LGV	130,484	184,975	-4,334 (-2%)	100 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	183,491	227,167	-6,864 (-3%)	181 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	6,456,462	8,216,640	-51,639 (-1%)	9,346 (0%)	9,686 (0%)	359 (0%)	-901 (0%)

User Class	IP, 2004	IP, 2030					
Car Business	541,155	631,682	2,104 (0%)	-62 (0%)	-21,411 (-3%)	226 (0%)	-40 (0%)
Car Commute	594,036	777,405	4,189 (1%)	-626 (0%)	10,537 (1%)	64 (0%)	-3 (0%)
Car Other	3,619,924	4,235,707	99,869 (2%)	206 (0%)	23,383 (1%)	394 (0%)	-53 (0%)
LGV	133,414	187,254	1,515 (1%)	-116 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	197,770	241,961	1,890 (1%)	-106 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	5,086,299	6,074,009	109,567 (2%)	-704 (0%)	12,509 (0%)	684 (0%)	-95 (0%)

User Class	PM, 2004	PM, 2030					
Car Business	448,891	571,996	-9,473 (-2%)	646 (0%)	-20,908 (-4%)	174 (0%)	-178 (0%)
Car Commute	2,195,643	2,995,072	-24,331 (-1%)	1,054 (0%)	33,485 (1%)	559 (0%)	-314 (0%)
Car Other	3,461,457	4,189,981	16,346 (0%)	4,359 (0%)	-1,293 (0%)	586 (0%)	-816 (0%)
LGV	122,166	173,649	-2,716 (-2%)	232 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	120,971	148,946	-3,150 (-2%)	177 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	6,349,128	8,079,644	-23,324 (0%)	6,468 (0%)	11,284 (0%)	1,319 (0%)	-1,307 (0%)

- 5.2.1.3. Freight demand is fixed across all elasticity model tests and is held constant by the Elasticity Model. However, this is not the case for the VDM.
- 5.2.1.4. The VDM demand in the 'Without Scheme' case is slightly lower than the 'Reference' for both peak periods, indicating that congestion is suppressing these trips. However, because the model contains time-period choice, the inter-peak trips are in fact significantly higher than the 'Reference', as demand is shifted out of the peaks (which are more congested) into the inter-peak period.
- 5.2.1.5. When the scheme is added, traffic increases in the VDM, as expected. Again, the inter-peak exhibits a reverse-effect, as the scheme moves trips back into the peaks through time period choice.
- 5.2.1.6. The effect of the Elasticity Model on 'Reference' demand is comparable to the VDM in terms of overall scale, although the size and even the sign of each individual impact varies substantially. This is probably because the Elasticity Model and VDM use different methods for calculating generalised cost (unlike in the A46 Model, where they were the same), with the VDM method having a speed dependence, and the positive elements (reducing fuel cost) and negative elements (increasing congestion) being fairly well-balanced.
- 5.2.1.7. Unlike the A46 elasticity model, the M25 Elasticity Model is substantially less sensitive than the VDM for the scheme impact, about a fifth as sensitive overall. As with the A46, it exhibits growth in the inter-peak in contrast to the VDM, which, via time-period choice, moves trips out of the inter-peak.
- 5.2.1.8. The reason for this reduced sensitivity is not obvious; as discussed under the A46 scheme, there are good reasons to expect the Elasticity Model to appear more sensitive in terms of trips. It may be related to differences in the way in which the VDM and Elasticity Model calculate generalised cost and in particular, the trade-off between fuel cost benefits and congestion disbenefits.
- 5.2.1.9. Unexpectedly, the hybrid VDM/Elasticity approach returns trip changes of the opposite sign to the full Elasticity model. This is a convergence artefact; traffic and trip distance changes are very similar, as are the user benefits.
- 5.2.1.10. The Contingency Model results are supplied in the separate table below.

Table 5-4: Trip Total Impacts of M25 Demand Contingency Models, 2041, PCUs

	UFM Matrices Comparison- Demand in PCUs			
	Base Model		Contingency Model	
	Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme
User Class	AM, 2004	AM 2030		
Car Local	54,462	59,281	3,826 (6%)	113 (0%)
Car Strategic	59,003	67,017	11,922 (17%)	-35 (0%)
LGV	9,721	11,392	-4 (0%)	0
HGV	22,474	25,246	-16 (0%)	38 (0%)
Total	145,660	162,936	15,728 (9%)	116 (0%)

User Class	IP, 2004	IP 2030		
Car Local	36,474	39,813	5,170 (12%)	147 (0%)
Car Strategic	37,609	44,315	11,956 (24%)	254 (0%)
LGV	9,833	11,603	-4 (0%)	361 (2%)
HGV	25,122	28,277	19 (0%)	70 (0%)
Total	109,038	124,008	17,141 (12%)	832 (1%)

User Class	PM, 2004	PM 2030		
Car Local	55,783	60,511	4,720 (7%)	94 (0%)
Car Strategic	60,922	69,266	13,340 (18%)	-53 (0%)
LGV	10,156	11,783	-4 (0%)	0
HGV	15,894	17,752	-23 (0%)	22 (0%)
Total	142,755	159,312	18,033 (10%)	63 (0%)

5.2.1.11. The 'Reference' to 'Without Scheme' effect is comparable with that of the un-cordoned models. However, the scheme itself induces very few trips, with the strategic car impact actually being negative. This surprising result is due to significant suppression for a number of relatively short strategic movements, perpendicular to the scheme and along the M25 beyond either end of the scheme. The scheme does, however, induce vehicle kilometres analogous to the effect in the un-cordoned models, as discussed in the following section.

5.2.2. Vehicle Distance

5.2.2.1. The consistency of the traffic impact can be illustrated more clearly by examining total trip distance (in terms of PCU kilometres) instead of total trips. This is shown below.

5.2.2.2. In the peaks, the sensitivity of the Elasticity Model and VDM are much closer in terms of total distance travelled than they are in terms of trips for 'Reference' vs 'Without Scheme' effect; indeed for non-business travel they exhibit very similar changes, demonstrating that their overall sensitivity has been calibrated similarly. The Elasticity Model is very slightly more sensitive in traffic terms for the 'Reference' to 'With Scheme' impact.

Table 5-5: M25, 2030, Impact of Demand Models on Trip Distances, PCU km

	Demand Matrices Comparison-Trip Distances (PCU km)						
			VDM Model		Elasticity Model		VDM Elasticity Hybrid
	Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme	Reference to Without Scheme	Without Scheme to With Scheme	Without Scheme to With Scheme
User Class	AM, 2004	AM, 2030					
Car Business	7,264,919	9,023,096	-188,868 (-2%)	123,151 (1%)	-564,805 (-6%)	12,529 (0%)	12,012 (0%)
Car Commute	14,752,853	17,686,010	2,468,208 (14%)	98,632 (0%)	2,465,942 (14%)	5,788 (0%)	15,304 (0%)
Car Other	8,940,087	11,610,100	1,252,817 (11%)	58,304 (0%)	1,111,646 (10%)	10,048 (0%)	11,880 (0%)
LGV	2,585,119	4,137,714	103,683 (3%)	9,674 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	7,381,899	10,357,739	73,637 (1%)	22,870 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	40,924,877	52,814,659	3,709,477 (7%)	312,631 (1%)	3,012,783 (6%)	28,365 (0%)	39,196 (0%)

User Class	IP, 2004	IP, 2030					
Car Business	6,866,876	8,623,877	323,213 (4%)	10,289 (0%)	-353,331 (-4%)	14,335 (0%)	14,922 (0%)
Car Commute	2,434,707	2,950,436	644,965 (2%)	-995 (0%)	618,490 (21%)	3,526 (0%)	2,947 (0%)
Car Other	11,958,755	15,654,382	2,611,404 (17%)	11,976 (0%)	2,246,886 (14%)	24,016 (0%)	24,124 (0%)
LGV	2,561,907	4,109,719	318,769 (8%)	-25 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	8,199,720	11,517,295	591,205 (5%)	-3,364 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	32,021,965	42,855,709	4,489,556 (10%)	17,881 (0%)	2,512,045 (6%)	41,877 (0%)	41,993 (0%)

User Class	PM, 2004	PM, 2030					
Car Business	6,428,907	8,104,293	-313,534 (-4%)	36,809 (0%)	-562,300 (-7%)	10,289 (0%)	12,230 (0%)
Car Commute	13,530,602	16,178,492	2,297,630 (14%)	89,856 (0%)	2,498,672 (15%)	24,666 (0%)	15,022 (0%)
Car Other	13,265,836	17,080,256	1,421,808 (8%)	76,748 (0%)	1,466,050 (9%)	22,446 (0%)	14,704 (0%)
LGV	2,642,174	4,226,418	140,681 (3%)	11,099 (0%)	0 (0%)	0 (0%)	0 (0%)
HGV	5,615,951	7,892,377	128,366 (2%)	8,154 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	41,483,470	53,481,836	3,674,951 (7%)	222,666 (0%)	3,402,422 (6%)	57,401 (0%)	41,956 (0%)

- 5.2.2.3. However, the scheme impact is still significantly smaller in the Elasticity Model; as for trips, the overall elasticity model changes are around 20% of the VDM.
- 5.2.2.4. The reason for the substantially lower traffic sensitivity in the M25 Elasticity Model compared with the VDM probably relates to the strategic nature of the scheme and wide scope of the model. The M25 Model as a whole was calibrated to a slightly-below -0.30 fuel cost elasticity for both the VDM and elasticity model, so they should overall have similar sensitivity to fuel cost. However, the trips using the M25 are atypically long and strategic. The Elasticity Model exhibits lower sensitivity for these trips because the proportional cost change (the trips being long) is low; the VDM being based on absolute cost changes is more sensitive.
- 5.2.2.5. In contrast with the trip totals, in terms of vehicle distance the VDM/Elasticity hybrid returns changes broadly similar to those of the full Elasticity Model.
- 5.2.2.6. The Contingency Model vehicle distances are shown below. The scheme effect is very similar to that in the un-cordoned models (in contrast to the trip totals in the previous section). The 'Reference' to 'Without Scheme' effect is of course much smaller in absolute terms, the cordoned model being smaller, but comparable proportionally.

Table 5-6: Trip Distance Impacts, M25 Contingency Models, 2041, PCU Km

	UFM Matrices Comparison-Distance in Vkm			
	Base Model		Contingency Model	
	Base Year	Reference	Reference to Without Scheme	Without Scheme to With Scheme
User Class	AM, 2004	AM 2030		
Car Local	867,143	1,022,043	59,138 (6%)	3,871 (0%)
Car Strategic	1,229,978	1,448,328	169,630 (12%)	26,648 (2%)
LGV	175,914	273,736	-145 (0%)	0 (0%)
HGV	533,782	742,242	-481 (0%)	1,268 (0%)
Total	2,806,817	3,486,349	228,142 (7%)	31,787 (1%)

User Class	IP, 2004	IP 2030		
Car Local	510,261	617,302	76,961 (12%)	3,347 (0%)
Car Strategic	890,303	1,105,041	168,838 (15%)	28,118 (2%)
LGV	188,206	291,154	-105 (0%)	0 (0%)
HGV	655,727	942,719	-11 (0%)	1,800 (0%)
Total	2,244,497	2,956,216	245,683 (8%)	33,265 (1%)

User Class	PM, 2004	PM 2030		
Car Local	884,693	1,052,818	72,711 (7%)	3,703 (0%)
Car Strategic	1,289,310	1,561,835	185,467 (12%)	29,280 (2%)
LGV	179,903	282,089	-148 (0%)	0 (0%)
HGV	391,632	546,921	-628 (0%)	785 (0%)
Total	2,745,538	3,443,663	257,402 (7%)	33,768 (1%)

5.2.3. Network Flows

5.2.3.1. The effect of the demand model on the 'Reference' demand assignment is shown graphically below for the 2030 inter-peak, in both the VDM and elasticity model cases. Blue bars represent reduction in flow; green bars increase in flow. The bar width is proportional to the size of change.

Figure 5-1: M25, 2030, Inter-peak, 'Without Scheme' Minus Reference, VDM

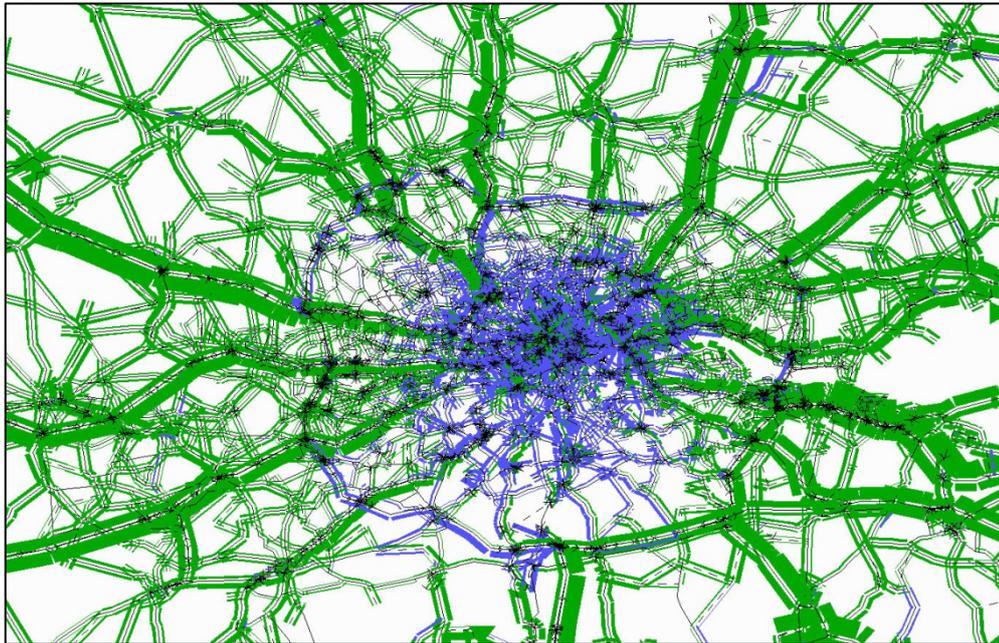
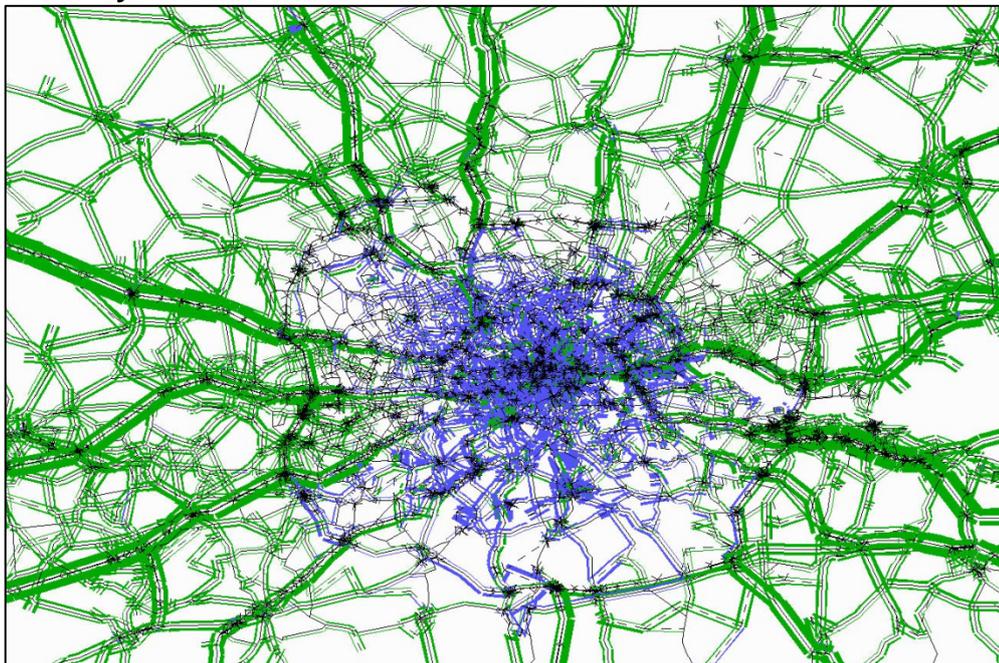


Figure 5-2: M25, 2030, Inter-peak, 'Without Scheme' Minus Reference, Elasticity Model



5.2.3.2. Here the models do not differ too greatly from one another. Both models suppress traffic in the Greater London area and show radial routes experiencing large increases.

Figure 5-3: M25, 2030, Inter-peak, Effect of Scheme in VDM

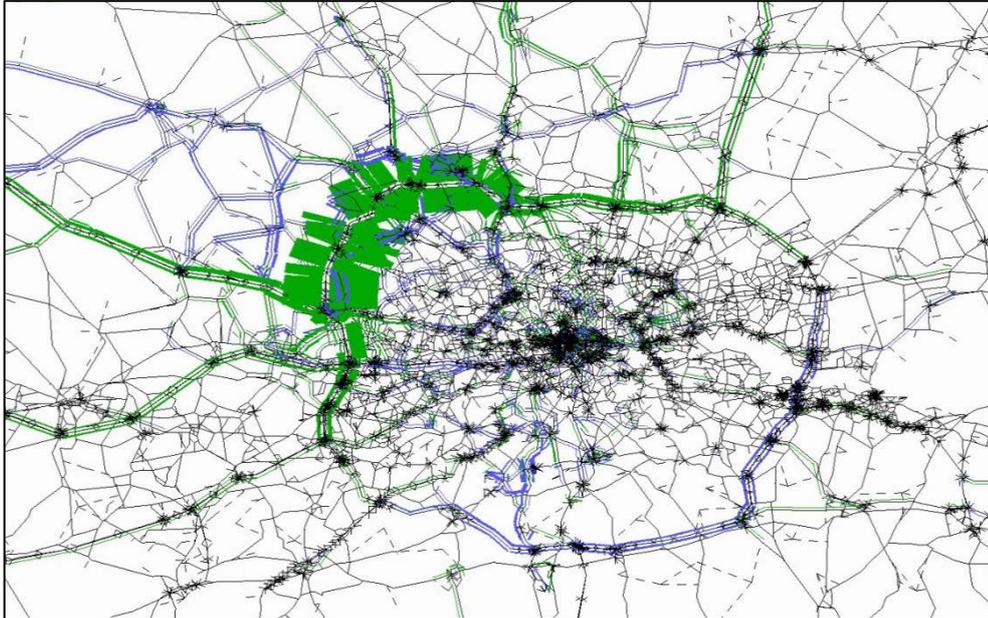


Figure 5-4: M25, 2030, Inter-peak, Effect of Scheme in Elasticity Model

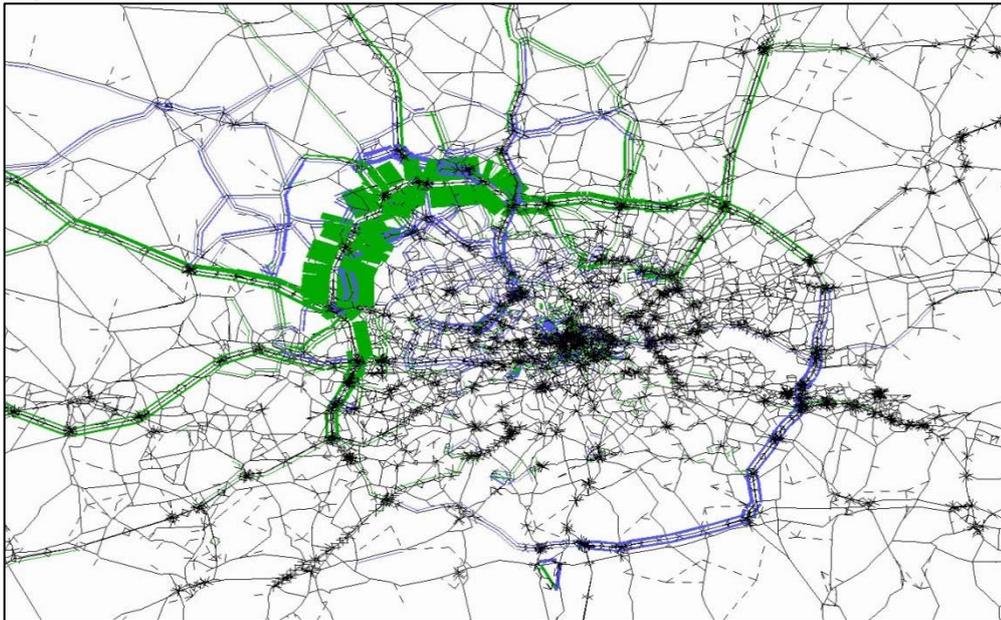


Figure 5-5: M25, 2030, Inter-peak, Effect of Scheme in Fixed Demand Model

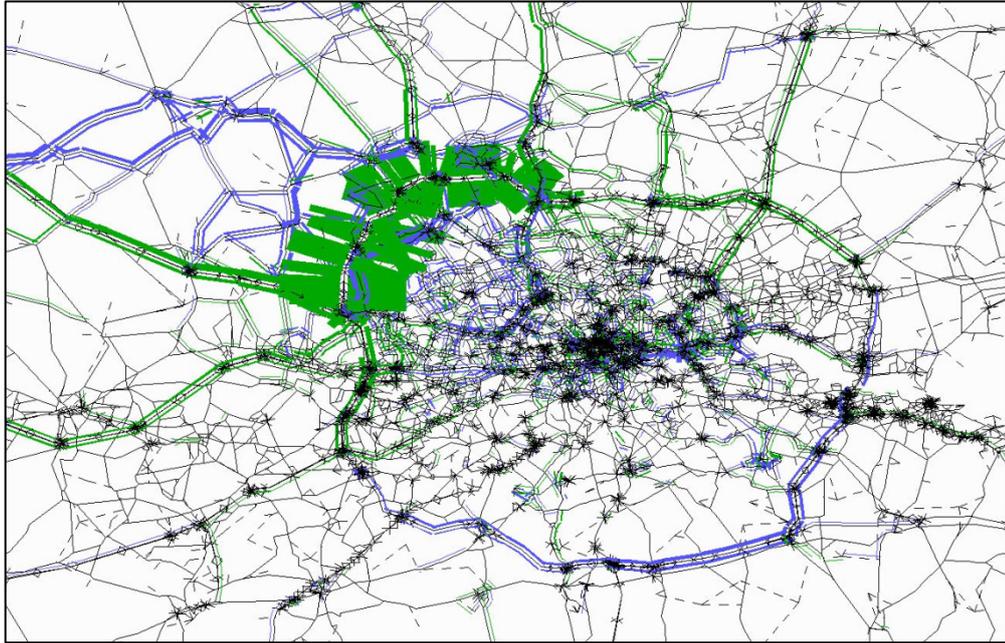


Figure 5-6: M25, 2030, Inter-peak, Effect of Scheme in VDM Fixed Hybrid

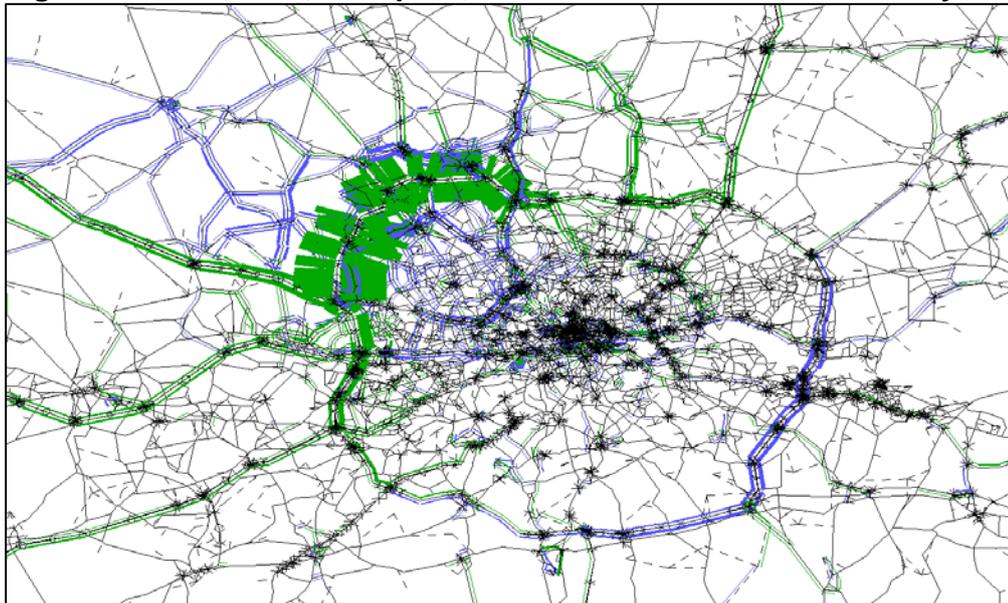
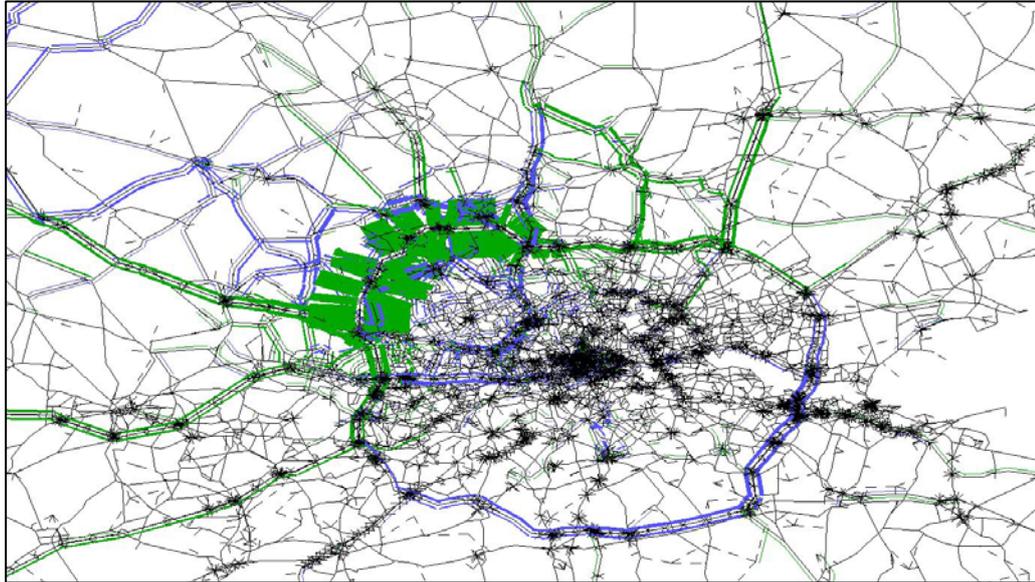


Figure 5-7: M25, 2030, Inter-peak, Effect of Scheme in VDM Elasticity Hybrid



- 5.2.3.3. The models appear to have a broadly similar impact, mirroring their counterparts for the A46, certainly with strategic traffic on the scheme itself seeing a large increase in traffic flow. However, similar to the above, the VDM has a greater tendency to suppress traffic on some routes, particularly on routes parallel to the scheme. There is some suppression evident in the Elasticity Model, as rerouteing is modelled; however trip redistribution is not.
- 5.2.3.4. Somewhat counter-intuitively, **the Fixed Demand Model shows the largest increase in traffic along the scheme**, despite the additional induced traffic in the other two models. This apparent anomaly appears to be related to much higher delays on the scheme route in the 'Without Scheme' case, causing more rerouteing when the scheme is introduced than in the other two models.
- 5.2.3.5. These findings are in contrast to the trip and traffic statistics quoted in the previous section which showed much larger differences between the models. The flow changes exhibited by the scheme tend to look similar, independently of any trip total changes, because a large part of the effect of any scheme is related to rerouteing, which is similar in all models.
- 5.2.3.6. The Contingency Model flow changes are shown below. Both are similar to those of the uncordoned model. Between Reference and 'Without Scheme' we see increases on the radial routes, and very little change on the M25. With the scheme in place, we see increases on the scheme route, and decreases on parallel roads. The 'With Scheme' plots do show less increase on the M25 before and after the scheme; this is because the flows in the Contingency Model are close to capacity and there is thus no spare capacity to allow an increase in actual flow outside of the scheme area.

Figure 5-8: M25, 2030, Inter-peak, 'Without Scheme' Minus Reference, Contingency Model

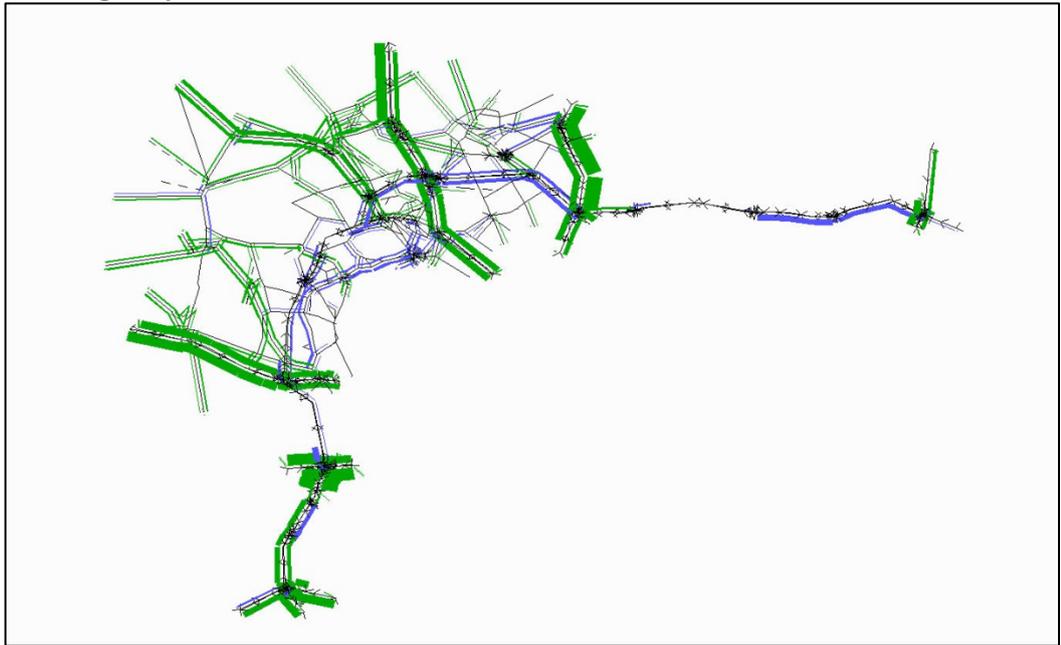
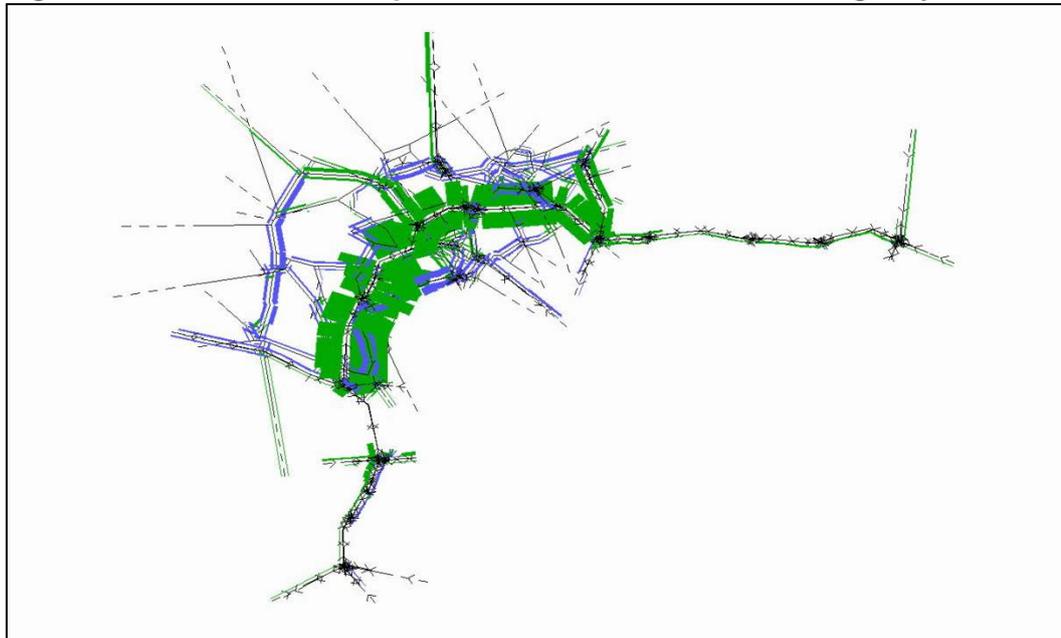


Figure 5-9: M25, 2030, Inter-peak, Effect of Scheme in Contingency Model



5.2.4. Scheme Flows

Table 5-7: M25, 2030, AM, Flow Changes

Model	Anticlockwise		Clockwise	
	Flow	Change	Flow	Change
Base Year	5,066		5,864	
Reference	5,727		6,687	
Elasticity Without	5,741		6,687	
Elasticity With	7,395	1,654	7,939	1,252
VDM Without	5,770		6,534	
VDM With	7,201	1,431	7,712	1,178
Fixed Demand Without	5,715		6,687	
Fixed Demand With	7,465	1,750	8,190	1,503
VDM Fixed Hybrid With	7,115	1,382	7,649	962
VDM Elasticity Hybrid With	7,295	1,562	7,795	1,108
Contingency Without	5,805		6,687	
Contingency With	7,234	1,429	7,612	925

Table 5-8: M25, 2030, Inter-peak, Flow Changes

Model	Anticlockwise		Clockwise	
	Flow	Change	Flow	Change
Base Year	4,991		5,524	
Reference	5,764		6,590	
Elasticity Without	5,743		6,559	
Elasticity With	6,931	1,188	7,348	789
VDM Without	5,731		6,521	
VDM With	7,322	1,591	7,582	1,061
Fixed Demand Without	5,814		6,635	
Fixed Demand With	7,735	1,920	8,138	1,503
VDM Fixed Hybrid With	7,291	1,561	7,618	1,096
VDM Elasticity Hybrid With	7,449	1,719	7,739	1,217
Contingency Without	5,875		6,553	
Contingency With	7,123	1,248	7,239	686

Table 5-9: M25, 2030, PM, Flow Changes

Model	Anticlockwise		Clockwise	
	Flow	Change	Flow	Change
Base Year	5,077		6,040	
Reference	5,516		6,687	
Elasticity Without	5,516		6,687	
Elasticity With	7,176	1,661	8,280	1,593
VDM Without	5,527		6,687	
VDM With	7,071	1,544	8,105	1,418
Fixed Demand Without	5,504		6,687	
Fixed Demand With	7,142	1,638	8,280	1,593
VDM Fixed Hybrid With	6,988	1,461	8,118	1,431
VDM Elasticity Hybrid With	7,174	1,647	8,280	1,593
Contingency Without	5,570		6,687	
Contingency With	6,973	1,403	7,923	1,236

- 5.2.4.1. The VDM scheme flow increases are generally smaller than the Elasticity Model and Fixed Demand Model, largely due to the VDM having the least congested 'Without Scheme' case. As noted above, the fixed demand flow increases are largest, because the 'Without Scheme' case is most congested. The Contingency Model flow increases are a little lower than those of the Elasticity Model.
- 5.2.4.2. Some of these findings contrast with the A46 Model; the A46 Model demonstrated the perhaps more intuitive case where fixed demand flow changes were the lowest, due to the lack of induced traffic.
- 5.2.4.3. Many flows in the tables above are identical with one another; for example, 6,687 appears several times. This is because road capacities have been reached and the demand cannot increase further.
- 5.2.4.4. The 'Base' and 'Reference' flows for the Contingency Model are slightly different from the un-cordoned model used for the other three models; however the differences are minimal (<2%) so they are not shown separately. Despite the minimal actual flow differences, there is non-negligibly more delay in the 'Reference' Contingency Model than in the un-cordoned 'Reference' models; this is discussed further in the next section.
- 5.2.4.5. The Contingency Model generally demonstrates the highest flows in the 'Without Scheme' case, although it does not pull in as much traffic from surrounding roads as the Fixed Demand Model (because there are fewer surrounding roads in the cordoned model), resulting in 'With Scheme' flows that are lower than the Fixed Demand case. This partly due to minor problems in cordoning the Contingency Model that resulted in slightly higher flows in the 'Reference' case than in the un-cordoned model. However, there are also larger increases between the 'Reference' and 'Without Scheme' cases in the Contingency Model.
- 5.2.4.6. The hybrid approaches are also somewhat interesting. The VDM/Elasticity approach returns trip changes pretty close to the VDM and Elasticity Model, generally somewhere between the two as might be expected, although if anything closer to the Elasticity Model. The VDM/Fixed hybrid has the lowest

flow growth on the scheme of any test. This is because it combines a reasonably low-congestion starting point (VDM 'Without Scheme' rather than heavily over-congested Fixed 'Without Scheme') with a lack of induced traffic.

5.2.5. Demand Impact by Distance

- 5.2.5.1. The effects of the two forms of demand model on trips by distance band are plotted below, both for the 'Reference' to 'Without Scheme' effect and for the 'Without Scheme' to with scheme.
- 5.2.5.2. The pattern is similar to that seen for the A46 Model in the case of the scheme impact (4.2.42). However, the 'Reference' to 'Without Scheme' effect appears quite different.
- 5.2.5.3. For longer trips, both models increase trips, the VDM by more, especially for the longest trips; this is similar to the scheme impact itself. The inclusion of fuel effects in the demand modelling allows the 'Reference' to forecast an effect of an increase of traffic rather than suppression of it. For the shorter trips, primarily in central London, the main effect of the models is inverted, and trips are in general suppressed. The VDM increases trips in the very shortest band, because it achieves suppression in London partly by shortening London trips.
- 5.2.5.4. The London / outside London effect can also be seen in Figure 5-1 and Figure 5-2.

Figure 5-10: M25, 2030, Inter-peak, Effect on Demand by Distance (km), 'Reference' to 'Without Scheme'

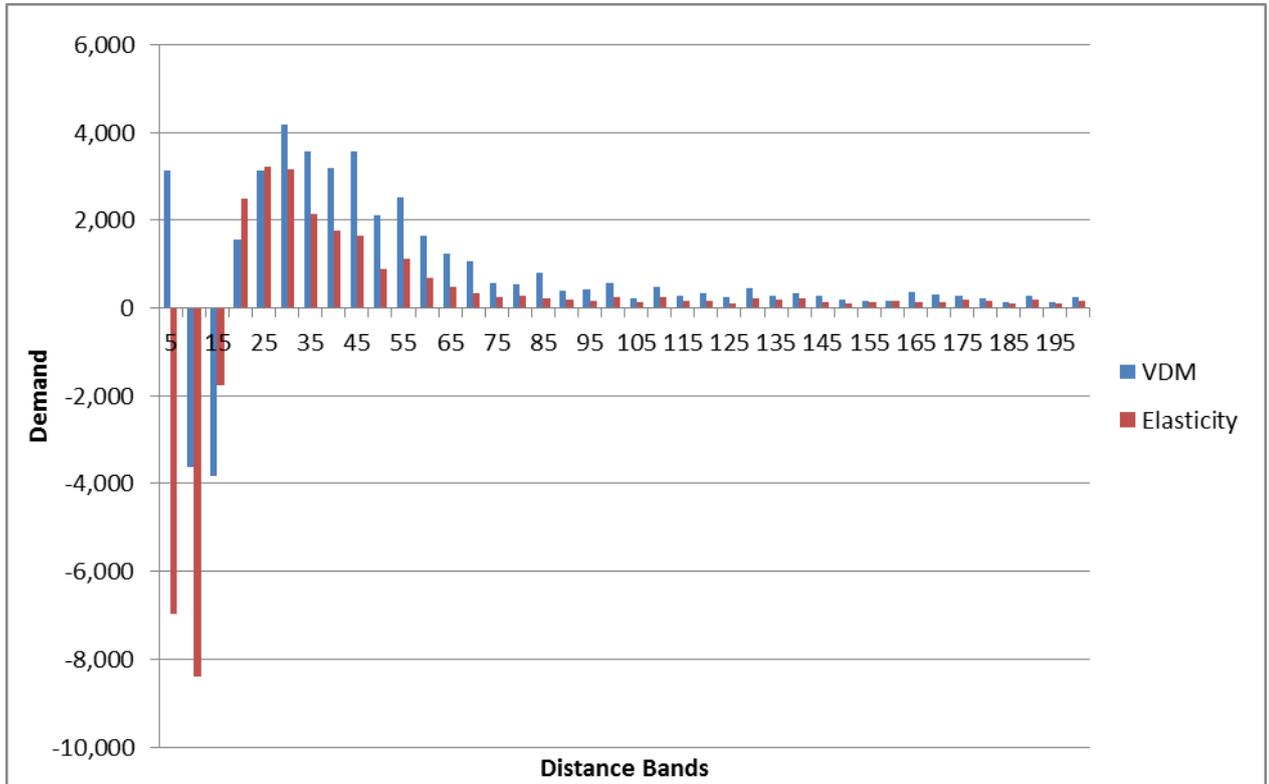
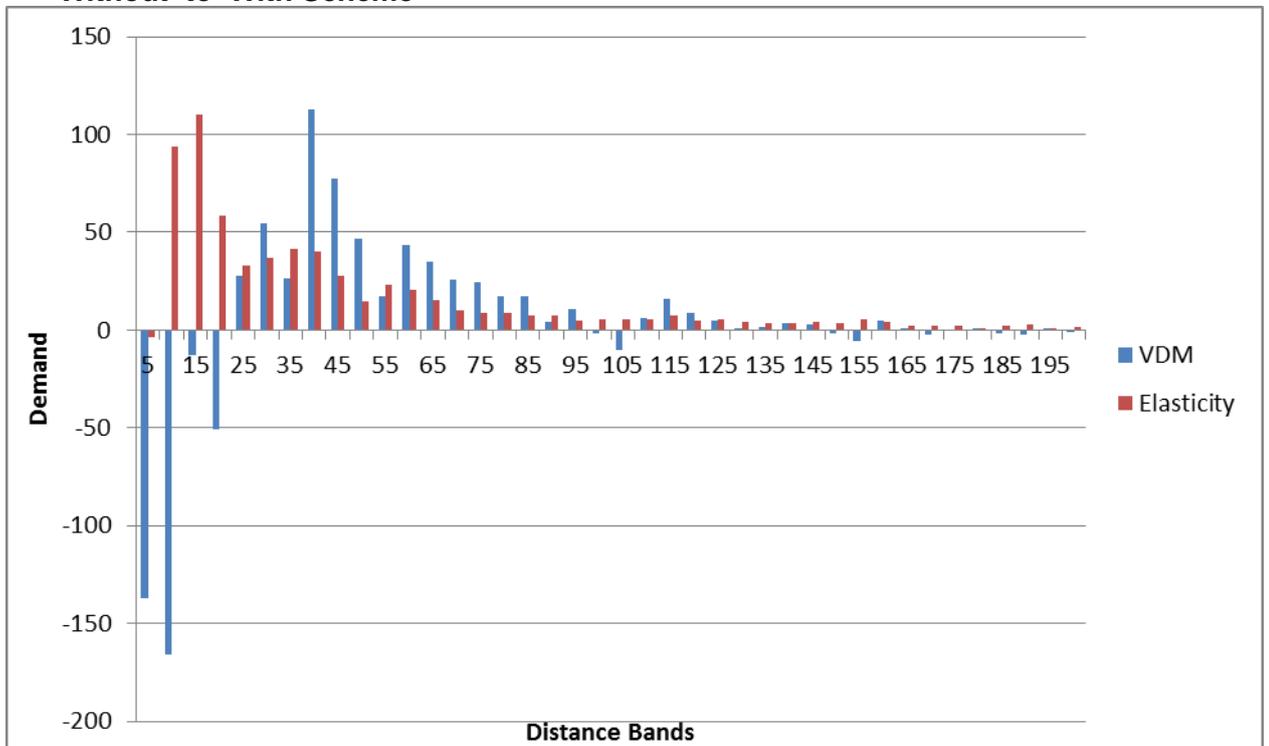


Figure 5-11: M25, 2030, Inter-peak, Effect on Demand by Distance (km), 'Without' to 'With Scheme'



5.2.6. Cost-Benefit Analysis

5.2.7. Scheme Journey Time Savings

5.2.7.1. The 'Base' and 'Reference' journey times for the Contingency Model are noticeably different from the un-cordoned equivalent times used for the other three models. Therefore, these are shown separately.

Table 5-10: M25, 2030, AM Scheme Journey Time Savings, Minutes

Model	Anticlockwise		Clockwise	
	Time	Saving	Time	Saving
Base Year	26.1		29.0	
Reference	34.5		36.9	
Elasticity Without	34.5		37.0	
Elasticity With	29.4	-5.1	31.0	-6.0
VDM Without	32.3		34.9	
VDM With	27.8	-4.6	29.8	-5.1
Fixed Demand Without	35.8		39.8	
Fixed Demand With	29.8	-6.0	31.9	-7.9
VDM Fixed Hybrid With	28.2	-4.1	29.1	-5.8
VDM Elasticity Hybrid With	28.6	-3.8	29.7	-5.2
Contingency Base Year	26.6		29.7	
Contingency Reference	35.4		40.7	
Contingency Without	36.2		40.8	
Contingency With	29.6	-6.6	30.9	-9.9

Table 5-11: M25, 2030, Inter-peak Scheme Journey Time Savings, Minutes

Model	Anticlockwise		Clockwise	
	Time	Saving	Time	Saving
Base Year	26.1		26.2	
Reference	35.0		34.1	
Elasticity Without	33.0		32.3	
Elasticity With	27.5	-5.6	27.4	-5.0
VDM Without	34.9		34.2	
VDM With	29.2	-5.6	28.7	-5.5
Fixed Demand Without	38.7		37.4	
Fixed Demand With	32.2	-6.6	31.5	-5.9
VDM Fixed Hybrid With	29.5	-5.4	28.7	-5.5
VDM Elasticity Hybrid With	30.0	-4.8	29.1	-5.1
Contingency Base Year	26.5		26.4	
Contingency Reference	36.8		36.8	
Contingency Without	37.7		36.8	
Contingency With	30.3	-7.4	28.6	-8.2

Table 5-12: M25, 2030, PM Scheme Journey Time Savings, Minutes

Model	Anticlockwise		Clockwise	
	Time	Saving	Time	Saving
Base Year	26.6		28.7	
Reference	34.5		38.7	
Elasticity Without	35.0		38.3	
Elasticity With	28.6	-6.4	32.7	-5.6
VDM Without	33.1		36.9	
VDM With	27.8	-5.3	31.3	-5.6
Fixed Demand Without	36.4		41.3	
Fixed Demand With	28.4	-8.1	34.2	-7.1
VDM Fixed Hybrid With	27.6	-5.5	30.6	-6.3
VDM Elasticity Hybrid With	28.2	-4.8	31.3	-5.5
Contingency Base Year	27.3		30.0	
Contingency Reference	36.5		42.6	
Contingency Without	37.5		41.7	
Contingency With	28.0	-9.5	31.8	-9.9

- 5.2.7.2. As with the A46 Model, the M25 VDM generally predicts the smallest journey time saving. The fixed demand model predicts higher time savings; again this relates primarily to high travel times in the 'Without Scheme' case.
- 5.2.7.3. The Contingency Model journey time savings are substantially higher, higher even than the Fixed Demand Model. As usual, this is primarily due to high delays in the 'Without Scheme' case. This is partly due to problems in cordoning the model as noted above that were not fully resolved, leading to higher flows in the 'Reference' case, but this does not account for all of the effect. It appears in general that the reduced scope for rerouteing in the Contingency Model has a notable negative impact on travel times in general.
- 5.2.7.4. One cause is increases in radial (e.g. M40, M1, A1(M)) traffic in the Contingency Model between 'Reference' and 'Without Scheme' (due to fuel cost savings) leading to significant increases in delay on the M25. In the uncordoned models, this can be compensated for by both delays in London suppressing the radial traffic increases, and by M25 traffic rerouteing elsewhere. Neither is possible in the cordoned Contingency Model.
- 5.2.7.5. The hybrid approaches both perform better relative to the VDM than their respective fully Fixed and Elastic Models. In particular, the VDM/Fixed Hybrid does not exhibit the large travel time changes seen in the fully Fixed Model due to the latter's lack of suppression of traffic.

5.2.8. Accidents

- 5.2.8.1. Accident benefits have been calculated for each approach using COBALT, as follows.

Table 5-13: A46, Accident Benefits, 60y, Forecasting Approach, 2002 Prices

	Cost (£m)			Accidents		
	With	Without	Benefit	With	Without	Benefit
VDM	1,342	1,264	-78	28,252	26,632	-1,621
Elasticity	1,343	1,267	-77	28,280	26,683	-1,596
Fixed	1,361	1,291	-71	28,856	27,371	-1,485
Contingency	1,283	1,224	-59	27,025	25,810	-1,215

5.2.8.2. For comparison, the original appraisal found accident benefits of +£0.3m (essentially zero), but it was acknowledged that decisions concerning use or otherwise of local accident rates made a significant difference to the results, and no local accident rates were used in the assessment above. Differences in COBA/COBALT version and associated default rates will also affect the result, but probably less than choices about local accident rates.

5.2.8.3. **All approaches return accident benefits of a similar order**, as with the A46 model. As noted for the A46, the main driver of the accident benefit that varies with forecasting approach will be the level of flow on the new scheme, and while this does vary by forecasting approach, it doesn't vary by more than 10-20% or so (see Table 4-11).

5.2.8.4. The fixed demand approach returns slightly less disbenefit than the others. This is consistent with the A46 model in that **fixed demand makes the scheme look better with respect to accidents**, interestingly because the A46 benefits were positive. This is because the scheme will induce extra trips and traffic, and more traffic means more accidents. In the other three models, this effect generates additional accident disbenefit. In the fixed demand case, there is no induced traffic, so the effect is smaller.

5.2.8.5. **The contingency scheme results show notably less accident disbenefit** also. This is because some induced vehicle kilometres that would generate accidents have in effect been removed from the assessment. This effect was not obvious in the A46 model because the A46 model is already cordoned, so the contingency scheme model is no smaller than the full elasticity and VDM models.

5.2.9. User and Provider Benefits

5.2.9.1. The scheme benefits derived from TUBA using inputs from each of the three modelling approaches are summarised below in Table 5-14. The Elasticity Model and fixed demand results have been calculated as part of this work, while the VDM results have been extracted from TUBA output files received from the original forecasting appraisal.

5.2.9.2. Data for reliability benefits (marked with a '**') were included from the scheme Economic Appraisal Report in order to provide consistency with the appraisal results; these have not been recalculated using the new models.

5.2.9.3. The conclusions from the POPE (Post-Opening Project Evaluation) review of the scheme following its completion are also included. It should be noted that the published Economic Appraisal Report quotes, in the appraisal results, slightly (about 3%) different benefit values from those quoted under "VDM" above. This discrepancy is sufficiently small not to affect any conclusions.

- 5.2.9.4. **As with the A46 results, the Fixed Demand Model predicts higher benefits than the VDM**, while the Elasticity Model predictions are slightly smaller. The differences are more marked than the A46, with the fixed demand model being nearly 50% too high.
- 5.2.9.5. The Contingency Model is also significantly too high relative to the VDM by about 25%, albeit less than the Fixed Demand Model. This is in contrast to the A46, where the Contingency Model was low. However, for both schemes, the Contingency Model returns significantly lower operating cost, indirect tax, and carbon benefit due to the failure to capture complete trip lengths.
- 5.2.9.6. The Contingency Model appears to suffer from some weaknesses similar to the Fixed Demand Model, albeit to lesser degrees. It here overstates 'Without Scheme' delay due to a lack of complete responsiveness of demand (due to fewer routing options rather than a lack of a demand model in this case).
- 5.2.9.7. The POPE for this scheme concluded that the scheme value had actually been underestimated, due primarily to journey time savings achieved being much greater than forecast. Again, the POPE does not provide any evidence for the VDM results being significantly better than the other two models; indeed in this case the Fixed Demand and Contingency Model results are actually closest to the POPE, although this should be considered fortuitous rather than evidence that fixed demand or Contingency-style models are the most accurate.
- 5.2.9.8. As with the A46 Model, the VDM/Elasticity Hybrid performs well, and indeed here it is slightly clearer that it is generally closer to the VDM than to the full Elasticity Model. The VDM/Fixed Hybrid, on the other hand, does not reproduce the VDM at all well. It does return benefits consistently closer than a full Fixed approach, but they are generally poor. It retains the issue of understating tax, carbon and operating cost benefits, while also, unlike the A46 version, overstating time benefits as well.
- 5.2.9.9. Using complete trips lengths in an otherwise "Contingency" approach appears to entirely correct issues in that approach with calculating tax and carbon benefits. However vehicle operating cost benefits remain quite different from the VDM, and the time benefits are very similar (as expected).
- 5.2.9.10. A more detailed breakdown of user benefits is shown on the following page, in Table 5-15.

Table 5-14: M25 Scheme, TUBA Benefits, 60 Years, 2002 Prices, £m

Benefit	VDM	Elasticity	Fixed Demand	VDM Fixed Hybrid	VDM Elasticity Hybrid	Contingency Full Trip-Length	Contingency	POPE
Time	1,443	1,393	2,127	1,961	1,447	1,754	1,793	2,209
Vehicle Operating Costs	-116	-157	-47	-94	-166	-57	-58	-56
Indirect Tax	126	92	45	69	121	124	98	111
Carbon	-15	-17	-6	-10	-17	-17	-10	-15
Reliability*	72	72	72	72	72	72	72	94
Present Value Benefits (PVB)	1,509	1,383	2,191	1,998	1,457	1,876	1,894	2,343
Present Value Costs (PVC)	244	244	244	244	244	244	244	295
BCR (indirect tax in PVB)	6.2	5.7	9.0	8.2	6.0	7.7	7.8	7.9

Table 5-15: M25 Scheme, User Benefits, 60 Year Appraisal, 2002 prices, £m

	Vehicle Type	VDM	Elasticity	Fixed Demand	VDM Fixed Hybrid	VDM Elasticity Hybrid	Contingency Full Trip-Length	Contingency
Time	Business Car	733	717	1167	1002	712	973	973
	Non business Car	407	353	498	493	352	420	420
	LGV	153	152	213	239	200	160	160
	HGV	150	172	249	227	183	201	201
Fuel	Business Car	-4	-1	0	-0	1	-2	-5
	Non business Car	2	-1	10	5	-7	2	-2
	LGV	3	4	6	6	-0	4	2
	HGV	-81	-40	-86	-117	-95	-49	-56
Non-fuel	Business Car	7	9	16	16	11	18	18
	Non business Car	-48	-72	-14	-15	-75	-70	-48
	LGV	-3	-1	-2	-2	-6	2	2
	HGV	9	-55	23	13	5	38	38

- 5.2.9.11. The Fixed Demand Model non-fuel benefits for non-business car, are, as for the A46, much lower than the other two models, for the same reason. Other than this, the models return broadly similar breakdowns, particularly for the larger numbers. The Elasticity Model returns disbenefits for HGV non-fuel in contrast to the other two models; this is not understood, but given the scale, could be a convergence anomaly.
- 5.2.9.12. The fuel benefits are always negligible, except for HGV, while the non-fuel benefits are always negligible, except for non-business car. It is interesting to note that the full trip-length version of the Contingency scheme model does “correct” the understatement of non-business non-fuel benefits in the Contingency Model, relative to the other Elasticity Model. It also returns lower HGV disbenefit, largely cancelling this out. The latter is down to variation in trip average speeds depending on whether access and egress distances are included

5.2.10. Time Benefits by Sectorised Movement

- 5.2.10.1. The user time benefits, which, here as in most appraisal contexts, tend to dominate the overall benefit, have been extracted by sectorised movement. “Internal” refers only to an area covering the scheme section of the M25 and the immediate vicinity, not the entire internal area of the M25 Model, which covers all of greater London and a significant band outside it.
- 5.2.10.2. The strategic impacts across the three models are less similar than for the A46 Model, especially for the fixed demand. However, it is still true that differences are more marked for the internal trips. The fixed demand in particular generates substantial benefit for E-I and I-E trips; it may be that delays for traffic entering and exiting the M25 along the scheme are particularly marked in the fixed demand model.

Table 5-16: M25 Scheme, Time Benefits by Sector Movement, 60 Years, 2002 Prices, £m

Sector Movement	VDM	Elasticity	Fixed Demand	VDM Fixed Hybrid	VDM Elasticity Hybrid	Contingency Full Trip-Length	Contingency
Strategic Along Scheme	390	405	451	475	378	321	321
External-External	644	476	794	772	555	714	714
External-Internal (and I-E)	316	385	706	526	378	572	572
Internal-Internal	93	128	175	188	136	146	146
Total	1,443	1,393	2,127	1,961	1,447	1,754	1,754

5.2.11. Convergence and Stability of Impacts

- 5.2.11.1. Both scenarios of the M25 elasticity models were run twice more with additional iterations of assignment in each loop to gauge the impact of convergence on the results. The stability is notably less good than that of the A46 Model, despite benefits having been “masked” (in the same way as was done in the original appraisal) to exclude benefits between unlikely pairs of sectors, for example, Scotland to North England.
- 5.2.11.2. The variation in benefits between sets of iterated models was generally of the order of 5-10%. The time and overall benefits varied by less than 5%; the fuel cost and non-fuel cost were less stable, with one difference of 40%, but generally around 10%. This is low enough to conclude that the results are valid overall, but some detailed breakdown, especially for non-time benefits, may be dominated by model ‘noise’.
- 5.2.11.3. Unlike the A46 Model, the M25 Model has a large number of links and nodes with an extensive external network, making the sort of reported convergence obtained for the A46 Model much harder to achieve. Given improvements to SATURN since 2007/8 and increases in processing power, it would nevertheless have been possible to re-run all the models to a significantly higher level of convergence; this was not done owing to time constraints relating to re-running the original VDMs, which would have required additional time in obtaining the VDM process and reproducing results.

5.3. Summary of Findings

- 5.3.1.1. The results of analysis of forecasting methods for the M25 model are largely consistent with and confirm those for the A46 model. Fewer sensitivity tests were run in the M25 model; some of the A46 conclusions relating to sensitivity tests therefore are not applicable here.
1. All approaches return accident benefits of a similar order; fixed demand makes the scheme look better with respect to accidents
 2. Fixed Demand Model benefits are generally larger than the VDM, while the Elasticity Model benefits are smaller
 3. The Contingency Model does not fully represent the complete length of trips using the scheme, and therefore omits much induced traffic and thus fuel and emissions impacts
 4. The Fixed Demand Model shows the largest increase in traffic along the scheme. This was not observed in the A46 model, but it relates to the failure of the Fixed Demand model to suppress traffic sufficiently in the ‘Without Scheme’ scenario.

6. Study Conclusions

6.1. Schemes and Models Chosen

- 6.1.1.1. The two schemes chosen for assessment and their associated models are different in many ways: the A46 Model is a 'cordon' model, while the M25 Model covers a wide geographic area in detail; the A46 Model allowed only congestion effects to influence demand forecasts, while the M25 Model included fuel and non-fuel cost effects as well; the A46 is a dual-carriageway scheme, while the M25 is a motorway; the A46 Model was implemented using DIADEM while the M25 Model uses a bespoke model. **This provides some reassurance that the conclusions have general application.**
- 6.1.1.2. However, the schemes also have some similarities. Both represent road-widening / congestion-relief schemes. A new link or bypass could produce different results, and earlier DfT research⁴ did consider missing link (but not bypass) schemes and did find different conclusions for these. Both models, largely coincidentally, also contain time-period choice, which is actually relatively unusual for VDMs in practical use and is not in general required by guidance.
- 6.1.1.3. The elasticity models were implemented in such a way as to most closely represent how an elasticity model would be applied in practice, while avoiding introducing unnecessary differences between the Elasticity Models and VDMs. Particularly in the case of the M25 Model, this means that some differences exist between the VDM and elasticity models not strictly related to the difference in model form; for example, the VDM uses costs from a simplified Emme model while the Elasticity Model uses costs directly from SATURN.

6.2. Model Form

- 6.2.1.1. Many of the tables and plots in this note show that the Elasticity Models and VDMs affect overall demand in quite different ways. This is partly due to the form of expression used; VDMs consider absolute differences in generalised cost (albeit subject to cost-damping in many cases), while elasticity models consider ratios. It also relates to the VDMs ability to redistribute trips among attractions and time periods.
- 6.2.1.2. It should be noted that mode choice, probably the most familiar type of choice model, is actually the element of the VDM that differs least from an elasticity approach for highway appraisal as this has a similar impact to an elasticity model in that it affects the demand for a single zone or zone pair independently of any other demand. Public transport and walk benefits will usually not be considered in appraisal of a scheme of this sort as the highway scheme is unlikely to generate significant cost changes for them. Trip distribution (attraction choice) and the less-often-used time period choice, on the other hand, generate demand effects of a form that an elasticity model cannot reproduce.
- 6.2.1.3. Despite being calibrated to the same overall sensitivity, usually via the fuel cost elasticity guidance in WebTAG, elasticity and variable-demand models can exhibit very different apparent sensitivities to specific scheme interventions,

⁴ *Use of Elasticity Models to Model Variable Demand*, March 2007, Mott MacDonald and Faber Maunsell for the DfT

largely due to the differences in expression form. This is particularly true for trip totals, since the calibration is to vehicle-distance or traffic.

6.3. Scale of Benefits

- 6.3.1.1. **This study concludes that fixed demand models generally overstate benefits, while elasticity models generally understate them.** Both of the models showed this, despite some notable differences in the model impacts, such as on flows and vehicle kilometre totals, and despite the inclusion of fuel effects in the two demand models for the M25 (not included in the A46). This therefore suggests that this pattern (fixed demand benefits high; elasticity benefit low), is likely to be quite pervasive across appraisals. The DfT research in 2007 came to the same conclusions using two different models and nine separate scheme tests. The exponential elasticity form also understated benefits compared with a VDM, by a similar amount to the power one.
- 6.3.1.2. The reason for this effect in the case of the fixed demand model is very clear; in both models the fixed demand approach resulted in significantly higher congestion on and around the scheme in the 'Without Scheme' model due to the fixed demand model's failure to suppress traffic. This was particularly true with respect to access to/from the scheme, although through journey times were also higher for strategic traffic through the scheme. Fixed demand models' overstatement is not primarily due to lower journey times in the 'With Scheme' case (although there is a small element of this too); generally the scheme will be sufficiently high-capacity to result in minimal delays in the final forecast year in all models.
- 6.3.1.3. The reasons for the Elasticity Model undervaluing schemes are less clear-cut, and may result from a combination of several factors. They appear to under-forecast benefits on roads other than the scheme, because they cannot redistribute traffic (other than by rerouteing). While it is clear that this is a factor (it was also observed in the DfT research), it is not certain that it is the main or only one.
- 6.3.1.4. In the case of the A46 Model, the Elasticity Model consistently forecast slightly lower with-scheme flows, which will limit scheme benefits, but this was not true in the M25 Model and in both models the Elasticity Model forecast larger journey time savings than the VDM. This strongly suggests that it is not strategic users of the scheme whose benefits are under-forecast by the Elasticity Model. Table 4-21 and Table 5-16 confirm this.
- 6.3.1.5. The possibility of the scheme conclusions in this respect being coincidental appears slight given the identical conclusion of the DfT research and other studies and anecdotal evidence. In neither of the models assessed was the model convergence poor enough to permit the conclusions to be an artefact of convergence noise.
- 6.3.1.6. In both models, the elasticity approach under-forecast total benefit (relative to the VDM) only slightly, by around 6-10%. The fixed demand overstatement was larger in both cases; being 12% in the A46 and nearly 50% in the M25. **This suggests that, in the absence of a VDM, an elasticity model is 'better than nothing'; it is likely to return more accurate results than the fixed demand.** The DfT research supports this conclusion as well. The elasticity benefits are also likely to be conservative.

- 6.3.1.7. It is perhaps slightly surprising, given the differences in demand impact discussed in Section 5.2.13, that elasticity and variable demand models return such similar appraisal results. They are not only similar in themselves, but notably closer to each other than the fixed demand results, indicating that benefits are not independent of the existence of a demand model of some form.
- 6.3.1.8. In both cases the POPE concluded that the original appraisal was significantly different from one repeated using data from the (now open) schemes themselves, so much so that this discrepancy was larger than the differences between the three model forms. In fact, in neither case was the VDM actually the closest of the three models to the POPE results.
- 6.3.1.9. It is true that a (largely) unforeseen recession occurred between the original scheme appraisals and the POPEs, and that this was the primary reason for the discrepancy in the case of the A46. However, the M25 POPE concluded that benefits had actually been understated (due to difficulties in modelling and forecasting without scheme journey times along the link); this was not an effect of the recession. Furthermore unexpected changes in the economy are not unusual; accurately and precisely predicting economic trends is largely futile, so **it is reasonable to conclude that errors in all scheme forecasting are quite likely to be of a similar order to differences between the methods.**
- 6.3.1.10. This does not imply that VDMs should never be considered in modelling (or that modelling itself is worthless); any increase in expectation of accuracy is valuable in planning, even if substantial uncertainty remains, and both transport modelling and VDMs are cheap by comparison with the schemes they are used to assess. However, it does underscore a proportionality requirement in determining the appropriate detail in modelling and appraisal.
- 6.3.1.11. Further POPE analysis as more schemes appraised using VDMs open will inform this. The POPE study reports discuss reasons for discrepancies (and demonstrate that modelling appears to be becoming more accurate over time) in more detail.

6.4. Benefits by Type

- 6.4.1.1. **Certain categories of benefit are forecast particularly poorly by a fixed demand approach.** These included in our study, carbon, indirect tax and non-business non-fuel operating costs. Were we to have assessed them, noise, air quality and physical activity impacts may also have fallen in this category. This is because these benefits relate primarily to changes in the level of demand, and are not dependant primarily upon travel times. Since fixed demand models do not forecast any change in demand at all, they cannot meaningfully appraise these.
- 6.4.1.2. Somewhat surprisingly, accident benefits were not wildly mis-assessed by the fixed demand approach, although there was evidence of a consistent bias in the direction of making the scheme look better. In both assessed schemes (and many practical schemes, it is suspected), a large portion of the accident benefits, positive or negative, relate to changes in category of road. Consequently, only a small portion of benefits relate to level of induced traffic and thus the fixed demand model is not at a major disadvantage. This might not apply to all appraisals, though.
- 6.4.1.3. Despite this demand-dependence, there does not appear to be much evidence that elasticity models are significantly worse at assessing benefits of

this kind (relative to VDMs) than, they are at, for example, time benefits. Similar discrepancies with the VDM of around 10% were observed in the elasticity models for these demand-dependant impacts.

- 6.4.1.4. It is possible, although not supported by our study so far, that some distributional impacts of appraisal, such as SDI (Social and Distributional Impacts) analysis and analysis of impacts by trip-length, may be more strongly influenced by the use of a VDM versus an elasticity model because of the influence of variable demand models on trip distribution and wider impact on trips not using the scheme itself. Such impacts may require a VDM to robustly assess.

6.5. Contingency Scheme Methodology

- 6.5.1.1. The Contingency Scheme methodology has been tested to an extent in both models. In both **cases it returned results of a similar order to those of the VDM and slightly closer than those of a fixed demand model**. There was no consistent pattern of over or under forecasting benefits. Since one of the two models tested was already largely a cordon model, and the other (the M25) is in a context in which the Contingency Scheme elasticities derived by URS for the M6 might be regarded as less applicable, it is difficult to generalise about whether the method would be expected generally to under or over-forecast benefits.
- 6.5.1.2. On balance we are inclined to suggest that the M25 Model results are likely to be more typical for application of the Contingency Scheme methodology to a randomly selected scheme without derivation of new elasticities, although it may be that either an under or an over-statement of benefit are quite possible.
- 6.5.1.3. The Contingency Scheme methodology appears to suffer to some extent from weaknesses similar to those of a fixed demand approach, albeit to a slightly lesser degree. **Like a fixed demand model, it tends to substantially under-forecast benefits related to the level of additional traffic (i.e. carbon, indirect tax, noise, air quality)**. Specifying centroid connectors with suitable lengths largely addressed this problem.
- 6.5.1.4. Also like a fixed demand model, a Contingency Scheme methodology may over-state 'Without Scheme' delays due to a lack of fully available demand responses; here there is less scope for trip rerouting than in reality. This is particularly likely if the elasticities derived for the M6 Model (upon which the Contingency Scheme methodology was derived) are taken out-of-context for a significantly different area or scheme. It could occur even where the M6 Model elasticities would appear applicable, however, since the elasticities cannot vary fully by movement.
- 6.5.1.5. A particular problem observed in the models used was that the low elasticity for local car trips (Table 3-2) of -0.30 was too low to suppress traffic effectively where problems with junction performance occurred as a result of scheme-induced traffic.
- 6.5.1.6. A number of observations regarding particular areas for caution when applying a similar approach elsewhere have arisen from this study.
- 6.5.1.7. Suitably long connector links representing a full range of trip lengths for all strategic entry and exit points should be specified, and these should have plausible speeds as well, reflecting if possible broad global speed changes over time.

- 6.5.1.8. Elasticities derived from a suitably relevant model context should be used.
- 6.5.1.9. The plausibility of forecast flows and especially journey times in the 'Without Scheme' case should be checked carefully as this is probably the main likely source of significant errors in the calculation of time savings.
- 6.5.1.10. **However, with care taken in these aspects it appears that the Contingency Scheme methodology is unlikely to be substantially at variance with a more complete approach.**
- 6.5.1.11. Finally, in one respect a cordoned model without long connector links, such as the contingency scheme approach, might conceivably return more accurate benefits than any other approach. Because average speeds will be calculated for the scheme over shorter distances probably relating to stretches of road with broadly consistent speeds along their length, the calculation of fuel consumption as a function of speed in the with and without scheme cases may be more reasonable and may return more plausible fuel consumption benefit. However, this should not be taken as a reason to avoid long connectors; rather a reason to refine or treat with caution the TUBA approach to calculation of fuel-related benefits.

6.6. Previous Research

- 6.6.1.1. The Department for Transport commissioned a study in 2006, entitled Use of Elasticity Models to Model Variable Demand. This had similar objectives to this work, and accordingly its results have been compared with these.
- 6.6.1.2. The DfT study, carried out by Mott MacDonald and Faber Maunsell (now AECOM), considered two existing transport models and a number of schemes within each, with a focus on ranking different schemes. It also considered alternative formulations of the Elasticity Model. However, no POPE studies were available for comparison, and the schemes used were invented specifically for the research.
- 6.6.1.3. **The findings from this current study are supported well by the previous DfT research;** that fixed demand overstates benefits significantly, and elasticity models tend to understate by smaller amounts (although for some schemes in the DfT research the elasticity model overstated), largely because of an under-forecast of impacts away from the scheme itself; and that the demand impacts by distance are of very different character across the two model types.
- 6.6.1.4. The DfT research did not consider secondary benefits such as carbon and indirect tax specifically; while fairly obvious, the observation that fixed demand is particularly poor here was not made in the previous work.
- 6.6.1.5. The DfT study did look at a new missing-link scheme, as distinct from road widening schemes. These actually returned elasticity model impacts that were slightly higher (again, around 10%) than the VDM, suggesting that the general conclusion may be only applicable to road-widening or similar capacity-improving schemes. A bypass scheme was not considered in previous research.
- 6.6.1.6. One scheme in the DfT study, a toll road scheme, returned very different results, with the fixed demand model benefits being lowest and the elasticity being much higher. This was the only scheme (out of nine) for which fixed demand was lower than VDM, and there were some concerns about the

assignment model's ability to robustly assess toll schemes, so this finding may be anomalous.

- 6.6.1.7. The DfT study also looked at exponential formulations of an elasticity model. As with this research, it found this tended to understate benefits. However while here in the A46 model we found that the exponential results were very comparable with the power elasticity results, only very slightly worse; in the DfT research the exponential elasticity model performed very poorly indeed: returning benefits of the wrong sign in two cases and always being very substantially off.
- 6.6.1.8. However, **both studies agree that there is little reason to consider an exponential elasticity model over a power one.**

6.7. Sensitivity Testing

- 6.7.1.1. A number of sensitivity tests were carried out to understand how the conclusions might be affected by certain modelling decisions.
- 6.7.1.2. **The use of a macro-time period choice model had very little effect on appraisal results in the A46 model**, less than any other modelling change made. This is not very surprising, as time period choice is less significant than trip distribution or mode choice in most variable demand models.
- 6.7.1.3. Varying user perceived operating costs over time in line with DfT forecasts by contrast had a substantial effect on the appraisal, resulting in benefits some 35% higher due to significant demand induced by falling perceived cost of motoring. **Given current DfT advice, perceived operating costs should be varied over time.** On the basis of the research here, it does not seem to make much difference whether these changes are incorporated into highway assignment routing parameters; the important thing is that the demand forecasting method takes account of them. We would tend to suggest that consistency between assignment and demand modelling is maintained where possible, however.

6.8. Hybrid Approaches

- 6.8.1.1. Two hybrid forecasting approaches where a full variable demand model is used to calculate without scheme demand, but then either a fixed demand or elasticity approach is used to generate with scheme demand were tested.
- 6.8.1.2. The VDM/Fixed approach was better at forecasting all kinds of benefit relative to a VDM than a pure fixed approach. In the A46 model it produced very similar time benefit to the VDM approach, although other benefits (i.e. those related strongly to changes in vehicle kilometres induced by the scheme) were only marginally improved from a fixed approach. In the M25 model, all components of benefit were closer to a VDM than a pure fixed approach, but none was a very good match.
- 6.8.1.3. The VDM/Elasticity approach performed very well in both the A46 and M25 models; reproducing the VDM closely and better than a pure elasticity model did. On the basis of this research, **there is little reason to suspect that the VDM/Elasticity hybrid would perform any worse than a full VDM approach.**
- 6.8.1.4. However, it perhaps should be noted that in many contexts, it may be just as easy, or easier, if a VDM exists already, to apply it to the scheme as well, and if

the two options are equally straightforward, or the VDM approach is only very marginally more difficult, we would still suggest using it, for consistency.

- 6.8.1.5. We would tend to suggest that **a VDM/Fixed approach would not be suitable for most purposes, although it is likely to give overall benefits of a broadly appropriate order.**

6.9. Recommendations

- 6.9.1.1. Department for Transport guidance (unit M2, section 2.2) is to use full variable demand models for all schemes of significant size involving any traffic congestion problems (which would be almost all Highways England schemes). The research carried out here suggests that while this is certainly not bad advice, it may in some circumstances be possible to get robust results with a slightly simplified approach.
- 6.9.1.2. The weaknesses of a fixed demand model are such that we would advise against its use; the fixed demand model could substantially overstate scheme benefits.
- 6.9.1.3. If the 'Without Scheme'/'Do Minimum' demand has been derived with reference to a VDM or other demand model, the fixed demand model may be suitable for assessing time benefits, only.
- 6.9.1.4. **Fixed demand models are entirely unsuitable for assessing environmental, physical activity, accident or tax benefits**, unless these relate primarily to non-demand effects (such as re-routing a road away from a residential area to improve air quality without affecting journey times).
- 6.9.1.5. **There is a very good case for using an elasticity model over a fixed demand model**; all research to date suggests that the former should produce results much closer to those of a VDM and orders-of-magnitude better for many of the secondary benefits.
- 6.9.1.6. **It appears likely that an appraisal made using an elasticity model will return benefits of a broadly appropriate scale**; for testing whether a scheme makes broad economic sense (for example, PCF1: option identification), an elasticity model is certainly adequate (that is, no worse than a VDM).
- 6.9.1.7. However, there may still be case for using a VDM to rank very similar schemes or finalise a business case for a larger scheme towards the end of the assessment process (for example, PCF3: scheme development). Should POPE research conclude that an elasticity approach was notably biased downwards (as seems probable), caution should be exercised in using a method with a known bias, even a small one, as this could lead to under-investment in transport infrastructure.
- 6.9.1.8. The research to date has not explored the extent to which ranking of similar options would be affected by use of different forecasting approaches; only the benefits for a single scheme option were studied in each case.
- 6.9.1.9. The use of a variable demand model to create a 'without scheme' model, and then (presumably following cordoning or importing demand to a more local model) an elasticity model to account for the scheme effect appears to be entirely suitable for scheme appraisal. WebTAG unit M2, 2.2.2 acknowledges this, although it continues to recommend use of the VDM for both models.
- 6.9.1.10. If no cordoning or transfer between a strategic and local model are involved, we would agree with WebTAG and suggest continuing to use the VDM rather

than trying to construct a new elasticity model, as consistency is to be preferred if there are no significant cost-savings to be made.

- 6.9.1.11. Fixing the demand at the 'without scheme' level, even if a VDM has been used to derive the 'without scheme' demand, is not suitable for most purposes.
- 6.9.1.12. Finally, we would advise care in future application of the Contingency Scheme methodology; however we consider it probably superior to a Fixed Demand Model, even one with a larger complete network. **Given the potential weaknesses and problems that can arise, it is unlikely to be worthwhile to cordon a scheme model out of a larger one for appraisal unless considerable savings in model run times can be thus made or convergence is otherwise impossible to achieve.** It may well, however, be proportionate to construct (with care) a small cordon model rather than one with a wider scope if no suitable larger model exists.

APPENDICES

APPENDIX 1 – Long List of Potential Schemes/ Models

Note: Table has been sorted with VDM schemes/models at the top

Scheme Name	Date	Traffic Model Software	Model Name	Demand Modelling Method	LMVR Provided to POPE team?	Are forecast journey times available?	Outturn Traffic data available Post Opening	Comments
A419 Blunsdon Bypass	2005	SATURN	Swindon Area Traffic Model	VDM	Yes	No	Yes	Taken from Traffic Modelling, Forecasting and Economic Appraisal Report November 2004.
A419 Commonhead Junction	2005	SATURN	Swindon Area Traffic Model	VDM	No	No	Yes	Taken from the Forecasting, modelling and Economic Report January 2005
A421 Bedford to M1 Improvement	2007	SATURN	Bedford DC model.	VDM	Yes	No	Yes	Figures taken from LMVR and Forecasting Report (2006 and 2007)
M25 J23-27 HSR (Section 5)	2012	SATURN	M25 North of Thames Assignment Model	VDM	Yes	See Comments	No	Forecast Average Journey Speed Available
M25 J5-7 HSR (Section 2)	2011	SATURN	M25 Demand Model	VDM	Yes	See Comments	No	Forecast Average Journey Speed Available
A45/A46 Tollbar Improvement	2003	SATURN	A45/A46 Tollbar End traffic model	VDM	Yes	Yes	No	
A14 Kettering Southern Bypass Widening	2012	SATURN	A14 J7-9 Kettering Improvement	VDM	Yes	No	No	

			Model					
A1 Leeming to Barton Improvement	2013	SATURN	A1(M) Leeming to Barton Improvement	VDM	Yes	No	No	
A3 Hindhead Improvement	2005	SATURN	A3 Hindhead Traffic Model	VDM	Yes	Yes	Yes	
A46 Newark - Widmerpool Improvement	2007	SATURN	A46 Newark - Widmerpool Improvement Model	VDM	Yes	Yes	Yes	
M25 J16-23 Widening (Section 1)	2007	SATURN	M25 North of Thames Assignment Model	VDM	Yes	See comments	Yes	Forecast Average Journey Speed Available
M25 J27-30 Widening (Section 4)	2007	SATURN	M25 North of Thames Assignment Model	VDM	Yes	See comments	Yes	Forecast Average Journey Speed Available
A453 Widening (M1 J24 to A52 Notts)	2005	VISUM & DIADEM	A453 MULTI MODAL MODEL	VDM	Yes	Yes	No	Obtained from LMVR Draft Dec 2008
A2/A282 Dartford	2006	SATURN	Kent Thames side Model	VDM	No	No	Yes	Diadem used.
A500 City Road and Stoke Junction	2002	CUBE	North Staffordshire Traffic Model (NSTSIII)	VDM	No	No	Yes	NSTSIII owned by Stoke City Council. Variable demand used but assessment of induced traffic and elasticity calculations showed minimal levels of induced traffic
M1 J25-28 Widening	2006	SATURN	East Midlands M1 Traffic Appraisal Model (EMM1TAM)	VDM	Yes	Yes	Yes	Obtained from MVR, Forecasting Report and EAR, 2006
M40/A46 Longbridge Junction	2006	SATURN	M40 Junction 15 Traffic Model	VDM	Yes	Yes	Yes	Figures taken from LMVR and Forecasting Report (2006)
M25 J1b-3 Widening	2005	SATURN	Kent Thames side Model	VDM	No	No	Yes	Diadem used.
M1 J19/M6 Improvement	2012	SATURN & DIADEM	M1 Junction 19 model	VDM	Yes	Yes	No	
M1 J28-31 HSR	2012	SATURN	M1 Junction 28 - 31 Managed Motorway Model	VDM	No	Yes	No	
M3 J2-4a HSR	2013	SATURN	M3M4 Highway Assignment Model	VDM	Yes	Yes	No	
M62 J25 to 30 HSR	2009	SATURN	South and West Yorkshire Multi Modal Study	VDM	Yes	Yes	No	Peaks only

A1 Bramham Wetherby	2005	SATURN	-	Elasticity	Yes	Yes	Yes	
A1 Ferrybridge to Hookmoor	2001	TRIPS	A1 DBFO Darrington to Dishforth	Fixed	No	Yes	Yes	economic model in COBA. Source A1 D-D draft COBA economic report
A1 Peterborough to Blyth Improvement	2005	ARCADY and COBA	-	Elasticity	No	No	Yes	
A1 Stannington GSJ	2001	Excel	-	Fixed	No	No	Yes	source:MON1, economic model in COBA
A1 Wetherby to Walshford Improvement	2001	TRIPS	A1 DBFO Darrington to Dishforth	Fixed	No	Yes	Yes	economic model in COBA. Source A1 D-D draft COBA economic report
A1 Willowburn to Denwick	????	????	-	Fixed	No	No	Yes	assumed fixed due to COBA
A10 Wadesmill Bypass	1990	ROADWAY & Excel	-	Fixed	No	No	Yes	Original local model dates from late 80s updated in 200 with observed flows and revised growth factors
A1033 Hedon Road Improvement	1993	Excel	-	Fixed	No	Yes	Yes	Source: BAM. economic model in COBA
A11 Attleborough Bypass	2004	Excel	-	Fixed	Yes	No	Yes	The traffic model adopted consists of a spreadsheet model representing local link and junction flows within the area of the Scheme. The rationale behind this choice of model that the main through flows on the A11 will remain largely unaffected, changes being limited to those flows that currently enter or leave the A11 within the Attleborough area. (Taken from LMVR)

A11 Roudham Heath to Attleborough	1991	????	-	Fixed	Yes	No	Yes	"It was assumed that no traffic generation occurs as a result of the improvements" - London to Norwich Trunk Road A11 Roudham to Attleborough improvement: Scheme assessment Report and Recommendation 1989. Therefore fixed trip method assumed
A120 Stansted to Braintree Improvement	1996	SATURN	-	Fixed	Yes	Yes	Yes	
A14 Haughley	2006	SATURN	-	Fixed	Yes	Yes	Yes	
A14 Rookery Crossroads	2002	Excel	-	Fixed	No	No	Yes	Safety only scheme
A2 Bean Cobham Phase 2	2006	SATURN		Elasticity	No	Yes	Yes	
A2 Bean to Cobham Improvement Phase 1	2001	SATURN /TRIPS	Kent Thames-side model (KTS)	Fixed	No	No	Yes	Sources:MON1, Traffic Forecasting report (2001) Decision to use Fixed Trip based on assessment of elasticity and multi-modal modelling
A21 Lamberhurst Bypass	2002	Excel	-	Fixed	No	No	Yes	modelling based on spreadsheet calc using NTEM etc
A249 Iwade to Queenborough Improvement	1996	SATURN	-	Fixed	Yes	Yes	Yes	MON1:traditional highway assignment model using buffer network only
A27 Polegate Bypass	1992	SATURN	-	Fixed	No	No	Yes	Source: Forecasting Report
A27 Southerham to Beddingham Improvements	2005	VOYAGE R	-	Elasticity	Yes	Yes	Yes	
A30 Bodmin to Indian Queens Improvement	2003	SATURN	-	Elasticity	Yes	Yes	Yes	Source: Forecasting Report

A30 Merrymeet	2004	SATURN	-	Fixed	Yes	No	Yes	Variable demand consider in FORECASTING & ECONOMIC ASSESSMENT REPORT but deemed not needed.
A34/M4 Chieveley	2000	SATURN	Eastern Regional Traffic Model	Fixed	No	Yes	Yes	source: Final Forecasting and Induced Traffic Report
A38 Dobwalls Bypass	2004	SATURN		Elasticity	Yes	No	Yes	
A41 Aston Clinton Bypass	1995	????	-	Fixed	No	Yes	Yes	Assumed fixed as COBA used
A421 Great Barford Bypass	2002	SATURN	The Great Barford Bypass Traffic Model	Mostly Fixed	Yes	No	Yes	Fixed Matrices were deemed appropriate in the main, except on specific congested arterial routes within the urban area in Bedford which "capped" at a nominal level above the existing level. / Data obtained from the LMVR and Forecasting Report
A428 Caxton to Hardwick Improvement	2002	SATURN	CHUMMS	Fixed	Yes	Yes	Yes	Sources: MON1, Economic Forecasting Report
A43 Silverstone Bypass (inc Syresham Bypass and M40-B4031 Dualling)	1990	Excel	-	Fixed	Yes	No	Yes	source TAM16. original model by Northants CC in 1980s. SACRA assessment in 1995 said low risk of induced traffic. Impact of M40 modelled based on forecasts (rather than observed after opening)
A46 Newark to Lincoln Improvement	1997	????	-	Fixed	No	Yes	Yes	Original Documentation missing. COBA model based on limited network 1992 updated flows 2001. Induced traffic not considered as not bypass!
A47 Thorney Bypass	2001	Excel	-	Fixed	Yes	No	Yes	*no evidence of elasticity's and a manual assignment so probably fixed

A5 Nesscliffe Bypass	1991	Excel	-	Fixed	No	Yes	Yes	economic model in COBA.
A5 Weeford Fazeley	2002	SATURN	A5 Development Control Model	Elasticity	Yes	Yes	Yes	source: Traffic Forecasting Report
A500 Basford, Hough, Shavington Bypass	2000	ROADWAY/ ARCADY	-	Fixed?	No	Yes	Yes	*no evidence of elasticities so is likely to be fixed as its too old to be variable demand
A590 High and Low Newton Bypass	2005	COBA	-	Fixed	No	No	Yes	
A6 Alvaston Bypass	1999	SATURN	A6 Alvaston Bypass Model	Elasticity	No	No	Yes	Based on Raynesway SATURN model. Taken from Scheme Assessment Report, Stage 3, Part A - Engineering Report. Vol 2, 1999
A6 Clapham Bypass	1997	ROADWAY	-	Fixed	No	No	Yes	source BAM
A6 Great Glen Bypass	1991	Excel	-	????	No	No	Yes	source: BAM , economic appraisal based on COBA
A6 Rothwell and Desborough Bypass	1993	Excel	M1 - A1 model	Fixed	No	Yes	Yes	Origin model from 1980s makes some use of M1-A1 model (i.e.. the A14). economic model in COBA
A6 Rushden to Higham Ferrers Bypass	1991	????	-	Fixed	No	Yes	Yes	economic model in COBA.
A63 Melton GSJ	2002	SATURN	A63 Melton Grade Separated Junction Traffic Model	Fixed	No	Yes	Yes	

A63 Selby Bypass	1995	ROADW AY & SATURN	NYCC Selby bypass model	Fixed?	No	Yes	Yes	
A64 Colton Lane GSJ	2000	Excel	-	Fixed	No	No	Yes	source : Traffic and Economics report
A650 Bingley Relief Road	1997	SATURN	Airedale Model	Elasticity	No	No	Yes	Cumbria - Bradford DBFO Route traffic forecasting report
A66 Carkin Moor Improvement	2002	Excel	-	Fixed	No	No	Yes	No traffic model produced. economic model in COBA
A66 Greta Bridge Improvement	2002	Excel	-	Fixed	No	No	Yes	No traffic model produced. economic model in COBA
A66 Long Newton Junction	2008	COBA		Fixed	No	No	Yes	No assignment model was used.
A66 Stainburn & Great Clifton Bypass	1999	ROADW AY	-	Fixed	No	Yes	Yes	
A66 Temple Sowerby	2005	Excel	-	Fixed	Yes	Yes	Yes	economic model in COBA
A69 Haydon Bridge Bypass	2004	????	-	Fixed	Yes	Yes	Yes	
M1 Junction 31 to 32 Improvement	2005	SATURN	South and West Yorkshire Multi Modal Study	Fixed	No	Yes	Yes	
M1 Junction 6a to 10 Widening	2005	SATURN	M1 J6a to 10 Model	????	Yes	Yes	Yes	
M25 Brook Street Improvement	2006	VISSIM	London to Ipswich (LOIS) model (To derive future year traffic flows)	Fixed	No	No	Yes	Not many documents were obtained for this scheme
M25 J12 to 15 Widening	1996	SATURN	NAOMI	Elasticity	Yes	No	Yes	Modelling 1995
M27 J11-12 Climbing Lane	2006	COBA	-	Fixed	No	Yes	Yes	Obtained from Forecasting and Economics Report.

M27 Junction 3 to 4 Widening	2006	SATURN	M27 ITS Model	Elasticity	Yes	Yes	Yes	Obtained from LMVR.
M4 J18 Eastbound Diverge	2004	PARAMICS	South West Area Multi-Modal Model (SWAMMS) (To derive future year traffic flows)	Fixed	No	No	Yes	Obtained from Traffics and Economics Report. SWAMMS used alongside PARAMICS.
M40 Handy Cross Junction	2004	PARAMICS	-	Elasticity	Yes	Yes	Yes	Simplified elasticity method described in DMRB - as described in Traffic Forecasting Report
M5 J17 to 18a Northbound Climbing Lane	2004	PARAMICS	South West Area Multi-Modal Model (SWAMMS) (To derive future year traffic flows)	Fixed	Yes	No	Yes	Obtained from Traffics and Economics Report. SWAMMS used alongside PARAMICS.
M5 J19 to 20 Northbound Climbing Lane	2005	PARAMICS	South West Area Multi-Modal Model (SWAMMS) (To derive future year traffic flows)	Fixed	Yes	No	Yes	Obtained from Traffics and Economics Report. SWAMMS used alongside PARAMICS.
M5 J19 to 20 Southbound Climbing Lane	2005	PARAMICS	South West Area Multi-Modal Model (SWAMMS) (To derive future year traffic flows)	Fixed	Yes	No	Yes	Obtained from Traffics and Economics Report. SWAMMS used alongside PARAMICS.
M6 Carlisle to Guardsmill Improvement	2005	????	-	Fixed	Yes	Yes	Yes	
M60 J5 to 8 Widening	2000	TRIPS	-	Fixed	No	No	Yes	taken from Revised Forecasting and Economic Assessment Report March 2002
M62 J6	2006	PARAMICS and SATURN	-	Fixed	No	No	Yes	
A5117/A550 Deeside Park Junctions Improvement	2005	SATURN	A5117 Deeside SATURN traffic model	Elasticity	Yes	No	Yes	Obtained from LMVR(November 2004)
A11 Fiveways - Thetford Improvement	2010	SATURN		????	Yes	No evidence in currently available documents	No	Report on Traffic Modelling, Vol 1 and 2 includes validation and forecasting
M1 J32-35a HSR	POPE Document / Data Collation has not yet been undertaken.							

A556 Knutsford to Bowdon Env Improvement	POPE Document / Data Collation has not yet been undertaken.							
M60 J8-M62 J20 Manchester Managed Motorway	POPE Document / Data Collation has not yet been undertaken.							
M1-A5 Link (Dunstable Northern Bypass)	POPE Document / Data Collation has not yet been undertaken.							
A30 Temple to Carblake	POPE Document / Data Collation has not yet been undertaken.							
A1 Lobley Hill	POPE Document / Data Collation has not yet been undertaken.							
M25 J30 - A13 Corridor Improvement	POPE Document / Data Collation has not yet been undertaken.							
A21 Tonbridge to Pembury Improvement	POPE Document / Data Collation has not yet been undertaken.							
M20 J10a Improvement	POPE Document / Data Collation has not yet been undertaken.							
A160 / A180 Immingham Imp	POPE Document / Data Collation has not yet been undertaken.							
A595 Parton - Lillyhall Improvement	2006	Excel	A595 Parton to Lillyhall Improvement Model	Fixed	Yes	Yes	Yes	
M6 J8-10a Managed Motorway	2009	VISUM	West Midlands Strategic Model	????	No	Yes	Yes	
A1 Dishforth to Leeming Improvement	2005	SATURN	A1 Trunk Road Dishforth to Barton Improvement Model	Fixed	Yes	No	Yes	
M1 J10 to 13 HSR & Junctions	2010	SATURN	East of England Regional Model' (EERM)	????	Yes	Yes	No	
M4 J19 to 20 & M5 J15 to 17 HSR	2009	SATURN /VISSIM	G-BATS3 Greater Bristol Modelling Framework	????	Yes	See Comments	No	Forecast JT presented graphically