NTM Future Development

Quality Report

Department for Transport

November 2019

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This document has 253 pages including the cover.

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	Draft structure and initial content to DfT for info	CLFL		TJG	TJG	25/07/2019
2.0	Parts 1 & 2 to DfT	TJG	TJG		TJG	16/08/2019
3.0	Complete Quality Report issued for DfT review	CL, TJG, SFA	SB, SFA	CS, AA	AA	30/08/2019
4.0	Final for issue	CLFL, DA	TJG	TJG, RLC	RLC	19/11/2019

Client signoff

Client	Department for Transport
Project	NTM Future Development
Job number	Client
Client signature / date	

Contents

Tables

Figures

Executive Summary

Purpose of Quality Report

This Quality Report provides a summary of the National Transport Model v5 (NTMv5). This report is the first in a hierarchy of three tiers of documentation accompanying the model, the other two tiers being a User Guide for model users, and a Developer Guide to inform expert modellers about long-term maintenance and development of the model. The purpose of the Quality Report is to inform stakeholders about what NTMv5 is, how it can be used for different purposes, and the quality standards to which it has been developed. Considerations to overcome technical challenges with the size of the model, use of data and / or quality challenges are mentioned briefly in this report and elaborated in other tiers of the documentation.

Model development team

The model has been developed for the Department for Transport (DfT) by a project team led by Atkins (a member of the SNC Lavalin Group). The full project team includes RAND Europe, PTV Group, Basemap, MDS Transmodal, and the Health and Safety Laboratory, who have all played critical roles in the provision of data, software and analysis.

Structure of Quality Report

The NTMv5 Quality Report is presented in four parts:

Part 1: Model Overview. A description of the model, its purpose, structure and main functions.

Part 2: Technical information. A detailed technical specification and description of the model, including an explanation of the model design and development.

Part 3: Model performance. This demonstrates highway and demand model validation, demand model realism testing, and whole model sensitivity tests.

Part 4: Quality Assurance. This section details the quality assurance framework applied in the model development.

Purpose of NTMv5

The DfT has over the past two decades operated a National Transport Model (NTM), which has been used to produce national road traffic forecasts and estimates of the impacts of national policies on levels of traffic, congestion and transport emissions. The existing NTM (denoted NTMv2R) is a spatially aggregate model with no formal transport network. The DfT identified a need for a full National Transport Model for England to allow analysis of transport demand and supply characteristics at a more spatially detailed level, allowing individual roads and locations to be taken into account. The potential applications of the model were formed into six use cases set by the Department as follows:

UC1 Strategic Roads Investment and Resilience: To analyse the impacts of packages of roads schemes at a national level. This could include high-level calculation of value-for-money (VFM), points of expected congestion, and analysis of resilience of the network.

UC2 Road User Charging and other potential policy: Flexibility to adapt to road policies in future Parliaments. This could include various forms of road pricing, parking policy in urban areas, or other behavioural devices such as High Occupancy Vehicle (HOV) lanes.

UC3 Local Investment and Policy: Variety of analysis including national impacts of congestion relief schemes; Policy impacts of introducing public transport improvements (eg light rail). This could potentially include travel demand management in future parliaments.

UC4 General Support for DfT Teams (other than Roads / Local): Environmental analysis of transport policies relating to carbon and/or an approximation of air quality emissions, and also aviation surface access.

UC5 Scenario-based National Traffic Forecasting: Understanding of changes in population or travel trends (eg driving rates amongst young people), with scenarios around GDP, car ownership, fuel price, road tax.

UC6 Exploring the unknown: Testing new policies or technical developments that have not been modelled before (eg CAVs). Testing new policies or technical developments of whose existence we are not currently aware.

The new model (NTMv5) has been developed, taking the use cases as a guide, to provide a range of analytical and policy-testing capabilities, centred on the production of scenario-based road traffic forecasts, but also allowing for testing related to road investment and resilience, user charging, local investment, environmental impacts and experimental applications such as new modes (autonomous vehicles and Mobility as a Service).

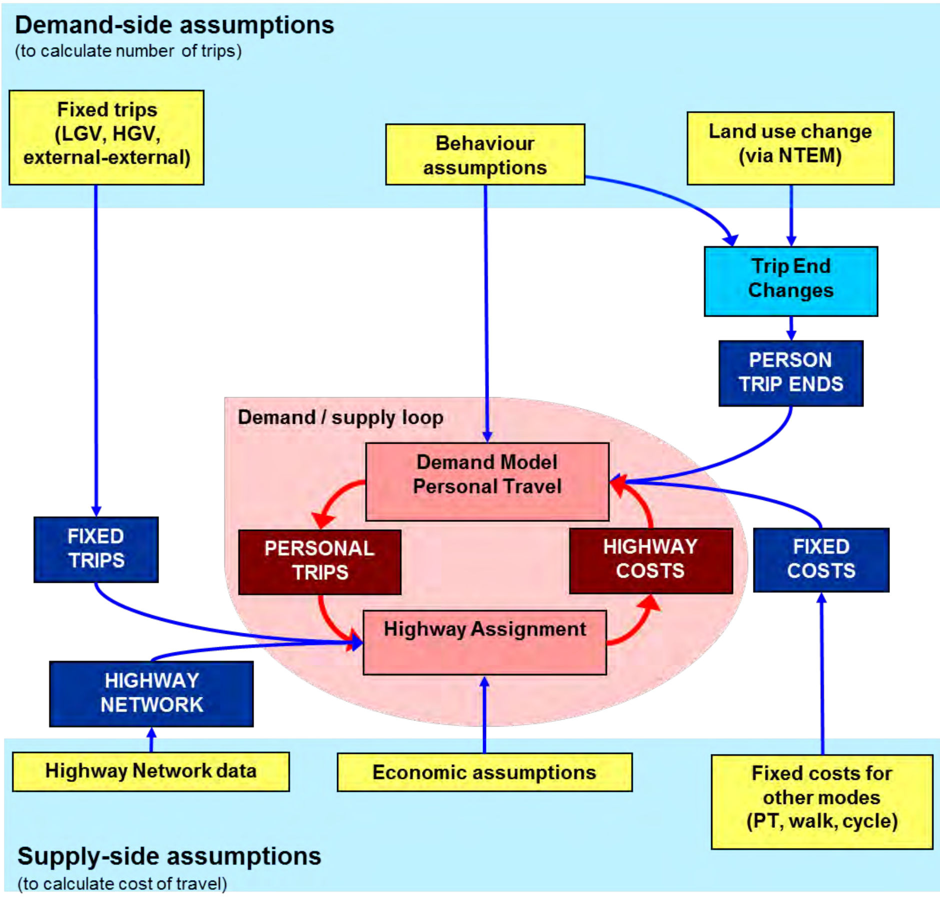
The model has been developed to meet stringent quality assurance requirements, achieve manageable run times, be easy-to-use by the Department's transport modelling staff and transparent to external stakeholders.

Model structure scope

The NTMv5 is a spatially detailed model, which follows the established conventional (four-stage) transport model structure with a high level of spatial detail across England. This was an important design requirement to represent the use cases the model is designed to support.

The demand model forecasts personal trip patterns by mode, based on inputs which represent the generation and attraction of trips based on land use activity, the highway network and cost matrices representing the bus, rail, walk and cycle times, distances, plus public transport (PT) fares. The resulting car vehicle demand is assigned to the highway network. The model operates iteratively so that the congestion effects feedback into the demand model.

Model outputs include the travel demand choices (mode shares, PT volumes etc), highway flows and congestion, as well as travel cost information which can be used for economic analysis. The model is summarised in the diagram below.



The geographic scope of the model covers the whole of England, with trips to and from Scotland and Wales also considered. The travel modes represented are: car driver, car passenger, bus, rail, walk and cycle.

The highway model includes all motorways, A roads, the majority of B roads and local roads as required; and models AM, interpeak and PM peak average hours. Vehicle trips are assigned to the network segmented into five user classes: business, commuting, other car, LGV and HGV.

The model has been implemented using PTV Visum, a widely available, advanced transport modelling system licenced by PTV Group, which provides all the core functionality needed to prepare, run, store and carry out basic analysis of results. Additional tools have been developed to assist with preparation of inputs and further output analysis.

Model development and quality assurance

The model development has followed a process agreed by the DfT, with scope and quality assurance standards for each stage agreed and checked. Key stages have included: specification stages for each task; checks on software and feasibility; model development tasks; model calibration and validation; and finally a series of sensitivity tests.

Refinement of the design of the model has also been carried out throughout the work. Each stage has been subject to appropriate levels of quality assurance and sign-off by the DfT, and extensive documentation prepared of the processes followed.

Model performance

The project has achieved its aim of producing a national model incorporating both a choice model and highway assignment model with a high level of spatial detail. The final form of the model is conventional in design and uses standard software. This standard approach, along with the documentation provided, ensures that the system is transparent to external stakeholders, and can be operated, maintained and developed by the Department's staff in future. In tests on Atkins' local system installation, the model has achieved the desired run time target of completing four supply-demand iterations within 48 hours.

As detailed in this report, the model has also achieved acceptable calibration and validation of highway assignment, and has demonstrated realistic responses; both in line with Transport Analysis Guidance. Sensitivity tests have also been carried out to demonstrate model functionality and performance as defined by the use cases. Five tests were carried out testing the following themed scenarios:

1. Growth in demand – relating to changes in population and land use activity through time;
2. Highway infrastructure – major changes to the detailed highway network;
3. Public transport service provision – changes in level of service between specified locations;
4. Road user charging – demonstrating ability to reflect potential alternative transport policy; and
5. Urban strategy – bringing together a package of measures focused on travel to and within urban areas.

These tests are designed to demonstrate potential applications of the model, and provide assurance that the functionality has been implemented and reasonable results are achieved. As with any transport model, skill and care will be required in the application of the model and interpretation of results both in these areas and for the wider use cases.

Future model development and maintenance

Given the scale and complexity of the model a structured programme of model performance monitoring, maintenance and enhancement is recommended. The development of the model has indicated areas where focus could potentially be directed to increase confidence in model forecasts. This includes the potential for:

- enhancing highway assignment validation;
- refining elements of the realism responses;
- the responses of urban area speeds; and
- enhancements to model convergence monitoring.

Part 1: Overview of NTMv5

This part of the document provides an overview of the National Transport Model (NTM) which is intended for a less technical reader, and includes the following:

- Chapter 1: an introduction to the Quality Report as a whole and the NTM Future Development Project;
- Chapter 2: a discussion of intended uses of the model; and
- Chapter 3: an overview of the model scope and structure.

1. Introductory topics

1.1. Requirement for NTMv5

The use of a national model provides a systematic means of testing the national consequences of alternative national transport policies or widely-applied local transport policies, taking into account a range of background scenarios such a demographics and economic performance.

The Department for Transport (DfT) has over the past two decades developed, maintained and operated a National Transport Model, known as NTMv2 (recently updated and refresh and now referred to as NTMv2R)[1], which they use for a variety of policy analyses including:

- regional road traffic forecasts;
- aggregate national-level analysis of strategic roads reforms such as increasing road capacity and options for user charging;
- national-level analysis of local transport policy or its impacts (including nationwide impacts of local roads investment, changes to public transport fares, and incorporating the impacts of "soft measures" such as promotion of cycling and walking); and
- traffic analysis for carbon budgets.

NTMv2R is a spatially aggregate model, and the DfT have identified a need for a full National Transport Model for England which would allow analysis of transport demand and supply characteristics at a more spatially detailed level, allowing individual roads and locations to be taken into account. The new model was further required to:

- meet stringent quality assurance requirements;
- have manageable run times;
- be sufficiently easy-to-use by the Department's staff; and
- be transparent to external stakeholders.

In 2015, the DfT's Transport Appraisal and Strategic Modelling (TASM) team specified a new model, termed NTMv5, which would meet this requirement.

1.2. Project team and acknowledgements

This project has been led by Atkins, a member of the SNC Lavalin Group. The Atkins team have a long history of involvement in the development and application of strategic national scale transport models, including the DfT's existing National Trip End Mode (NTEM), and National Transport Model v2 (NTMv2R), as well as national models for Turkey, Malawi and Oman, and a variety of regional models in the UK and Ireland.

We would like to acknowledge the contributions made by our partners who have played a critical role in the provision of data, development of components and delivery of the NTMv5 model:

- RAND Europe are experts in the design and calibration of Variable Demand Models (VDM). RAND Europe carried out the estimation which determined the structure, segmentation and formulation for the VDM, and have advised throughout the work on the design and testing of the demand model;
- PTV Group are one of Europe's leading transport modelling consultancy and software providers, and developers of the PTV Visum software which has been used to develop and implement NTMv5, PTV have provided expert advice on the use of PTV VISUM, carried out early feasibility tests for the model, and have reviewed the model implementation;
- MDS Transmodal (MDST) are experts in analysis and advice on strategic, commercial and economic issues related to freight transport and logistics, and developers of the Great Britain Freight Model (GBFM). They have developed the base freight matrices for both LGVs and HGVs, which are incorporated in the NTMv5 base year vehicle matrix;

[1] More information on the National Transport Model including reports on NTMv2R is available here: https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools#the-national-transport-mode

- BaseMap are a leading supplier of transport data solutions, and developers of the TRACC software for accessibility planning. BaseMap have provided consistently derived travel time information for public transport, walking and cycling which form a critical component of the travel information in NTMv5; and
- Health & Safety Laboratory (HSL). The HSL are part of the Health & Safety Executive and maintain land use and travel data products at an extremely detailed level. They have provided land use data for the model base year (2015) which has been essential to the development of the base travel matrices.

We would also like to acknowledge the contribution of the DfT Transport Appraisal and Strategic Modelling (TASM) team, who have led this project from the client side and been involved throughout the design and development of the model.

1.3. Document purpose

This NTMv5 Quality Report is the top-level report for the new model and forms the gateway to the information provided in the following companion reports:

- User Guide – providing more details on topics covered here for those using the model; and
- Developer Guide – providing more detail on the information and methods used to develop NTMv5 of relevance for those undertaking further development or updating the model.

The Quality Report provides model users, policy makers and stakeholders with information on NTMv5 in terms of the model scope and structure; what the model is designed to do and its limitations; and why certain features are included or excluded. The data and evidence underpinning the model is set out, and the quality of the results obtained presented.

Information provided in this report is not duplicated in the other reports. Model users would typically read this report and the relevant sections of the User Guide; while model developers would read both of these before relevant parts of the Developer Guide.

Chapters 2 and 3 of the report are specifically intended for non-technical readers. Note that a glossary and list of abbreviations is provided in Appendix A for reference.

1.4. Document structure

This document is separated into four parts of follows:

Part 1: Model Overview. An introduction and overview of the model itself, its purpose, structure and main functions. This is intended as an introduction both for the technical reader, and an overview for the non-technical reader.

Part 2: Technical information. A detailed technical specification and description of the model, including key elements of the model design and development.

Part 3: Model performance. Evidence of the model performance, largely dealing with highway and demand model validation and related topics. This includes the derivation of the demand matrices, calibration and validation of the highway model, and both the estimation and realism testing of the demand model. Five whole model sensitivity tests are also described including model results.

Part 4: Quality Assurance. This section details the quality assurance steps carried out during model development.

Part 1 has the following structure:

- Chapter 1: an introduction to the Quality Report as a whole and the NTM Future Development Project;
- Chapter 2: a non-technical discussion of intended uses of the model; and
- Chapter 3: a non-technical overview of the model scope and structure.

Information on the structure of each subsequent Part is included in the divider pages.

2. Intended uses and applications of NTMv5

2.1. Introduction

This section describes the intended uses of NTMv5 and provides general information about the potential for use of the model for a range of applications.

This is considered in the form of a series of 'use cases' which were agreed with the DfT early in the project itself, which are outlined in Section 2.4. However, to provide context for this, a more general description of the purpose of transport modelling in general, and NTMv5 in particular, is given first.

Note that a glossary and list of abbreviations is provided in Appendix A for reference.

2.2. Purpose of transport modelling and NTMv5

The DfT's Transport Appraisal Guidance (TAG) Unit M1 provides the following summary of the purpose of transport models, and of the forecasts they produce:

> *A transport model is a tool (usually an automated computer program) that converts readily available forecasting assumptions into a forecast of demand (number of trips) and supply (level of service / cost of travel) on the transport network. (TAG Unit M1.1 Para 2.3.1)*
>
> *Assessment of any intervention (transport or otherwise) requires an appreciation of expected future benefits and disbenefits. Being in the future, these benefits and disbenefits cannot be measured or observed at the time the decision needs to be made, and so they need to be estimated by comparing two forecasts – one excluding the intervention, the other including the intervention and no other changes. (TAG Unit M1.1 Para 2.2.1)*

The existing National Transport Model (NTM) fulfils this role by providing a systematic means of comparing the national consequences of alternative national transport policies or widely-applied local transport policies, against a range of background scenarios. The Department uses the existing NTMv2R for a variety of policy analyses including:

- aggregate national-level analysis of strategic roads reforms (which, during the lengthy lifetime of the model, has included increasing road capacity and consideration of options for user charging);
- national-level analysis of local transport policy or its impacts (including nationwide impacts of local roads investment, changes to public transport fares, and incorporating the impacts of "soft measures" such as promotion of cycling and walking); and
- traffic analysis for carbon budgets.

The spatially detailed NTMv5 is intended to complement NTMv2R by providing additional capabilities for assessing the impact of major new road schemes, packages of transport improvements or spatially based charging arrangements.

To understand the purpose of a transport model in more detail, it can be helpful to first consider the overall structure in terms of inputs and outputs which are addressed in the next section.

2.3. NTMv5 model inputs and outputs

NTMv5 has been implemented essentially as a four-stage transport model, which means that it has a structure which separates the following stages:

- **Trip Generation:** Forecasting the number of trips which will be made, based on information about land use and trip-making (trip rates);
- **Mode choice:** Determining the proportion of the total trips which will be made by each modelled mode, based on the comparative cost (or disutility[2]) of each mode, and the assumed preferences of the traveller;
- **Distribution:** Predicting the pattern of trip origins and destinations, based on the cost of trips for each origin-destination pair by the given mode, and again assumed preferences of the traveller; and

[2] Journey disutility, sometimes colloquially termed cost, is used to combine the journey time, monetary cost and perceived importance of other characteristics such as public transport interchanges.

- **Assignment and routing (supply modelling):** Assignment of each origin-destination trip to an appropriate transport network (in NTMv5, a national Highway Assignment Model, or HAM), which produces a forecast of link loadings and any impacts of congestion on journey time.

The purpose of this type of model can be described simply as taking a set of inputs, and transforming them by an agreed and repeatable process using known assumptions, into a required set of outputs.

Figure 2.1 provides a high-level overview of the inputs to the model and general structure, which was provided by the DfT as part of the project service description. The main model inputs shown are:

- A set of person trip ends which define the number of trips being produced in, and attracted to, each model zone, by person type and journey purpose;
- A highway network which represents the road system of England, Scotland and Wales;
- A set of public transport, walk and cycle travel characteristics, used to calculate **fixed costs** of journeys by these modes;
- Freight movement matrices, providing a set of fixed trips for LGV and HGV goods movements by time of day; and
- Model assumptions including **economic assumptions** (fuel cost, personal values of time) and behavioural assumptions (model sensitivity parameters and cost weightings).

It should be noted that there is no detailed public transport modelling within NTMv5 and similarly there is no representation of public transport crowding and its impact on travel.

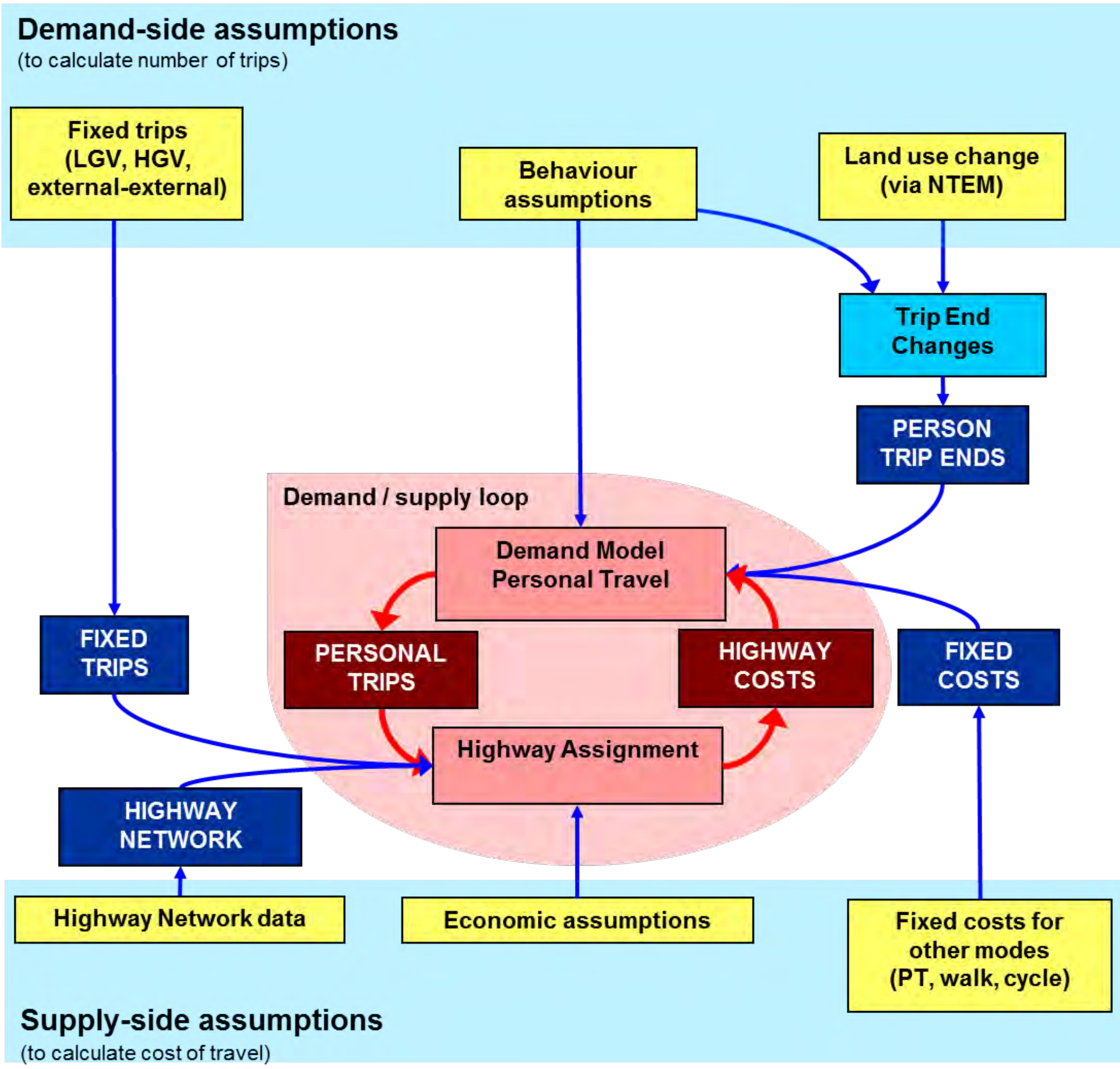


Figure 2.1 - High level overview of NTMv5 structure (from DfT Service Description)

Each of these areas of input have been developed for the Base Year (2015) model based either on data obtained directly by the project team, or produced through a process of analysis, estimation and calibration.

For any forecasting (including model tests in 2015), it is necessary to produce and input to the model appropriate revisions to each of these inputs.

This allows the model to produce a series of outputs, principally:

- Forecast travel demand (personal trips) which is segmented at the most detailed level by origin-destination, trip purpose, traveller type, travel mode and (for personal vehicle trips) by time of day;
- Highway network loadings, and related impacts on levels of congestion and journey time (highway costs), which can be summarised by highway link or origin-destination route; and also
- For each origin-destination and segment of travel demand, detailed journey characteristics by mode, including journey time, distance, money cost and the model's disutility.

From these three types of model output, a wide range of information can be derived to meet the requirements for transport modelling outlined in TAG. These can be broadly grouped as follows:

- **Forecasts of future travel demand:** Forecasting the demand for travel, and the related impacts of the transport system, as is applied for the DfT's Road Traffic Forecasts; and
- **Testing of interventions:** As outlined in the extract from TAG above, the use of the model to compare a scenario with or without a specific intervention, either in a future year or the current year, and reveal the comparative impacts.

It is also useful to make a distinction between primary analysis of the model outputs to understand either of the above, and secondary or downstream analysis of the outputs to produce derived measures. Primary analysis involves studying the model's immediate outputs (listed above). Secondary analysis includes appraisal of welfare and economic impacts, and analysis of environmental impacts such as emissions, air quality and noise. Secondary analysis is of course based on the same model outputs as the primary analysis, but is carried out downstream and separately from the model.

It is important that, for any given scenario test, before secondary analysis is carried out sufficient primary analysis is conducted to understand and validate the model responses.

The use of NTMv5 by DfT will entail both primary and secondary analysis, as outlined in the use cases in the next section. However, it should be noted the scope of the NTMv5 model itself, and of the project work to produce the model, entails only primary analysis, and assurance that sufficient outputs are available to carry out secondary analysis such as appraisal and environmental impact testing.

2.4. Use Cases

To guide the detailed design of the model, six 'use cases' were identified, describing the areas of traffic forecasting and policy making for which the DfT intends to use NTMv5. This has a primary focus of National Traffic Forecasting, but also includes cases relating to the identification of 'gaps' in the national network and testing of transport policies.

The DfT proposed six use cases as set out below:

UC1 Strategic Roads Investment and Resilience: To analyse the impacts of packages of roads schemes at a national level. This could include high-level calculation of value-for-money (VFM), points of expected congestion, and analysis of resilience of the network.

UC2 Road User Charging and other potential policy: Flexibility to adapt to road policies in future Parliaments. This could include various forms of road pricing, including pricing on strategic roads (tollbooth, distance-based or vignette), urban roads (eg congestion charging vignette), or parking policy in urban areas, or other behavioural devices such as High Occupancy Vehicle (HOV) lanes.

UC3 Local Investment and Policy: Variety of analysis including national impacts of congestion relief schemes; Policy impacts of introducing public transport improvements (eg light rail). This could potentially include travel demand management in future parliaments. It is noted that parking is covered in use case 2.

UC4 General Support for DfT Teams (other than Roads / Local): Environmental analysis of transport policies relating to carbon and/or an approximation of air quality emissions, and also aviation surface access.

UC5 Scenario-based National Traffic Forecasting: Understanding of changes in population or travel trends (eg driving rates amongst young people), with scenarios around GDP, car ownership, fuel price, road tax.

UC6 Exploring the unknown: Testing new policies or technical developments that have not been modelled before (eg CAVs). Testing new policies or technical developments of whose existence we are not currently aware.

It was agreed that use case 5 (UC5, National Traffic Forecasting) should be considered first for the following reasons:

- Production of National Road Traffic Forecasts (RTF) is an existing use and the most fundamental purpose of the National Transport Model;
- UC5 includes scenario-based forecasting, and it is likely that many of the questions arising in UC1 and UC2 will be considered as scenarios for RTF; and
- In order to robustly forecast road traffic for the RTF, it will be necessary for NTMv5 to include the influence of a wide range of factors. Those factors highlighted in other use cases can therefore be considered as implicitly features of UC5.

2.4.1. UC5 Scenario-based National Traffic Forecasting

The model includes appropriate segmentation to represent differences in travel behaviour, whilst maintaining reasonable run times. In addition, future scenarios can be assessed varying:

- Road infrastructure on motorways, A roads and B roads;
- Enhancements to other modes that may induce a mode shift away from personal vehicle trips;
- The cost of travel, such as fuel costs, tax other vehicle operating costs or public transport fares; and
- Externally forecast trends in vehicle occupancy and personal values of time (related to GDP).

As specified in the project brief, the overall process of producing the RTFs should be credible and transparent to external stakeholders. It is suggested that as the National Traffic Forecasts are publicly available, external stakeholders and end users are considered in the widest possible sense (i.e. not limited to DfT and national/regional government bodies). The use of standard TAG approaches should facilitate this transparency.

The DfT will be able to directly extract from the model forecasts of personal travel movements on the basis of:

- Zone-zone movements (Origin-Destination), segmented by purpose, mode, traveller type and time of day; and
- Link-based flows, with less detailed segmentation but including area type, road type, vehicle class and purpose (plus spatial aggregation such as Regions).

Assessment of the impact of varying urban road capacity on vehicle traffic cannot be practically implemented, given that personal vehicle costs in urban areas are influenced by factors such as parking capacity and the impact of pedestrian movements. A representation of the influence of trip end growth on urban congestion is included in the model, and it would be feasible to make modifications to urban capacity to represent other factors. However, these are beyond the scope of the model currently.

2.4.2. UC1 Strategic Roads Investment and Resilience

This use case has been designed to analyse the impacts of packages of roads schemes at a national level. Specifically, this has two elements:

- Identification of ‘gaps’ in the network. This is interpreted as meaning areas where the road capacity in future may be insufficient, leading to unacceptable rises in congestion and journey times. This may include lack of resilience, which is discussed further below; and
- Assessments of scheme proposals. The ability to test as a package whether proposed strategic investment will be effective.

Atkins believe that most major elements of this use case are met under UC5 above, with the following exceptions:

Network and routing detail: UC1 would require specific network changes on the motorways, A and B classified roads (MABs) to be coded in NTMv5, and the transport demand and journey characteristics reviewed at a local level. However, limitations in the detail of network coding should be noted.

Resilience: This relates to ‘a section of the road network becoming unavailable for a short or long period of time (due to roadworks, flooding or force majeure events), and the impact that this would have on traffic and the economy’. It would be possible to construct scenarios using NTMv5 where elements of the road network are removed, and the impacts tested as short term (highway routing only) impacts or longer term (demand) impacts.

Scheme assessments: As with any strategic model, specialist users and very careful interpretation of results will be required to ensure that robust conclusions are drawn from scheme assessments. As highlighted for UC5 above, NTMv5 should produce all of the raw model outputs appropriate to appraisal of road schemes. However, post-processing of these to provide a complete assessment of the scheme impacts (e.g. consumer surplus) and guidance on interpretation is not included in the current version of the model.

2.4.3. UC2 Road User Charging and other potential policy

This use case could include various forms of road pricing or parking policy, or other behavioural devices such as High Occupancy Vehicle (HOV) lanes.

The model design is suitable for various forms of link-based and area-based charging, following principles which are well established in transport modelling, and are demonstrated in the sensitivity test on road charging described in Section 15. The fixed urban traffic speeds could limit the impacts of modelling some forms of road user charging since any decongestion the benefits would not be internalised within model runs, though user adjustments could be made to take account of this. Some types of charge however are less straightforward to implement and would require additional work outside of the model scope. These include:

Vignette charges: Vignette normally involves road users purchasing an additional licence to use certain roads for a period of time greater than 1 day. There is little history of modelling this type of charge in the UK, and the structure of a TAG model does not necessarily capture all aspects of the decision to purchase a vignette.

High Occupancy Vehicle lanes (HOV): To model HOV lanes fully requires vehicles to be separated by occupancy during assignment. DfT have indicated that modelling of HOVs is not a priority use case for this version of the model and this has therefore not been included.

Routing responses – local roads: As NTMv5 will not include all local roads, it would not be possible to represent 'rat-running' responses down minor roads to avoid a charge.

Income segmentation in assignment: To represent differential routing responses to charges, income segmentation would be needed in the Highway Assignment Model (HAM), which is not included within the current scope.

Parking Policy: Parking charges are represented by area type, although are coded by zone. Within these parameters, it should be possible for a skilled user to draw conclusions on the level of impact from changes in parking policy.

2.4.4. UC3 Local Investment and Policy

This use case covers a variety of analysis including national impacts of congestion relief schemes, such as policy impacts of introducing public transport improvements (eg light rail), and could potentially include travel demand management in future parliaments (note that parking and user charges are covered in use case 2).

This use case is intended to assist DfT with considering local investment policies. The model is capable of providing analysis at a sub-national level, exceeding the capability of previous versions of the National Transport Model. This can be addressed by making adjustments to standard model assumptions at the local level, and reviewing outputs, and provides a wide range of facilities for representing and testing local policy. However, given the national scale of the model some caveats naturally apply to modelling specific local areas, as detailed local characteristics are absent (e.g. park & ride, bus service patterns, minor local roads); likewise the use of fixed urban area speeds within a model run restricts the representation of (de)congestion benefits. It should also be noted that validation of local model performance has not been possible.

2.4.5. UC4 General Support for DfT Teams (other than Roads / Local)

This use case covers environmental analysis of transport policies relating to carbon and/or an approximation of air quality emissions, and in addition, port and aviation surface access. NTMv5 has standard transport assignment model functionality, allowing the production of information on traffic flows and speeds for modelled links which is normally required for environmental analysis. However, some caveats will apply to the ability to represent emissions and noise impacts due to large zone sizes and urban area speeds and the lack of detailed validation within urban areas and Air Quality Management Areas (AQMAs) in particular. This is a natural limitation of a large scale strategic transport model which would need to be considered at the time any environmental assessments are made.

NTMv5 represents surface access to major ports and airports but does not differentiate them from other leisure, business and commuting trips. Freight movements to/from port and airport zones are included in the freight matrices. This provides a representation of the impact of these hubs on the strategic road network, and to some extent the accessibility of the ports and airports.

There are some further caveats on the validation and forecasting of airport flows which are worth noting:

- Highway trips to/from each airport zone are represented to the extent that this can be determined from observed data. However, no separate and additional validation of airport flows has been carried out; and
- There is no separation of traveller types specifically designed to represent air travel as a purpose or higher values of time, other than using the segments incorporated elsewhere within the model.

2.4.6. UC6 Exploring the unknown

This use case includes testing new policies or technical developments that have not been modelled before (eg CAVs). These requirements are by their nature hard to anticipate, however by providing a national strategic highway network and matrices of national trips, a very wide range of explorations should be possible.

The use case makes specific reference to the introduction of new modes to represent (for example) Mobility as a Service (MaaS) and connected and autonomous vehicles (CAVs). Neither are covered within the basic model scope however it is anticipated that modifications could be made to represent them through:

- **The ability to add additional modes within PTV Visum.** The functionality exists within the software to add modes to an existing model, and this is not expected to be a major task in itself;
- **Setting of parameters for new modes.** The model design allows access to and adjustment of all relevant parameters by a skilled user; and
- **Interpreting the impact of new modes.** The impact of any new modes introduced in future on the demand model would need careful consideration, to ensure that no biases or misleading results are produced. Advice on this is beyond the current project scope.

2.5. Model user roles

The NTMv5 User Guide provides information likely roles and processes for the use of NTMv5, which should be consulted for further information. However, it is useful to note that involvement with the use of the model can fall into three main categories: run specification; model set-up and running; and interpretation and communication of results.

It is advised that expert users of NTMv5 are involved in all stages of the work, and critically are available to advise in specification of results and interpretation of outputs. A non-technical manager should be able to use information in this section and the following one to understand the model capability and outline broad requirements for model tests. These should be reviewed with an expert user and refined into detailed test specifications.

The run set-up and model running may be carried out by an analyst who has been trained in the relevant software, but should be done under the supervision of an expert user, and with relevant checks on inputs and set-up.

Results should be carefully reviewed by an experienced user to provide interpretation, to assign meaning to the model results in terms suitable for a non-technical person, with appropriate caveats included.

3. NTMv5 scope and structure

3.1. Introduction

This section provides a complete overview of the NTMv5 model scope and structure, including the main functionality, geographic coverage and high level structure. This is intended to complement Chapter 2 above, by providing a non-technical reference to the main parts of the model.

3.2. Scope: travel demand and modes

To meet the requirements and intended uses of NTMv5, the scope of the model includes the features set out below.

- NTMv5 includes all personal trips made to or from the internal model area – irrespective of their length and for all land-based modes of travel. This includes surface access trips to/from ports and airports in the highway assignment model;
- Trip ends (travel demand) are taken as an input to the model ie trip generation has been carried out for the Base Year 2015, and forecast trip end growth is an input to the model;
- Mode choice is carried out within the demand model, and separates out car, bus, rail, walk and cycle modes (i.e. six separate modes modelled);
- Trip distribution allocates trip productions to attraction zones to create matrices of travel demand;
- Assignment and routing of personal and freight highway trips within England, and with more limited detail within Scotland and Wales;
- The demand model operates for a 24-hour weekday with the assignment model operating for specific time periods during the weekday; and
- Mode and destination choices in the demand model are influenced by changes in highway congestion, fed back via an iterative process from the highway assignment model.

The main things excluded from the model scope are:

- Generation or demand choices related to freight or goods vehicles, though routing of these vehicles is included in the highway assignment model;
- Travel frequency responses, since these are not required when including all personal travel including trips using active modes;
- Car ownership or availability responses, since these are input as part of the trip ends;
- Assignment of public transport and active modes;
- Representation of parking capacity; and
- Other urban and local transport supply characteristics which cannot be represented.

The implications of the model scope, and the limitations, have been discussed in more detail in relation to the use cases in Section 2.4 above.

3.3. Geographical coverage

The geographic scope of the model is to cover all travel demand within England, and major connections to Scotland and Wales. At a high level, the most critical issue is to determine which areas are treated as internal, and which are external. This makes a fundamental difference to their treatment as follows:

- **Internal areas:** For these areas, all trip ends for person trips are included, and all travel choices within scope are determined in the model. This means that for each trip generated in the internal area, the mode and distribution choice apply fully.
- **External areas:** NTMv5 models responses for all internal-external and external-internal trips, but not external-external trips.

Analysis was carried out of the 2011 Census Journey to Work data to identify areas of Scotland and Wales which should potentially be treated as internal. Wrexham and Flintshire in north-east Wales were selected for inclusion, but not other areas. Figure 3.1 shows the model extent differentiating internal and external areas.

Figure 3.1 - Map showing extent of modelled area

3.4. NTMv5 overall structure

The design and structure of NTMv5 is intended to remain as close as practical to a conventional TAG design for a four-stage transport demand and assignment model. A simple summary of the structure is shown in Figure 3.2, which can be compared with the conceptual structure provided by the DfT (See Figure 2.1).

The model has been prepared with a base year of 2015, which means that all model inputs have been developed based on this year, and that the calibration of the highway model also relates to 2015. There is no difference between the structure used for 'Base' and 'Forecasting' model runs, with model forecasts or scenarios being created simply by altering the appropriate demand or supply-side inputs.[3]

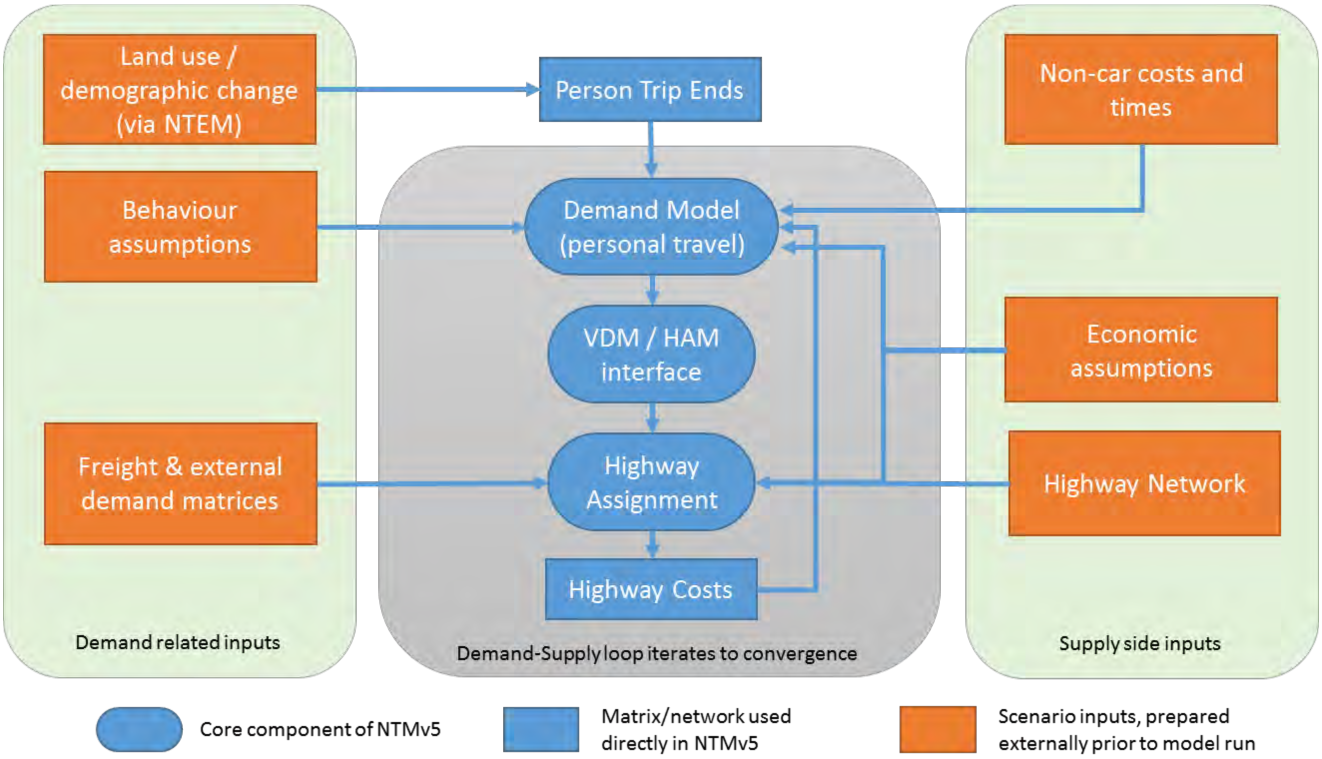


Figure 3.2 - Overview of NTMv5 core components and structure

The basic structure and principles of the model can be summarised as follows:

- **Person trip ends:** In the Base Year model, an exercise was carried out to calculate trip productions and attractions by zone, separated by trip purpose and person type. These trip ends are used as the basis for any model scenario tests, with changes input either as scalar growth or additive changes;
- **Demand model (VDM):** A logit based variable demand model (VDM) is used to determine personal choices of travel mode choice and destination. These choices are informed by the disutility for each possible journey, calculated based on journey time, distance and money costs (red arrows);
- **VDM/HAM interface**: The synthetic personal travel information calculated by the VDM is converted into vehicle trips by time period, and used to apply changes to the Base Year highway assignment matrices;
- **Freight and external matrices:** The highway assignment matrices include matrices of freight Origin-Destination trips in the Base Year. Forecast growth or other changes in freight trips are determined externally and applied within the model;

[3] The operation of the model differs in that the base runs used for the base year model set-up and highway calibration do not include any iteration of the demand model and HAM: a single pass of the demand model is used to create synthetic base year demand, with a separate and single assignment of the base year vehicle matrices to produce costs. The VDHM/HAM interface and feedback are therefore not used. Conversely a forecasting or scenario test with varied inputs carries out iterations typically with 4 full passes of the demand and assignment modules.

- **Highway assignment model (HAM):** Network assignment is carried out for highway only to determine routing and links flows, and to extract highway costs (distance, time and any toll charges) for O-D zone pairs by time period;
- **Network pre-loads:** The highway assignment network includes pre-loads of scheduled public transport services (bus and coach) which can also be adjusted during scenario tests;
- **Non-car costs**: Travel costs, times, and fares related to bus, rail, walk and cycle are input as fixed matrices for the base year, which can be adjusted for scenario tests, but are not influenced by model results during iteration;
- **Behaviour assumptions and economic assumptions**: These can be altered during scenario tests to determine the impact e.g. of changes in fuel costs or values of time; and
- **Model iteration:** For scenario testing the model includes a supply-demand loop which allows for iteration of VDM choices and highway congestion levels.

Key components and features of the model are discussed in the following sections.

3.5. Variable Demand Model (VDM)

The model applies a Production-Attraction (P/A) approach, that is to say all trips with a home-end are treated as home-based linked to the Production zones, and other trips are treated as non-home-based. This is in contrast to a fully tour-based approach which would identify tour purpose from chains of trips starting and finishing at home, which was agreed during the inception stage to be beyond the scope of the current model.

The demand model is designed so as to represent all personal trip-making to/from and within the internal model area, explicitly covering all trip purposes, trip lengths and modes. To achieve this, the VDM distinguishes between six transport modes: car driver, car passenger, bus, rail, walk and cycle. The VDM segments demand into trip purposes and person types, which were selected to be comparable with the National Trip End Model (NTEM) segmentation. The relative sensitivity of mode and destination choice, and the possibility of mode nests (e.g. for public transport modes) was determined through model estimation using travel diary data from the National Travel Survey.

The main inputs to the VDM are:

- Total personal travel demand in the form of trip productions (trips generated from homes or other locations by any mode) and weights for the attractiveness of locations for trips to terminate based on land use activity by location (person trip ends in Figure 3.2);
- Travel distances, costs and times to move between each combination of zone pairs in the model for each mode of travel represented (highway costs and non-car costs in Figure 3.2); and
- Choice model parameters which determine both how the overall utility of a trip is perceived by the different types of traveller represented (ie how they combine time and money costs) and how sensitive their choice of mode or destination is to the relative differences in utilities between the options available (behavioural and economic assumptions in Figure 3.2).

The demand for travel in the base year was derived from land use, demographic and economic datasets, and can be modified for alternative scenarios to reflect changes through time or alternative growth and economic scenarios.

The choice model parameters were estimated for the model base year to obtain a good match in behaviour to observed patterns. The majority of these parameters will not change for alternative scenarios, though parameters reflecting the balance of time and money costs (values of time) would typically change for forecasting scenarios in line with transport modelling guidance.

3.6. Highway Assignment Model (HAM)

The most fundamental requirement for the highway model was for a spatially detailed national model, representing the complete motorway and A road networks, and with sufficient coverage of other road links to ensure adequate connectivity between zones.

In response to that requirement the HAM includes a network representation of all motorway and A Roads in England, along with the majority of B Roads and other local roads as required. The network is based predominantly on the networks developed for Highways England Regional Traffic Models (RTMs).

In order to provide a robust model, the HAM has been developed to rigorous standards covering the DfT TAG guidance on model standards, with some minor adaptations given the national scope and size of NTMv5 as set out in Chapter 12.

The HAM operates on the basis of vehicle trips, which are segmented into five assignment user classes (AUCs) in line with TAG guidance: personal car business, personal car commuting, personal car other, LGVs and HGVs. The LGV AUC includes both personal and goods movements using light goods vehicles.

The NTMv5 highway network was built using the five stitched and combined Regional Transport Model (RTM) networks as a starting point. Connectors were also coded specifically for the NTMv5 based zoning system as the points at which trips starting and ending in each area emerge and depart from the modelled highway network.

3.7. Base Year highway vehicle matrices

Highway trip matrices were built for the model base year (2015) to represent the demand for travel by different vehicles types between the model zones at each time period represented. There are two stages to the creation of the base year highway matrices. Firstly prior trip matrices were developed from a range of data sources on land use activity and travel demand. These were then adjusted during the model calibration stage to better reflect the traffic observed on the road network. The adjustment process created a set of “post” matrices which are taken forward as the base year matrices in the full NTMv5 model.

3.8. Linking of VDM and HAM

As discussed above, the VDM and HAM operate with different forms of demand: the VDM having what is termed a ‘synthetic 24-hour person matrix of productions and attractions’, and the HAM requiring separate AM, IP and PM matrices of vehicle trips on an origin-destination basis. To link these, the VDM / HAM interface comprises several data transformations carried out as part of a model run. These include:

- Transforming the 24-hour production-attraction car person trips output by the VDM into average hour matrices of origin–destination personal vehicle trips for the morning, interpeak and evening peak periods represented in the HAM; and
- A ‘pivot’ process to adjust the base year assigned highway matrices based on forecast changes in personal trips from the VDM.

The pivoting process is used in any scenario test where changes from the VDM are to be applied in the HAM. At the simplest level the pivoting process uses percentage growth to adjust the base highway matrices. This is modified with adjustments and caps to ensure inappropriate extreme changes do not occur (for example where there is no activity in the base year and new development in a scenario test), and that the high level patterns of change forecast by the VDM are not lost.

Note that only the highway trips are transformed in this way; public transport and active modes are not assigned in the model so are not progressed beyond the 24-hour production/attraction stage.

3.9. Model outputs

The primary output from the VDM is the set of average weekday trip matrices by trip purpose and travel mode. These are first derived as 24hr matrices of personal production/attraction trips, but highway vehicle trips are also produced as AM, IP and PM vehicle origin-destination trips.

These can be combined with the matrices of distance, cost and time to provide a wide range of statistics such as those listed below. The matrices can also be aggregated to give information on trips starting or ending in specific locations and the zones can be aggregated to form sectors (such as Regions or local authority districts) to present summary results. Potential analyses include:

- Trips by purpose and mode for the categories of travel included in the model;
- Total and average distances, costs, times and speeds of travel by purpose and/or mode; and
- Comparisons between runs to give changes in trips and characteristics.

The HAM model determines routes through the network for the trip matrices provided, taking into account changing levels of congestion. The output is a loaded network with the flows of vehicles by type on each link, the updated time and if applicable cost (eg tolls) of travelling on each link.

This information is also used to skim matrices of distance, toll cost and time of travel between each zone pair for each category of trip assigned in each time period.

From the information stored it is possible to interrogate the model to understand:

- Routes used between specific locations;
- Journey times for travel between specified locations;

- Loads on links relative to the capacity of the link;
- Mix of vehicle types (eg % HGVs); and
- Comparisons between the base model and scenarios to look at changes in flows and speeds on links.

3.10. Wider model system and user interface

The design of the model has considered the whole user process for applying NTMv5, including a wider system which takes into account the need to prepare inputs, analyse outputs and communicate results, as well as management of the many model runs and scenarios expected to be undertaken. In effect, the core model sits within a wider system as shown in the user interface diagram in Figure 3.3. The user interface is discussed in more detail within the NTMv5 User Guide.

Wherever possible, components have been implemented directly within the PTV Visum transport modelling software. Input data and parameters to the model are prepared using spreadsheet, GIS and scripting processing tools (UI1), or for highway networks via direct editing in PTV Visum (UI2). The functionality to set up and run scenario tests using the model is via the inbuilt user interface provided by Visum (UI3 and UI4 in the diagram). To allow rapid review of results, standard Visum output diagnostics are made available in pre-prepared spreadsheets which summarise results (UI5). The raw run results themselves are stored within Visum (UI6), though care must be taken due to the very large size of files with full demand matrices and assignment results stored.

Graphical analysis of results can be carried out within Visum (UI7) based on maps of highway link (including flows, speed or capacity), or with analysis of matrices and link data. However, for non-graphical summaries of results it has been found more convenient and flexible to export summaries of results for external analysis. A suite of tools has been created allowing analysis or comparison of runs by sector, trip length, zonal totals, and further bespoke analysis is possible.

Finally, and most critically, the wider model system must be considered to include run and version logging, filing and maintenance. Logging of both the model runs, versions of input data and scenarios created is vital to achieving consistent, transparent and high quality results. Similarly, attention should be paid to the maintenance of the wider model, including the software installation, filing and requirements for adjustments/updates. An active team with working knowledge of the model is vital to ensure that this is achieved.

Further information on the use of NTMv5 and examples of scenario testing implementation are provided in the NTMv5 User Guide.

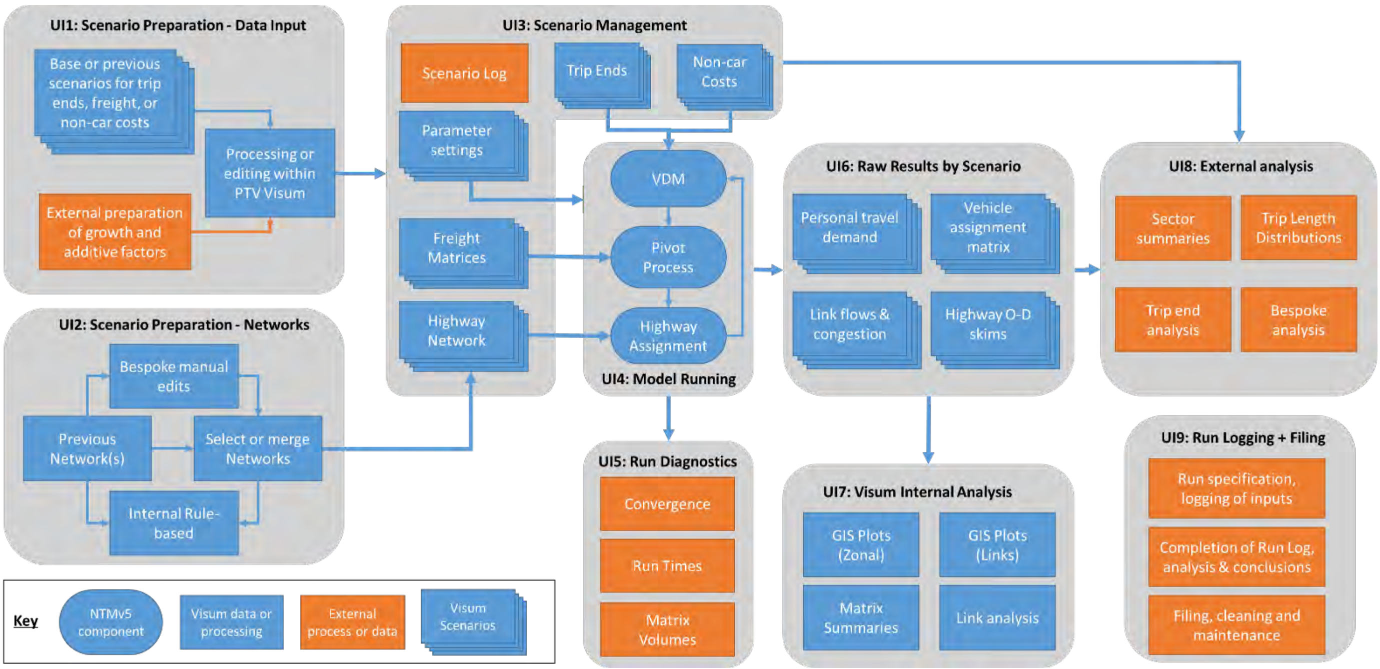


Figure 3.3 - NTMv5 User Interface showing wider model system

Part 2: Technical Specification

This part of the document provides a technical specification for the model, including detailed records of the model design and implementations. The sections cover:

- Chapter 4: the core model structure and definitions, including dimensions and scope;
- Chapter 5: details of the variable demand model (VDM) structure and segmentation;
- Chapter 6: details of the base year demand data, source data and development of base year highway matrices;
- Chapter 7: travel cost and characteristics, including specifications and formulae applied;
- Chapter 8: the highway assignment model, definitions of link types and assignment algorithm;
- Chapter 9: the linking of the VDM and HAM via the pivot process, rational and implementation;
- Chapter 10: demand model estimation, demand model design and segmentation; and
- Chapter 11: specification of the NTMv5 forecasting model, including input changes available.

4. Technical overview

4.1. Introduction

This section provides an overview of the model structure and definitions, together with further narrative on the development and rationale behind key design decisions. This is intended for the more technical reader, or anyone wishing to understand a little more about the detailed model design decisions and implementation.

Section 4.2 first provides a more detailed overview of the model itself and discussion of key components, followed by a series of sections addressing elements of the model design in more detail.

4.2. Basic structure

The core components of NTMv5 and their interaction are shown in Figure 4.1. The two main components of the model are the demand model (VDM) for personal travel and the highway assignment model (HAM). To improve the forecasting capabilities, the VDM operates with many demand segments (types of trips) and a whole day, whereas the highway assignment model is more closely linked to observed data and operates for few segments (types of traffic) and at specific times of the day.

Attributes for other modes are a user defined input, as are the travel demand: trip ends for personal trips and vehicle trip matrices for freight movements by light and heavy goods vehicles.

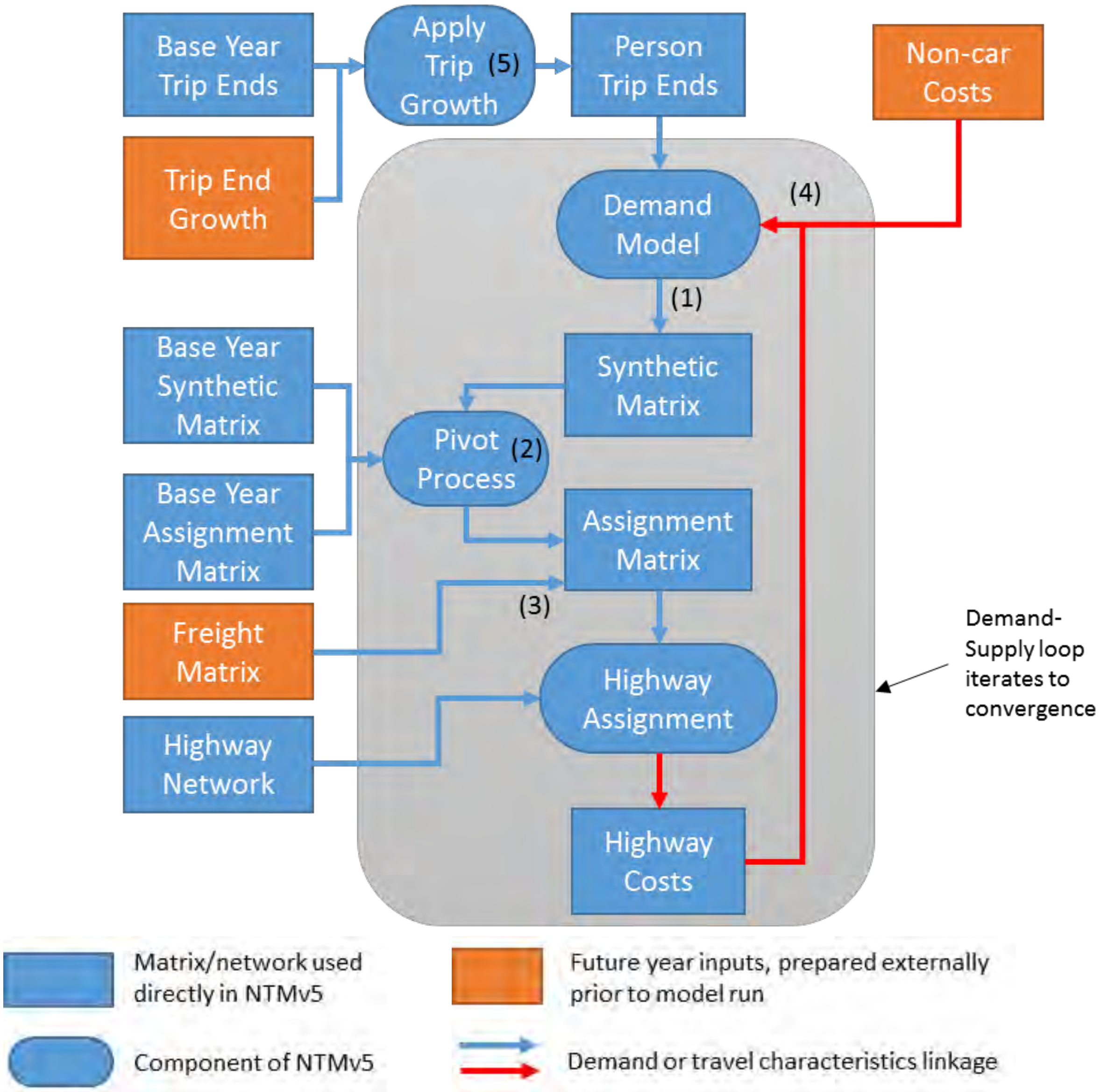


Figure 4.1 - NTMv5 model running structure

Figure 4.1 also identifies additional data transformations which will be carried out within the Visum software as part of the model run, namely:

(1) 24-hour Production/Attraction car person trips, transformed into AM, IP and PM average hour Origin-Destination personal vehicle trips;
(2) Pivot process to adjust base year assigned highway matrices based on forecast changes in personal trips from VDM;
(3) Future year assignment combined with future freight matrix, and any 'external-external' growth added;
(4) Utilities derived by Visum from component matrices; and
(5) For runs with alterations to trip ends, growth factors are imported to NTMv5 and applied to the Base trip ends within the model.

As can be seen, as per a conventional four-stage model, the HAM plays a central role in the functioning of the overall model.

4.3. Software tools

NTMv5 has been implemented using PTV's Visum software (v17), which includes the VDM and Highway Assignment tools linked in a way to provide automated running of any future year forecast (i.e, the Demand/Supply loop is implemented entirely in Visum). In addition, the highway network itself is developed and held within Visum.

PTV Visum was chosen as the software package to be used given its ability to flexibly meet the objectives required by the DfT's use cases, as set out in Section 2.

4.4. Spatial detail

Spatial detail is determined in the model through division of the country into model zones each of which generate and attract trips, and the representation of connectivity between those zones in the form of networks. The model zoning is based on the Middle Super Output Areas (MSOAs) developed by the Office for National Statistics as a standard spatial unit and used for the 2011 Census of Population. The definition of the MSOAs is based on the population within an area; hence the zone definitions were refined to better represent major attraction locations which are more focused on employment and leisure facilities, and special attractors such as ports and airports. The resulting zone shapes were hence a mix of, in the majority of cases, MSOA polygons, and some point zones representing ports, seaports and freight hubs.

A zone type classification system is used to denote the different types of zone within NTMv5. In most cases, port, airport and freight hub zones are represented by point zones which exist to provide a network connection to an external area, or for freight interchange between road and rail. Figure 4.2 shows the zoning system and Table 4.1 summarises the zones by type and Region identifying both polygon and point zones.

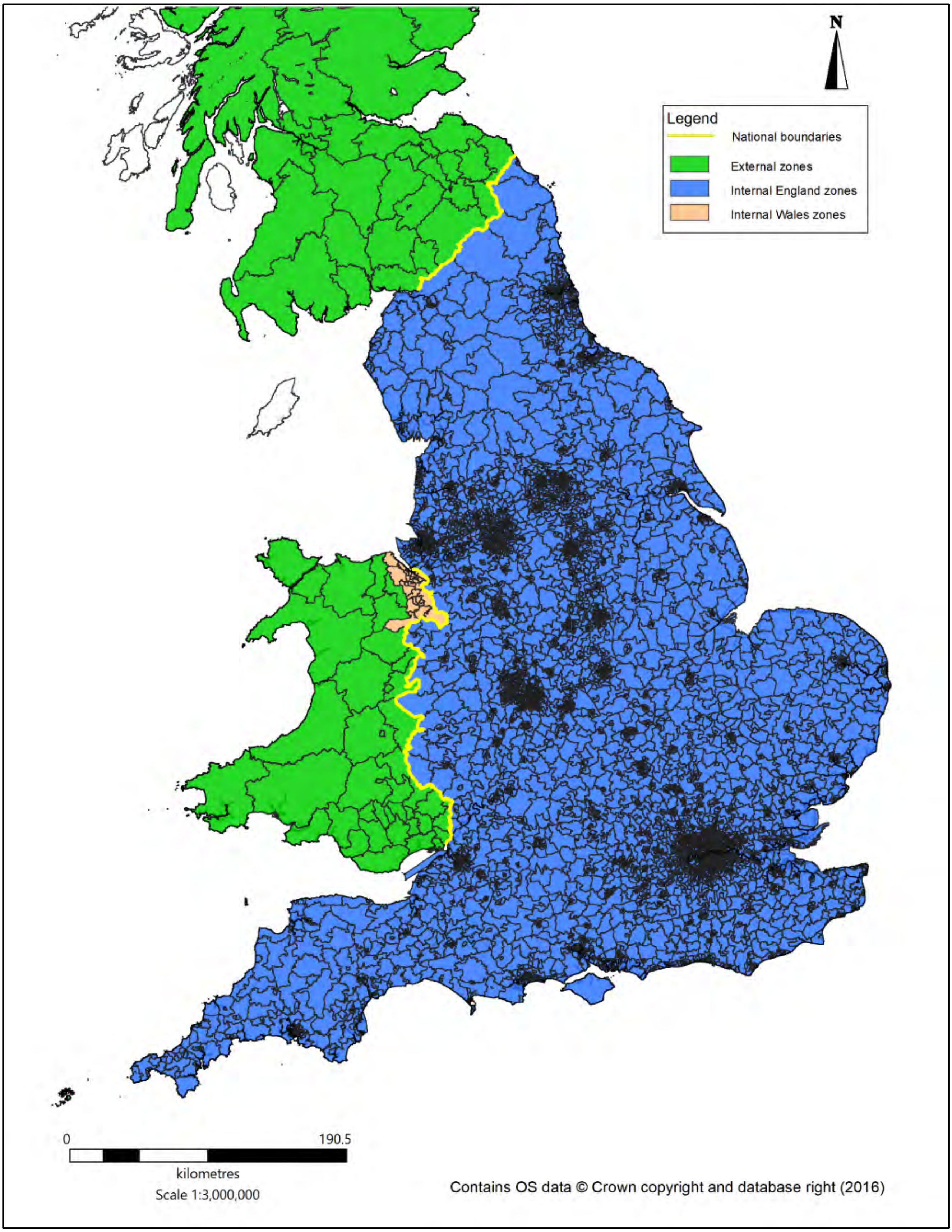


Figure 4.2 - NTMv5 zoning system

Table 4.1 - Summary of NTMv5 zones (v6.5) by type and region

Region	1 Standard	2 Enterprise Zone	3 / 4 Airport/Seaport		5-8 Major Attractors	9 Freight hub		All
	polygon	polygon	polygon	point	polygon	polygon	point	
NE	339	3	7	3	5	-	3	360
NW	924	8	6	10	4	-	2	954
Y&H	691	6	7	2	5	-	4	715
EM	573	3	2	2	5	-	1	586
WM	735	4	1	-	1	-	4	745
EoE	736	9	11	9	4	-	1	770
Lon	983	1	4	3	5	-	1	997
SE	1,091	9	10	13	12	1	-	1,136
SW	700	6	11	13	12	-	1	743
Wa	68	-	-	7	-	-	-	75
Sc	27	-	-	23	-	-	-	50
Total polygons	6,867	49	59	-	53	1	-	7,029
Total points	-	-	-	85	-	-	17	102
Overall total	6,867	49		144	53		18	7,131

4.5. Base and forecast years

The model base year was agreed as being mid-year 2015, though it is worth noting that based on agreement with the DfT there are slightly different interpretations of this in the VDM and HAM. The base year demand development has used a variety of data (population, employment and other attractors) representing June and July 2015. For the HAM, the existing count database from the Regional Traffic Models (RTMs), which was used for model calibration and validation, corresponded to an average weekday in March 2015, was to be used for model calibration and validation.

It was agreed that it is acceptable to have slightly incompatible months for the demand and supply data. For demand, June seems more appropriate, but for the supply (counts and journey time), March was deemed more suitable.

For forecasting purposes, the model design is flexible, allowing the potential to run the model independently for any year in which input data (trip ends, network supply etc.) can be ascertained. It is worth noting that the DfT may wish to run model scenarios within the base year, and that scenario test can therefore be conducted for 2015.

4.6. Time periods

The time periods represented in NTMv5 are shown in Table 4.2. The VDM models 24-hour weekday trips which are then split into morning (AM), interpeak (IP), evening (PM) and off-peak (OP) periods. The HAM covers representative periods in the AM, IP and PM. There is no assignment of trips in the off-peak period.

Table 4.2 - Model time periods by component

Description	Variable demand model (VDM)	Highway assignment (HAM)
Weekday (Monday – Friday) 24-hour	Used for trip generation	N/A
Split from 24 hour in VDM		
Weekday AM	7am – 10am	Average hour of 7am-10am
Weekday IP	10am – 4pm	Average hour of 10am-4pm
Weekday PM	4pm – 7pm	Average hour of 4pm-7pm
Weekday OP	7pm – 7am	No assignment

4.7. Treatment of urban areas

4.7.1. Approach and rationale

In terms of assignment, urban road capacity, road speeds and congestion are undoubtedly important to some use cases to represent overall road traffic forecasting, both in terms of the intra-urban trips themselves, and the impact of the 'last mile' costs on mode and distribution choice for inter-urban trips. However, it was agreed with the DfT during model development that full link-based modelling of road capacity and related journey time responses could not be achieved at present, and therefore a simplified approach has been applied.

This decision was taken for a number of reasons, including the fact that a national model which excludes a large proportion of urban roads would not be able to represent the capacity and routing to a sufficient extent. Moreover, it is now widely appreciated that urban road speeds and congestion are impacted by a complex set of interrelated factors such as junction control, parking, pedestrian movements and other on-street activities. To use standard speed/flow curves or additional link detail to attempt to represent urban congestion and capacity is unrealistic in a national context. An individual is likely to consider urban congestion, parking constraints and charges, options for park and ride etc. together, all of which are factors which cannot be unpicked in the current national model.

For similar reasons, the Regional Traffic Models at the time of NTMv5 development were embarking on a process of using fixed speed networks (based on TrafficMaster observations) in urban areas, with forecasting functionality to adapt the speeds in scenario tests based on area wide formulae. It was therefore agreed with DfT that a similar approach should be adopted within NTMv5.

4.7.2. Base year urban area speeds

As discussed above, in urban areas fixed link speeds are applied to the NTMv5 highway network. The derivation of the speeds and links included were taken from the source Highways England Regional Traffic Models (RTMs).

During the development of the NTMv5 networks it became clear there were inconsistencies between the approaches taken in each RTM for urban areas and fixed speed links, which means there is some variation across the base NTM network. Moreover, it was understood that at the time there was no firm consensus on the 'right' approach to be taken and with a new technique naturally there has been much to learn about the best approach.

More information on the coding of the urban area speeds in the highway network is provided in Section 8.4.

4.7.3. Forecasting urban area traffic speeds

The model design allows for variation of the speeds on links in urban areas which have fixed speeds in the Base Year. While changes could potentially be at a link level, it is more practical that adjustments be made to groups of links, for example by road and / or area type. The challenge was to develop a method that could be implemented in the NTMv5 project based on information available.

The RTMs had faced the same challenge and tested two alternative methods for updating urban area speeds:

- Use change in speed by region and link type according to the existing National Transport Model (NTMv2R) forecasts as given by road traffic forecast (RTF) statistics; and

- Start with the speed flow curves for urban roads, and infer the flow indicated by the base year speed. Apply the localised matrix percentage growth to the extracted flow, and calculate a new speed given the SFC, and use that speed for the forecast speed.

The RTM results showed that both methods gave similar results and adopted the first method as it is simpler to apply. For NTMv5, we clearly could not use the first method as it would involve circular calculations requiring results from the NTM itself. The second method was therefore adopted as set out in Section 11.4.

4.8. Role of freight and goods in NTMv5

Freight and goods traffic are included within the Highway Assignment Model of NTMv5 only, and are not considered by the VDM, though their impact on journey times (via the congested highway costs fed from the HAM to the VDM) is considered.

Therefore, the routing of freight and goods is included (as part of the HAM assignment), based on fixed Origin-Destination matrices by time period imported to NTMv5. Those input matrices can be updated wholesale through import of new values, or scaled using a mixture of global factors, zonal and zone-pair scalings as desired.

The only segmentation of freight and goods traffic within the model is that used in the HAM for assignment, separating light and heavy goods vehicles (LGV and HGVs) into different assignment user classes (AUCs). The treatment of LGVs however considers both personal and goods trips, which are discussed further in the next section.

4.9. Treatment of LGVs

Light goods vehicles (LGVs) are modelled as a single assignment user class (AUC) which includes all vans, ie vehicles that are not cars or heavy goods vehicles. This is consistent with the terminology used in the DfT’s traffic count data, even though LGVs are often not used for carrying goods.

LGVs are a very important segment of the traffic, not least because they have for several years been the fastest growing class of traffic by a large margin. However, data describing LGV movements is less readily available than for car and HGV trips, partly because they represent a mixture of very different purposes:

- Freight (movement of goods / commodities);
- Travelling between jobs, e.g. servicing and repair trips; and
- Personal – e.g. commuting, shopping and carrying passengers.

A non-trivial proportion of the LGV trips are personal travel, however their treatment in the demand model is challenging because car and LGV as modes are difficult to separate. In principle to do so, one would need to distinguish the availability of LGVs relative to cars for each person segment and trip purpose, as well as the differences in cost at a person level.

Because of the limited data and evidence available, it is very difficult for separate modelling of LGV trips to be achieved. The following approach was therefore adopted for the inclusion of this important category of trips in the NTMv5 model:

a. The personal LGV trips are modelled alongside car trips in the VDM for all trip purposes and demand segments. Outputs from the VDM are split into those trips by car and those by LGV.
b. For assignment purposes, a single LGV user class is adopted, combining the mixture of freight, personal, and service trips, as advised by current appraisal guidance.

To facilitate this approach, Base Year LGV trip matrices were developed for each trip purpose, then scaled and combined to reflect data available on LGV kilometres travelled and the mix of purposes occurring. Chapter 6 provides information on the derivation of the Base Year demand.

For forecasting purposes, the growth in LGV freight trips must be derived externally to the model, and provided as an input (as with HGVs). The growth in personal (non-freight) LGV trips will be derived from the VDM. The two forecasts are combined to create a forecast LGV user class matrix for the HAM.

5. Variable demand model structure

5.1. Introduction

This section provides more detail on the structure and segmentation of the variable demand model (VDM), which is a key component of NTMv5 used to determine personal travel demand choices, based on the input trip ends and travel costs.

5.2. Choice model structure

The VDM covers a whole day (average weekday) and considers the choice of mode and destination given the input trip ends and travel characteristics (level of service / accessibility) between zone pairs.

The model works on a Production-Attraction (P/A) basis so all trips with a home-end will be treated as home-based linked to the P and A zones and all other trips will be treated as non-home-based where the P/A is the same as the O-D. The NTMv5 VDM operates as an absolute model applied incrementally (AMAI), which means that full matrices of travel demand on a zonal P/A basis are developed, in contrast to a purely incremental cost-pivot model which would focus only on how changes in disutilities impact on travel choices.

The model structures for each trip purpose were determined by model estimation rather than defined at the outset. The estimation investigated the relative sensitivity of mode and destination choice, and the possibility of mode nests (e.g. for public transport modes). Information on the demand model estimation process is summarised in Chapter 10 and the performance of the resulting models recorded in Chapter 13.

5.3. Demand segmentation

5.3.1. Criteria for determining VDM segmentation

Demand segmentation covers the following aspects of the model:

- Segmentation of journey purpose (e.g. commuting, shopping);
- Segmentation of person types used to consider changes in trip generation and traveller characteristics (e.g. values of time, income, household car availability, ticket types for PT usage);
- Whether the segmentations used vary at different components of the demand model (i.e. trip generation, mode choice, and distribution); and
- Whether any non-standard segmentations are introduced, such as the distance band approach used in NTMv2R.

The segmentations for NTMv5 were not prescribed. The following factors were considered to define appropriate model segmentation:

- Segmentations needed at each level of the VDM to meaningfully represent variations in travel behaviour which is relevant to the model use cases;
- Availability of robust evidence available to estimate the model parameters from the National Travel Survey data, and other national datasets where appropriate;
- Availability of robust data to allow the construction of the Base Year model, including population and employment segmentation, locations of attractions, and evidence of variations in mode choice, time of day and trip distribution or trip lengths;
- Availability or ease of collating data for forecasting using the model; and
- The practicalities of model size for a specific degree of segmentation: time required and computing requirements in terms of memory limitations and space limitations from the computing equipment and software available.

Consistent with previous versions of NTM, trip end growth (both productions and attractions) for the demand models within NTMv5 will be fed in from NTEM. NTEM is the DfT's forecasting dataset and provides an established approach to trip end growth across the whole of Great Britain. Though the Base Year trip end values themselves were derived for NTMv5 (and not taken directly from NTEM for 2015) it was helpful to consider the NTEMv7 segmentation as a starting point, as:

1. They represent a known and well understood segmentation which can be considered and modified if necessary; and

2. The forecasting process proposed using NTEM all mode trip ends by default for growth, and hence the VDM segmentations should be reasonably compatible with this (though they could be more detailed if considered appropriate).

DfT research has shown that it is becoming more important to represent behaviours by age and hence this was ranked highly on the list to test. Some division based on car availability and / or licence-holding is important for the mode choice stage of the demand model. Following detailed discussions with the DfT, the peer reviewers for the project and the NTMv5 development team, it was agreed that car availability would be defined by number of adults and number of cars in the household, rather than driving licence holding.

A wider list of variables was identified relating to the economic or working status of the individuals, income levels and location, though it was known that the scale of the model meant it was unlikely all the variables identified as statistically significant could be included in a practical model implementation.

Following testing on the feasible scale of model and discussion with the DfT, the focus for the variables considered during the VDM estimation was on the subset shown in Table 5.1.

Table 5.1 – Potential segmentation variables

Variable type	Potential variables for segmentation (not all implemented)
Demographic	Individual: Age, Gender Household: Size, Number of adults, Number of children
Socio-economic	Individual: Working status, Occupation Household: Car availability, Income
Other (location)	Residential location, Population density

The VDM segmentation implemented for NTMv5 is summarised in Section 10.3 and based on:

- the findings from the demand model estimation process set out in Chapter 10 to identify which segmentation variables showed statistically significant improvements in fit to the mode-destination choices observed in the National Travel Survey (NTS) data – this was the main factor determining the age segmentation adopted in NTMv5 which in some cases is more detailed than NTEM, and has a different lower bound to the eldest age group;
- segmentations important for improved representation of the identified use cases, and materiality of the segment;
- constraints on the quantity of segments that could be handled by the software at certain stages of the model (doubly constrained trip distribution being the most memory intensive); and
- balancing levels of detail in segmentation with target model run times to provide a useable modelling tool.

5.3.2. Trip purposes

The starting point for the definition of the trip purposes was to retain the six home-based (Hb) and two non-home-based (NHb) travel purposes used in the more spatially aggregate NTMv2R currently in use by DfT. These purpose definitions can be defined by the NTS data and also map readily to the more detailed trip purposes that are represented in NTEM, as shown in Table 5.2.

Table 5.2 - Trip purposes in NTEMv7 and NTMv5

NTEMv7 trip purpose	NTMv5 trip purpose
Hb work	Hb work
Hb employer's business	Hb employer's business
Hb education	Hb education
Hb shopping	Hb shopping and personal business
Hb personal business	
Hb recreation / social	Hb recreation / social and visiting friends and relatives
Hb visiting friends and relatives	
Hb holiday / day trip	Hb holidays and day trips

NTEMv7 trip purpose	NTMv5 trip purpose
NHb employer's business	NHb employer's business
NHb work	NHb other
NHb education	
NHb shopping	
NHb personal business	
NHb recreation / social	
NHb holiday / day trip	

This level of segmentation was made on the basis that the existing purposes have been judged appropriate to assess policy at a national level in NTMv2R, and further that it ensures consistency with the purpose definitions used in NTEM 7.2 which will be used to forecast trip-end growth.

Analysis of the NTS data on the variation in observed mode and destination behaviour across purposes as recorded in NTS data was carried out. This used the purposes set out above differentiating those trips escorting others (eg to school) from the main trip purposes. It showed some variations in mode usage for escort trips but similar trip length profiles to the main purpose. As the NTS sample sizes for escort trips are relatively small and NTEM does not differentiate them, it was decided to keep these trips with the associated main trip purpose of the person being escorted.

5.4. Travel modes in the VDM

Six personal travel modes were considered for representation in the VDM:

- car/LGV driver (non-freight LGV trips only);
- car/LGV passenger (non-freight LGV trips only)
- rail (including London Underground, light rail and trams in metropolitan areas);
- bus / coach;
- cycle; and
- walk.

It was agreed during the inception stage that domestic air travel is outside the scope of the VDM. However, the surface access leg to / from airports for domestic / international travel should be included in the highway assignment model. It was also agreed that no explicit representation of bus Park & Ride sites was within the scope of the model.

The car mode includes travel by taxi and motorcycles which will have limited relevance and market share for longer inter-urban travel at the national level, accounting for approximately 2% of "car" type trips and less than 1.5% of kilometres travelled in the NTS. Such modes might have some impact in urban areas, where a specific modelling approach is being applied as explained in Section 4.7.

Because there are benefits of maintaining this level of modal distinction for the use cases, particularly those relating to public transport (bus or rail), the working assumption was that the six modes identified would be used throughout the VDM. The possibility of reducing the number of modes during the model development programme was identified as a means of reducing the scale of the model, should:

- Emerging evidence from demand model estimation indicate differentiation was less critical;
- Testing of the model implementation suggest that the model size is problematic.

The benefits of retaining the differentiation between bus and rail in particular are considerable so aggregation was not desirable unless there were severe restrictions on the model size. Initial testing did not suggest the scale issues would be best addressed through a reduction in the number of modes, and the estimation process provided the basis for retaining the differentiation. No changes to the modes were therefore made and the six modes listed above were implemented in the NTMv5 VDM.

5.5. Demand inputs to the VDM

5.5.1. Trip productions

Total trip productions are input to the VDM for each model zone for each demand segment (purpose and traveller type combination) defined in the model. Values are required for a 24-hour average weekday.

For the Base Year, the zonal trip productions were derived as part of a unified approach which also defined the prior Base Year trip matrices for the HAM. Further information on this process can be found in Chapter 6.

5.5.2. Trip attractions

The trip distribution function uses trip attraction weights to denote, all other things being equal, the relative attractiveness of a location as a destination. So, for example, zones with high levels of retail activity will attract more shopping trips than other locations with similar levels of accessibility.

The selection of these attractor weights for NTMv5 was based on:

- Data available in the Base Year and for forecasting to determine the most appropriate attractors;
- Evidence from the demand model estimation of the most relevant attractors, including segmentations needed; and
- Any emerging evidence from the development of the Base Year trip matrix on the most appropriate use of attractor data by purpose and segment to produce reliable results.

As noted in TAG unit M2 on variable demand modelling: "it is common to use doubly-constrained models for forecasting commuting and education trips, so that each zone attracts and generates a fixed total of work trip ends". In these cases, trip attraction inputs to the VDM are the required (target) number of trips to be attracted to the zone.

For NTMv5, commuting and education trip purposes have been implemented as doubly constrained models in line with best practice.

The trip attraction inputs to the VDM are the identified set of attraction weights for each trip purpose and trip attraction constraints for commuting and education (for the trip purpose without segmentation).

Further information on the definition and creation of the Base Year trip attraction constraints and weights can be found in Chapter 6.

5.6. Utility functions

The VDM choice models for mode and destination use utilities to reflect the attractiveness (accessibility) of the alternatives available. These utilities combine travel time, cost and, where appropriate, distance into a single measure of utility along with segmentation specific utility terms (eg adjustments for a specific age group).

Experience suggests that a non-linear formulation for the (monetary) cost contribution to the utility typically gives both a better fit to the observed choice data and improved realism test results, in particular for the fuel cost elasticity test. This can be achieved in a variety of ways, often using a "cost damping" term. For NTMv5 a mix of linear and logarithmic cost terms are used in the VDM utility definition which introduces a form of cost damping.

The perceived money costs of car travel are assumed to be shared between drivers and passengers with the proportions paid by the drivers and passengers determined as part of the demand model estimation. The rationale for the approach is that rather than assuming drivers perceive all of the car costs, passengers may also perceive some of the car costs and if this is the case the amount of car cost perceived by the driver should be reduced accordingly.

Following best practice, the different time components relating to staged journey by public transport, such as waiting and interchanges, are weighted to reflect their inconvenience. The weights applied were taken from the TAG unit M3.2 on public transport modelling.

6. Base Year demand

6.1. Introduction

Forecasting of travel demand is best achieved through synthetic estimates of demand derived from trip ends which are in turn related to land use and demographic information. This allows for future year travel demand to be directly determined from land use change and growth in trip ends.

Base year highway movements, traffic levels and congestion are normally determined from data observed on roads which cannot be readily linked back to the land use and demographic information.

However, it is advantageous for both the personal travel demand in the VDM and the base year vehicle matrices to be established using a single set of input assumptions and processes. To facilitate this, a common set of data sources and processes has been used to determine the follow sets of demand data for the NTMv5 Base Year model:

1. Trip ends for input to the VDM;
2. Vehicle trip matrices for input the HAM.

This means that the final highway matrices are developed in two stages:

- first as a set of matrices linked to land use and activity data (known as “prior” matrices);
- then adjusted to better reflect the observations on the highway network (known as “post” matrices).

This chapter describes the development of the prior trip matrices in daily Production/Attraction (P/A) format, including the data used, the development of base year trip ends, and of the matrices themselves.

These matrices are then converted to O-D trip matrices by time period using the same approach and parameters as embedded within the full model and set out in Section 9.3. The adjustments made to better reflect traffic conditions are part of the model calibration process and covered in Chapter 14.

6.2. Output requirements

6.2.1. Trip ends

As noted in Section 5.5 the zonal trip ends required are trip productions and trip attraction weights and constraints, for the average weekday 24-hour period represented in the VDM for each trip purpose defined (Section 5.3.2) and at the level of demand segmentation used (Section 10.3).

The Base Year trip ends have been developed for NTMv5 as set out in section 6.4, using the data sources collated for NTMv5 described in section 6.3 and are hence not the same as the NTEM v7.2 trip ends. The NTEM dataset is used to provide travel growth for input to NTMv5 when developing forecast scenarios.

6.2.2. Trip matrices

Trip matrices are required for vehicles using the highway network in the model base year. These trip matrices are assigned to the networks developed for each time period modelled and calibrated to provide an adequate match to observed data for the proposed applications of the model which is demonstrated through highway model validation.

Two sets of trip matrices are developed for NTMv5:

- Personal trip matrices are those vehicles (cars and LGVs) used for making personal trips which include people travelling on business to meetings but exclude commercial movements such as deliveries and series of calls by professionals whose work involves travelling.
- Freight (goods) trip matrices are those vehicles (LGVs and HGVs) travelling for the purposes of moving materials and commercial movements (servicing) in LGVs.

These two sets of matrices have been developed separately but using some common datasets (such as employment). The development of the personal trip matrices follows on directly from the creation of the personal trip end inputs to the VDM. This approach of common datasets and integrated approach maximises the consistency of the different components of the model at the outset, though it should be noted that this linkage is diluted by, and hence monitored during the model calibration process.

The base year matrices are updated during scenario runs of NTMv5 with changes in personal trips being estimated by the demand model and changes in freight matrices being provided by the user as outlined in Chapter 11.

6.3. Data sources

One of the key aspects of the approach used to develop the base year trip matrices for NTMv5 is the use of spatially detailed, highly segmented data from maintained national datasets.

The Health and Safety Laboratory (HSL) maintain the National Population Database (NPD), which consists of several population-related datasets, summarised in seven categories:

- Residential;
- Education;
- Health and care;
- Transport;
- Tourism;
- Retail; and
- Employment.

These provide the basis for most of the indicators used to determine the overall attraction weightings for each trip purpose and have been supplemented by bespoke datasets to fulfil additional requirements specific to the development of NTMv5.

The data sources used in the base year demand development process were:

- HSL National Population Database (as set out above);
- UK Census of Population 2011;
- Mid Year Population estimates for 2015;
- National Travel Survey (NTS), 2010-2015;
- Schools Census (formerly PLASC);
- Addressbase Premium;
- Mastermap – building polygons;
- TrafficMaster OD data;
- DfT's trip rate forecasting tool (underpinning NTEMv7.2) for trip rates;
- CAA Surveys;
- Continuing Survey of Road Goods Traffic (CSRGT);
- DfT van surveys (2002-2005);
- Valuation Office Agency data on non-domestic property ratings (England and Wales);
- Scottish Assessors Association rateable values;
- Eurostat agriculture data; and
- DfT published traffic statistics 2015 / 2016.

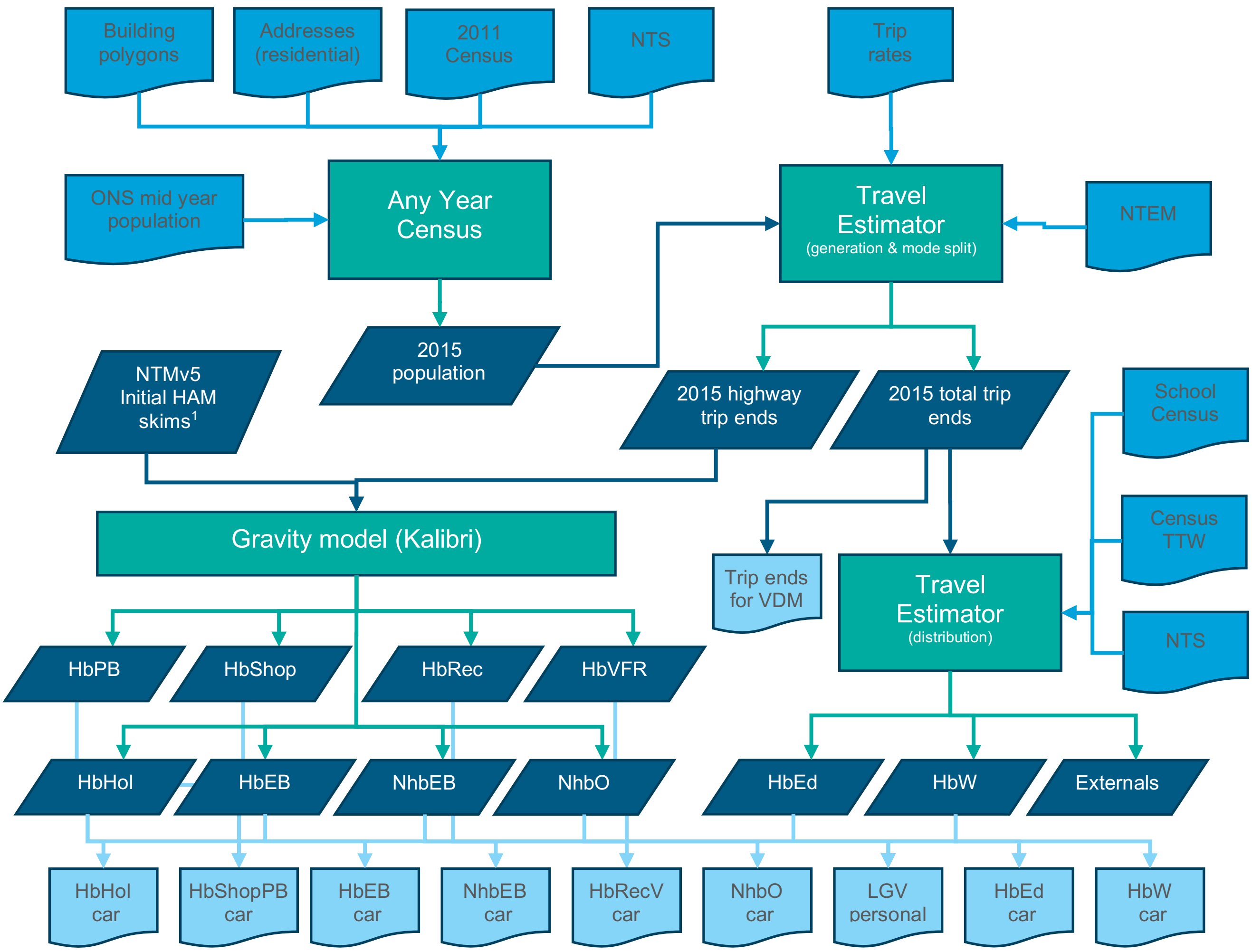
6.4. Personal trips

For personal travel the process starts with the creation of trip ends for use in the VDM, from which the prior highway personal trip matrices were estimated. The final stages of the matrix building process were matrix shaping followed by matrix estimation to calibrate the matrices as set out in Section 14.5.

The build process for personal highway trips maintains the link between land use and demographic data to maximise consistency with the inputs to the demand model and important for forecasting and hence is carried out on a production-attraction (P/A) basis. The main steps were as follows and shown in Figure 6.1.

- Population estimates derived for each model zone by combining detailed property and address data with 2011 Census and 2015 mid year population data in the Any Year Census process.
- Total trip productions generated (comparable with the NTEM dataset) from population and trip rates for all home-based trip purposes for travel using all modes for an average weekday.
- Trip attractions derived from land use data as shown in Table 6.1 below.
- HbW and HbEd (school) mode splits and distribution patterns (car) were applied from Census journey to work and Schools Census data to utilise information on observed travel patterns available.
- Synthetic matrices created for the remaining trip purposes using gravity models.

- LGV proportions derived from NTS data for each trip purpose applied to the highway matrices to give average weekday car and LGV personal trips.



[1] Iterative process - Matrix building updated and refined once HAM skims were available and improved.

Figure 6.1 - Base year personal prior trip matrix building process

The trip attraction weights were derived by combining fields from the range of population, employment and other land use activity data provided as set out in Section 6.3. The variables used for each trip purpose in the matrix building stage and in the final model implementation are shown in Table 6.1. The two stages differed initially, but once the VDM estimation was complete the attraction weights used in the Base Year matrix building were updated to be consistent.

Table 6.1 - Land use indicators for trip attractions in matrix building and VDM

Trip purpose	Indicators used for final matrix build and VDM (from estimation)
HbW	Total employment
HbEd	Number of primary age students Number of secondary age students Number of university students
HbShop HbPB	Employees in food retail Employees in non-food retail Population Employees in human health and residential care
HbRec HbVFR	Population Employees in restaurants and bars Employees in recreation and sport
HbHol	Population Estimated annual visitors (tourists) Campsite population and hotel bed spaces
HbEB	Total employment
NHbEB	Total employment
NHbO	Population Employees in convenience and leisure, food and non-food retail Employees in restaurants and bars Employees in recreation and sport

The daily P/A trip matrices were then converted to origin-destination matrices by time period using the same method as implemented within the VDM and factors derived from NTS data, and small numbers of external trips were added to the matrices.

This process was repeated iteratively to improve the gravity models with updated model generalised time skims from the improved HAM; and to develop the non-home-based trip matrices consistently with the home-based ones.

Personal port and airport trips

Estimates of surface access car trips to ports and airports were added separately for passengers / visitors intending to fly; those not travelling onwards from the (air)port (e.g. working on site) are included already in the personal demand process above. Most travellers to these sites are leaving the country and hence their trips are not covered by the NTS travel diaries. For trips to airports, CAA data was provided by the DfT for use in the development of the matrices, drawing on data the DfT use for their surface access modelling.

The data available on car passengers travelling to / from ferry ports was discussed with the DfT's maritime statistics team. Unlike air travel and surface access to airports, the DfT do not carry out detailed modelling of the access arrangements to ports for passenger movements. Hence detailed information and surveys of sea passengers is not available, and the published annual statistics by port were recommended as the most appropriate data source available (Table PORT0499)[4].

The UK major port traffic statistics do not include any information for Eurotunnel usage. The number of vehicles (for passenger movements not freight) were taken from the Eurotunnel website for 2015 (https://www.getlinkgroup.com/uk/group/operations/traffic-figures/).

A synthetic trip distribution was then set up using population as a weighting variable and generalised costs from the HAM for these port and airport trips. The resulting supplementary matrices were added to the results from the previous matrix build steps to create the prior trip matrices for each HAM time period.

[4] https://www.gov.uk/government/statistical-data-sets/port04-individual-port-traffic#table-port0499

6.5. Freight trips

For freight the requirement is for a base year (2015) origin-destination (O-D) matrix for heavy goods vehicles (HGVs) and an equivalent matrix for light goods vehicles engaged in freight activities (including travelling between servicing jobs). LGV journeys associated with other journey purposes (such as carrying passengers) are estimated from the personal trip matrices by purpose and combined with the freight data to provide a base year matrix of LGV trips. As for personal travel the freight matrices are built from a series of steps estimating trip ends, patterns of travel and time period of travel.

6.5.1. HGV matrices

Matrices of HGV vehicle trips have been estimated from first principles by MDST using an approach which draws on their experience developing and updating the GB freight model (GBFM). The full process is described in detail MDST's report "HGV & Van Origin-Destination Matrix Documentation for the National Transport Model".

Matrices of tonnes moved are initially developed from "Supply" and "Use" data for goods produced and consumed in Great Britain. This information is supplemented with data on goods traded with Europe and outside Europe using ferries and bulk cargo data.

As such the matrix building comprised a number of stages relating to:

- Domestic cargo;
- Unitised port traffic;
- Non unitised (bulk) port traffic; and
- Rail freight related trips.

Volumes of freight were determined from the data sources then gravity models were used to determine travel patterns between defined activities. The annual matrices generated were converted from tonnes of goods into vehicles and then PCU movements. A further step was included to account for the movement of empty goods vehicles. These annual matrices were then allocated to the HAM model time periods.

6.5.2. LGVs

MDST was responsible for producing the initial (prior) origin-destination matrices associated with LGVs carrying freight and travelling-between-jobs.

Gravity models were developed for non-stop freight and between jobs trips from the land use activity data and highway skims. The resulting matrices were then scaled to control totals derived at a sector pair level from the DfT's 2002 to 2005 van surveys.

A further set of models were developed for multi-stop trips as although the multi stop nature of the trips is defined in the DfT van surveys, the locations of the en-route stops are not. TrafficMaster data was used to identify the stopping trip patterns and an estimate of the multi-stop trips developed. The estimated multi-stop journeys were then matched, by origin and destination zone, to the multi-stop journeys from the DfT survey data. The results were further scaled to match the vehicle kilometres from that survey data and added in to the one-stop journey data.

The final step was converting the annual matrices of LGV trips for freight and "between jobs" purposes to the average weekday AM peak, interpeak and PM peak flows required for the HAM. This was achieved using data in the DfT's published traffic statistics (Table TRA0308). Data for 2016 was used because this provided a breakdown of vehicle type which was not available in the 2015 dataset.

7. Travel costs and characteristics

7.1. Introduction

This chapter describes the formulation and sources for travel costs and other trip characteristics used in the model. This includes the form of both the HAM generalised costs and the VDM utility function, and the derivation of vehicle costs, parking fees, tolls, PT fares, PT travel characteristics and active mode time and distances.

7.2. Generalised cost and utility formulation

7.2.1. Definitions

Generalised cost and utility are two alternative forms of a combined measure of time and money cost, and potentially distance, on which travellers make choices. The generic term in Visum is the impedance value.

The VDM combines the distance, cost and time attributes into a utility measure which varies by mode and for the different trip purposes and traveller types represented. The utility is used in the logit choice models of mode and destination choice.

The HAM uses distance, time and toll information to provide the generalised cost of travel along different routes in the highway network and for each user class makes route choice on this basis.

7.2.2. HAM generalised cost

The impedance function for the HAM is presented as generalised cost in minutes, to be consistent with standard practice for most strategic highway models in the UK. In line with TAG, the generalised cost for route choice by each user class in the HAM can be assumed as a function as:

$$GenCost_{o,d,auc} = \left(\frac{PPK_{auc} d_{o,d,auc} + toll_{o,d,auc}}{VOT_{auc}} + t_{o,d,auc}\right) \qquad (7.1)$$

Where:

PPK_{auc} denotes the vehicle operating cost per unit distance travelled for the assignment user class auc

VOT_{auc} is the value of time for the assignment user class auc

$d_{o,d,auc}$ is the distance travelled from origin o to destination d by the auc in the HAM

$t_{o,d,auc}$ is the time taken to travel from origin o to destination d by the auc in the HAM

$toll_{o,d,auc}$ is the toll incurred by the auc travelling from origin o to destination d in the HAM

Both parameters are derived from the TAG databook with assumptions on average speeds of travel and vary by user class as set out in Sections 7.3 and 7.4.

7.2.3. VDM utility

The general form of the utility function is shown in equation (7.2). It should be noted that not all terms are relevant to all modes and demand segments. For example, walking trips have no monetary cost and for modes with money cost, distance is only included for specific segments where this was found to be beneficial during the demand model estimation process (in most cases on the car passenger mode to reflect shorter trip distances).

$$Utility = \sum k + f(cost) + f(time) + f(distance) \qquad (7.2)$$

Where:

k are constants specific to the mode, trip purpose, demand segment or zone

$f(cost)$ is a function of the money cost of travel (see Section 5.6)

$f(time)$ is a function of the travel time

$f(distance)$ is a function of the travel distance

Defining the utility function in this way and estimating separate parameters to the time and cost terms, as set out in Chapter 10, means that the values of time are an output from the model estimation, rather than a fixed input. Checks on the implied values of time obtained were part of the process to measure the quality and acceptance of the estimated models. The values obtained are reported in Section 13.3.

7.3. Vehicle operating costs and occupancies

The base year vehicle operating costs (VOCs) for NTMv5 were derived from the functions and parameters in the TAG databook (v1.9.1 December 2017). In line with guidance, fuel costs were included for all trip purposes, whilst non-fuel costs were only perceived by the employer's business trips in the modelling.

The VDM includes the VOCs for cars as part of the utility calculations and uses speed (distance / time) for each zone pair to determine the VOCs by segment using the TAG databook formula shown in equation (7.3) and parameters shown in Table 7.1.

$$VOC_{,o,d,auc} = \left(\frac{a_{auc}}{v_{o,d,auc}} + b_{auc} + c_{auc}v_{o,d,auc} + d_{auc}v^2_{o,d,auc} + a1_{auc} + \frac{b1_{auc}}{v_{o,d,auc}}\right) \quad (7.3)$$

Where:

$v_{o,d,auc}$ is the average speed of travel for from origin o to destination d for the assignment user class auc

a, b, c, d are parameters determining the fuel cost

$a1, b1$ are parameters determining the non-fuel costs

The VOC parameters used for car in the base year VDM are shown in Table 7.1. The equivalent information for LGVs and HGVs is not shown as they are not included in the VDM.

Table 7.1 – VDM vehicle operating cost parameters (pence per kilometre, 2015 prices and values)

Parameter to VOC	Non work TAG databook A1.3.13	Work TAG databook A1.3.12 and A1.3.15
a	88.7029	73.9191
b	5.8951	4.9129
c	-0.0376	-0.0313
d	0.0004	0.0003
$a1$	0.0000	5.3514
$b1$	0.0000	146.6594

Source: TAG databook (version 1.9.1 December 2017)

The choices of mode and destination made in the VDM thus take into account differences in speed of travel between the alternatives available. In the VDM the vehicle operating costs (per vehicle) will be explicitly shared between the car drivers and passengers as set out in Section 5.6 and hence the full cost per vehicle will be taken into account without making any input assumptions about vehicle occupancy.

The HAM uses the same formula shown in equation (7.2) with an assumed average speed of travel to give a cost per vehicle per unit distance. This simplification is typically used in assignment models for route choice since the TAG formulae are intended to be used with average speeds of travel and not considering variations on a link by link basis. Naturally, the calculation of VOCs has depended on the assignment vehicle classes and purpose segmentations (user classes) in the assignment model. Note that the VOC for HGVs was derived from a weighted average of the OGV1 and OGV2 costs in TAG, where the ratio was assumed to be 40:60.

The vehicle operating cost parameters use in the HAM for the 2015 base year are shown in Table 7.2 with the assumed speeds of travel on which they are based. The average speeds of travel were taken from preliminary runs of the HAM as part of the model refinement and calibration. The speeds were checked and those for business and HGV trips updated before the final HAM calibration runs.

Table 7.2 - Vehicle operating cost for 2015 base year (pence per metre in 2015 prices)

User class	Average network speed (km/hr)	HAM VOC parameter (total)	HAM fuel cost parameter	HAM non-fuel cost parameter
Car: Commute	54	0.0067	0.0067	0.0000
Car: Business	65	0.0130	0.0054	0.0076
Car: Other	54	0.0067	0.0067	0.0000
LGV	54	0.0147	0.0070	0.0077
HGV	65	0.0481	0.0300	0.0182

Source: TAG databook (v1.9.1 December 2017)

For scenario testing the VDM generates changes in the car driver person trip matrices which can be translated directly to changes in the car vehicle matrices. Occupancy will therefore be an output from the VDM.

7.4. Highway values of time

The values of time (VoTs) per vehicle in the HAM were taken directly from the TAG databook A1.3.5 for the appropriate user classes. The 2015 base year values converted into the units for input to the model are shown in Table 7.3. These will include the vehicle occupancy assumptions embedded in the TAG databook.

The values of time given in the TAG databook A1.3 for HGVs relates to the driver's time rather than any influence of the owners on the routes used. TAG unit M3.1 notes that to achieve reasonable routing in highway assignment models "it may be more appropriate to use a value of time around twice the TAG Unit A1.3 values". Guidance also suggests that if a higher value of time is used then a sensitivity test should be run. In the NTMv5 HAM a factor of 2.5 was applied to the HGV values of time. Sensitivity testing was carried out as part of the HAM calibration.

Table 7.3 - Values of time (pence per second) - 2015 values and prices

User Class	AM Peak	Inter Peak	PM Peak
Car: Commute	0.3608	0.3666	0.3620
Car: Business	0.5380	0.5513	0.5457
Car: Other	0.2489	0.2651	0.2607
LGV	0.3802	0.3802	0.3802
HGV	0.9651	0.9651	0.9651

Source: TAG databook A1.3.5 (v1.9.1 December 2017)

For the VDM, the implied values of time are an output from the estimation process and validated against the values set out in the TAG guidance as shown in Chapter 13.

7.5. Parking charges

In order to represent the complete costs of car journeys, it is desirable to include parking charges. The design decisions relating to the introduction of parking charges were as follows:

- Parking charge locations. Which zones parking charges are applied to, and how those locations are determined consistently across the model area.
- Demand segments receiving charge. Which person segments and trip purposes incur parking charges.
- Calculation of charge. How the parking charge is calculated, for example to what extent it is taken directly from observed charges, and to what extent from a formula.

Each of the above was considered. The issues and effort involved in collating car parking charges across the entire country and how this data relates to what people typically pay to park, meant this approach was ruled out. The working assumption adopted for parking charges was aligned to the implementation in the more spatially aggregate NTMv2R, where charged zones relate to area types (levels of urbanisation) and have a typical parking charge and proportion of trips paying the charge for each trip purpose in each type of area.

The model calibration had the option of refining these parking assumptions to improve the performance of the mode should this be found necessary.

For NTMv2R, the typical parking charges by trip purpose and area type were derived from NTS data, as were the proportion of car trips typically paying to park. These data were combined to give the average parking cost paid by each trip purpose in each area type as shown in Table 7.4 to Table 7.6. These parking charges have been implemented in the base year VDM.

Table 7.4 - Average costs (pence) for those paying to park by destination by purpose

Purpose	Area types (NTMv2R model zones)											
	1	2	3	4&5	6&7	8&9	10	12	13	14	16	17
HbW	2,000	517	467	335	245	176	256	455	249	275	211	251
HbEB	576	576	978	661	550	322	477	340	760	597	246	317
HbEd	191	191	360	244	351	296	301	241	300	241	225	140
HbShopP	367	367	215	336	189	283	247	301	208	257	192	133
HbRecV	576	576	435	497	313	345	315	304	204	284	219	287
HbHol	717	717	2,001	2,748	1,621	595	435	367	202	202	414	533
NHbEB	491	491	850	358	444	358	323	215	600	602	246	317
NHbO	503	503	293	354	237	335	305	290	198	322	203	240

Table 7.5 - Proportion of car trips actually paying for parking by destination by purpose

Purpose	Area types (NTMv2R model zones)											
	1z	2	3	4&5	6&7	8&9	10	12	13	14	16	17
HbW	25.0%	4.4%	2.2%	5.8%	5.8%	3.3%	3.3%	4.0%	4.0%	2.1%	1.2%	2.4%
HbEB	14.4%	14.4%	8.3%	13.0%	13.0%	5.7%	5.7%	8.4%	8.4%	4.4%	5.1%	1.0%
HbEd	1.0%	1.0%	0.8%	2.0%	2.0%	0.6%	0.6%	1.9%	1.9%	0.9%	1.0%	0.7%
HbShopP	8.5%	8.5%	7.7%	7.6%	7.6%	5.2%	5.2%	7.8%	7.8%	8.5%	7.4%	7.2%
HbRecV	4.2%	4.2%	4.2%	3.1%	3.1%	1.4%	1.4%	2.6%	2.6%	3.3%	3.1%	1.7%
HbHol	7.8%	7.8%	5.7%	6.8%	6.8%	5.3%	5.3%	5.4%	5.4%	8.3%	6.7%	7.4%
NHbEB	17.0%	17.0%	3.4%	11.1%	11.1%	2.6%	2.6%	3.5%	3.5%	5.3%	3.5%	1.7%
NHbO	5.6%	5.6%	4.3%	4.4%	4.4%	3.3%	3.3%	3.2%	3.2%	5.0%	5.0%	4.7%

Table 7.6 - Average parking costs for all car trips (pence) by destination zone by purpose

Purpose	Area types (NTMv2R model zones)											
	1	2	3	4&5	6&7	8&9	10	12	13	14	16	17
HbW	500	23	10	19	8	7	5	5	6	13	5	2
HbEB	83	83	81	86	31	27	21	17	8	36	9	4
HbEd	2	2	3	5	2	6	3	3	2	2	2	0
HbShopP	31	31	17	26	10	22	21	22	15	26	15	5
HbRecV	24	24	18	15	4	9	11	9	3	10	5	4
HbHol	56	56	114	188	85	32	36	25	15	22	20	31
NHbEB	84	84	29	40	12	12	17	8	10	26	9	4
NHbO	28	28	13	16	8	11	15	14	9	13	9	6

7.6. Tolls

Distance based costs and tolls are referenced by the government's website (https://www.gov.uk/uk-toll-roads). The existing toll charges on roads, bridges or tunnels on Motorways, A road and minor roads (if coded in the network) are coded in the NTMv5 as optional network objects using the Toll link attribute so the costs are included within the generalised cost.

Many of the toll values were transformed from the RTM networks used as source networks for the NTM, with the values then checked against the government website.

In the case of the central London congestion charge, rather than using the in-built Visum area charging tool, a simplified approach was taken, where tolls were charged on each link that crosses the boundary of the area. This is again in line with the methodology adopted for the RTMs. The congestion charges were taken from SERTM which in turn took them from Transport for London's highway model for Central London, CLoHAM.

The derivation of the charges was set out in the SERTM model validation report as follows:

> *"Since it is difficult to obtain an accurate estimated discount for vehicles liable to the congestion charge, the approach adopted in TfL's Central London Highway Assignment Model (CLoHAM) was adopted, which assumes the charge rates of 80p for car, 180p for LGV and 190p for HGV in the base year 2009.*
>
> *The charge rates above in CLoHAM were based on previous daily charge (£10) in 2009 prices. With the daily charge rate increase to £11.5 and price base changed to 2010 (using GDP deflator rate, a rate of 1.03 would be applied), the charge rates were then recalculated as 95p for car, 215p for LGV and 225p for HGV."*

For the NTMv5 the SERTM values were taken and converted from 2010 to 2015 prices using the GDP deflator from the TAG databook.

The tolls coded in NTMv5 are shown in Table 7.7. Tolls for car business trips are the same as other cars but exclude the VAT.

Table 7.7 - Tolls (in pence) coded in NTMv5 2015 base year (in 2015 prices)

ID	Toll Description	Road name	Region	Car work (pence)	Car non work (pence)	LGV (pence)	HGV (pence)	Source
1	London Congestion Charge	A4	London	84	101	227	239	SERTM
2	Dartford Crossing	A282	East of England	201	241	241	483	SERTM
3	Dartford Crossing	A282	South East	201	241	241	483	SERTM
4	Itchen Bridge	A3025	South East	48	58	97	2012	SERTM
5	Itchen Bridge	A3025	South East	48	58	97	2012	SERTM
6	Swinford Bridge	B4044	South East	4	5	97	8	SERTM
7	Whitchurch Bridge	B471	South East	32	39	201	Banned	SERTM
8	Tyne Tunnels	A19	North East	137	164	266	266	NRTM
9	M6 Main Toll	M6 Toll	West Mids	475	570	805	805	MRTM
10	M6 Local Toll	M6 Toll	West Mids	354	425	805	805	MRTM
11	Severn Bridge (WB)	M48	South West	451	541	901	1344	https://www.severnbridge.co.uk/Home.aspx?.Parent=&FileName=toll-price12
12	Second Severn Crossing (WB)	M4	Wales	451	541	901	1344	

ID	Toll Description	Road name	Region	Car work (pence)	Car non work (pence)	LGV (pence)	HGV (pence)	Source
13	Dunham Bridge (EB)	A57	East Mids	32	39	48	80	MRTM
14	Mersey Tunnels-Queensway	A41	North West	137	164	274	547	TPS
15	Mersey Tunnels-Kingsway	A59	North West	137	164	274	547	TPS
16	Humber Bridge	A15	Yorks &Hum	121	145	322	966	TPS
17	Warburton Bridge Rd	B5159	North West	10	12	10	10	TPS
18	Clifton Suspension Bridge	B3129	South West	40	48	40	40	http://www.tolls.eu/united-kingdom
19	Tamar Bridge	A38	South West	121	145	241	241	http://www.tolls.eu/united-kingdom

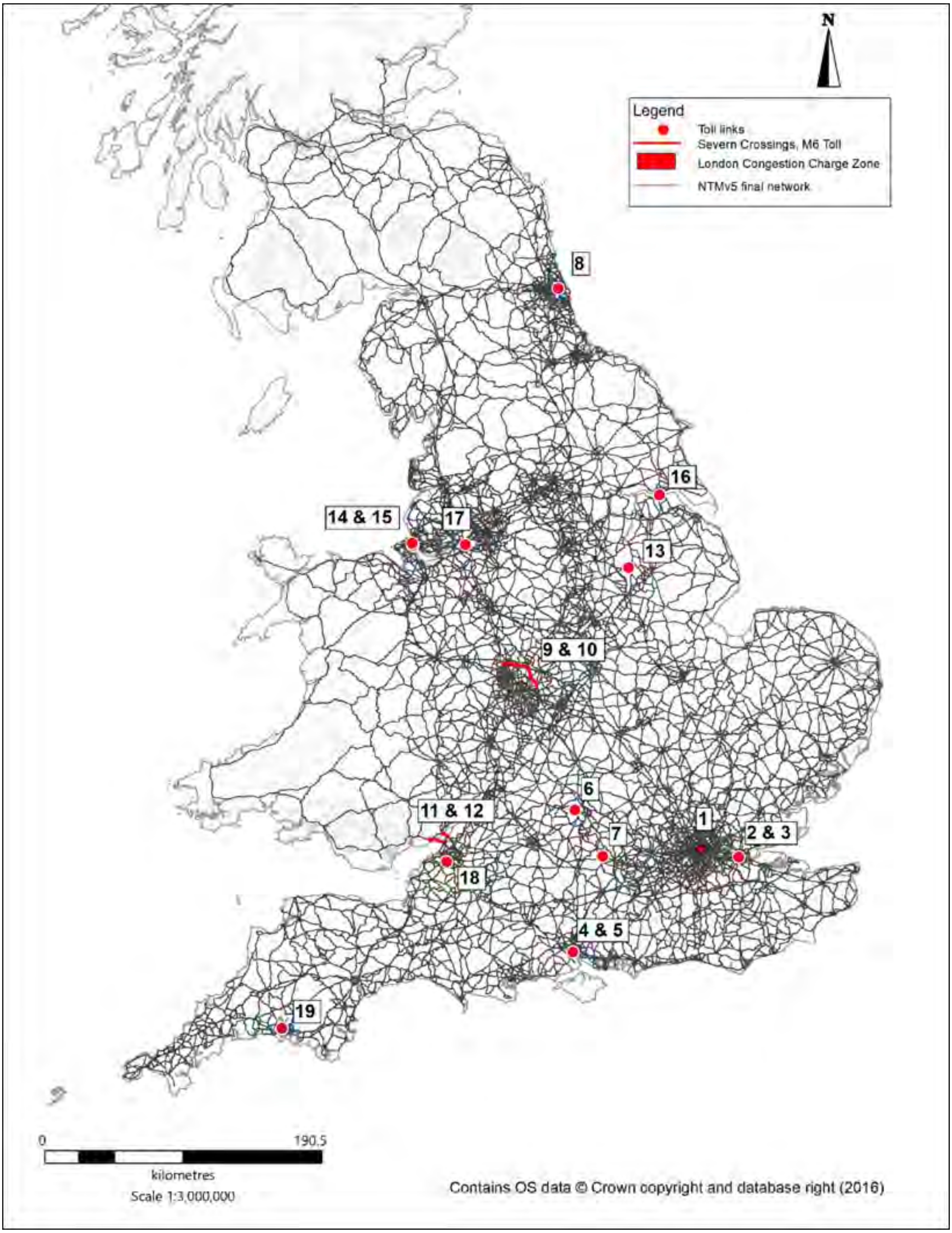


Figure 7.1 - Toll links in NTMv5

7.7. Public transport fares

Public transport fares have been developed for each of the bus and rail modes for use in the VDM for each trip purpose, as described below.

7.7.1. Rail fares

Rail fare matrices were derived by ticket type and time period (morning and interpeak) from MOIRA 2 demand and revenue information for 2015/2016, rather than trip purpose. Rail stations in MOIRA were assigned to NTMv5 model zones in two ways. Station groups included all stations associated with a model zone, while primary station groups related the stations classified as “primary” in MOIRA to model zones. Fares were then derived by ticket type for each zone pair using the station group information groups in two ways: one for all station groups and the other for the primary station groups. Where station group information was available this was used, if not the primary station group fares information was taken for the NTMv5 zone pairs.

Distance based fares were then derived to infill fares for any zone pairs where distances were defined (see Section 7.8) but fares had not been obtained from the station to zone allocation process. The pence per kilometre values for full, reduced, advanced and season tickets were calculated based on the MOIRA 2 data using journey weighted averages. The resulting distance-based fares are shown in Table 7.8.

Finally, the full fares were capped at £275 and the other three fare types at £165. Furthermore, the minimum fare value was set to £2. The selection of £275 as the maximum value was based on the full fare cost from Penzance to Wick of approximately £250 and one of the longest train journeys in the country and many other long distance single fares being observed from national rail website information to be between £200 and £240. An additional 10% was added to this fare of £250 to ensure no valid fares were discarded.

Table 7.8 - Average rail fare cost per kilometre (pence per kilometre)

Ticket type	Pence per kilometre
Full Standard	29
Reduced Standard	17
Advance Standard	12
Season Standard	17

Source: MOIRA 2

The ticket types and time period assumed most relevant for each trip purpose is shown in Table 7.9. The rail fares by trip purpose were obtained on this basis.

Table 7.9 - Source of rail fares by purpose

Trip purpose	Source of rail fare
HbW	2 x Season (AM)
HbEd	2 x Reduced (AM)
HbShopPB	2 x Reduced (IP)
HbRecV	2 x Advanced (IP)
HbHol	2 x Advance (IP)
HbEB	2 x Full (AM)
NHbEB	1 x Full (IP)
NHbO	1 x Reduced (IP)

7.7.2. Bus and coach fares

Each model zone pair was assigned a bus or coach fare based on the origin and destination areas and distance travelled between the zones using the same data and rules as implemented in NTMv2R.

Four fare functions are used to represent bus and coach fares by trip end area type:

1. local bus fares in London;
2. local bus fares for trips under 25 miles in metropolitan areas outside London;

3. local bus tariffs for trips under 25 miles in other areas, and
4. coach fares for all trips 25 miles and longer.

Bus and coach journeys are defined by distance travelled, where journeys longer than 40 kilometres (25 miles) are classified as coach journeys. The two sets of fare functions are reasonably close at around £8.50 (2015 prices and values) for a 25 mile journey.

Fares are of the form **fare = *ax* + *b***, where *a* is the cost per unit distance *x* and *b* is a fixed constant charge. Table 7.10 presents the parameters for the four bus fare functions. For trips between types of areas the dominant area is defined as the most urbanised. So, London fares are used for trips with one end in London, Metropolitan fares for trips with one end in a Metropolitan area and the other outside London.

Table 7.10 - Bus and coach fares, 2015 values and prices

'Dominant' area definition and distance band			Cost function parameters (pence)		
Area	Distance	Type	Fixed cost	cost per mile	Cost per km
London	Under 25 miles	Local bus	50	30.83	19.16
Metropolitan area			50	34.92	21.70
Other area			50	31.74	19.72
All areas	25 miles and above	Coach	500	14.18	8.81

7.8. Public transport times and distances

The public transport time components were derived from the TRACC accessibility software based on October 2015 timetables and the ITN network. Separate attributes are required for bus and rail as defined in NTMv5.

The TRACC software is a fully integrated accessibility analysis tool and includes bus and rail timetables with routes based on the most efficient use of the public transport options available. Each TRACC run provided the information shown in Table 7.11.

Table 7.11 - Data fields provided by TRACC

Field	Description
Access Time (minutes)	This is the walking / access time (minutes) from origin zone to stop, from stop to stop (any interchanges) and walking from end stop to destination zone at the assumed access speed. It excludes any wait time.
Service Frequency (services per hour)	The existing TRACC algorithm assumes no initial wait time. It will work out the correct time to leave the origin in order to get on the service at the correct time. .
In Vehicle Time (minutes)	Total in-vehicle time by sub-mode for any journey legs combined together
Total Travel Time (minutes)	Total travel time will be provided from origin to destination taking into account all the legs of the journey combined together (including access and wait times)
Total Distance (metres)	This will be a total distance from origin to destination. For the walking / access elements of the journey this represents the distance calculated to and along the road network whilst the in-vehicle journey will be represented by a straight line distance between transport nodes (ie along the route) that represent the journey patterns of any sub-modes.
Total number of interchanges	Total number of interchanges by sub-mode used when getting from origin to destination.

The main mode of travel (bus or rail) was determined by the mode used for the longest distance[5] of the trip.

Four separate travel time components were derived from the TRACC outputs for bus and rail as the main mode for the morning and interpeak periods and used to give zone to zone attributes:

1. Access time: access, between stops / stations (interchange) and egress combined;
2. Wait time: initial and at any interchanges combined;

[5] This was estimated from times (and assumed speeds) by stage as TRACC does not provide distances of each stage.

3. In vehicle (ride) time – for all public transport modes used; and
4. Number of interchanges.

There is no representation of crowding on public transport included in NTMv5.

7.9. Walk and cycle times

For active modes, distances between zone pairs were obtained using TRACC information which has the benefit of the road network and urban path network layers providing more detailed connectivity information than typically included in assignment models and more realistic than a function of crow-fly distances between zone pairs.

To obtain times, speeds were assumed as follows:

- walk speed of 4.8 kilometres per hour; and
- cycle speed of 16 kilometres per hour on roads, reduced to 4.8 kilometres per hour if paths are used.

7.10. Intrazonal attributes

Intrazonal trip characteristics are required to provide a realistic choice between travelling to destinations within a zone, versus travelling to other destinations. As the NTMv5 zones are, in general, quite large at MSOA level, the number of intrazonal trips are also potentially large and therefore it is important that attributes are included for these trips.

TAG unit M2 suggests a variety of methods for calculating intrazonal costs, largely based on the distance and time (or more directly the generalised cost) of travel to neighbouring zones. A common approach has been to consider half the interzonal cost as representative of the intrazonal cost. However, this can produce a gross over-estimate of typical intrazonal costs if the zone is large with a single built-up area for example.

For car the intrazonal distances and times were taken as 50% of the minimum interzonal values for the origin zone from the HAM skims. No tolls were assumed for intrazonal movements.

For walk and cycle, intrazonal distances of 50% of the minimum interzonal distance were assumed and the same speeds of travel applied as for other zone pairs (ie 4.8 kph for walk and 16kph for cycle) to give the intrazonal times used in the model. In rural areas there may be an issue with dependency on whether the population within the zone is "clumped together" within a small part of a large zone or dispersed in, say, several villages. It was noted that the function of interzonal distance could give unrealistically long walk distances, in these cases. The extent to which this was an issue was reviewed during model calibration and a cap on the maximum walk and cycle times introduced of 30 minutes and 24 minutes respectively.

For bus travel, the stage related attributes were derived as shown in Table 7.12. Intrazonal travel was initially assumed to be irrelevant for rail travel, then included for zones containing more than one station using the same rules set out for bus.

Table 7.12 - Public transport attributes for intrazonal trips

Attribute	Source of value
Access Time (minutes)	Minimum interzonal access time recorded for zone
Service Frequency (services per hour)	Maximum service frequency for zone (from interzonal records)
Wait Time (minutes)	Derived from service frequency using same wait time to frequency relationship as interzonal movements
In Vehicle Time (minutes)	Proportion of the minimum interzonal ride time
Total number of interchanges	None (hence no interchange penalty)
Fare	Calculated as for interzonal zone pairs

During the model calibration some adjustments were made and the proportion of interzonal ride time used for bus and rail reduced to 37.5% of the minimum interzonal value.

8. Highway assignment model

8.1. Introduction

The NTMv5 HAM is a conventional strategic highway assignment model that comprises:

- A representation of the road network as a series of links and nodes with attributes defining the nature of the links, and connectors representing the point at which trips are assumed to join or leave the road network;
- Matrices of highway trips, segmented into assignment user classes, that are assigned to the network to determine their choice of route and resulting travel times and costs;
- Relationships defining how the speed of travel varies on links based on the level of traffic demand; how and these rules vary by vehicle type;
- An assignment (route choice) algorithm that determines how paths are built through the available network; and
- Options to control the iteration of the model to reach stable conditions where traffic congestion and travel times are in equilibrium with the amount of traffic using each route.

Aspects of a HAM often found in urban area models, but excluded from the NTMv5 for reasons of scale and efficiency are:

- Detailed junction modelling; and
- Speed flow relationships on some links in urban areas, instead setting urban area speeds for the base year using observed data and providing a means of adjusting these assumptions through time (see Section 4.7).

Chapter 6 provides information on the process to develop matrices of highway trips. The remaining components that define the HAM are described in this chapter.

8.2. Assignment segmentation

The HAM user classes are very aggregate in comparison to the VDM, with segmentation based chiefly on differences in value of time in line with guidance provided in TAG unit M3.1.

Five assignment user classes are implemented in NTMv5 as shown in Table 8.1.

Table 8.1 – Assignment User Class (AUC) definitions

User class	Vehicle type	Purpose	Identifier
1	Car	Business	CB
2	Car	Commute	CC
3	Car	Other	CO
4	LGV	All	LGV
5	HGV	All	HGV

8.3. Highway network

8.3.1. Highway network components

The highway network comprises three main components:

- Network of road links and nodes of different types representing the main highway network for travelling between zones;
- Centroid connector links which provide access between the road network representation and the zones where trips start and end; and
- Volume delay functions for links which determine how the speeds and travel times change with the amount of traffic on the link.

8.3.2. Road links and nodes

The starting principle for the highway network development was to utilise the networks developed for the five Highways England Regional Traffic Models (RTMs) which cover most of the NTMv5 core study area. Although the five RTMs were developed by separate teams, an overarching technical consistency group and a single RTM network coding manual set out to maximise consistency in the implementation of the five models.

The versions of the five RTMs provided for this purpose were as follows:

- South East Regional Traffic Model (SERTM) DF1, 02/09/2016;
- South West Regional Traffic Model (SWRTM) DF1, 02/09/2016;
- Midlands Regional Traffic Model (MRTM) DF1, 02/09/2016;
- TransPennine South Model (TPS)[6] DF1, 26/09/2016; and
- North Regional Traffic Model (NRTM) DF1, 02/09/2016.

Each RTM had its own region of focus (RoF) with detailed network representation where links and junctions were coded in greater detail, called simulation network in the SATURN assignment modelling software. Apart from NRTM, all RTMs shared overlapping areas with their neighbouring RTMs.

A process was developed for NTMv5 to import the RTM networks to Visum. This was carried out in three stages:

1. Reviewing the quality of the networks obtained and any errors or warning messages generated when they were compiled for use.
2. Stitching the five regional networks together to give a national SATURN highway network.
3. Importing the national network to Visum.

The resulting NTMv5 network contained all motorways and A-roads, the majority of B-roads and a small number of minor roads where required for connectivity, since this is what was available from the RTM networks. The structure and level of coverage is shown in Figure 8.1.

[6] Following an agreement with Highways England, the former Northern Power House Regional Traffic Model (NPHRTM) was renamed to TPS, which covers east-west from Hull to Liverpool.

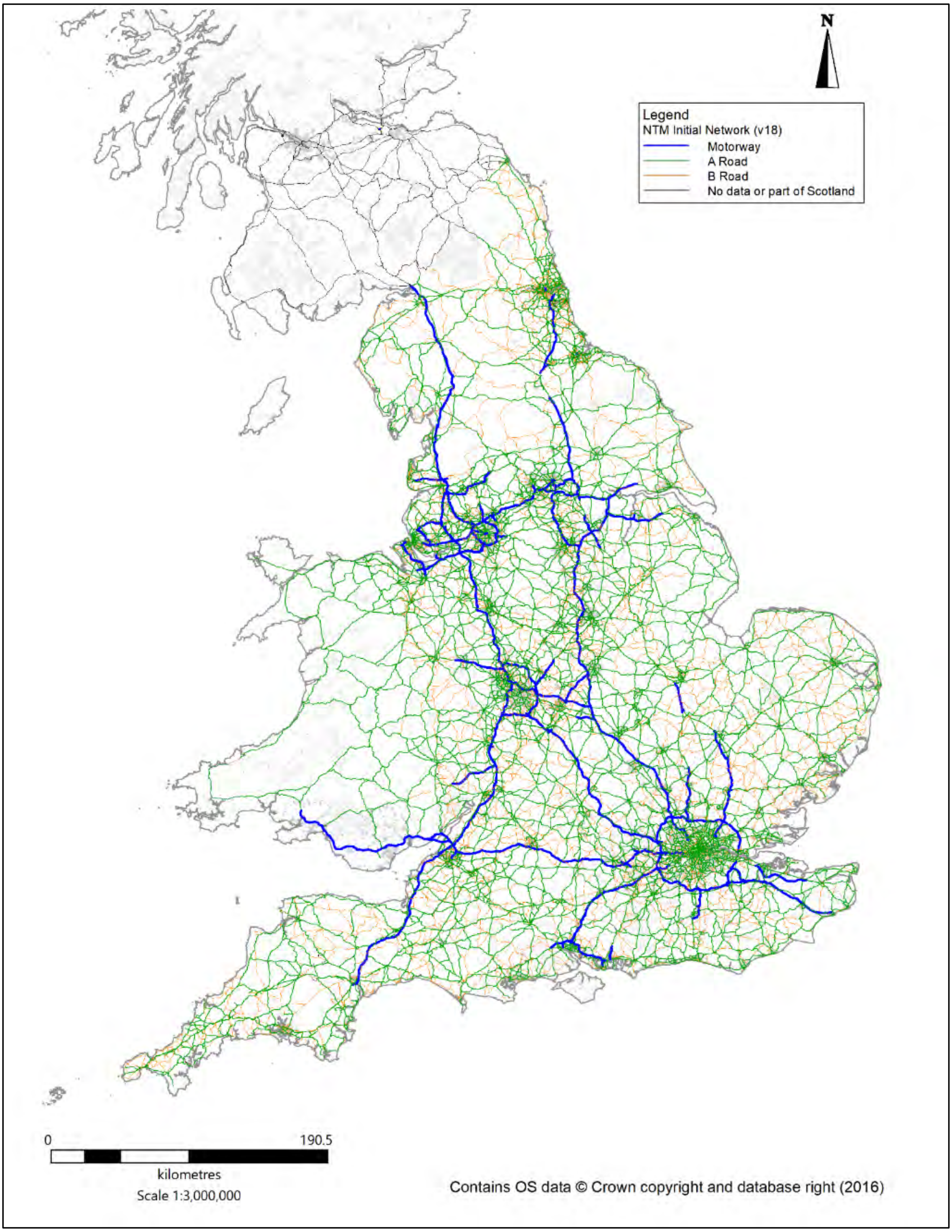


Figure 8.1 - Initial NTMv5 highway network structure

8.4. Volume delay functions and speeds

In a Visum highway network, each link has a link type. It is the link type which defines a set of attributes, such as free-flow speed and the volume delay function (VDF), which is used to calculate the flow related travel delay for vehicles travelling through a link.

The NTMv5 link types were taken from the RTMs and differentiate the different standards of road amongst other attributes. The VDFs implemented in NTMv5 were defined to closely match the shape of the speed flow curves used in the RTMs from which the network was sourced.

The transfer of link types and volume delay functions from the RTMs to the NTMv5 helped to reduce the efforts in network coding (and model calibration and validation) and should be beneficial in keeping consistency between these strategic traffic models.

The treatment of speed variations by different vehicle types (modes) on links is implemented in Visum by assigning a maximum speed to each mode on each link type. The free flow speed for the mode is then taken as the minimum of the free flow speed for the link type and the maximum speed for the mode (on the link type).

The maximum speeds for the vehicle types were set in NTMv5 as the following:

- Car = 130 kph for all link types;
- LGV = 120 kph for all link types; and
- HGV = 70 kph for single carriageway links and 96 kph for dual carriageway links

The urban area fixed speed approach described in Section 4.7 has the advantage of providing a stable representation of the speed in the central area of major cities and towns with significantly reduced requirements in data collection and network coding. Typically, in urban areas, the delays caused by pedestrian, signals, bus services, roadside parking, and commercial activities are unlikely to be successfully captured by traditional link SFC, or volume delay functions (VDF).

Outside the fully modelled area (ie in the external areas) the total demand for travel is not included and the network representation is more skeletal. In these areas it is therefore not appropriate to model changes in speed based on modelled changes in the demand. Fixed speed links were therefore also identified for these peripheral parts of the network.

8.5. Junction modelling

Junction modelling is explicitly included in the RTMs from which the NTMv5 network was sourced. The scale and strategic nature of the NTMv5 along with the desired run time targets, meant that detailed junction modelling was not be applied for NTMv5 highway models. In view of this, a simplified and proportionate junction model to capture delays occurring at junctions was adopted, taking account of junction geometry, the overall demand at the junction and the movement being made (straight ahead, turning right etc).

8.6. Bus (public service) pre-loads

There is no assignment of public transport trips in NTMv5 and no explicit representation of bus services and the capacity they occupy on the road network.

NTMv5 has processed 2015 outputs from the TRACC accessibility modelling software which contains timetable information to determine the links in the network used by bus routes and the number of buses using these routes in each time period.

A small sample of the NTM links and their associated preload data was then compared to DfT counts from 2015 to determine whether the PSV preloads were broadly in line with the counts in order of magnitude by time period. The data was found to match reasonably well for the count sites chosen. Almost every site showed the NTMv5 preload to have a lower volume than the count of buses/PSVs. However, as the preloads are based on scheduled public service buses, they do not include private hire buses and coaches; which may account for the differences on the more strategic routes.

Hence the NTMv5 preload values derived are considered a good representation of capacity occupied by buses and appropriate for use within the highway assignment model.

8.7. Assignment routing algorithm

Following best practice and to meet the requirements set out in the use cases for the NTMv5, the HAM required an “equilibrium” assignment routing algorithm, i.e., one that takes account of varying congestion levels. Following some experimentation, the LUCE (Linear User Cost Equilibrium) algorithm was selected as it provided a better level of convergence.

9. Linking VDM and HAM

9.1. Principles

The VDM produces synthetic demand forecast matrices of daily P/A trips by mode for each demand segment implemented within NTMv5 (purpose and traveller type combinations). The demand for personal highway travel by car and LGV is combined with inputs on freight and external movements and passed to the HAM to estimate traffic flows, congestion and associated impacts.

In forecasting travel demand it is quite common for future-year forecasts to be derived from accurately known pattern of base-year observed flows. The "accurate" base-year flows generally do not come directly from strategic travel models. By focussing the modelling effort on predicting changes it is possible to make significant reductions in the expected forecast error. The process of taking a fixed base point and making forecasts relative to that is incremental modelling.

The introductory section of TAG Unit M2, states that 'the Department's long-established preferred approach is to use an incremental rather than an absolute model unless there are strong reasons for not doing so'. NTMv5 has therefore been developed using an incremental modelling approach as set out in Section 9.2.

The VDM and HAM are the core components of NTMv5 and are both implemented within Visum. The full model is delivered as a single operational Visum file for each run year. Any passing of data between these components (and manipulation of the data during this process) is also implemented within Visum.

9.2. Incremental model approach

Two alternative incremental approaches were considered for NTMv5, namely:

- absolute models applied incrementally (AMAI), which use base and scenario absolute VDM estimates to apply changes to a base matrix; and
- incremental pivot-point models (IPP), which use cost changes in the VDM to estimate changes in the number of trips relative to a base matrix.

The AMAI approach was recommended by the team for NTMv5 and following acceptance at a meeting with the Department and their Peer Reviewers in July 2016 was taken forward for implementation. The AMAI implementation in Visum makes use of the built-in matrix manipulation functionality.

The basic calculation for the AMAI type of pivoting implemented for NTMv5 is given in Equation 9.1:

$$F = B \cdot \frac{S_f}{S_b} \qquad (9.1)$$

where:

S_f	is the modelled, i.e. 'synthetic' trips for a future year from the VDM;
S_b	gives the synthetic trips for the base year from the VDM;
B	is the observed (base) matrix from the validated HAM.
F	is the resulting forecast highway assignment matrix for input to the HAM

Any of the three input components can be zero, with different implications for the forecast. The principles adopted in setting calculation rules to handle zeroes or extreme growth, are to use the basic multiplicative equation as above whenever possible, but to switch to an additive function when multiplication becomes unreasonable. As far as possible the functional forms are chosen so that small changes in the inputs cannot lead to large changes in the outputs, e.g. when one of the components acquires a small positive value rather than zero.

When pivoting is carried out solely at the cell level, there are a number of reasons why the aggregate result can differ from that which would arise if the matrix totals were simply scaled. This naturally occurs in the special cases where additive growth is used, but can also occur due to differences in the modelled synthetic base and the validated highway base matrices built using observed data. Normalisations are carried out by summing the zone-zone matrices to a suitable sector-sector level, and then repeating the pivot process at this level. The results of the zone-level pivoted matrices are then scaled so that the sector-sector totals match the results of the sector-level pivot.

9.3. Conversion of VDM P/A matrices prior to pivoting

Before the AMAI pivoting approach is applied, the VDM output matrices must be converted into the same format, units and time period as the HAM assignment matrix (B). This involves the following conversions:

- Splitting the daily 24-hour P/A trips across departure (from home) time periods during the day. Time period factors were derived from NTS data, analogous to the parameters used in NTEMv7.2 and vary by trip purpose and distance band.
- Converting the VDM Production-Attraction (P/A) format to Origin Destination (O-D). This involves transposing the P/A trips and determining return periods for each trip production time period. This is carried out using parameters from NTEMv7.2, also based on National Travel Survey data.
- Aggregating the VDM segments to the HAM assignment user classes for each time period.

9.4. Iteration and supply-demand convergence

When conducting scenario tests the model iterates the demand and supply components as shown in Figure 4.1. The model follows a standard iteration procedure whereby:

- At the first model pass (Iteration 0) mode and destination choice is determined without taking account of highway cost changes using:
  - seed HAM skims (from the Base HAM);
  - input non-car attributes (bus, rail, walk and cycle) skims and parking costs;
  - input trip end changes; and
  - input VOC, VoT parameters.
- At the end of Iteration 0, the revised and pivoted highway demand is combined with any freight matrix adjustments and assigned in the HAM, and revised skims fed into the model for Iterations 1+;
- The model then iterates either for a fixed number of passes, or until a convergence criterion is reached.

PTV Visum includes functionality to apply a stopping criteria based on a TAG compliant gap calculation for the demand model[7]. However, it has not been possible to test the convergence of the full model using this facility at this stage, and instead the process is stopped after the third iteration (fourth pass). It is recommended that scenario-specific checks are conducted on key elements of the model, making comparisons of final and penultimate iterations to check that convergence is satisfactory for specific scenario tests. More information on this is included in the NTMv5 User Guide.

[7] See online Visum User Guide: https://cgi.ptvgroup.com/vision-help/VISUM_18_ENG/#1_Nachfragemodell/1_3_Nested_Demand_Modell.htm (> Visum – Fundamentals > Demand model > Demand modeling procedures > Nested demand model)

10. Demand model estimation

10.1. Approach

The mode-destination models were estimated as discrete choice models from disaggregate observations of individual-level travel choices. The key dataset for the model estimation work was NTS data supplied by DfT. The NTS provides a rich dataset that captures individuals' observed mode-destination choices by travel purpose alongside person and household level information. For example, together with trip-level information recording an individual's journey to work (mode, destination, time of travel and so forth), person and household level information such as car ownership, person type and income is recorded. The availability of this person- and household-level information at the individual level allows segmentation terms to be directly incorporated in the data and models, a feature that is not possible in datasets where information has already been aggregated up across individuals to the matrix level.

A phased approach was used to determine the choice hierarchy structure for the VDM:

1. Set up and estimate multinomial logit models (ie all alternatives being equally sensitive);
2. Test alternative nesting structures: such as mode above destination and destination above mode; and
3. Sub nesting of modes: eg bus and rail as a sub nest of a public transport mode.

As well as testing structures, the performance of the model estimation was also tested for:

- Varying the mix of log and linear cost terms in utility functions to determine the cost formulation;
- Alternative levels of car driver and passenger cost sharing; and
- The impact of alternative segmentation variables and destination constants.

In addition, for the commuting and education trip purposes, the aim was to test singly versus doubly constrained destination choice models.

The remaining sections in this chapter set out the data and issues associated with each of these stages. The results from the model estimation process are provided in Chapter 13.

10.2. Criteria for success

The demand model estimations use maximum likelihood estimation procedures that identify the model parameters that give the best fit to the observed choices in the data for a given model specification. While the primary measure of success for the mode-destination model estimations is the log-likelihood, i.e. the fit to observed choices, a range of other criteria were also considered:

- the values of time by mode that are implied by the estimated cost and in-vehicle time parameters;
- the ratios of key parameter values, for example ratios of car in-vehicle time to train and bus in-vehicle time;
- the model elasticities, in particular the fuel cost elasticity, by carrying out realism tests; and
- the ability of the model to replicate the trip length distributions by mode and purpose that are observed in the NTS choice sample.

The validation measures (realism tests and trip length distributions) were initially considered for the NTS sample of data used for the estimation – ie how well the estimated models matched the data from which they were derived. The next stage was to implement the models on the full trip end datasets, as set out in Chapter 5 and review the performance of the full VDM again in terms of elasticities and trip length distributions. The results from these tests are set out in Chapter 13 on the performance of the VDM.

10.3. Final segmentations

The estimation process demonstrated that gender, employment, car availability and age were the segmentations shown to have the highest significance in explaining travel behaviour.

Non-home-based trips are generated within the VDM from the home-based trip attractions. The segmentation structures suggested by the estimation process were refined to improve compatibility between the NHb segmentation and the Hb purposes from which the NHb trips are generated.

Table 10.1 shows the segments defined and how they been slightly modified from those recommended by the estimation to provide the necessary compatibility between the Hb and NHb trip purposes. The segments highlighted in green are where the NHb models have been aggregated to be in line with the Hb models; the yellow cells represent where the Hb models have been disaggregated at the production level (the model parameters remain the same) and red cells represent where the Hb models remain more aggregate than the NHb model.

Table 10.1 - Final Demand Segmentation (improved consistency between Hb and NHb segments)

Variable	HbW	HbEd	HbShopPB	HbRecV	HbHol	HbEB	NHbEB	NHbO
Gender	Male	Male	Male	Male	Male	Male	Male	Male
	Female	Female	Female	Female	Female	Female	Female	Female
Employment	FT Workers	FT Workers	FT Workers	FT Workers	FT Workers	FT Workers	FT Workers	FT Workers
	Other	Students	Students	Other	Other	Other	Other	Other
		Other	PT Workers					
			Other					
Car Availability	Full Car	Full Car	Full Car	Full Car	Full Car	Full Car	Full Car	Full Car
	No/Part Car	No/Part Car	No/Part Car	Part Car	Part Car	No/Part Car	Other	Other
				No Car	No Car			
Age		0-15	0-15	0-15	0-15			0-15
	16-29	16-29	16-29	16-29	16+	16-29	16-29	16-29
	30-44	30-64	30-64	30-64		30-44	30-44	30-64
	45-64					45-64	45-64	
	65+	65+	65+	65+		65+	65+	65+
Total Segments	**32**	**48**	**64**	**48**	**24**	**32**	**32**	**32**

Hb trips are more aggregate than desired for NHb trip generation for HbHol trips generating NHbEB and NHbO trips and for HbEd, HbShopPB and HbRecV trips generating NHbEB trips. Given that only 0.6% of NHbEB and 7.2% of NHbO trips are generated by HbHol, the segmentation is unchanged, and factors have been calculated from the source trip productions to determine the proportion of trips that belong in each NHb age band.

The proportion of NHbEB trips following HbEd, HbShopPB and HbRecV is 5-6% in each case and hence similarly the HB trip attractions are split into the appropriate age bands for generating the NHb trips with factors from the production data.

Furthermore, to reduce the number of demand segments to be in line with the suggested maximum of 100 recommended from development and software testing, it was decided to remove the gender segment from all purposes and average the gender-specific constants by zone.

Removing the gender category from the demand model segmentation leaves 156 possible combinations. Of these 156, there are particular combinations that have been removed due to the combination of age group and employment status. It is assumed that there are no full-time employees or students (those in further or higher education) either under the age of 16 or over the age of 65.

11. Forecasting model

11.1. Forecasting approach

For forecasting alternative scenarios, the user has options for updating a wide range of inputs. Once these are updated and input to the model scenario runs can be undertaken.

As already indicated, NTMv5 will apply an AMAI (Absolute Model Applied Incrementally) approach. This means that NTMv5 will produce an absolute synthetic matrix from the VDM in each future year, and use this to derive a scaled version of the Base Year Assignment matrix. The HAM is then run to update the highway routing and congestion information.

The model then runs iteratively to update congestion impacts from the HAM in further runs of the VDM. The process will continue for a specified number of iterations or potentially be run to a given level of convergence.

The iterative process followed when running the model for scenario testing is shown in Figure 11.1.

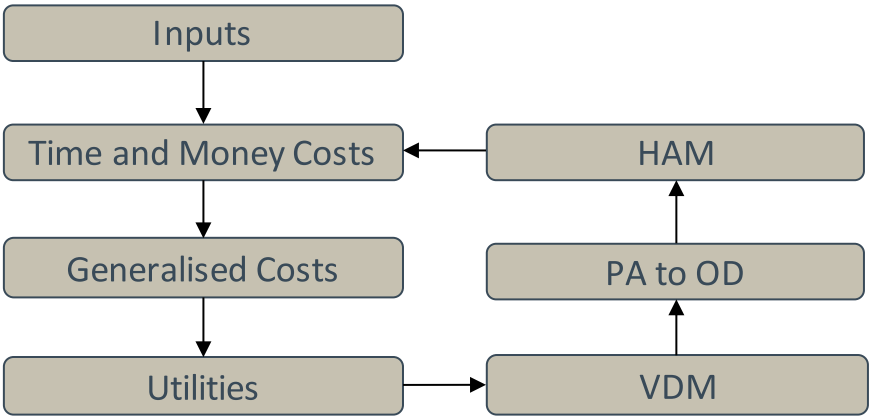


Figure 11.1 - High level NTMv5 flow chart

The following sections consider each of the changes or inputs required in the model for the forecasting to take place.

11.2. Trip end growth

A set of Base Year trip ends were derived for the model as outlined in Sections 5.5 and 6.4. Scenario tests using NTMv5 import growth factors for each zone, suitably segmented, to allow a set of future year trip ends to be derived. This process applies to both to the trip production and attraction trip end inputs to the model.

The DfT's NTEM dataset is expected to be the primary source of growth in travel demand. To facilitate the implementation of scenarios using NTEM travel demand growth, a tool has been developed to process the NTEM datasets and provide inputs to NTMv5.

The process requires correspondences to be defined between:

- NTEMv7 traveller types and trip purposes and NTMv5 demand segments; and
- NTEMv7 zones and NTMv5 model zones.

11.2.1. Segmentation

Most demand segment definitions can be mapped exactly from NTEMv7 to NTMv5 by design. The age correspondence is the primary variable for which an exact correspondence is not possible.

NTEM defines 3 age groups, namely 0-15, 16-74 and 75+, while NTMv5 has age groups 0-15, 16-29, 30-44, 45-64 and 65+ (although some trip purposes have some of these bands combined). The simplest matching is to assume growth in the 75+ age group is not too unrealistic for the age 65+, and that growth for the intermediate (working age) groups can be represented by NTEM's 16 to 74 age band.

During the testing phase of work on NTMv5, the implications of assuming the 75+ age group NTEM growth applied to the 65+ age group in the NTMv5 resulted in significant over-estimation of the growth in total trip ends. An approach was therefore developed for the Demand Growth sensitivity test to apply a final global adjustment to the trips by age band to match the overall levels of growth in NTEM for each trip purpose.

11.2.2. Non-home-based trips

In a similar manner to NTEM, the non-home-based trip productions in NTMv5 are derived from the Hb attractions. Therefore, it is not necessary to derive growth factors for the NHb productions explicitly. There is a need to alter the attraction weights used in the NHb distribution process in the same manner as Hb attraction weightings.

11.2.3. NTEM growth

NTEM forecasts are only created for every fifth forecast year from 2011: 2016, 2021, 2026 etc. The NTEM results are therefore interpolated to obtain the required years for forecasting growth (2011 and 2016 to obtain the 2015 NTMv5 Base Year and a pair of forecast years for scenario testing).

NTEM based growth is derived from the weekly trip productions, attractions and attractor weights converted to an average weekday and aggregated to the corresponding NTMv5 segments and mapped to the NTMv5 zones.

In addition to the NTEM based growth, the user can further modify or replace the derived growth factors using alternative data to reflect specific major developments, or to constrain the results more closely to overall NTEM forecasts.

11.3. Highway network changes

Highway network changes can be coded directly into the model using the VISUM front-end. These can include modifications to the link type attributes defining speed-flow curves and capacities of links. Bus pre-loads, tolls and other link-based attributes are also available for modification.

11.4. Urban area speeds

The fixed nature of the urban area speeds in the base year model, means they will not respond to changing demand. For forecasting this is not realistic since population growth and changing land use activity is likely to increase traffic levels and thereby result in lower speeds. A methodology was required which enabled the user to make changes to the Base Year urban area speeds and provide these as an input to the NTMv5 scenario tests based on likely changes in demand, without modelling the changes in demand.

Alternative potential approaches were considered before it was agreed to implement a method where speeds respond to overall growth in trip ends and not any capacity changes on the network.

To achieve this the ratio of the base year speeds to free-flow speeds were used to provide “speed reduction factors” for the base year to reflect the levels of congestion at that level of demand then adjusted for the forecast scenario based on trip end growth.

It should be noted that this approach effectively applies an area wide speed reduction related to a change in area wide flow but does not relate to any changes in capacity between base and forecast years. The reasoning for this is clear, in that NTMv5 does not model all roads in the urban areas, and therefore no capacity cap is possible.

11.5. Costs and values of time

The model contains a set of parameters providing values of time and vehicle operating costs which are derived directly from the TAG databook. These parameter tables can be updated with information taken from the TAG databook for alternative years and imported to the model following the instructions set out in the NTMv5 User Guide.

Alternatively, the user will be able to apply simple modifications to the stored parameters (such as percentage changes in fuel costs or total VOCs), or create further bespoke sets of values for each year, in order to test non-standard scenarios.

Zonal parking charges for each trip purpose are also calculated for the Base Year and can be modified for scenario testing.

11.6. Public transport supply and active mode changes

Public transport network changes are not modelled explicitly in NTMv5. The input matrices of time and cost attributes can be modified by the user applying adjustments to the Base Year values for scenario testing.

Table 11.1 shows the matrices of Base Year public transport attributes, their units and how they are used (ie whether they impact on the choices and behaviour within the model or are used for summarising results for model analysis.

Table 11.1 - Base Year public transport matrices of attributes

Mode	Attribute	Units	Demand segmentation	Time period	Use in Visum
Walk	Distance	kms	None	None (all)	Analysis only
	Time	minutes	None	None (all)	Utility calculations
Cycle	Distance	kms	None	None (all)	Analysis only
	Time	minutes	None	None (all)	Utility calculations
Bus	Distance	kms	None	AM and IP	Analysis only
	Fare (cost)	pence (2015)	None	None	Utility calculations
	Access (walk) time	minutes	None	AM and IP	Utility calculations
	Wait time	minutes	None	AM and IP	Utility calculations
	PT ride time	minutes	None	AM and IP	Utility calculations
	# interchanges	unitless	None	AM and IP	Utility calculations
Rail	Distance	kms	None	AM and IP	Analysis only
	Fare (cost)	pence (2015)	Full / Reduced / Season / Advance mapped to trip purpose	AM and IP	Utility calculations
	Access (walk) time	minutes	None	AM and IP	Utility calculations
	Wait time	minutes	None	AM and IP	Utility calculations
	PT ride time	minutes	None	AM and IP	Utility calculations
	# interchanges	unitless	None	AM and IP	Utility calculations
Each non car mode	Quality 0 (additive)	Minutes	None	None	Utility calculations
	Quality 1 (multiplicative)	unitless	None	None	Utility calculations

The derivation of the Base Year model attributes is summarised in Chapter 7. More information is provided in the Developer Guide and User Manual to assist modellers with the implementation of scenario adjustments.

11.7. Freight demand

The Base Year LGV freight and HGV matrices can be modified by scaling rules within Visum to reflect changes in freight demand. Adjustments can be applied at the zonal level, eg for specific ports, or at any specified aggregation of the model zones.

11.8. Behavioural changes

Alternative specific constants (ASCs) were estimated for the base year demand model as set out in Chapter 10. These constants are typically held constant through time. They denote preferences for specific types of people (eg by age / working status), location (London v elsewhere) primarily for the use of specific modes and in some cases a sensitivity to distance (over and above the impacts of cost and time).

There are some scenario interventions where adjustments to these ASCs would be appropriate. This would not have any direct impact on the actual travel costs and times within the model, but would alter how a mode was perceived. An example of where this might be appropriate includes cycle policy affecting the perception of safety / convenience of the mode for specific segments of the population. RAND Europe recommend that:

- Any adjustment is specified in terms of equivalent minutes of in-vehicle time, allowing the mode specific constant values be remain unchanged; and

- That tests are made to check that the resulting changes in mode share are plausible, and if necessary, the numbers of reduced/additional in-vehicle time minutes are adjusted in light of the tests.

The full set of ASCs coded in the VDM are set provided in the Developer Guide and the User Guidance provides more information on their adjustment.

Similarly, the calibrated parameters applied to the monetary terms might be modified to reflect changing perceptions for particular groups of travellers (children / elderly). These parameters would have no impact on the actual money costs incurred in the model and reported but would change perception of them within the utility function and hence impact on behaviour. Again, care and sensitivity testing would be required.

Part 3: NTMv5 Performance

This part of the document provides evidence of the performance of the model, including records of highway calibration, realism tests and sensitivity tests. The sections cover:

- Chapter 12: model standards applied for calibration and validation;
- Chapter 13: the demand model estimation and validation process, including realism tests;
- Chapter 14: highway model validation; and
- Chapter 15: Sensitivity tests carried out on the full model.

12. Model standards

12.1. Introduction

This section of the Quality Report sets out the target standards and acceptability guidelines adopted for the calibration and validation of NTMv5. The starting point for the model standards for NTMv5 were those set out in TAG for demand modelling in Unit M2 and for highway assignment modelling in unit M3.1. TAG is however written primarily for modelling in support of scheme appraisal, urban and regional studies rather than a national transport model. Not all aspects of the standards are as applicable for national scale models, though the range of measures considered is the same.

12.2. Demand model standards

DfT's Transport Appraisal Guidance (TAG) notes how challenging it can be to obtain sufficient "local" data to calibrate parameters for mode and destination choice models that both reflect the observed patterns: mode shares and trip length distributions for trips in the Base Year and provide the correct elasticity of response to changes in travel costs and times when used for forecasting. However, it is preferable to estimate model structures and parameters where there is sufficient data available to do so. A national model is quite different to the local models providing illustrative parameters in the TAG M2 guidance, including a more detailed representation of long-distance trips (above 50 miles) and hence estimating the parameters was highly desirable. Following this approach, the most important model standards by which the performance of the model could be gauged were:

- How well the modelled mode share and trip length distributions match the observed data in the base year;
- Comparison of the estimated values of time with those set out in the TAG databook; and
- Sensitivity of the model to changes in cost and time for specific modes of travel (elasticities).

Validation of mode shares and trip lengths is presented in Section 13.4. The elasticities relating to cost changes for car fuel and public transport fares have specific standards set out in the guidance which were agreed as appropriate for the NTMv5 as set out in Section 13.5.

12.3. HAM validation criteria and acceptability guidelines

The applicability of the standard HAM validation criteria, set out in TAG unit M3.1 for modelling highway schemes, was discussed with the DfT. Given the very large scale of the model and strategic nature of the movements being captured, it was not considered that full adherence to TAG criteria would necessarily be possible or appropriate for the NTMv5 HAM. For this reason, specific criteria were agreed. These are outlined with further commentary in the following sections.

It was further agreed that in considering any shortfall in the performance against these criteria, the DfT would consider:

- whether the validation of the model is sufficient to meet the use cases (see Chapter 2);
- the extent to which the condition(s) have not been met;
- whether there is strong evidence that a further calibration would make sufficient improvement to be worthwhile.

An iterative approach to model calibration was agreed with the DfT, with a maximum of four iterations of HAM calibration/validation to be carried out (see Chapter 14).

12.4. Trip matrix validation

For trip matrix validation, the percentage difference between modelled flows and counts is monitored. Comparisons at screenline level provides information on the quality of the trip matrices. Table 12.1 sets out the standards used for validation in NTMv5, and as set out in TAG Unit M3.1 (January 2014).

Table 12.1 - Screenline flow validation criterion and acceptability guideline

	Criteria	Acceptability Guideline
NTMv5	Differences between modelled flows and counts should be less than 10% of the counts.	>80% of all screenlines.
TAG	Differences between modelled flows and counts should be less than 5% of the counts.	All or nearly all screenlines.

TAG goes on to say that regarding screenline validation, the following should be noted:

- screenlines should normally be made up of five links or more;
- the comparisons for screenlines containing high flow routes such as motorways should be presented both including and excluding such routes;
- the comparisons should be presented separately for:
  - roadside interview screenlines where they exist;
  - the other screenlines (made up of ATC for example) used as constraints in matrix estimation (excluding the roadside interview screenlines even though they have been used as constraints in matrix estimation); and
  - screenlines used for independent validation;
- the comparisons should be presented by vehicle type (preferably cars, light goods vehicles and other goods vehicles); and
- the comparisons should be presented separately for each modelled period.

12.5. Link flow validation

Two measures are used for individual link validation: flow difference and GEH. The flow measure is based on the relative flow difference between modelled flows and observed counts, with three different criteria set depending on the scale of observed flows.

The GEH measure uses the GEH statistic as defined below:

$$GEH = \sqrt{\frac{(M-C)^2}{(M+C)/2}}$$

Where: GEH is the GEH statistic;

M is the modelled flow; and

C is the observed flow.

Table 12.2 shows the link flow validation criteria and acceptability guidelines used for NTMv5, and as set out in TAG Unit M3.1 (January 2014).

Table 12.2 - Link Flow Validation criteria and acceptability guidelines

Criteria	Description of criteria	TAG acceptability guideline	NTM acceptability guideline
1	Individual flows within 100 veh/h of counts for flows less than 700 veh/hour	>85% of cases	>75% of cases
	Individual flows within 15% of counts for flows from 700 to 2,700 veh/hour	>85% of cases	>75% of cases
	Individual flows within 400 veh/h of counts for flows more than 2,700 veh/hour	>85% of cases	>75% of cases
2	GEH <5 for individual flows	>85% of cases	>75% of cases

Regarding flow validation, the following should be noted:

- The comparisons should be presented for cars and all vehicles but not for light and other goods vehicles unless sufficiently accurate link counts have been obtained;

- The comparisons should be presented separately for each modelled period; and
- It is recommended that comparisons using both measures are reported in the model validation report.

12.6. Journey time validation

Journey time validation is measured with the percentage difference between modelled and observed journey times, subject to an absolute maximum difference. Table 12.3 sets out the criteria and acceptability guidelines used in NTMv5, and as set out in TAG Unit M3.1 (January 2014).

Table 12.3 - Journey time validation criterion and acceptability guideline

	Criteria	Acceptability guideline
NTMv5	Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher than 15%)	>75% of routes
TAG	Modelled times along routes should be within 15% of surveyed times (or 1 minute, if higher than 15%)	>85% of routes

Regarding the journey time validation, the comparisons should be presented separately for each modelled period.

12.7. HAM convergence criteria and standards

To monitor the NTMv5 model convergence, the following Stability and Proximity measures were identified:

1. Proximity: The difference between the costs along the chosen routes and those along the minimum cost route, summed across the whole network, and expressed as a percentage of the minimum costs, usually known as the “Delta” or “%GAP”;
2. Stability (1): The percentage of links on which flows change by less than 1% between successive iterations, known as “P”; and
3. Stability (2): The percentage of links on which flow-weighted average costs change by less than 1% between successive iterations, known as “P2”.

NTMv5 directly uses the TAG guidance on convergence criteria. The advice on model convergence as set out in TAG Unit M3.1 (January 2014) is reproduced in Table 12.4.

Table 12.4 - Summary of convergence measures and base model acceptable values

Criteria	Acceptability Guideline
Delta and %GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Less than 0.1% or at least stable with convergence fully documented and all other criteria met	Four consecutive iterations greater than 98%
Percentage of links with flow change (P)<1%	Four consecutive iterations greater than 98%

PTV Visum reports a %GAP which is compliant with the TAG definition, and this has been used to monitor proximity. A %GAP of 0.0001% is used as a stopping criteria for the inner assignment iterations so that this is assured.

However, PTV Visum does not allow a standard measure or stopping criteria related to Stability as defined by TAG. For this reason, it was agreed with DfT that the link stability would be monitored via a manual process. This involves running the HAM first with a %GAP stopping criteria and noting the number of assignment iterations required. The model is then re-run for one less assignment iteration, and the difference in link flow between the penultimate and final assignment iteration thus calculated. This allows the stability measure to be calculated for the final iteration only. However, given that this is available by link, a detailed investigation of areas of instability is possible.

12.8. Impact of matrix estimation

TAG Unit M3.1 states that the changes brought about by Matrix Estimation (ME) should be carefully monitored by the following means:

- scatter plots of matrix zonal cell values, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R2 values);
- scatter plots of zonal trip ends, prior to and post matrix estimation, with regression statistics (slopes, intercepts and R2 values);
- trip length distributions, prior to and post matrix estimation, with means and standard deviations; and
- sector-to-sector level matrices, prior to and post matrix estimation, with absolute and percentage changes.

The changes introduced by the application of ME should be understood and may be assessed using TAG Unit M3.1 (January 2014), as shown in Section 14.6.

Table 12.5 - Significance of matrix estimation changes

Measure	Significance Criteria
Matrix zonal cell levels	Slope within 0.98<Slope<1.02 Intercept near zero R^2 in excess of 0.95
Intercept near zero	Slope within 0.99<Slope<1.01 Intercept near zero R^2 in excess of 0.98
R2 in excess of 0.95	Means within 5% Standard deviations within 5%
Matrix zonal trip ends	Differences with 5%

The unit states that it is important that the fidelity of the underlying trip matrices is not compromised to meet the validation standards. All exceptions to these criteria should be examined and assessed for their importance for the accuracy of the matrices in the Fully Modelled Area.

The comparisons should be presented by vehicle type (preferably cars, light goods vehicles and other goods vehicles). The comparisons should also be presented separately for each modelled period or hour.

13. Demand model estimation and validation

13.1. Introduction

As outlined in Chapter 10 the VDM structure and parameters were estimated using NTS travel diary data, land use indicators for trip attractions and utilities built up from the full VDM inputs, namely distance, time and toll skims from the HAM, plus parking charges and matrices of cost and time information for non-car trips derived as summarised in Chapter 7. This demand model estimation process is the calibration stage for the demand model where the structure and choice model parameters are derived to best match the observed data.

The independent validation of the resulting model is then completed by checking mode shares, trip length distributions and implied values of time; and carrying out the standard set of realism tests recommended by TAG unit M2. These validation steps were completed for:

- the sample of data used to estimate the VDM to confirm the estimation process had created a robust and valid model; and
- for the full model implementation to ensure the findings still held when applied to the full set of base year trip end information in the NTMv5 implementation.

This chapter provides the outcomes from the calibration (estimation) process in terms of the model structures and parameters obtained and presents the validation statistics and results from the realism tests.

13.2. Calibration: mode choice and distribution

13.2.1. Methodology

The principles and scale of the model estimation process were tested initially with very preliminary information from the HAM. A full model estimation was then undertaken using cost data developed from an interim HAM that was, at that stage, still to be subject to final calibration and validation, as is standard practice in sequencing model estimation. The network model was already in a well-developed state at this stage having been sourced initially from Highways England's Regional Traffic Models and then subjected to further systematic improvement to form a national model. The estimation enabled the VDM structure, segmentation and cost formulation to be determined.

The demand model estimation considered a wide range of variables and structures, all of which depend on one another. For efficiency a series of steps were defined for the estimation process, such that the outcomes of the later stages are dependent on the results from the earlier ones. The robustness of this approach was checked by some repetition of the steps to update parameters without repeating the experimentation to determine the segmentation and variables for inclusion.

The steps in the estimation process were as follows:

1. Determining attraction size variables to be included in the destination choice models;
2. Level of service specification and money cost specification to define the utilities of travel;
3. Identification of segmentation variables and destination constants;
4. Structural tests for relative sensitivity of mode and destination and testing for public transport and active mode nests.

A final set of parameters were to be estimated using the final calibrated and validated Base Year highway assignment model (HAM) model skims. The aim of this additional estimation phase was to improve confidence in future model performance by understanding the potential impact of using cost data from the fully calibrated/validated HAM on the model parameters. There was no expectation of revisiting the model structure tests and relevance of segmentation variables.

Due to the level of changes in the final HAM skims from those used in the model estimate, the HbW (commuting) model was re-estimated to assess the potential impact of the changes. The re-estimation process identified some changes in the cost and time parameters with little impact on the segmentation parameters. Given the scale of change observed in the coefficients, the effort involved and the performance of the initial models in the full implementation, it was concluded that re-estimating the choice models was not the priority at this time.

13.2.2. Estimated model parameters

This section provides the core mode-destination choice model parameters in terms of mode specific constants and time and cost coefficients which do not vary by demand segment (by definition). The distance parameters, where relevant for specific segments, are also shown in this section.

Mode specific constants

The choice model for each trip purposes includes a set of mode specific constants adjusting how each mode is perceived relative to the car driver mode. These mode specific constants apply to all traveller types and destination areas with the values shown in Table 13.1, in utility units.

Table 13.1 - Estimated mode specific constants (utility units)

Mode	HbW	HbEd	HbShopPB	HbRecV	HbHol	HbEB	NHbEB	NHbO
Car Driver	0	0	0	0	0	0	0	0
Car Passenger	-0.7859	-4.3815	0.7084	-1.6955	-0.8365	-2.2817	-3.6657	-0.5596
Bus	0.6035	-3.1491	2.9654	-0.9747	-1.2759	0.6751	0.7476	-7.6544
Rail	-1.2826	-5.5136	-0.1095	-4.9712	-3.3179	-2.5355	0.3841	-13.1362
Walk	1.5379	-2.0381	-0.9537	-0.8328	-4.8175	0.8369	-6.3602	0.4912
Cycle	-2.0259	-9.8098	-7.2465	-6.3210	-0.6562	-2.0311	-10.9706	-20.0045

Time, distance and cost coefficients

The estimated time, distance and cost coefficients to the utility functions for each trip purpose are shown in Table 13.2. It is noted that these coefficients are applied to return tour costs. As set out in Section 5.6 it was not possible to estimate a robust model with the log-linear cost sharing formulation and implied value of time. Hence the default TAG utility function was implemented with the value of time function and parameters as set out in Section 5.6. The remaining utility parameters were estimated in the same way as other trip purposes with the results shown in Table 13.2.

Values of the cost damping term, β were also tested starting from a value of 1 (no damping). From these tests it was concluded that a value of $\beta=0.3$ gave a significant improvement in fit relative to the initial value of 1 and furthermore reduced the fuel cost elasticity, which was the aim of introducing the cost damping. It should be noted that damping is only required for NHbEB as the log-linear cost formulation for the other purposes results in damped costs.

Table 13.2 - Time, cost and distance parameters by purpose

Matrix	Mode	Segments	HbW	HbEd	HbShopPB	HbRecV	HbHol	HbEB	NHbEB	NHbO
Time	Car Driver	All	-0.0379	-0.0821	-0.0506	-0.0438	-0.0220	-0.0204	N/A	-0.1171
	Car Pass	All	-0.0379	-0.0821	-0.0506	-0.0438	-0.0220	-0.0204	N/A	-0.1171
	Cycle	All	-0.0447	-0.0839	-0.0910	-0.0650	-0.0390	-0.0441	-0.0630	-0.0978
	Walk	All	-0.0349	-0.0441	-0.0466	-0.0417	-0.0169	-0.0339	-0.1127	-0.0952
Generalised Time	Bus	All	-0.0151	-0.0133	-0.0137	-0.0136	-0.0082	-0.0199	N/A	-0.0312
	Rail	All	-0.0105	-0.0194	-0.0136	-0.0067	-0.0043	-0.0033	N/A	-0.0163
	All non active modes	All							-3.4510	
Distance	Car Pass	All	-0.0163	-0.0117	0.0075	0	0	0	0.0056	0.0092
Car Distance	All	Age 65+	-0.0036	-	-	-	-	-0.0023		-
	All	Full time							0.0077	
	All	Part Time / Other	-0.0244	-	-	-	-	-0.0168		-
	All	Student		-0.0133	-	-	-	-		-
Linear Cost	All	All	-0.0017	-0.0029	-0.0019	-0.0027	-0.0012	-0.0003	N/A	-0.0043
Log Cost	All	All	0.1053	-0.7236	-1.2062	-0.3704	-0.1158	-0.2024	N/A	-0.4594
Car Cost Share	Car Driver	All	0.8977	0.8793	0.6998	0.7413	0.8666	0.9470	0.9747	0.7380
	Car Pass	All	0.4246	0.0847	0.3979	0.3744	0.3659	0.4259	0.4340	0.3642
Damping	All non active modes								0.3	

13.3. Validation: estimated values of time

The form of the utility function used for the VDM and the model estimation approach described previously, means that the values of time are implied by the relationship between the estimated cost and time parameters for each trip purpose which varies according to the cost of the trip.

The exception is for non-home-based employer's business trips where a robust model could not be estimated, and the value of time was an input using the distance function provided in the TAG databook (version 1.9.1. December 2019) as set out in Section 5.6.

The resulting values of time at the median cost of each modal person trip are shown in Table 13.3 compared with the average (all mode) perceived values of time provided in the TAG databook.

Table 13.3 – Implied values of time (£/hr) at median trip cost by mode (2015 prices and values)

Trip purpose	TAG A1.3.1	Car driver	Rail	Bus
Hb work	11.47	10.50	3.24	4.63
Hb employer's business	18.66	21.83	4.77	16.66
Hb education	5.23	6.58	2.49	1.78
Hb shopping and personal business	5.23	3.63	1.68	1.75
Hb recreation, social and visiting friends	5.23	5.27	1.11	2.26
Hb holiday and day trip	5.23	8.26	1.92	3.59
NHb Other	5.23	7.39	1.49	2.97

Source: TAG databook A1.3.1 (version 1.9.1 December 2017)

The values of time for car driver compare reasonably well against the TAG databook values particularly for commuting and recreation trips. The high values for holiday and the lower values for shopping are consistent with the average trip length of these purposes being different from the average "other" purpose for which the TAG values are provided.

The VoTs for public transport are consistently lower than the TAG all mode values. There are a number of reasons for this, including the fact that the cost per km for car trips is typically lower than that for PT trips. A weighted journey time in the model estimation for public transport, which applies weights for the wait and access stages of the journeys which are not included for car travel times.

In addition, it should be noted that the rail generalised time parameters are much lower in magnitude than the car time parameters. This may relate to the longer trip lengths associated with rail travel, though further research would be required to understand whether this relates to how people spend their time when travelling or the representation of utility using a linear time term.

The lower Bus VoTs may relate to the income profiles of those using bus being lower on average than those using other modes, though again further research would be required to better understand the results.

13.4. Validation: mode and destination choice

13.4.1. Mode shares

Two sets of validation checks were carried out on the modelled mode shares: first using the estimation data sample against the observations for that sample (ie how well the estimated model matches the observed data) and secondly when applying the estimated model to the full set of trip ends implemented in the NTMv5 Base Year. These shares are titled 'NTS' for observed, 'Sample' for predicted when applied to the estimation sample and 'Full' when applied to the full set of trip ends in the tables below.

This stepwise approach demonstrates that the model estimation process has produced models that match the mode shares well in the sample of data used and then that these models when applied to the synthesised trip ends, still gives a good match to the expected behaviour for each trip purpose.

The results of these comparisons are presented in Table 13.4 and Table 13.5 for the trip purposes. This shows that for home-based trip purposes the modelled mode shares generally match the NTS sample well with the full results being a similar proximity to the observed NTS as the sample results.

For non-home-based trips the challenges with the level of spatial detail in the estimated model has led to slightly larger differences for some modes, driven in part by differences for the very short (primarily walk) trips.

Table 13.4 – Comparison of modelled and observed mode shares by purpose (HbW, HbEd, HbShopP, HbRecV)

Mode	HBW			HBEd			HbShopPB			HbRecV		
	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full
Car Driver	60.7%	64.0%	63.6%	22.2%	21.6%	19.5%	41.9%	43.8%	43.5%	40.9%	43.5%	40.4%
Car Passenger	9.4%	7.9%	7.1%	25.9%	27.0%	23.6%	23.4%	24.7%	21.3%	30.3%	30.8%	29.4%
Bus	7.3%	6.6%	6.8%	10.4%	9.6%	10.9%	9.3%	8.2%	8.7%	6.6%	5.9%	6.8%
Rail	9.3%	9.2%	9.4%	1.9%	1.7%	2.0%	1.3%	1.0%	1.0%	2.7%	2.1%	2.5%
Cycle	3.7%	3.5%	3.3%	1.5%	1.3%	1.1%	1.0%	0.9%	0.9%	1.7%	1.5%	1.6%
Walk	9.7%	8.9%	9.7%	38.1%	38.7%	43.0%	23.1%	21.5%	24.6%	17.9%	16.2%	19.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 13.5 – Comparison of modelled and observed mode shares by purpose (HbHol, HbEB, NHbEB, NHbO)

Mode	HbHol			HbEB			NHbEB			NHbO		
	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full
Car Driver	46.7%	48.9%	45.3%	70.9%	74.2%	73.0%	71.3%	67.2%	66.8%	45.5%	47.1%	41.0%
Car Passenger	35.5%	35.8%	36.5%	7.0%	5.6%	5.7%	8.5%	10.5%	6.6%	25.2%	25.1%	19.9%
Bus	4.2%	3.4%	3.9%	4.8%	4.0%	4.4%	3.1%	3.7%	4.0%	4.6%	4.2%	4.3%
Rail	5.0%	4.1%	4.7%	10.8%	10.4%	9.7%	5.3%	5.8%	5.0%	2.8%	2.5%	2.1%
Cycle	8.5%	7.8%	9.5%	1.6%	1.5%	1.8%	1.0%	1.0%	1.1%	0.9%	0.8%	0.8%
Walk	0.0%	0.1%	0.1%	5.0%	4.3%	5.4%	10.8%	11.7%	16.4%	21.0%	20.2%	31.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 13.6 – Comparison of modelled and observed average modal trip lengths (kms) by purpose (HbW, HbEd, HbShopP, HbRecV)

	HBW			HBEd			HbShopPB			HbRecV		
Mode	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full
Car Driver	15.5	17.7	17.3	5.6	5.7	6.2	7.8	7.7	8.1	13.7	13.5	13.5
Car Passenger	11.9	12.7	12.9	5.4	5.8	6.4	9.1	9.5	9.9	15.4	15.6	15.4
Bus	8.6	8.1	7.7	7.4	6.0	6.1	6.2	5.6	5.6	8.7	6.4	6.3
Rail	27.3	30.8	35.7	20.2	31.4	32.7	24.1	24.4	24.7	46.2	37.8	40.4
Cycle	5.5	6.6	5.0	2.4	4.2	3.0	2.6	3.9	2.8	3.4	4.8	3.6
Walk	1.5	3.1	1.8	1.0	2.9	1.5	1.0	2.8	1.5	1.2	2.8	1.6
All modes	14.0	16.2	16.2	4.2	5.1	4.7	6.6	7.1	6.8	12.3	12.4	11.8

Table 13.7 – Comparison of modelled and observed average modal trip lengths (kms) by purpose (HbHol, HbEB, NHbEB, NHbO)

	HbHol			HbEB			NHbEB			NHbO		
Mode	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full	NTS	Sample	Full
Car Driver	32.0	35.9	35.4	36.8	36.6	32.3	23.0	23.7	19.9	12.1	15.4	9.7
Car Passenger	59.8	43.6	42.4	37.9	37.9	33.1	27.4	28.5	46.5	14.1	17.6	11.9
Bus	51.0	14.5	14.3	8.5	8.4	7.6	5.5	18.1	5.3	8.7	11.3	6.0
Rail	105.1	67.0	73.7	80.4	63.7	61.1	38.1	54.7	50.8	29.8	31.1	39.0
Cycle	7.9	7.5	6.1	5.2	6.5	4.9	4.8	12.2	3.8	4.8	10.2	4.6
Walk	2.1	5.4	3.8	1.2	3.1	1.9	1.0	11.0	1.9	1.0	9.7	1.3
All modes	44.3	37.0	36.1	37.9	36.5	31.9	21.1	24.2	19.5	10.5	15.0	7.9

13.4.2. Trip lengths

Average trip length

The validation of average trip lengths was completed as for mode shares looking initially at the estimation sample data, then at the full Base Year model implementation. The results from this process are shown in Table 13.6 and Table 13.7.

The trip lengths shown are the distances for a single leg trip (from home). The NTS observed data is based on the self-reported distances recorded in the travel diaries. The distances for the sample of trips is all from the highway model skims, whereas the distances for the full model are mode specific.

As for mode shares, the non-home-based trips have some the largest discrepancies particularly where the observed distances are very short. The differences for holiday trips are due to the consistency of the sample NTS data with the bus skims available that reduced the number of long distance bus trips being considered. For the majority of trip purposes and modes, the modelled results for both the sample and full model compare well with the NTS data demonstrating that the estimated distribution models have appropriate average trip lengths that are not altered significantly when implemented in the full model.

Trip length distributions

Trip length distributions (profiles) were generated for the NTMv5 Base Year run of the VDM on the full set of trip ends, comparing the modelled trips in distance bands (using the model distance skims by mode) with the proportion of NTS trips by distance band. The results for commuting are shown in Figure 13.1 while the results for all purpose and mode combinations are provided in Appendix A.

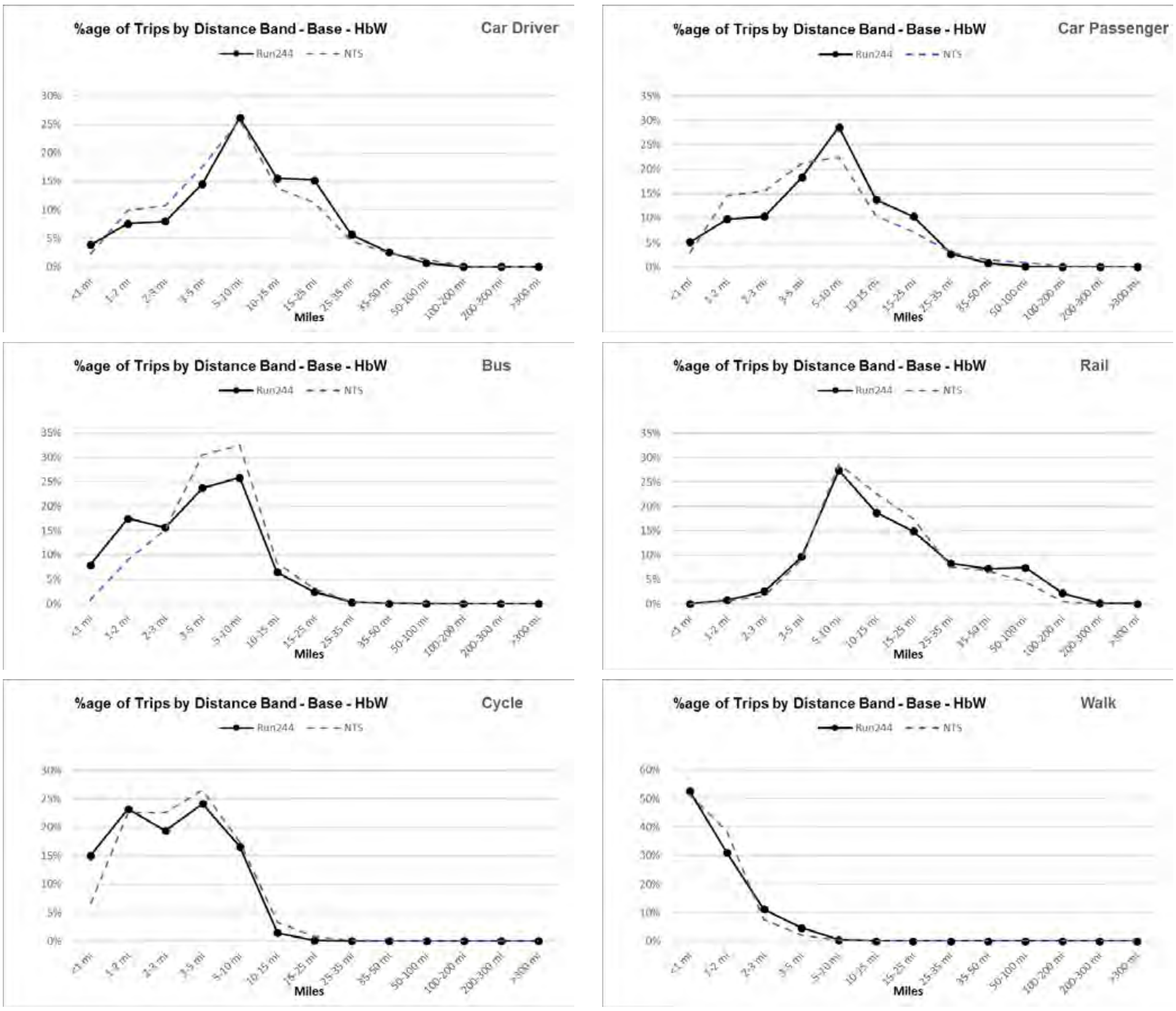


Figure 13.1 - Trip length distributions by mode for Hb Work trips versus NTS

The trip length distributions show that the model underestimates the volumes of car trips at the shortest distance bands, up to 5 miles for car driver and passenger trips for most purposes and overestimates the mid distance trips of 10 to 35 miles. Similarly, for most trip purposes, bus trips are over estimated in the very short distances up to 2 miles and under estimated for trips between 2 and 10 miles. Rail travel has a very different trip profile which is generally picked up by the model although there are generally more longer trips than the NTS suggests and fewer of the shorter trips. Walk and cycle trips naturally drop off very quickly with distance which is reflected in the model.

13.5. Validation: realism tests

13.5.1. Realism testing

The standard realism tests as defined in TAG unit M2 were then carried out varying fuel costs, public transport fares and highway journey times respectively. Two sets of realism tests were carried out to confirm the VDM performance. An initial set of realism tests were carried out as a final stage in the estimation process using the sample of NTS data used for the estimation, to confirm the selected and estimated parameters as described in Section 13.2 led to the desired level of responsiveness in the resulting model. These tests by definition are first order demand responses at the daily P/A level only.

The realism tests were then run using the implemented NTMv5 VDM and, where appropriate, iterated with the HAM to include responses due to changes in congestion.

The elasticity results obtained from these realisms tests are reported in this section to measure the performance against the expected responses set out in the Department's Transport Analysis Guidance (TAG unit M2). The estimation sample included only residents in England and hence results are presented for the full matrix. The NTMv5 model also includes trips from and to the external area. For P/A trip elasticities these are presented for trip productions in the internal model area.

13.5.2. Fuel cost realism test

Introduction

The fuel cost test has been implemented by increasing the fuel costs by 10%. In the full model this impacted on route choice in the HAM for all vehicle types including LGVs and HGVs; and mode and destination choice in the VDM for personal trips. The estimated model is looking only at the mode-destination choice impacts.

TAG unit M2 sets out the expected elasticity responses of a fuel cost realism test measured in terms of trip kilometres and states the following results:

- the annual average fuel cost elasticity should lie within the range -0.25 to -0.35 (overall, across all purposes);
- the annual average fuel cost elasticity should lie on the right side of -0.3, taking account of the levels of income and average trip lengths prevailing in the modelled area;
- the pattern of annual average elasticities shows values for employers' business trips near to -0.1, for discretionary trips near to -0.4, and for commuting and education somewhere near the average;

For NTMv5, an additional criterion was specified for the car passenger elasticities, based on the approach taken for NTMv2R. It is expected that the occupancies would increase when fuel costs increase, and that the elasticity would be weaker than -0.3 (for car drivers).

It should perhaps be noted that the elasticity values stated are normally used for local models, where there are typically few very long trips, and those that exist will have an external trip end and therefore only partial response. NTMv5 is different in nature as virtually all long trips are internal and have a full response. However, no separate guidance or analysis is available to help consider what response may be expected on this basis.

Daily P/A trip kilometre elasticities

Table 13.8 presents the car driver and passenger trip kilometre elasticities from estimated sample model and the full VDM for weekday trips by purpose. This compares the results from a single pass of the VDM with an iterated model run where changes in congestion are fed back through 4 iterations. As would be expected, the latter gives a lower overall elasticity and is the relevant statistic for validating the response. The overall elasticity for the unweighted sample of data is slightly outside the TAG suggested range but does not take into account the congestion feedback impacts. These reduce the elasticity as expected as seen in the full NTMv5 elasticity results, which do lie very close to the suggested TAG overall car vehicle elasticity.

The variations by purpose in both elasticity runs are reasonable and in line with the guidance. Discretionary purposes are close to -0.4, and HbW and HbEd are close to the average. HbEB is just positive in the full iterated model but not in the demand only test using the estimation sample data. The higher value of time for these trips means they are less responsive to the money cost increases and take advantage of small reductions in car traffic and congestion on the network. This was confirmed looking at the NTMv5 elasticities iteration by iteration, which showed the initial HbEB response gave a slightly negative elasticity that became positive once congestion feedback had an impact.

Table 13.8 - Car driver and passenger trip km elasticities by purpose

	Model estimation sample (no congestion feedback)		Full NTMv5 (with congestion feedback)	
Trip purpose	Car driver	Car passenger	Car driver	Car passenger
HbW	-0.43	-0.03	-0.28	0.05
HbEd	-0.39	-0.26	-0.41	-0.20
HbShopPB	-0.44	-0.46	-0.43	-0.42
HbRecV	-0.47	-0.28	-0.40	-0.22
HbHol	-0.51	-0.17	-0.39	-0.07
HbEB	-0.13	0.05	0.02	0.10
NhbEB	-0.16	0.08	-0.17	0.17
NhbO	-0.19	0.01	-0.25	-0.15
Total	-0.37	-0.22	-0.28	-0.19

Car passenger has a mixture of negative and positive elasticities. The positive elasticities are for the HbW, HbEB and NHbEB purposes which have the lowest occupancy and although the costs are shared between drivers and passengers, the drivers will be paying the majority of the costs for these trips.

The car driver elasticities were also analysed by purpose and car availability. As would be expected, the segments with lower car availability have higher elasticities, i.e. are more likely to reduce car travel in response to cost change. Overall full car available trips have an elasticity of -0.26 and those from no and partial car households combined have an elasticity of -0.34. Only very limited variation in elasticities by the Region of the trip productions was observed.

O-D Vehicle trip kilometre elasticities

Elasticities were also calculated from the full NTMv5 runs at the different model stages.

Table 13.9 shows the matrix-based car driver trip elasticities by assignment user class from the highway assignment model for each time period. As in the VDM, these show very slightly positive elasticities for the car driver business trips in the peak periods when congestion levels are higher, though not in the interpeak where non-home-based trips are more dominant and congestion lower.

Table 13.9 - O-D trip kilometre elasticities from highway assignment model matrices (all areas)

Assignment User Class	AM	IP	PM
Car driver (vehicle) business	0.004	-0.049	0.019
Car driver (vehicle) commuting	-0.370	-0.319	-0.345
Car driver (vehicle) other	-0.599	-0.684	-0.679
Total	-0.370	-0.544	-0.452

For commuting and other trip purposes the responses to the fuel cost increases are more elastic than observed in the VDM. The reasons for the higher elasticities from the HAM matrices was investigated further to understand the cause for these differences. The increased impact is due to differences between the VDM and HAM base year matrices being exaggerated during the pivoting process, particularly when looking at kilometres travelled in the longer distance bands. This arises because the HAM has more trips in these bands than the synthetic trip matrices; for example, the 100-200 mile length trips account for 0.6% of car driver trips in the Base Year HAM matrix, but only 0.1% of car driver trips in the VDM matrix.

The changes in vehicle kilometres, though large enough to affect the elasticity behaviour, account for a very small change in the profile of trips and vehicle kilometres overall. This illustrates the very high sensitivity of the vehicle kilometre results.

Network kilometre elasticities

The change in kilometres travelled on the links in the highway network (including intrazonals and connectors) were used to calculate network-based elasticities for car traffic and total traffic. These are shown in Table 13.10 for cars and total traffic for links within England. The total traffic elasticities include freight movements which have no demand response, purely a rerouting response and hence will be showing much lower elasticities and damp the overall level of impact.

Table 13.10 - Network kilometre fuel cost elasticities (England only)

Time Period	Car Km Elasticity	Total Veh Km Elasticity
AM	-0.37	-0.30
IP	-0.52	-0.40
PM	-0.45	-0.37

As expected, the network based elasticities are very similar to those found when using the trip matrices input to the HAM.

13.5.3. PT fares realism test

Introduction

The PT fares test has been carried out with an increase of 10% in the VDM. This is applied to the bus and rail fare matrices. NTMv5 was run for multiple iterations to take account of any congestion changes.

TAG unit M2 sets out the following expected elasticity results measured using person trips for a PT fares realism test:

- Elasticities should lie in the range -0.2 to -0.9;
- Discretionary purposes expected to have a stronger response than non-discretionary purposes; and
- Stronger response expected for trips with car available than those without a car available.

Daily P/A trip elasticities

The trip elasticities for bus, rail and PT overall are given in

Table 13.11 by purpose from the estimated sample model and from running the full NTMv5 for multiple iterations. As expected and observed for the fuel cost realism test, the elasticities from the full model run are lower than the first order demand only response from the estimation model on the sample data, with the exception of NHbEB trips where very similar elasticities are obtained.

Table 13.11 - PT, bus and rail fare trip elasticities by purpose

	Model estimation sample			Full NTMv5		
Trip Purpose	PT Trip Elasticity	Bus Trip Elasticity	Rail Trip Elasticity	PT Trip Elasticity	Bus Trip Elasticity	Rail Trip Elasticity
HbW	-0.65	-0.62	-0.67	-0.48	-0.61	-0.39
HbEd	-1.01	-1.00	-1.10	-0.84	-0.83	-0.90
HbShopPB	-1.31	-1.28	-1.50	-1.11	-1.09	-1.27
HbRecV	-1.08	-0.99	-1.34	-0.86	-0.78	-1.08
HbHol	-0.87	-0.80	-0.93	-0.82	-0.74	-0.89
HbEB	-0.44	-0.20	-0.53	-0.33	-0.14	-0.42
NHbEB	-0.52	-0.47	-0.55	-0.56	-0.46	-0.65
NHbO	-0.31	-0.32	-0.31	-0.25	-0.23	-0.31
Total	-0.91	-0.96	-0.81	-0.73	-0.80	-0.58

These are broadly in line with the range set out in TAG, with an overall PT elasticity value of -0.73. The pattern of elasticities by purpose is in line with guidance, with the lowest elasticities being for non-discretionary purposes such as HbW and HbEB. Very few business trips use buses, which is likely to be contributing to the low elasticity being obtained.

The variation in elasticity by car availability was reviewed for the full model outputs. As expected this showed a strong response for the "full car available" (-0.82) segments than those with no or partial car availability (-0.68).

13.5.4. Journey time realism test

Introduction

The journey time realism test was carried out with an increase of 10% applied to the car time skims read into the VDM (both the estimated sample and the full model). This has an impact on both the time components of the utilities used in the choice models and the VOC calculation, as this is carried out using speeds derived from time and distance skims. This test is non-iterative, with the increase only applied once to the seed skims fed into the VDM.

TAG unit M2 states that the elasticity for a journey time realism test should be no stronger than -2.0, although for NTMv5, an additional criterion has been specified based on experience with NTMv2R, which is that the car passenger elasticities should be negative.

Daily P/A trip elasticities

The trip elasticities by purpose are shown below. These are all below -2.0 and the car passenger elasticities are negative. The elasticities are furthermore of a similar order of magnitude and relative size to those observed for NTMv2R, which provides some reassurance. The results are very similar for the estimation sample and full model since this test is not iterated. The differences seen are the result of refinements made to the HAM since the skims provided for VDM estimation and between the sample of trips and the full set of trip ends.

Table 13.12 - Car driver and passenger time trip elasticities by purpose

	Model estimation sample		Full NTMv5	
Trip Purpose	Car Driver	Car Passenger	Car Driver	Car Passenger
HbW	-0.34	-0.30	-0.35	-0.25
HbEd	-0.22	-0.47	-0.39	-0.50
HbShopPB	-0.17	-0.34	-0.23	-0.40
HbRecV	-0.16	-0.33	-0.22	-0.39
HbHol	-0.14	-0.36	-0.18	-0.39
HbEB	-0.26	-0.55	-0.26	-0.45
NHbEB	-0.12	-0.12	-0.20	-0.57
NHbO	-0.10	-0.15	-0.11	-0.16
Total	-0.21	-0.34	-0.26	-0.38

The variation in car driver and passenger trip elasticities by car availability was reviewed. For each trip purpose a stronger car driver response is obtained for no and partial car availability segments (-0.40) than those will full car availability (-0.18). The car passenger responses follow a very similar pattern.

Overall, there is little regional variation in trip elasticity, however London does stand out as being consistently more elastic than the other regions (-0.47 car drivers). This is plausible given the greater availability of other modes in this region compared to other regions.

14. Highway model validation

14.1. Introduction

The model calibration and validation methodologies followed standard practice and criteria set out in TAG and DMRB. With the agreed model scope and data availability, the calibration and validation was focused on the long distance movement on the strategic road network, and on areas relevant to the use cases set out in Section 2.1, with reduced modelling attention in urban areas and the centre of major towns.

The specific calibration and validation processes that were adopted following the principles set out by TAG, along with the conclusions from a series of technical discussions with DfT previously. The guidance and experience from the ongoing development of RTM's from Highways England was also reviewed, with relevant information drawn from those studies.

In line with TAG the role of calibration is to develop a model that is fit for purpose and does not produce misleading or biased traffic forecasts that are material in the context of the schemes or policies being tested. Any adjustments to the model intended to reduce the differences between the modelled and observed data should be regarded as calibration. Validation simply involves comparing modelled to observed data that is independent from that used in calibration.

This section summarises the main principles and overall approach adopted for highway model validation, the data used in the process, and results of model validation.

14.2. Highway calibration and validation approach

Preparatory work for the HAM calibration and validation included:

- Development of calibration dashboards allowing interrogation of the model results, and covering screenline and count performance, trip length distributions, network vehicle kilometres and sector-sector movements.
- Initial shaping of the BYM following comparison with count data and vehicle kilometres. This included broad screenline sector adjustments to the BYM, applied by time period at the Origin-Destination level (for later refinement as described below);
- Tests of Matrix Estimation processes in PTV Visum, which confirmed the Method of Least Squares ran successfully at the scale required for NTMv5.

Having completed these preliminary exercises, formal HAM Calibration and Validation commenced and was undertaken in four iterations. Reviews were undertaken after each iteration to determine the potential areas of improvement and agree next steps with the DfT.

The final results of iteration 4 form the agreed deliverable for HAM Calibration and Validation and define the base year HAM network and assignment matrices for NTMv5. It should also be noted that all adjustments to model Trip Ends will be adopted for the model VDM, which maintains close alignment between the assignment matrices and synthetic VDM matrices.

14.3. Highway calibration and validation data

Two sets of data were collated and used for the calibration and validation of the HAM: traffic count data on volumes of traffic at a wide range of locations and journey time data along a selection of routes through the network.

14.3.1. Traffic counts and screenlines

The primary source of the traffic count data was the TRADS database consistent with the data used in the RTMs. This was supplemented with further counts from the DfT counts database for 2015 with the complete set of traffic counts used for the HAM calibration shown in Figure 14.1. The blue count locations in the figure show counts which form screenlines or cordons. Screenlines and cordons that group count data by direction, have the benefit of capturing area to area movements and hence provide a good measure to assess the quality of the matrices and highway assignment. A summary of the count data collated and used in the NTMv5 calibration and validation is shown in Table 14.1.

Consideration was given to the separation into calibration and validation screenlines. However, it was agreed with the DfT during the process that this would be unhelpful given the size of the model and the need to maximise the use the available screenlines for calibration. Therefore, all screenlines were used for calibration and a separate set of individual link counts were used for flow validation, as reported in Section 14.11.

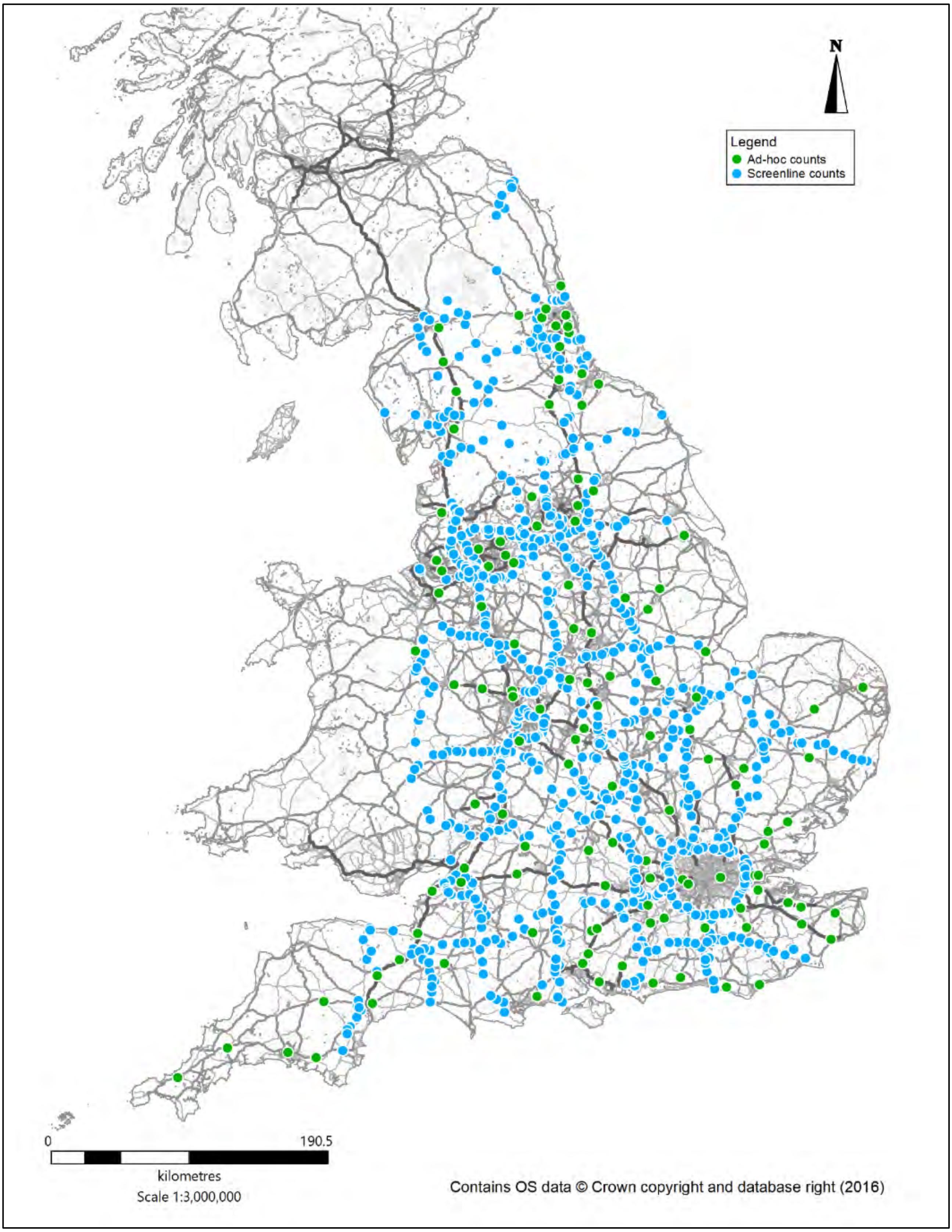


Figure 14.1 - NTMv5 count locations

Table 14.1 - RTM and DfT count data

Type of count	Number of Counts
Total RTM Counts collated	8,372
Total DfT Counts collated	34,017
NTM Screenline Counts Total	1,905
Of which RTM	1,867
Of which DfT	38
Ad hoc (all RTM) Counts	137

14.3.2. Journey times

Journey time routes were selected for validation in order to provide a suitable level of assurance over the quality of journey times in NTMv5. Routes were selected that are predominantly along the motorway and key A roads, mostly on the Highways England's Strategic Road Network (SRN) and did not traverse any urban area where the fixed speed approach is being applied. The extent of the routes was chosen so that journey durations were around 1 hour, commensurate with the modelled time period.

Following the main principles, 45 journey time routes were defined in England, including 27 A roads and 18 motorways. The total journey time route length for all routes combined is around 5,879 Kms, which is around 68% of the total road distance for all SRN roads. It is noted that some of the routes span over several regions, which need to be split into several sections. For example, the total distance for M1 is around 490 Kms. By using 100 km as the threshold, the route needs to be split into 5 sections.

In all, 101 journey time routes were identified and their median observed journey times recorded for comparison against modelled data. These routes are presented in Figure 14.2 and Table C.1 in Appendix C.

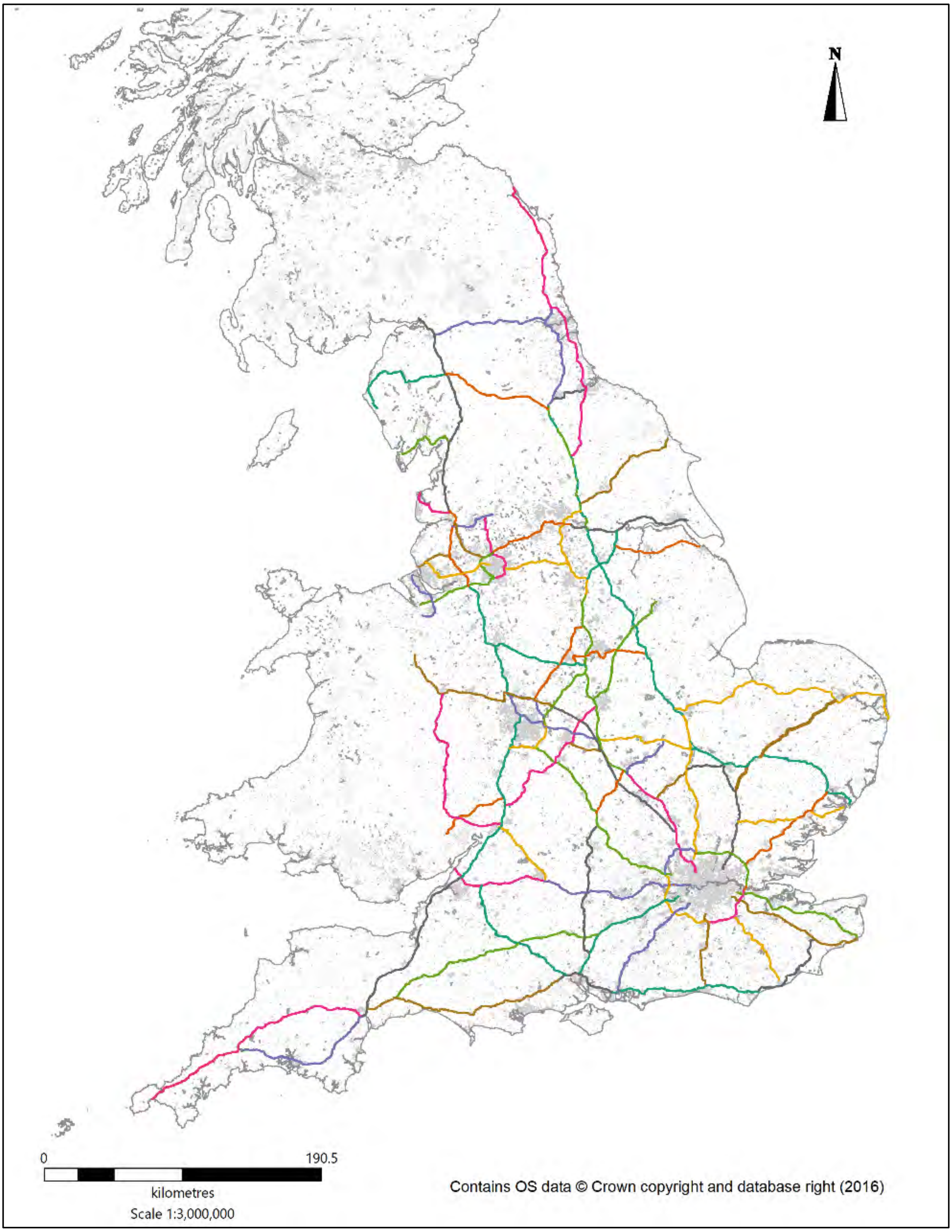


Figure 14.2 - Journey time routes

14.4. Network calibration and validation

The network calibration and validation process involved a continuous review of items on the network snagging list prioritising the revision of those features which impacted negatively on the model design and results. Checks of the coded attributes included a detailed review of the HGV restrictions and the coding of tolls on routes and for the London Congestion Charge.

Much of the work focused on reviewing the results of automated processes, for example the definition of centroid connectors. These automated processes were desirable from the consistency in approach introduced and essential to completing the network coding in reasonable timescales given the scale of the model. However, in some cases the resulting coding was not as desired and manual adjustments were made particularly relating to the centroid connector definitions and the to a lesser extent the classification of the link types when converting the networks from the source RTM models.

Other network calibration and validation checks included how the count data processed for calibration and validation, as set out in Section 14.3 compared with the network attributes, for example where counted traffic flows exceeded the capacity defined for the links. Routes through the network were also reviewed in uncongested (free-flow) and congested network conditions, to highlight any coding issues affecting routing, eg short diversions off and back on to motorways and major A-roads.

Following the enhancements and improvements to the HAM network during the four iterations the final HAM network is show in Figure 14.3.

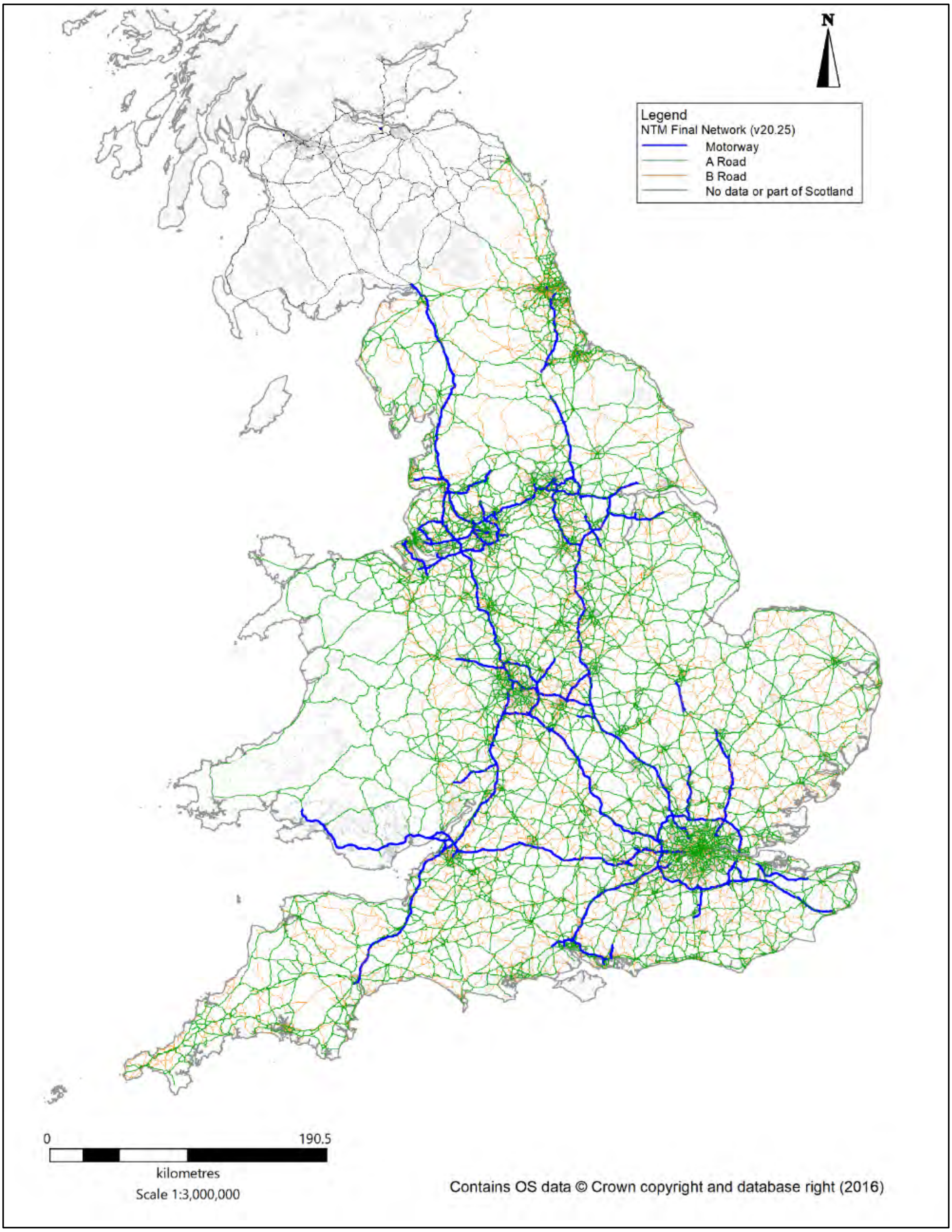


Figure 14.3 - Final NTMv5 Network Structure

14.5. Matrix calibration

14.5.1. Refinements to matrix build

The matrix build process was subject to a number of refinements as the model development progressed. Improvements included:

- Updating NTS data for consistency with other model inputs for the Base Year and the P/A to O-D process in the VDM.
- Adding a distance-based effect to the mode splitting process, including the LGV proportions, given that the length of the trip is likely to be correlated with departure time, whilst a higher proportion of longer trips are likely to be completed by van than short trips.
- Further adjustments were made by distance band to the 24hr P/A matrices for some purposes where the matrices initially built were not considered sufficiently close to the trip length profiles in the observed NTS data.
- HbW, HbEB and NHbEB all had a further occupancy increase of 2% to ensure that there was the correct level of traffic on the network. The level of variation in occupancies between the NTS, Census JTW and those in the TAG databook was sufficient to justify this level of change.
- Adjustments to the productions and attractions on the Isle of Wight to ensure that a reasonable number of trips cross to and from the mainline in a 24hr period and the remainder stay on the island.
- Sector-sector factors applied to the 24hr P/A matrices for car (and personal LGV), and the average hour O-D goods matrices, may be reflective of variations in time period splits, local trip rates as well as embedded travel patterns for historic reasons. These adjustments were primarily focussed on traffic levels to/from cities and between neighbouring sectors.
- HGV matrices were adjusted to account for variations in types of vehicle by area (effectively an adjustment to the PCU factors in the matrices supplied, eg rigid HGVs in urban areas).
- The TAG databook (December 2017) gives a split between personal and freight LGV trips of 88% goods vs 12% personal trips. In order to match this target, the proportion of personal LGVs sliced from the car matrices was increased by around 10%. This results in the same levels of traffic on the network as the number of car trips proportionally decreases but improves road km statistics.

14.5.2. Matrix estimation

As set out in the TAG unit M3.1 the main purpose of matrix estimation is to refine estimates of movements which have been synthesised (rather than derived from surveys) to bring them more in line with input (target) count data. For NTMv5, only the commute and education trip matrices have any underlying matrix (pattern) information. The other trip purposes are all synthetic and hence matrix estimation was expected to be required to better reflect the movements and traffic levels observed.

The count data used for the matrix estimation was the full set of screenlines defined by the counts shown previously in blue in Figure 14.1. These were broken down to shorter mini-screenlines as recommended by the guidance. Following extensive experimentation and agreement with DfT, the approach adopted also included individual link counts within the matrix estimation process. No constraints (targets) were set for the trip ends.

Further details on the matrix estimation functionality available in PTV Visum and the approach adopted can be found in Chapter 6 of the NTMv5 Developer Guide Volume 3.

14.6. Impact of matrix estimation

The four metrics from TAG unit M3.1 to measure the impact of matrix estimation as set out in section 12.8 have been reviewed. Although not specified by TAG it is also important to monitor the changes brought about by matrix estimation at the matrix total level.

The results of the matrix estimation process are set out in Appendix D for each of the required metrics, showing the impacts for light and heavy vehicles in each of the three modelled time periods. A summary of the impacts is provided in Table 14.2.

Table 14.2 – Summary of matrix estimation changes

Measure	Impact of matrix estimation
Matrix totals	Car and LGV trips reduced by less than 1.05% HGV trips increased between 4% and 6.5%
Matrix zonal cell levels • 0.98<Slope<1.02 • Intercept near zero • R^2 in excess of 0.9	Changes well within TAG criteria Slope between 0.9997 and 1.0000 Intercept between -0.0004 and 0.0001 R^2 values between 0.9906 and 0.9993
Matrix trip ends (origins) • 0.99<Slope<1.01 • Intercept near zero • R^2 in excess of 0.98	Light vehicles met criteria. HGVs accepted as close Slope between 0.99 and 1.00 for Lights, between 0.92 and 0.98 for HGV Lights intercept from 0.23 to 2.12. HGVs between 1.02 and 2.52 R^2 values between 0.99 and 1.00 for Lights, between 0.95 and 0.98 for HGVs
Matrix trip ends (destinations) • 0.99<Slope<1.01 • Intercept near zero • R^2 in excess of 0.98	Light vehicles met criteria. HGVs accepted as close Slope between 0.99 and 1.00 for Lights, between 0.94 and 0.99 for HGV Lights intercept from 0.23 to 3.77. HGVs between 0.89 and 1.02 R^2 values between 0.99 and 1.00 for Lights, between 0.96 and 0.98 for HGVs
Trip length distributions Means within 5% Standard deviations within 5%	Lights close to criteria, HGVs more change. Lights within -5.1%, HGVs within -17.3% Lights within -7.4% , HGVs within -18.7%
Matrix sector-sector trips Differences with 5%	A high proportion of sector to sector pairs change by more than 5%. Of the 676 sector pairs analysed over 50% have trip totals less than 100. When considering sector to sector pairs with significant flows the results improve and are considered acceptable.

The sparsity of the matrices was also reviewed and the impacts of matrix estimation on cells by scale of cell value reviewed to ensure the matrix estimation was not disproportionately scaling small cell values. The results of this analysis are presented in Section D.2 of Appendix D.

Where the changes in trip length distributions did not meet the TAG criteria additional analysis was carried out as presented in Section D.4 which confirmed the matrix estimation process was not overly distorting the matrices, though some trip lengths were more affected than others.

14.7. HAM calibration results

This section presents a summary of the results from the HAM calibration task presenting the modelled flows against the count data used in the matrix calibration (estimation) task. Figure 14.4 shows the locations of screenlines.

Mini-screenlines are subsets of screenlines, containing on average 14 count sites, therefore a single screenline can be made up of at least two mini-screenlines. In total, 1,901 counts were used in the calibration of the NTMv5 highway model, and are included in the results presented. The results show that the calibration criteria agreed with the DfT has been achieved in all time periods for each user class.

The link flow results were also check by Region, which showed that the flow or GEH criteria is satisfied in all regions expect for London in the inter-peak and PM peaks, which demonstrates that the NTMv5 model is calibrated to a consistent standard across the regions covered. The results by Region are provided in Appendix E.2.

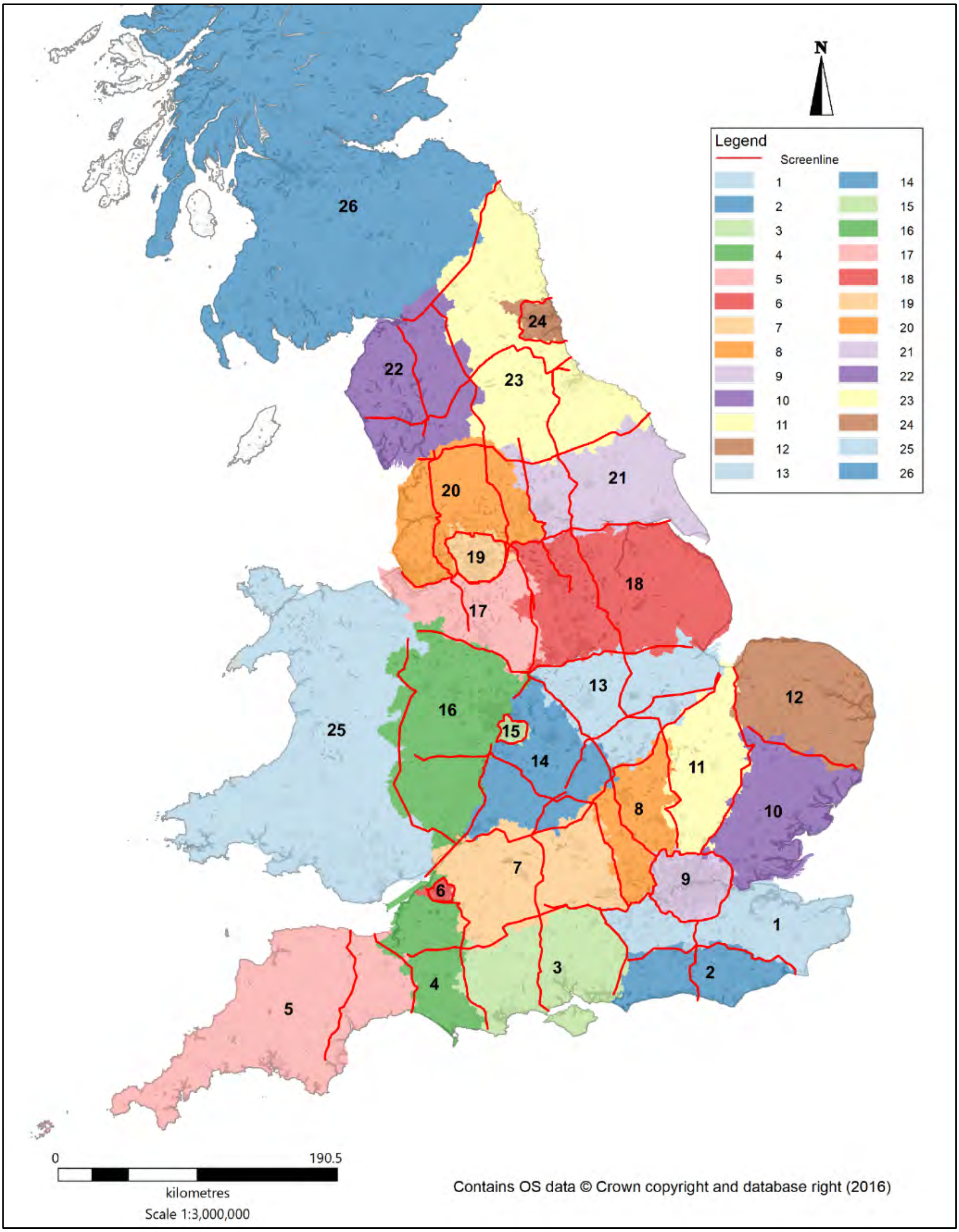


Figure 14.4 - Screenlines and sectors

Table 14.3 – Link and screenline calibration summary

Criteria		Time period	Lights	HGV	Total
Links (1901)	GEH (<5) or Flow Diff	AM	86%	99%	85%
		IP	92%	99%	90%
		PM	86%	97%	84%
Screenlines (68)	Flow Difference (5%)	AM	96%	96%	96%
		IP	97%	93%	97%
		PM	96%	90%	96%
Mini-Screenlines (134)	Flow Difference (5%)	AM	91%	89%	91%
		IP	89%	86%	90%
		PM	87%	83%	88%

14.8. Route choice calibration

An important part of the NTMv5 model development was the calibration of route choice in the model. Modelled routes were examined for an agreed series of origin to destination pairs and their paths checked to ensure these were both plausible and logical.

TAG M3-1 para 7.3.2 stipulates that the number of OD pairs, to be checked for routing, is:

Number of OD pairs = (number of zones)$^{0.25}$ x the number of user classes.

Given that the model contains ~7,000 zones and 5 user classes, this produces the requirement for 45 pairings of key locations to be checked. A list of OD pairs to check was agreed with DfT during network development. A full list is presented in Appendix F. Two complete checks have been carried out for these routes, one at the end of the network development, and one on completion of the HAM calibration.

In addition, informal checks were carried out on a selection of routes during the model calibration process. The final routing checks post-calibration are summarised in the table contained in Appendix F.

In the final checks, images were captured of the NTMv5 routing for both directions, identifying both light and heavy vehicle routes. These were checked for plausibility and compared with routes given by Google Maps for the relevant time period.

The Appendix F table shows that the majority of routes match well to the equivalent Google Map routes, across a range of locations and distances. For some routes, slight variations at either the route beginning, or end is noted due to variations in the existence of minor roads. Alternative routes are normally plausible, and frequently are also offered by Google as secondary routes.

The largest variation is noted around the metropolitan areas of London and Manchester. For certain routes (See Ref 2/3, 3/23 and 5/40, for examples), NTM tends to opt for smaller, local roads that pass through these urban areas, as opposed to using more plausible ring roads, such as the M25 or M60. For route Ref 2/3 this was found to be an issue in the AM, but not the IP and PM. This could indicate issues with the level of highway congestion in urban areas which may require monitoring in future model runs.

14.9. Journey time validation

The journey time validation compares the modelled travel times along specific routes with observed travel times for the same routes by direction and time period. For journey times specifically the acceptance criteria agreed with DfT as set out in Section 12.6 was that 75% of modelled journey times along routes should be within 15% of surveyed times (or 1 minutes, if higher than 15%) (TAG recommends 85% of routes).

Modelled journey times are compared against observed data for all time periods. Summaries of the overall modelled and observed journey time comparisons for each route are provided in Appendix G. The overall validation results are reported in Table 14.4 and Figure 14.5 below.

Table 14.4 - Frequency of routes within TAG criteria threshold

JT Difference	% difference from observed time										Pass
	<-100	-100 to -50	-50 to -25	-25 to -15	-15 to 0	0 to 15	15 to 25	25 to 50	50 to 100	>100	
AM Peak	0%	0%	0%	1%	25%	52%	16%	5%	0%	0%	**77%**
	0	0	1	2	50	105	33	10	1	0	**202**
IP Peak	0%	0%	0%	2%	30%	55%	9%	3%	0%	0%	**85%**
	0	0	0	5	60	111	19	7	0	0	**202**
PM Peak	0%	0%	0%	3%	22%	56%	12%	6%	0%	0%	**78%**
	0	0	1	6	45	113	25	12	0	0	**202**

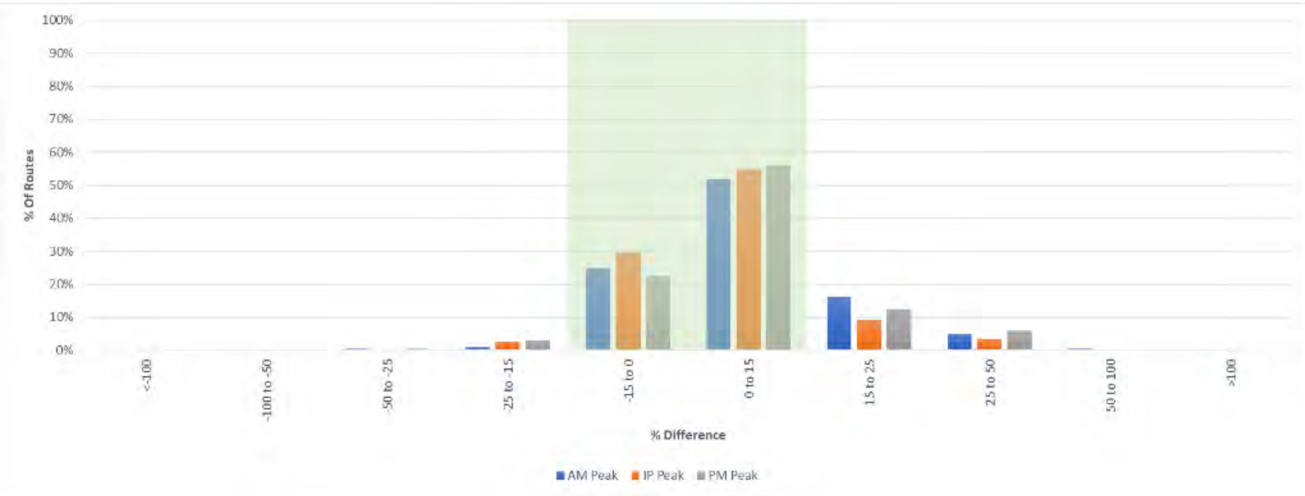


Figure 14.5 - Frequency of routes within TAG criteria threshold

In all time periods the TAG criteria have been achieved:

- In the AM peak 155 out of 202 routes (77%) satisfy the adapted TAG criteria;
- In the inter-peak 171 out of 202 routes (85%) satisfy the adapted TAG criteria; and
- In the PM peak 158 out of 202 routes (78%) satisfy the adapted TAG criteria.

The reported results demonstrate the NTMv5 HAM replicates observed journey times to acceptable standards.

14.10. Convergence

Both stability and proximity criteria are required to measure the convergence of the NTMv5 model, and, as outlines in Section 12.7, Table 14.5 summarises the criteria measured.

Table 14.5 - Summary of Convergence Measures and Base Model Acceptable Values

Criteria	Acceptability Guideline
Delta and %GAP (proximity)	Less than 0.1% or at least stable with convergence fully documented and all other criteria met
Percentage of links with flow change (P)<1% (stability)	Four consecutive iterations greater than 98%
Percentage of links with cost change (P2)<1% (stability)	Four consecutive iterations greater than 98%

The NTMv5 proximity convergence has been assessed using the PTV Visum definition of GAP which is compliant with the TAG criteria with a stopping target value of 0.0001%. As stated in Section 12.7, the standard measure of stability is not applied in PTV Visum therefore the link stability has been monitored manually. Stability has been assessed by rerunning the model for one less assignment iteration and the difference in link flow and cost between the penultimate and final assignment iteration calculated.

The convergence was checked at regular intervals during network development and calibration.

Table 14.6 - Convergence statistics

Criteria		AM	IP	PM
Delta and %GAP (<0.1%)	Car Business	0.007%	0.002%	0.007%
	Car Commute	0.010%	0.002%	0.011%
	Car Other	0.008%	0.004%	0.011%
	LGV	0.010%	0.004%	0.010%
	HGV	0.007%	0.003%	0.007%
Percentage of links with flow change (P) <1% for 98% of link		See below		
Percentage of links with cost change (P2) <1% for 98% of link		See below		

Table 14.6 shows that the NTMv5 model exceeds the required standards for %GAP by a comfortable margin. As a direct stability measure is not available in PTV Visum, it was agreed that monitoring of the changes in flows between the final two iterations would act as a proxy. Given that changes in link flows are not targeted by the assignment algorithm, it was thought possible that the criteria of 98% of links within 1% would not be met, and therefore it was further agreed that a sense-check should take place related to the absolute as well as percentage change.

The results have been collated in Table 14.8 to Table 14.10 below by percentage and absolute differences (rows and columns respectively), and Table 14.7 summarises the results. As can be seen, the proportion of links with <1% change in flow is in the range 95.5% to 97.2%, and therefore outside the TAG standards. However, if links with an absolute difference of less than 30 vehicles are included (dark green shading) the proportion in each case rises to 99.9% of links. Moreover, as can be seen in the detailed tables, in the majority of cases these links have a flow difference of <3%. More importantly, there are no links which have both a high percentage and absolute change.

It is therefore considered that the HAM is both converged both in the sense of %GAP and link stability. It is recommended that these statistics are checked for any major scenario tests which may alter highway convergence. The %GAP can be easily checked using run diagnostics, but the link stability will continue to require bespoke checks as below.

Table 14.7 - Summary of assignment link stability (10th Iteration – 9th Iteration)

	AM		IP		PM	
Category	# links	%age	# links	%age	# links	%age
<1% change	92,241	95.5%	93,891	97.2%	92,340	95.6%
<1% change or <30 Flow Diff	96,511	99.9%	96,556	99.9%	96,491	99.9%
>1% change, 30-100 Flow Diff	112	0.1%	67	0.1%	132	0.1%
1%-25% change, 100-500 Flow Diff	0	0.0%	0	0.0%	0	0.0%
25%+ change, 100-500 Flow Diff	0	0.0%	0	0.0%	0	0.0%
Total	**96,623**	**100.0%**	**96,623**	**100.0%**	**96,623**	**100.0%**

Table 14.8 - AM Assignment link stability (10th Iteration – 9th Iteration)

			Absolute Flow Difference									
	From	To	<30	<50	<80	<100	<200	<400	<500	> 500	Total	%age
%change in Link flow	0%	1%	92,235	6	0	0	0	0	0	0	92,241	95%
	1%	3%	3,142	39	5	0	0	0	0	0	3,186	3%
	3%	5%	416	17	6	0	0	0	0	0	439	0%
	5%	25%	268	27	12	0	0	0	0	0	307	0%
	25%	50%	39	5	0	0	0	0	0	0	44	0%
	50%	100%	112	0	0	0	0	0	0	0	112	0%
		100%	293	0	1	0	0	0	0	0	294	0%
	Total Count		96,505	94	24	0	0	0	0	0	96,623	100%
	%age of Total		99.88%	0.10%	0.02%	0%	0%	0%	0%	0%	100%	

Table 14.9 - IP Assignment link stability (10th Iteration – 9th Iteration)

			Absolute Flow Difference									
	From	To	<30	<50	<80	<100	<200	<400	<500	> 500	Total	%age
%change in Link flow	0%	1%	93,891	0	0	0	0	0	0	0	93,891	97%
	1%	3%	1,890	20	9	0	0	0	0	0	1,919	2%
	3%	5%	259	17	2	0	0	0	0	0	278	0%
	5%	25%	171	13	6	0	0	0	0	0	190	0%
	25%	50%	25	0	0	0	0	0	0	0	25	0%
	50%	100%	105	0	0	0	0	0	0	0	105	0%
		100%	215	0	0	0	0	0	0	0	215	0%
	Total Count		96,556	50	17	0	0	0	0	0	96,623	100%
	%age of Total		99.93%	0.05%	0.02%	0%	0%	0%	0%	0%	100%	

Table 14.10 - PM Assignment link stability (10th Iteration – 9th Iteration)

			Absolute Flow Difference									
	From	To	<30	<50	<80	<100	<200	<400	<500	> 500	Total	%age
%change in Link flow	0%	1%	92,336	4	0	0	0	0	0	0	92,340	96%
	1%	3%	3,071	73	1	0	0	0	0	0	3,145	3%
	3%	5%	367	25	3	0	0	0	0	0	395	0%
	5%	25%	260	17	6	0	0	0	0	0	283	0%
	25%	50%	33	5	0	0	0	0	0	0	38	0%
	50%	100%	148	1	0	0	0	0	0	0	149	0%
		100%	272	1	0	0	0	0	0	0	273	0%
	Total Count		96,487	126	10	0	0	0	0	0	96,623	100%
	%age of Total		99.86%	0.13%	0.01%	0%	0%	0%	0%		100%	

14.11. Assignment validation

14.11.1. Introduction

The NTMv5 model was validated by means of the following comparisons:

- Modelled and observed traffic flows on links, where ad-hoc count data not used in the matrix estimation process was available, compared for lights, HGVs and all vehicles by time period;
- Modelled and observed vehicle kilometres compared by road type, by region for lights, HGVs and all vehicles;
- Modelled and observed journey times along routes; and
- The level of model convergence.

As stated in Section 12, it was agreed with the DfT that adapted versions of TAG criteria should be adopted for NTMv5. For link flows it was agreed that 75% of modelled flows should meet the link flow criteria, whereas TAG recommends 85% of links should pass. No strict validation criteria were agreed for vehicle kilometres, but a comparison of modelled against reported vehicle kilometres is provided.

14.11.2. Flow Validation

The modelled and observed traffic flows on individual validation links have been compared against the acceptability criteria; Table 14.11 to Table 14.13 report the overall results, whilst Table 14.14 displays the results by region.

The validation statistics do not meet the usual standards stated for flow validation in the TAG guidance, an issue which was discussed with DfT during the process. It is believed that the use of isolated counts may make this type of comparison less relevant, and therefore plots were produced to compare the observed and modelled flows for each link, shown in Figure 14.6 to Figure 14.11. These show that the flows are certainly of the correct magnitudes, with an R-squared of around 80% in each case, and some improvement due to the matrix estimation.

Table 14.11 - Link Validation Summary; AM peak

% Pass		Lights	HGV	Total
Ad-Hoc Links (137)	Flow Difference	40%	80%	42%
	GEH (<5)	35%	73%	36%
	GEH (<7)	39%	79%	42%
	GEH (<5) or Flow Diff	50%	81%	48%

Table 14.12 - Link Validation Summary; Inter-peak

% Pass		Lights	HGV	Total
Ad-Hoc Links (137)	Flow Difference	91%	80%	56%
	GEH (<5)	56%	69%	52%
	GEH (<7)	66%	80%	65%
	GEH (<5) or Flow Diff	60%	80%	58%

Table 14.13 - Link Validation Summary; PM peak

% Pass		Lights	HGV	Total
Ad-Hoc Links (137)	Flow Difference	50%	85%	49%
	GEH (<5)	44%	73%	41%
	GEH (<7)	56%	82%	58%
	GEH (<5) or Flow Diff	50%	85%	49%

Table 14.14 - Regional Validation Summary; All vehicles

		NE	NW	Y&H	EM	WM	EoE	Lon	SE	SW
AM peak - % pass	Flow Difference	31%	36%	64%	36%	45%	50%	33%	41%	42%
	GEH (<5)	31%	27%	57%	21%	45%	50%	33%	37%	32%
	GEH (<7)	31%	36%	71%	43%	55%	57%	33%	56%	42%
	GEH (<5) or Flow Diff	31%	36%	64%	36%	45%	50%	33%	41%	42%
Inter-peak - % pass	Flow Difference	54%	36%	79%	57%	55%	71%	67%	59%	47%
	GEH (<5)	54%	36%	64%	57%	45%	57%	67%	52%	53%
	GEH (<7)	85%	45%	79%	64%	73%	86%	67%	59%	53%
	GEH (<5) or Flow Diff	62%	36%	79%	57%	55%	71%	67%	59%	53%
PM peak - % pass	Flow Difference	46%	45%	71%	57%	36%	50%	67%	52%	32%
	GEH (<5)	38%	41%	64%	43%	36%	43%	67%	33%	32%
	GEH (<7)	46%	50%	79%	79%	45%	50%	67%	63%	47%
	GEH (<5) or Flow Diff	46%	45%	71%	57%	36%	50%	67%	52%	32%

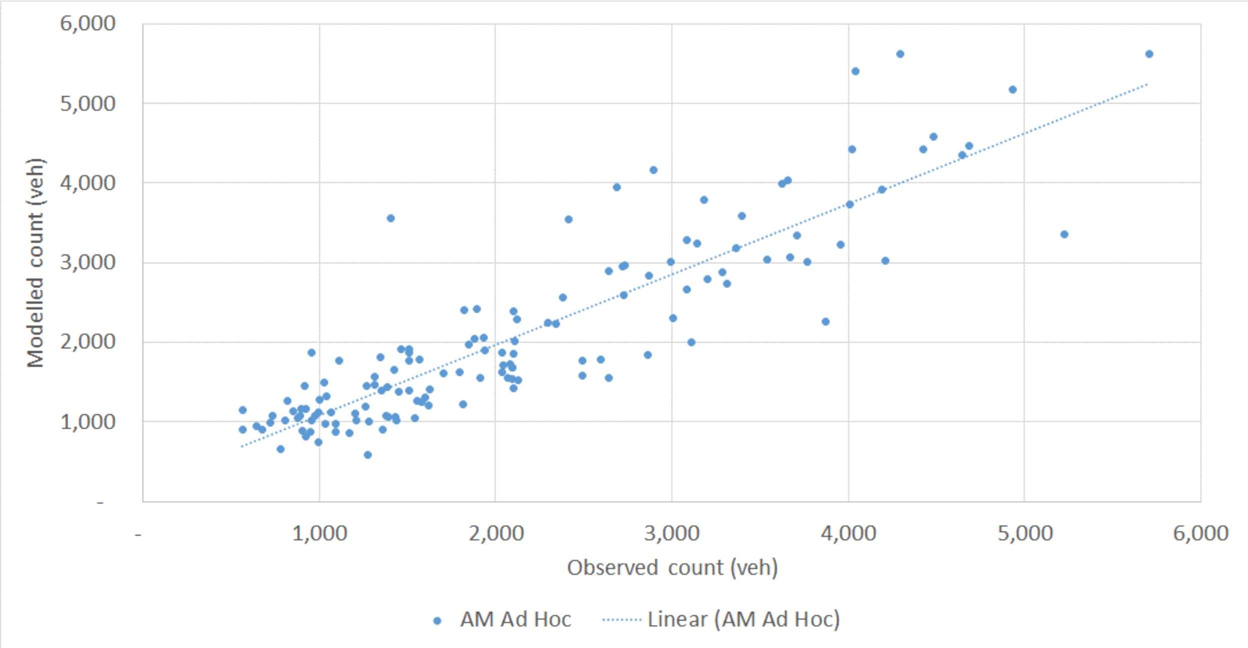


Figure 14.6 - Comparison of ad-hoc links, modelled vs observed; AM Total Vehicles - Prior-ME

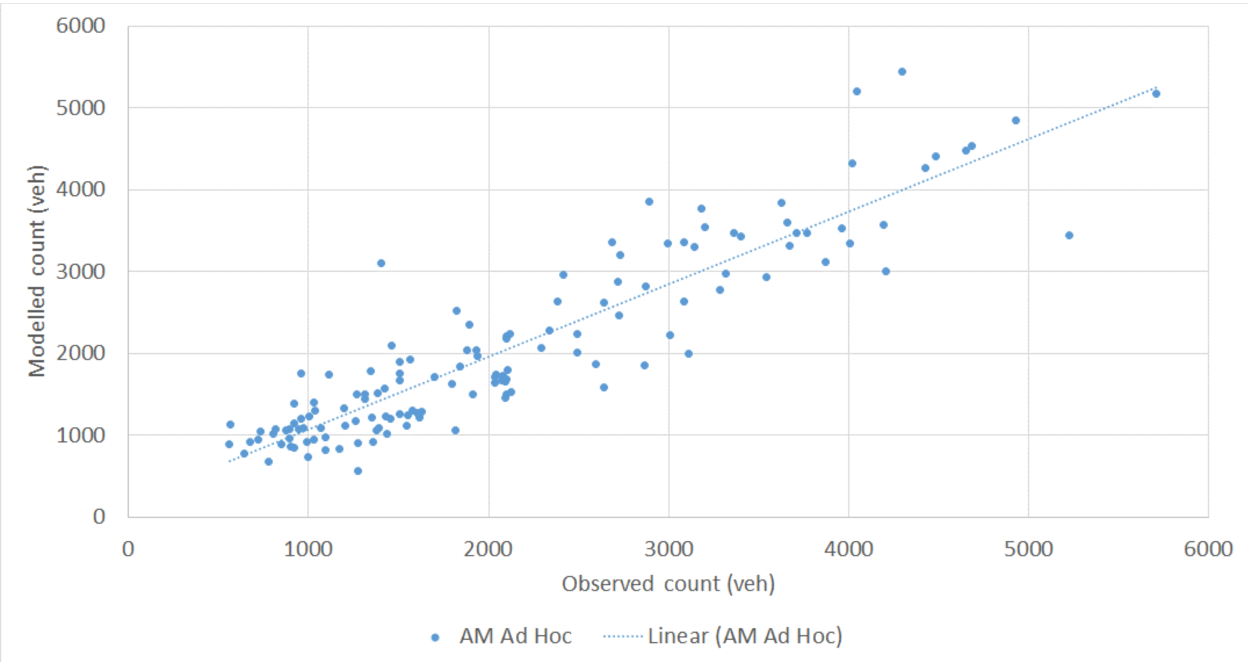


Figure 14.7 - Comparison of ad-hoc links, modelled vs observed; AM Total Vehicles - Post-ME

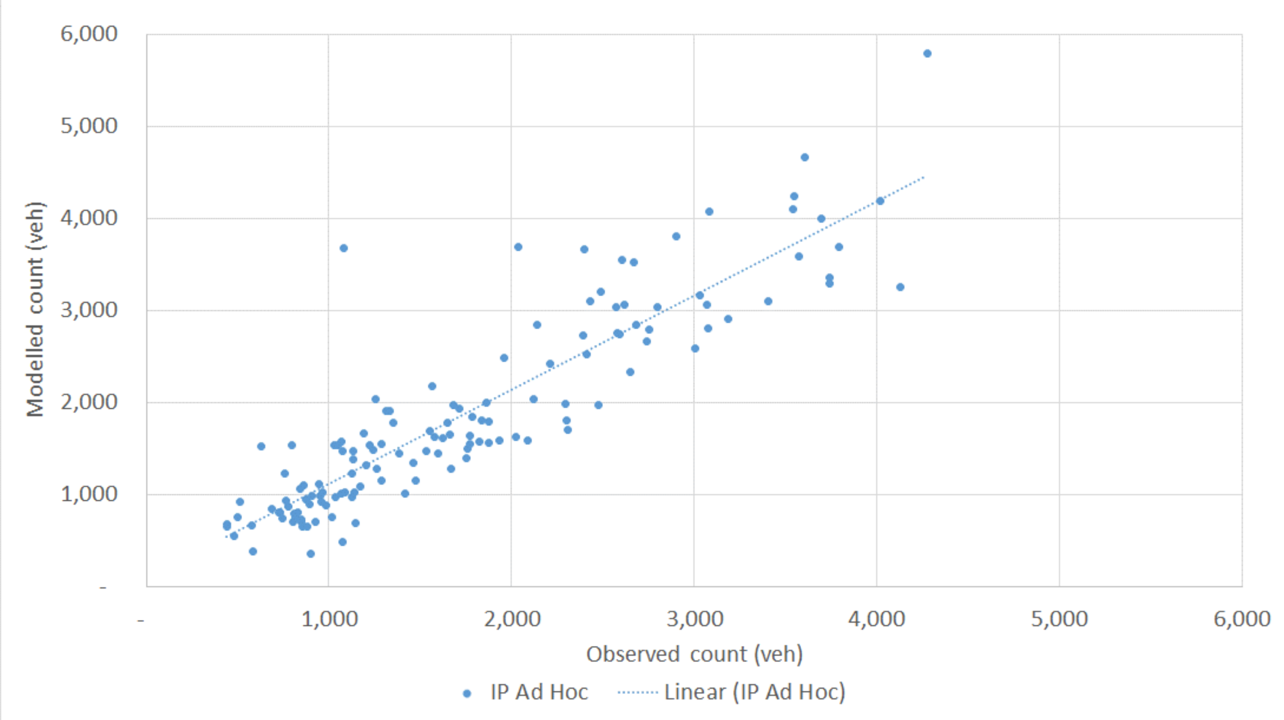


Figure 14.8 - Comparison of ad-hoc links, modelled vs observed; IP Total Vehicles - Prior-ME

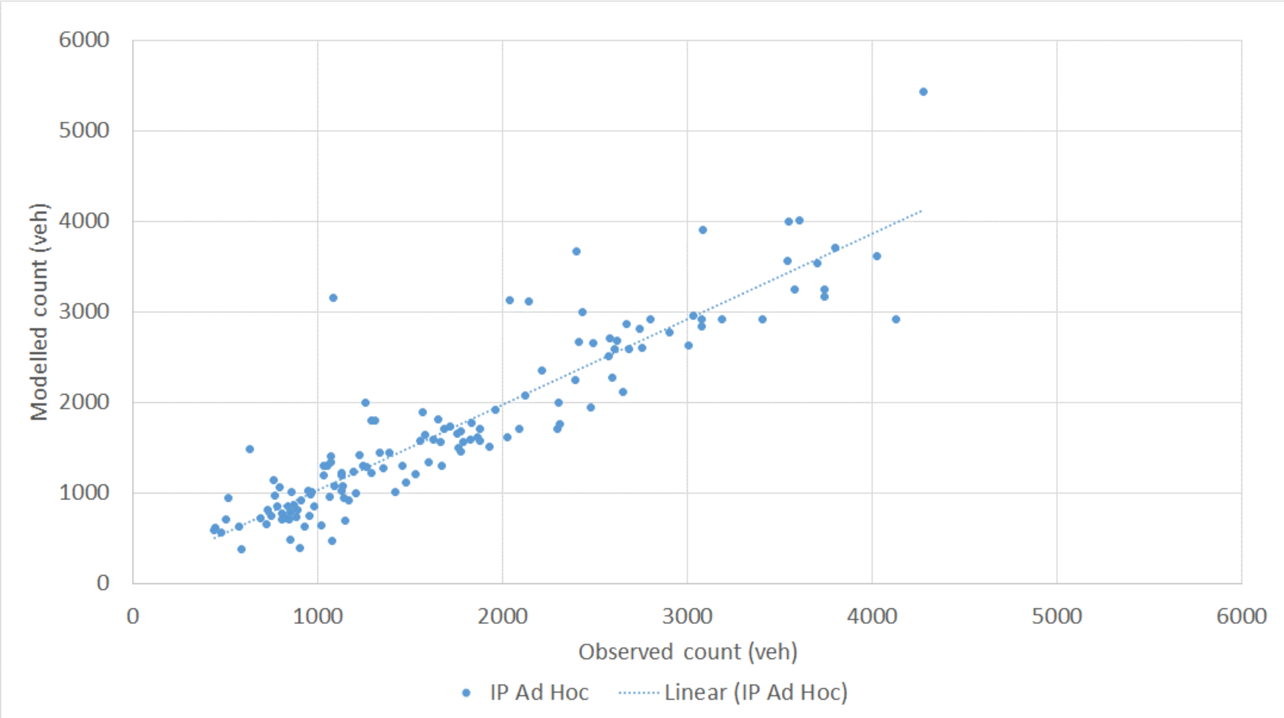


Figure 14.9 - Comparison of ad-hoc links, modelled vs observed; IP Total Vehicles - Post-ME

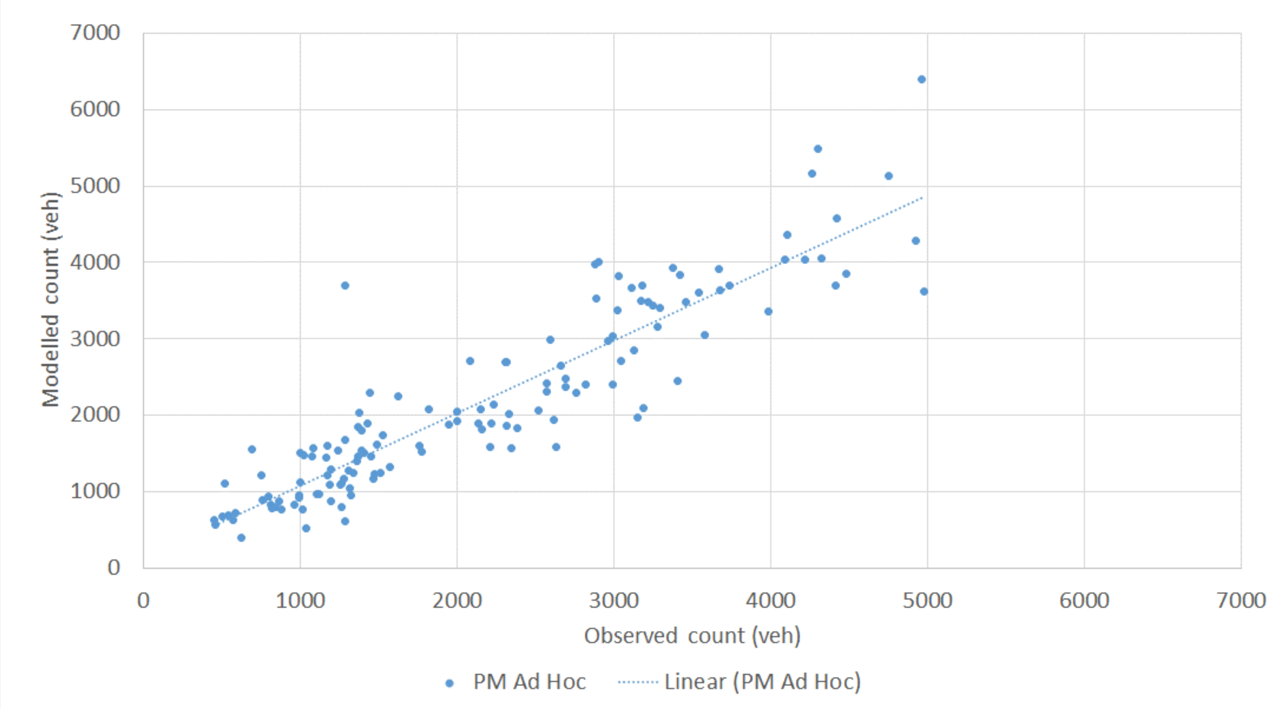


Figure 14.10 - Comparison of ad-hoc links, modelled vs observed; PM Total Vehicles - Prior-ME

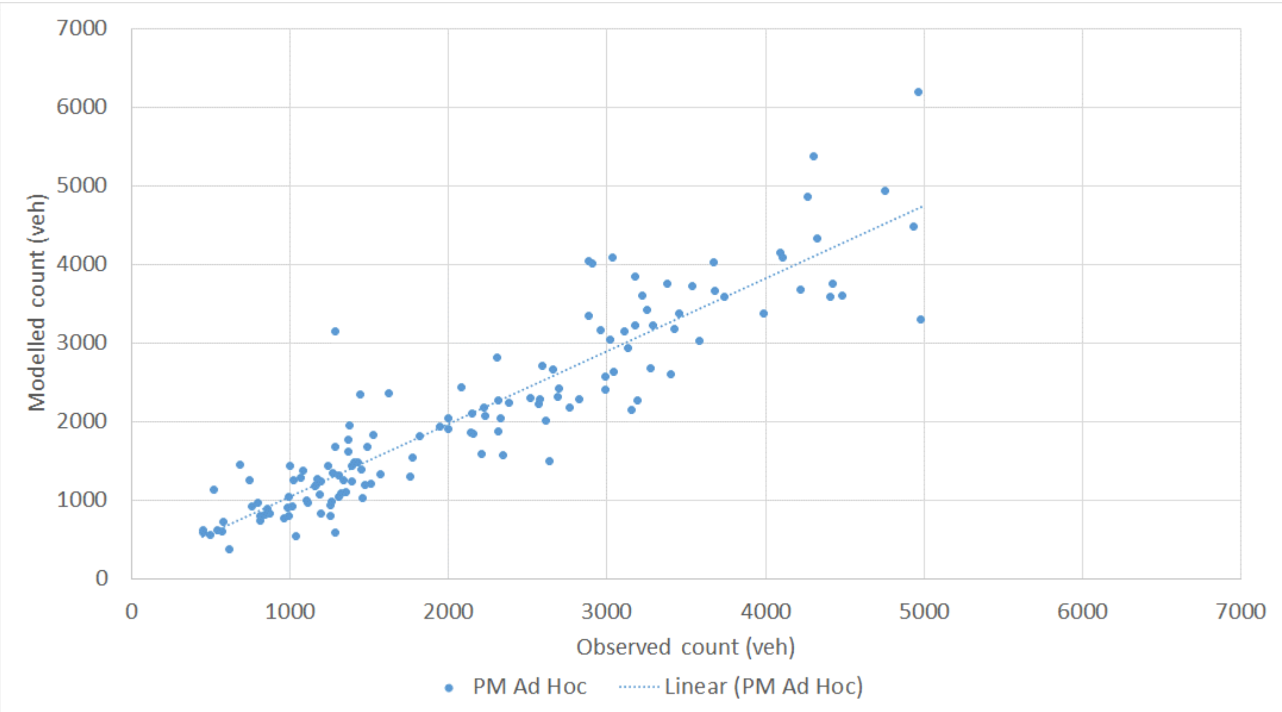


Figure 14.11 - Comparison of ad-hoc links, modelled vs observed; PM Total Vehicles - Post-ME

14.11.3. Vehicle kilometres

The modelled vehicle kilometres were compared with observed values published by DfT. The observed values were recalculated from DfT's AADF database [https://www.dft.gov.uk/traffic-counts/download.php, downloaded 14th March 2018] to give the three dimensions of region, vehicle type and road type – and the recalculated totals were checked against the published table 'TRA0204_(2015)_Veh_Roadtype'. Values are presented for the regions in England only, as Scotland and Wales are not fully represented in NTMv5 and so we would not expect the model to replicate their vehicle kilometres.

Comparisons for the main road types for each time period are provided in Appendix H with a summary for England as a whole presented in Table 14.15.

Table 14.15 – Summary of vehicle kilometres by road type and time period, England

Time period	Road type	Lights		Heavies		Total	
		Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
AM	Motorway	16.4	-8%	2.4	2%	18.7	-7%
	A-roads	34.5	6%	2.2	31%	36.6	8%
	All	79.3	-16%	5.0	17%	84.3	-14%
IP	Motorway	14.7	-14%	2.4	5%	17.1	-11%
	A-roads	30.9	-6%	2.2	25%	33.1	-4%
	All	71.1	-24%	5.1	15%	76.2	-21%
PM	Motorway	18.6	-11%	1.6	15%	20.2	-9%
	A-roads	39.2	-2%	1.5	22%	40.7	-1%
	All	90.2	-21%	3.4	17%	93.7	-20%

For motorways, the modelled vehicle kilometres for England are generally slightly lower than the published values (except for heavy vehicles). For A roads, the totals are slightly high in the AM peak but low in the IP and PM (again, except for heavy vehicles). The tables showing all road types, connectors and intrazonals do not provide a direct comparison since the model doesn't include all of the roads classified below A road, and so these results are unsurprisingly low.

Road kilometres have been considered alongside these results, although it is difficult to draw firm conclusions from this. We have compared both the DfT national statistics for road lengths and Highways England's published GIS layer of the Strategic Road Network to the NTMv5 road lengths. The DfT road length figures are generally higher than in NTMv5. For A Roads, the DfT road lengths are 7% higher than in NTMv5, which could potentially explain the disparity in vehicle kilometres. The Highways England GIS layer allows more investigation of the motorway and A Road figures, and in particular the allocation of slip roads. In the Highways England data, slip roads account for 20% of the motorway road km: 1,453km out of 7,338km in total for England. In the NTMv5 network only 11% of the motorway length is slip roads (733km of 6,901km). Therefore, it is possible that both the differences in motorway and A road lengths and vehicle km are explained in some part by differences in slip road lengths and allocations.

15. Sensitivity tests

15.1. Introduction

The NTMv5 sensitivity tests are designed to demonstrate how the model responds to user specified changes in inputs and ensure that model responses are satisfactory. The sensitivity tests are intended as "softer" tests compared with the more rigorous validation and realism testing. These are not designed to exhaustively test all model functionality, or responses to all possible tests, but to demonstrate overall model functionality and responsiveness.

As well as ensuring that the model runs technically, it is important that the model is demonstrated to produce sensible results and that stakeholders understand, and are satisfied with, the way the model runs and the nature of the results produced.

The five sensitivity tests chosen are set out in the table below.

Table 15.1 - Sensitivity test summary

Test and theme	Description
1 Demand growth	Growth in travel demand to 2030 (NTEM based) including changes in car ownership
2 Highway supply	Changes to highway infrastructure in some areas
3 PT changes	Changes to supply of bus or rail services in some areas
4 Targeted road user charging	Distance based charge on subset of the highway network
5 Urban area	Change to urban areas via speed limits and potentially parking charges, walk and cycle strategies.

The tests are entirely imaginary and have been defined to minimise the risk of them being considered as potential government policy by avoiding tests of schemes currently in development, or schemes or policies for which there is a reasonable likelihood they could be developed in the near future.

This section sets out an overview specification for each test, plus a brief summary of the results of the test. Full specifications and results have been provided separately.

15.2. Test 1: Demand growth

15.2.1. Test objectives

The specification agreed with DfT set the following objectives for this test:

1. demonstrate the functionality is operational for implementing changes in demand consistent in nature with the types of changes required for creating forecast scenarios (using NTEM trip end forecasts);
2. demonstrate the functionality is operational for implementing changes to economic parameters that would typically be required for forecasting, namely GDP and values of time;
3. investigate the running and performance of the model for increased demand levels; and
4. confirm responsiveness of model to increased demand through a set of indicators.

It should be noted that this is a demand growth test, which has used demand for a specific future year. It is not a full forecast test, as it does not include all elements which would be applied in a future year run.

15.2.2. Outline specification

Zonal trip production growth factors were derived from the 2015 and 2030 NTEM 7.2 weekday trip end forecasts for each demand strata. Linear interpolation was used where the required years were not directly available from NTEM. The segmentation in NTMv5 and NTEM is broadly consistent but not the same (See Section 5.3), with some additional age segmentation in the NTMv5 and additional household size and car ownership information available in NTEM.

Where NTEM is more aggregate than NTM, the same NTEM factors were applied to each NTM demand strata within that group. Where NTM zones are more spatially detailed than the NTEM MSOAs, the MSOA based factors were applied to multiple zones.

Similarly, zonal trip attraction growth factors were derived and applied to the trip attraction weights by purpose and the trip attraction constraints for the HBW and HBEd trip purposes which are doubly constrained. The trip attraction constraints were balanced to the total trip productions for the entire model.

This process, when applied to the NTMv5 base year trip ends, was found to give growth in trip productions that was not sufficiently close to the NTEM growth and produced too much growth particularly for shopping and recreation purposes. This was potentially for two reasons:

1. Differences in segmentation between NTEM and NTMv5 meant the factors applied were not the most appropriate for the traveller segments in NTMv5 (eg factors for those aged 75+ being applied to base year trip ends for those aged 65+)
2. Differences in the profile of trip ends in NTMv5 compared with those interpolated from NTEMv7.2.

Both aspects were reviewed to understand the differences and determine an appropriate adjustment to apply so that "NTEM growth" can be achieved for this test.

The differences in age segmentation (particularly the elderly) had already been noted as a possible issue. Hence differences in the population growth rates by age band was reviewed using the ONS mid-year population projections (2016 based) plus the mid-year population figures for 2015 (on a consistent basis). These were used to compare population growth differences by age independent of any further differences introduced due to varying trip rates. The growth rates for the NTEM and NTMv5 traveller type age bands are shown in Figure 15.1. This shows that the growth rate for those aged 75+ is between +40% and +50% while the growth rate for those aged 65+ is around +30%. Applying the higher growth rates for the 75+ to the larger set of trip ends for those aged 65+ was therefore found to be a major factor for the high growth obtained initially. As there is some variation for the other age bands and by Region (London in particular has a different trend to other areas), population correction factors were derived for each NTMv5 age band and region.

Correction factor = NTMv5 population growth factor desired / NTEM population factor applied (via trip ends)

The correction factors used are shown in Table 15.2. This shows that outside London the trip end growth for the 65+ age group is scaled back most, with some reductions in the younger adults (16-29) in most regions and some increases in the 30 to 44 and 45 to 64 age bands in selected regions.

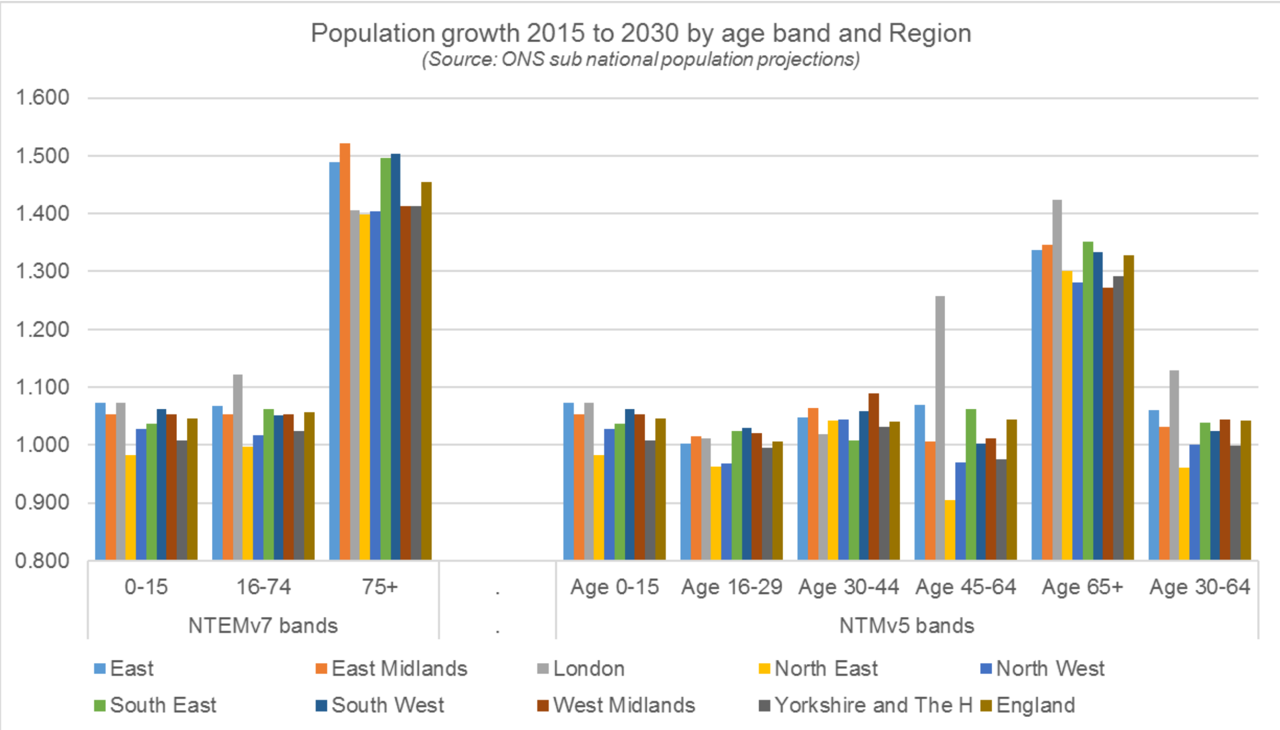


Figure 15.1 - Differential population growth by age band and Region

Table 15.2 - Population growth adjustments due to differential age bands

	Age 0-15	Age 16-29	Age 30-44	Age 45-64	Age 65+	Age 30-64
North East	1.000	0.965	1.046	0.907	0.930	0.962
North West	1.000	0.951	1.027	0.953	0.913	0.984
Yorkshire and The Humber	1.000	0.972	1.007	0.952	0.915	0.975
East Midlands	1.000	0.965	1.012	0.957	0.885	0.979
West Midlands	1.000	0.968	1.035	0.960	0.900	0.992
East of England	1.000	0.939	0.981	1.001	0.898	0.993
London	1.000	0.901	0.908	1.121	1.012	1.006
South East	1.000	0.965	0.949	1.000	0.903	0.978
South West	1.000	0.979	1.006	0.952	0.887	0.974
England	1.000	0.951	0.984	0.988	0.913	0.986
Wales	1.000	0.940	1.075	0.936	0.884	0.992
Scotland	1.000	0.894	1.084	0.926	0.947	0.990

The car ownership model includes assumptions on GDP growth based upon the DfT's TAG databook which are incorporated into this test scenario. GDP growth from 2015 to 2031 and its impact on travellers' values of time was taken from TAG databook version 1.9.1, December 2017 (as used in the NTMv5 base year model development) and growth applied by purpose in line with guidance.

The speed response for the urban area links has been implemented in this test using the trip end/capacity response method as outlined in Section 11.4.

Freight growth

For Test 1, forecast growth in freight traffic as published in RTF18 was taken as a proxy for freight trip growth.

The published traffic forecasts (RTF18) by vehicle type for Scenario 1 were used to calculate a single national growth factor for LGV and HGV trips. Although the traffic forecasts will include both personal and freight movements in vans (LGVs) for the purposes of this test it has been assumed they will grow at the same rate. Hence the LGV traffic growth rate has been applied to the base year LGV freight matrix. Changes in the LGV personal trips are forecast by the VDM where they are a small proportion of the car (and van) personal travel demand.

Data was used for England and Wales as a whole. The growth factors derived are shown in Table 15.3.

Table 15.3 – LGV and HGV growth 2015 to 2030 from RTF18

	LGV growth	HGV growth
England and Wales	+22.3%	+1.1%

15.2.3. Checks on inputs

Given the importance of the inputs and processing of NTEM data in creating the forecast demand growth for this test, extra quality assurance processes were applied to ensure the accuracy of the model inputs for this test. Comparing NTMv5 growth factors from base to forecast year against NTEM TEMPro growth factors showed close matches, particularly across HB trips, while across age profile and car availability, there were also similarities albeit with some small differences visible. However, it should be noted that the correspondence between NTM and NTEM age groups are not exact (for example NTMv5 uses 65+ whilst NTEM uses 75+).

Across the regions there were also very close similarities between TEMPro and NTMv5 growth rates. Overall, it should be noted that whilst Test 1 is conducted with future year demand growth, it does not feature changes to supply characteristics, notably vehicle operating costs or PT supply, and hence the resulting test cannot be considered a 'true' future year test.

15.2.4. Test results

In terms of outputs, the results generally confirm the expected impact of the changes in demand, from 2015 to 2030. Largely this has led to increases in P/A trips across purpose and region. By mode, the percentage changes for bus are the largest, at generally 30-40% increases across region. For car driver and rail these increases are around 10-20%, whilst car passenger trips increase by 0-10%. Active modes see a decrease in trips in the forecast year, with percentage decreases of 10-20% across most sectors. These mode shifts are not unexpected given that travel costs do not increase in this test, but value of time does. Further detail on changes in mode share are shown in Table 15.4.

Table 15.4 - Difference in mode share by car ownership; Test 1 - Base

Purpose	Car Availability	Car Driver	Car Pass	Bus	Rail	PT	Cycle	Walk	Total
HbW	Full Car	0%	0%	0%	0%	1%	0%	0%	0%
HbW	No/Part Car	-1%	-1%	2%	2%	3%	0%	-1%	0%
HbEd	Full Car	2%	-1%	4%	1%	5%	0%	-6%	0%
HbEd	No/Part Car	2%	-1%	5%	1%	6%	0%	-7%	0%
HbShopPB	Full Car	4%	0%	3%	0%	4%	0%	-7%	0%
HbShopPB	No/Part Car	3%	1%	7%	1%	8%	0%	-12%	0%
HbRecV	Full Car	2%	-1%	1%	1%	2%	0%	-3%	0%
HbRecV	Part Car	2%	-1%	2%	1%	2%	0%	-3%	0%
HbRecV	No Car	0%	0%	4%	2%	6%	0%	-5%	0%
HbHol	Full Car	1%	-2%	1%	1%	2%	-1%	0%	0%
HbHol	Part Car	1%	-2%	1%	1%	2%	0%	0%	0%
HbHol	No Car	0%	-3%	2%	2%	4%	-1%	0%	0%
HbEB	Full Car	0%	0%	0%	1%	1%	0%	0%	0%
HbEB	No/Part Car	-1%	0%	1%	2%	3%	0%	-1%	0%
NHbEB	Full Car	1%	0%	0%	0%	0%	0%	-1%	0%
NHbEB	No/Part Car	1%	-1%	0%	1%	1%	0%	-1%	0%
NHbO	Full Car	1%	0%	0%	0%	0%	0%	-1%	0%
NHbO	No/Part Car	1%	0%	1%	0%	1%	0%	-2%	0%
Total 24hr trips	**Full Car**	**2%**	**0%**	**2%**	**0%**	**2%**	**0%**	**-4%**	**0%**
	No/Part Car	**2%**	**0%**	**3%**	**1%**	**4%**	**0%**	**-6%**	**0%**
	Total	**3%**	**0%**	**2%**	**0%**	**3%**	**0%**	**-5%**	**0%**

Spatially, both attractions and productions see decreases around the periphery of England; in the South West, along the Welsh border and throughout Northumbria and the North East coast. These are countered by particularly strong growth in the South East of England, through the home counties and East Anglia. These patterns match the expected patterns for growth to 2030 (see Figure 15.2 and Figure 15.3).

It should be noted that the Isle of Wight shows a very large and prominent change. The Isle of Wight has been modelled as a single zone, which means it has a very large area and population compared with other zones. This prominence was observed for all the sensitivity tests and may mean that the Isle of Wight needs some separate consideration as small uncertainties in response can produce large impacts in the surrounding area.

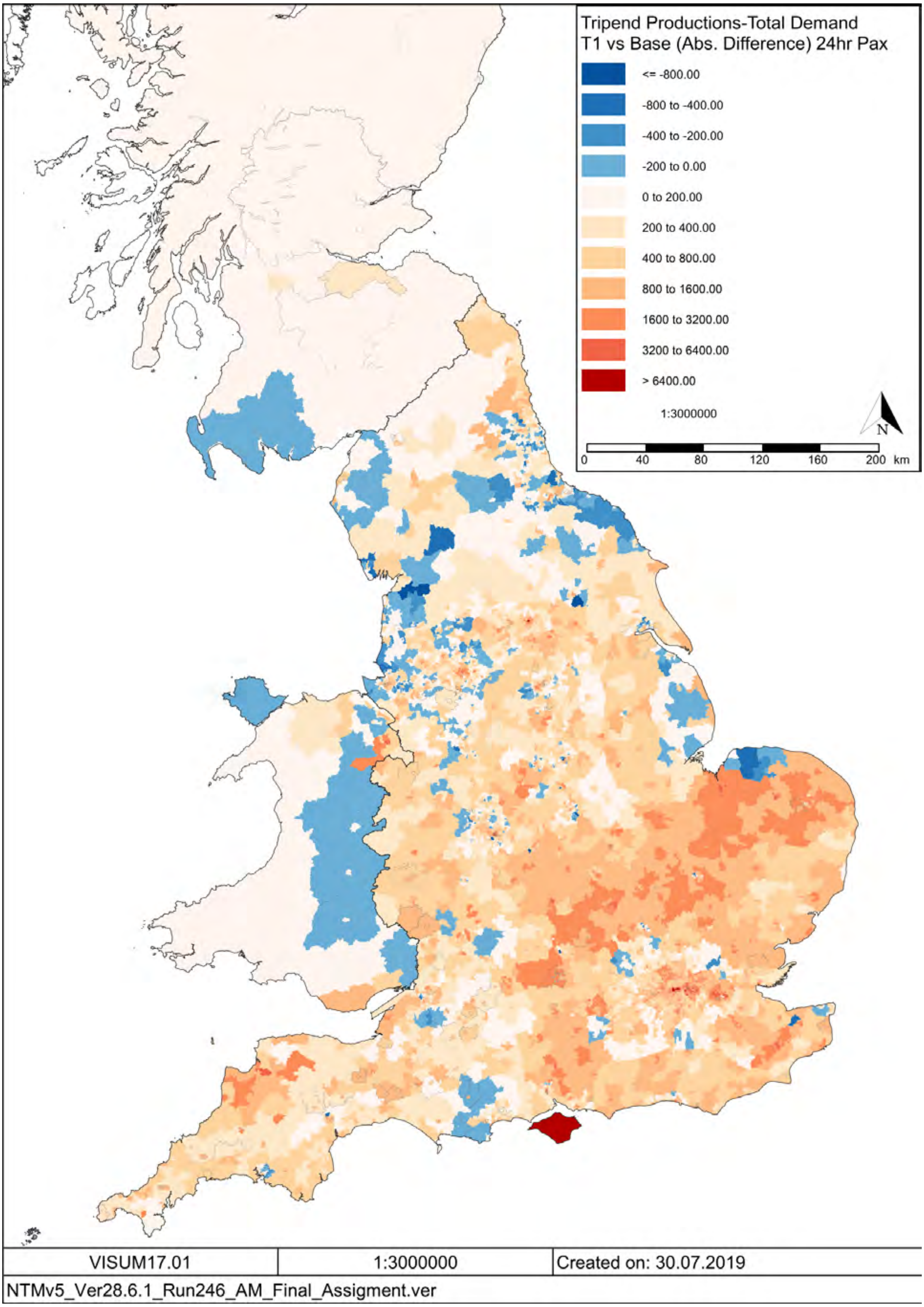


Figure 15.2 - Change in total 24hr trip productions; Test 1 - Base

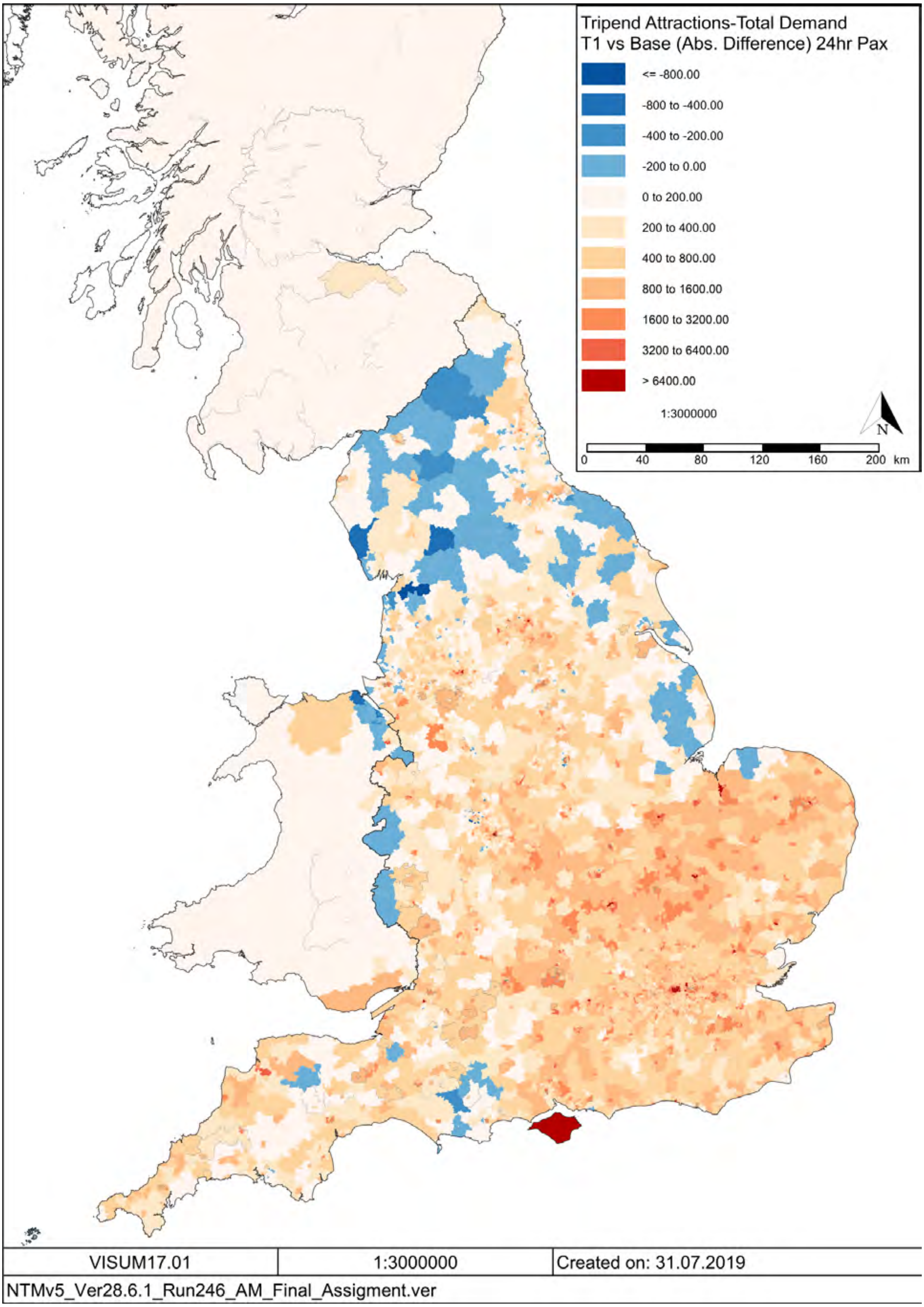
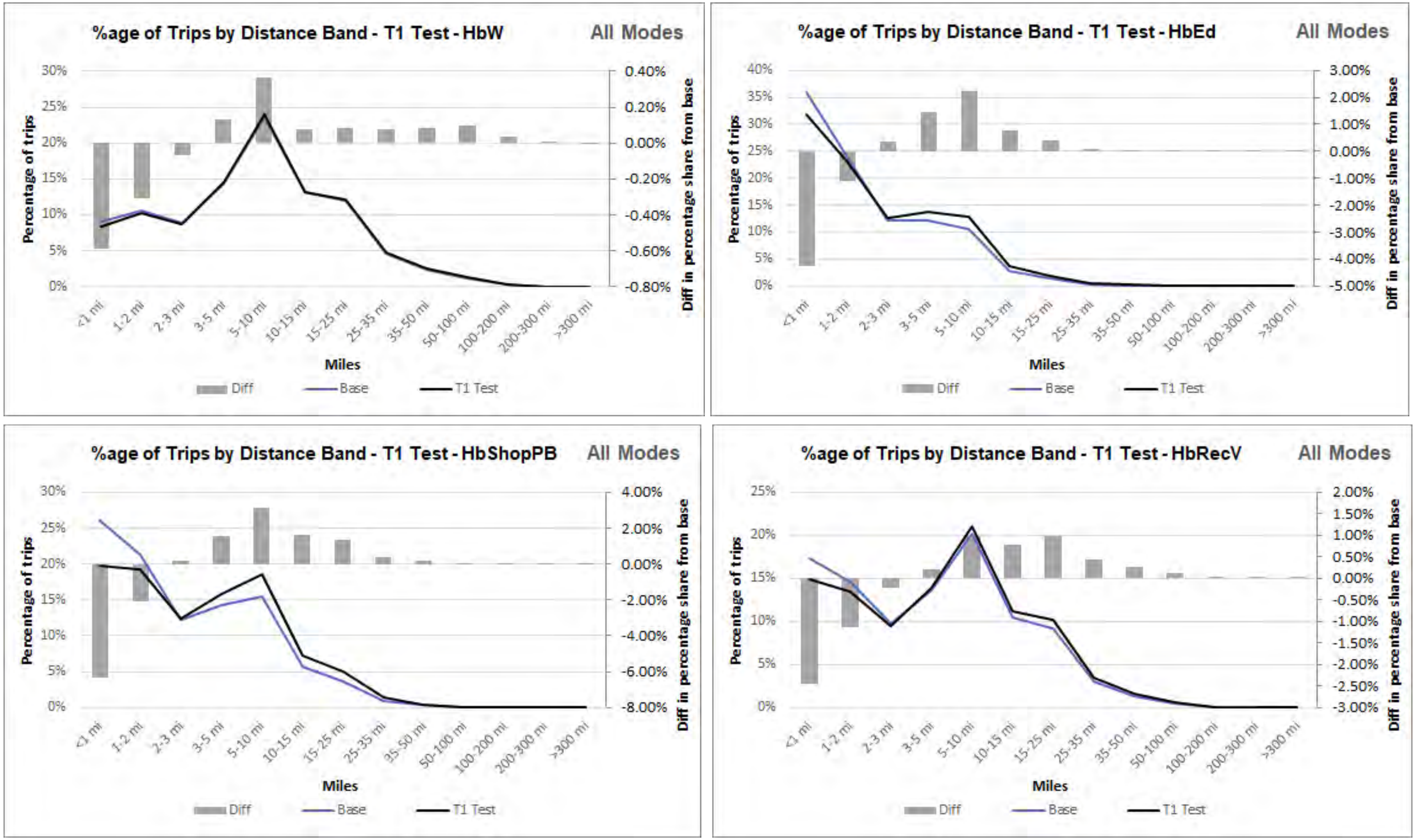


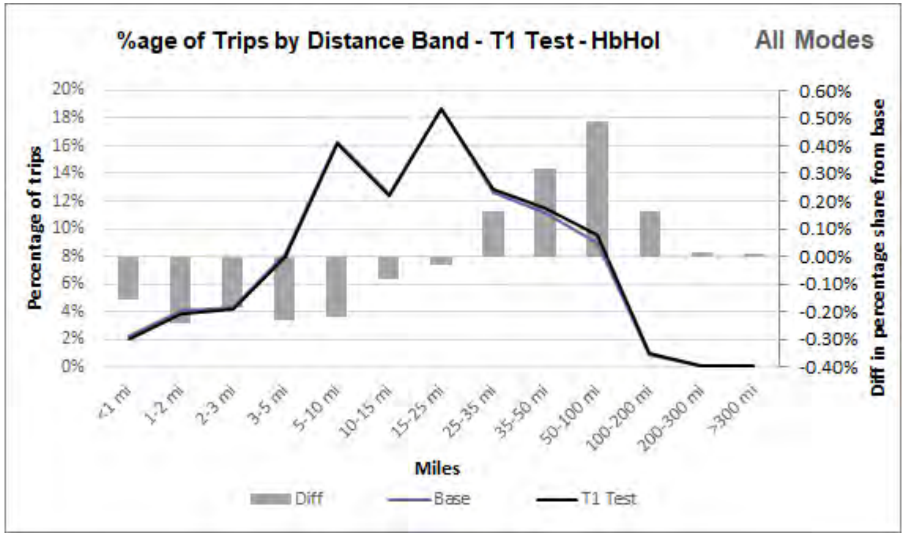
Figure 15.3 - Change in total 24hr trip attractions; Test 1 - Base

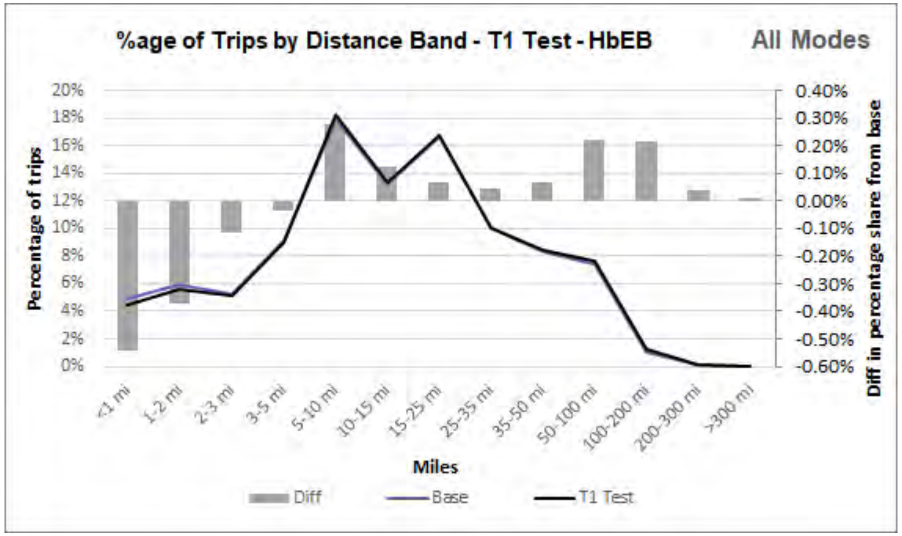
Within the highway model, the resulting changes in trips reflect the growth in the VDM, with highway trips increasing by roughly 10-20% across sector and time period. The IP shows a slightly larger increase, from base to Test 1, than the other time periods. Regionally, London and the South East shows a marginally greater percentage increase in trips, particularly in the IP and PM, compared with other sectors, but in general the changes are consistent across sectors.

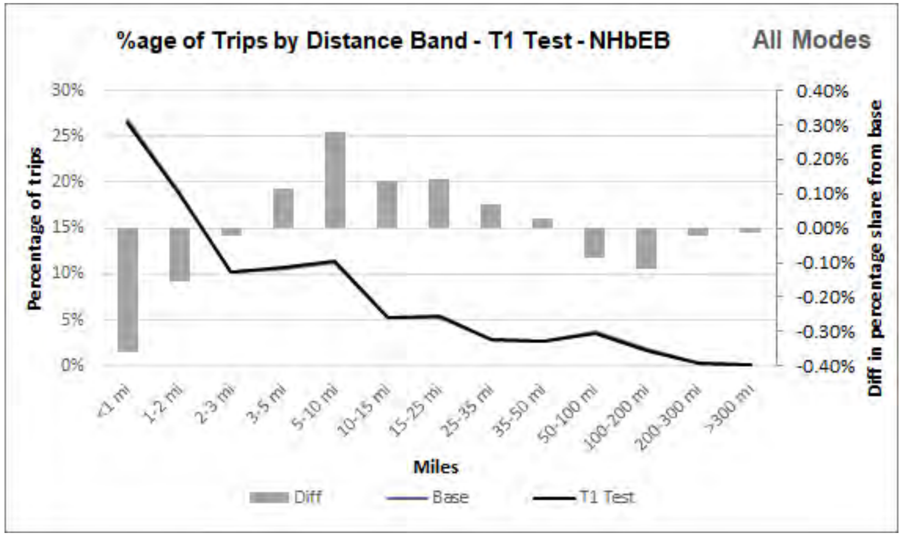
Average trip lengths and journey times show small increases across most purposes and modes. Bus journeys in particular increase across HbEd, HbShopPB and HbRecV purposes. This likely simply reflects both the increased volumes of trips from these purposes using the bus mode, where trips are generally longer, and also a shift from shorter bus journeys to more medium length trips, a pattern witnessed in the trip length distribution analysis. The trip length distributions generally show a shift from short to medium length trips, largely driven by car and bus trips.

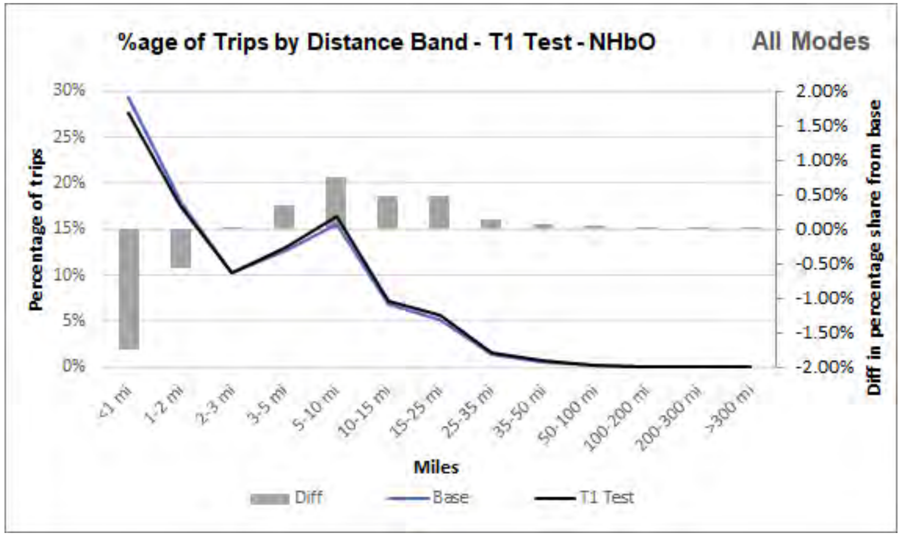
Figure 15.4 - All mode trip length distributions by purpose; Test 1 vs Base




%age of Trips by Distance Band - T1 Test - HbHol
All Modes
Percentage of trips
Diff in percentage share from base
Miles
Diff
Base
T1 Test


%age of Trips by Distance Band - T1 Test - HbEB
All Modes
Percentage of trips
Diff in percentage share from base
Miles
Diff
Base
T1 Test


%age of Trips by Distance Band - T1 Test - NHbEB
All Modes
Percentage of trips
Diff in percentage share from base
Miles
Diff
Base
T1 Test


%age of Trips by Distance Band - T1 Test - NHbO
All Modes
Percentage of trips
Diff in percentage share from base
Miles
Diff
Base
T1 Test

Given the minor changes in trip length, the total vehicle kilometres largely reflect the increased trip volume amongst light vehicles, with 15-20% increases in the AM and PM, and slightly larger, 20-30% increases in the IP. The regional patterns are largely similar across road type and time period (slightly greater increases in more rural areas, smaller increases in, for example, London) whilst the breakdown by road type shows that more of the extra kilometres are on motorway, followed by B Roads (and other more minor classifications) and finally A Roads. These patterns appear to be consistent with the basis of the test; an overall increase in demand across all regions and segments.

HGVs witness a much smaller change in vehicle kilometres, with generally 0-5% changes in regional totals, matching the input forecast growth changes for freight. However, the patterns of change echo those in the light vehicle data, with motorways seeing the greatest increase, followed by B Roads.

Given Test 1 is not a regionally-focused test like the other sensitivity tests, the spatial impacts on highway flows, congestion and link speeds are spread across the country. There are greater increases in flow and congestion, and greater decreases in speeds in regions such as London, the South East and East of England, where demand growth is greater.

15.2.5. Summary

Overall, this test has demonstrated the functionality of NTMv5 to implement both changes in forecast demand, and changes to economic parameters such as VoT. It has also shown the capability of NTMv5 in running successfully and effectively with increased demand levels. In terms of responsiveness, this test has largely demonstrated the expected impact of the changes made in the inputs; with changes in forecast growth, but a lack of changes in PT supply or VoC. Car and PT modes display increases in line with NTEM forecast growth, whilst decreases in walking and cycling can be explained by mode shifts brought on by a lack of changes in travel costs but increases in VoT. Trip length distributions show some small changes, with a slight shift from short trips to medium trips visible across car and bus modes. Whilst spatial patterns are sensible, with stronger demand growth in the South East of England, and growth in peripheral areas of England.

15.3. Test 2: Highway infrastructure

15.3.1. Test objectives

The specification agreed with the DfT describes the objectives of this test as to:

1. Demonstrate the functionality is operational for implementing changes in highway supply (network coding) and rules for coding network changes are sufficiently clear;
2. Investigate the running of the model for changes in highway supply (alternative networks);
3. Confirm responsiveness of the model to changes in highway supply through the primary set of indicators.

15.3.2. Outline specification

Following the brief from the DfT, a new motorway has been coded, between Southampton/Bournemouth and Stoke-on-Trent/Chester. This road is a 3-lane motorway throughout, with grade-separated junctions at major A-road and motorway intersections. The route follows the A36 between Southampton and Bath, before following the A46 to Stroud. Sections of entirely new routing between Gloucester and Leominster, and Ludlow and Market Drayton were supplemented with small sections ‘upgrading’ existing roads.

Given some of the route follows the path of existing links, such as the A36 and A49, those existing B-roads and more minor roads that currently intersect these links have be disconnected, and to retain existing movements, were connected to the nearest grade-separated junction on the new highway, using services roads parallel to the new highway.BB Between sections that follow existing roads, the new motorway has been coded following the route specified by the DfT. The new highway route is shown in Figure 15.5.

The links to be coded were identified from the NTMv5 network. The highway network coding included coding of new infrastructure (nodes/links) as well as converting the existing infrastructure (nodes/links) to Test 2 configuration.

Around 1,233 links have been coded as part of the test which include 904 new links and 329 links being upgraded/modified. The test involved coding a number of interchanges on the existing network. In total, 29 roundabout interchanges and 17 trumpet interchanges were coded. Also, two flyovers were coded, one at the intersection of A31 and A338 and other joining A4 and A36 over Bathampton, Bath.

The following guideline principles were followed for highway coding:

- Link Types 3 and 64 were adopted for the new Motorway and its corresponding slips;

- Link and Node Numbering Convention – Nodes and Link numbers for all the new objects coded start from 200001;
- Three new links UDAs were created for the identification of the scheme:
  - Scheme_ID – Describes the scheme and attached side roads. T2 used for the main corridor and T2_SideRoad for the roads cutting the motorway in Test 2;
  - Scheme_Category – Captures the detail of change in the network structure viz., Upgrade, New Road, Slip, Access Road, Roundabout and Ramp etc;
  - Scheme_Old/New - whether the network is already existing or it's a newly coded one (UDA created for graphic representation of the scheme);
  - In addition to the above UDAs, two of the existing UDAs namely, RoadType and UK_Region, were also updated in accordance to Test 2 coding. The definition of the existing UDAs is discussed in the NTMv5 User Guide; and
- It was ensured that the zone connectors are not directly connected to the proposed corridor (four connectors required modification).

Based on the principles discussed above, the link type definition was adopted for the links. The highway coding checklist presented in the NTMv5 User Guide was followed, illustrating the steps under highway coding. The highway network coding ensured compliance with the checklist. Node and turn definitions were applied as per the standard values used in NTMv5 as set out in the User Guide.

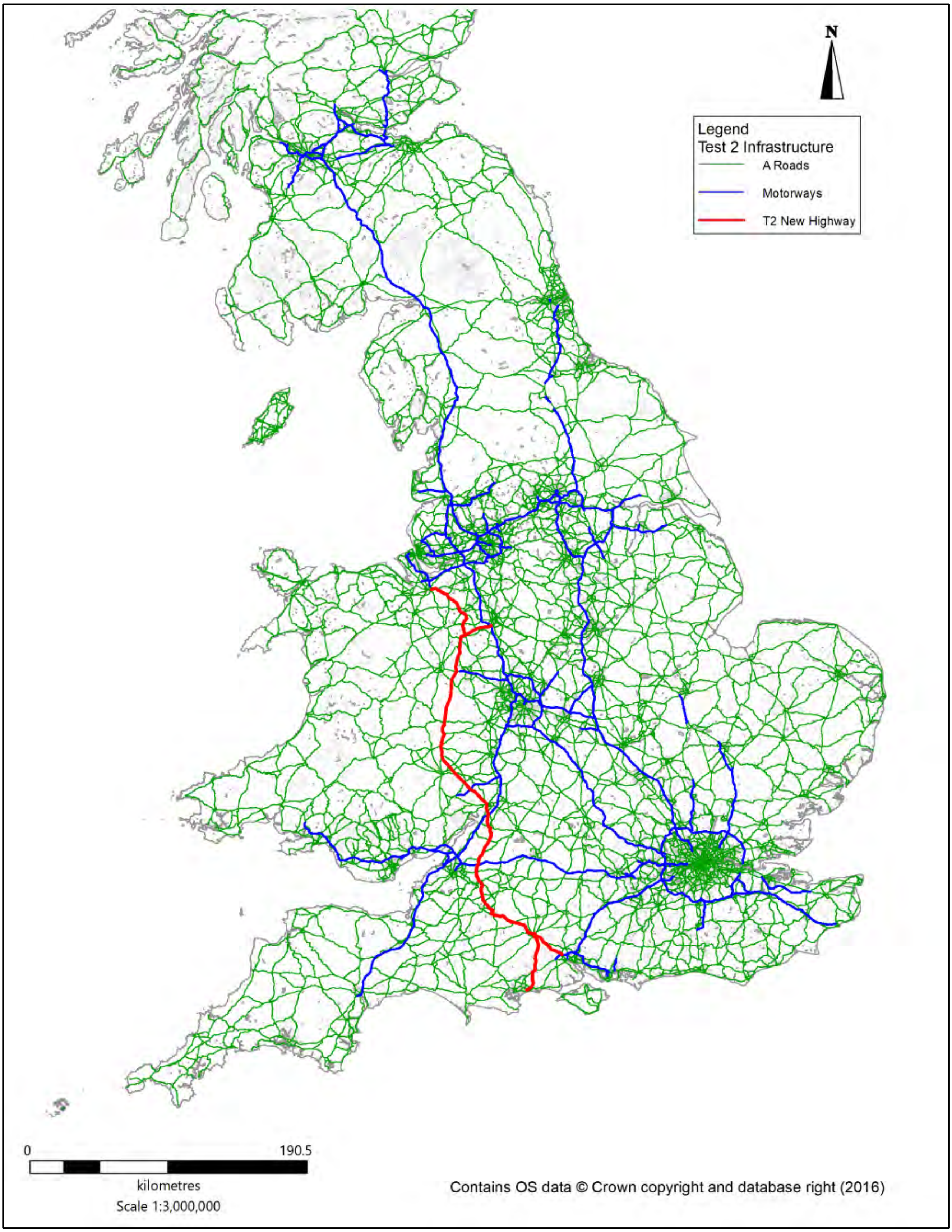


Figure 15.5 – Test 2 new highway route

15.3.3. Test results

The results generally confirm the expected impact of the changes in highway infrastructure. P/A trip productions and attractions show a very minor change across the model as a result of the test, with no regional/modal changes of greater than 1%. Car trips are largely consistent with base, with the largest percentage changes in car passenger trips occurring in the South West, External Wales, and West Midlands. These regions are consistent with the highway network changes made as part of the test. The fall in car driver productions in London is very small in percentage terms but reasonably large in absolute terms and may merit further investigation, potentially related to convergence.

The biggest modal changes occur for rail trips, which whilst overall seeing very minor changes from the base, see decrease concentrated in a few sectors (decreases in the South West, External Wales and West Midlands). These regions are consistent with the addition of the new highway into the network, suggesting a shift from rail to other modes (likely car).

This pattern is also highlighted by the results of average trip lengths and journey times, which increase for car driver and car passenger trips, and show a small decrease for rail trips. Average trip duration and trip speed match these patterns, with increases in both average time and speed for Car Driver and Car Passenger modes (particularly across ‘Other’ trip purposes) and decreases for rail. Other modes; bus, walk and cycle, are largely static from the base to Test 2.

Despite some small changes in average trip lengths, trip length distributions do not change significantly, with all distance band changes in percentage share from the base smaller than 0.2% across all purposes. The changes in vehicle kilometres for the test do however reflect the specification of the newly added highway, with the affected regions experiencing a shift in vehicle kilometres from A and B Roads towards motorway.

In particular, the South West and West Midlands, along with smaller changes in the North West and Wales, see a decrease in A and B Road kilometres, and an increase in motorway usage. Overall, the network change adds to total vehicle kilometres as would be expected (see example AM light vehicle results in Table 15.5).

Table 15.5 - Change in vehicle kilometres; T2 Test 2– Base, light vehicles, AM (Mil. kms)

Region	All Roadtypes + Connectors + Intrazonals		Motorway		A Road		B Roads + other roads	
	Diff. from base	% diff. from base	Diff. from base	% diff. from base	Diff. from base	% diff. from base	Diff. from base	% diff. from base
NE	-0.00	0.0%	-0.00	-0.2%	0.00	0.0%	-0.00	-0.1%
NW	0.09	1.1%	0.13	4.4%	-0.03	-0.9%	-0.01	-0.7%
Y+H	-0.00	-0.1%	-0.00	-0.1%	-0.00	0.0%	0.00	0.0%
EM	-0.01	-0.1%	-0.01	-0.8%	0.00	0.0%	0.00	0.1%
WM	0.26	3.5%	0.34	17.9%	-0.05	-1.4%	-0.03	-2.8%
EoE	-0.01	-0.1%	-0.01	-0.4%	-0.01	-0.1%	-0.00	-0.1%
Lon	-0.03	-0.6%	-0.00	-0.5%	-0.02	-0.7%	-0.00	-0.9%
SE	0.01	0.1%	0.04	1.1%	-0.03	-0.4%	-0.00	-0.1%
SW	0.47	6.0%	0.71	44.4%	-0.20	-5.0%	-0.03	-2.8%
Eng	**0.78**	**1.2%**	**1.20**	**7.9%**	**-0.35**	**-1.0%**	**-0.07**	**-0.9%**
Wal	0.04	1.9%	0.01	2.4%	0.03	3.8%	-0.00	-0.4%
Sco	-0.00	0.0%	0.00	0.0%	-0.00	-0.3%	-0.00	0.0%
GB	**0.83**	**1.1%**	**1.20**	**7.8%**	**-0.32**	**-0.8%**	**-0.07**	**-0.8%**

In terms of car driver trips, there is a mixed pattern of minor zonal changes across the country. The zones along the length of the new highway nearly all display increases in both attractions and productions. For attractions in particular, some hotspots of growth are visible, around Bath, Gloucester and Stoke-on-Trent. The impact of some of the severing and re-connecting of local roads may also have had some impact, with some local routes now longer than they were previously. This is likely to explain the large decreases witnessed in the area around Salisbury, where connections with the existing A36 and A338 were edited to make way for the new highway. Figure 15.6 and Figure 15.7 show changes in car driver attractions and productions, respectively.

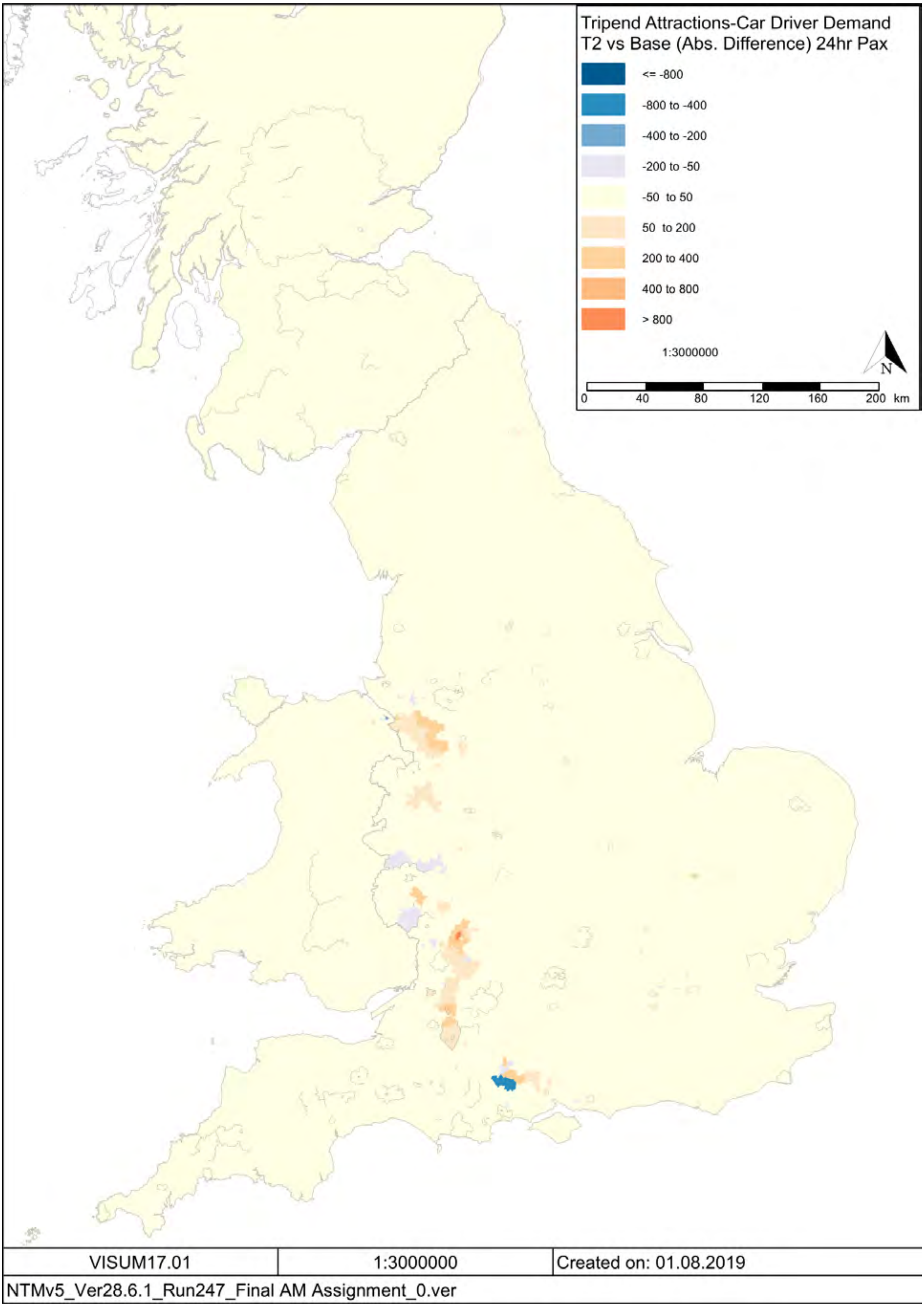


Figure 15.6 - Change in Car Driver 24hr trip attractions; Test 2 - Base

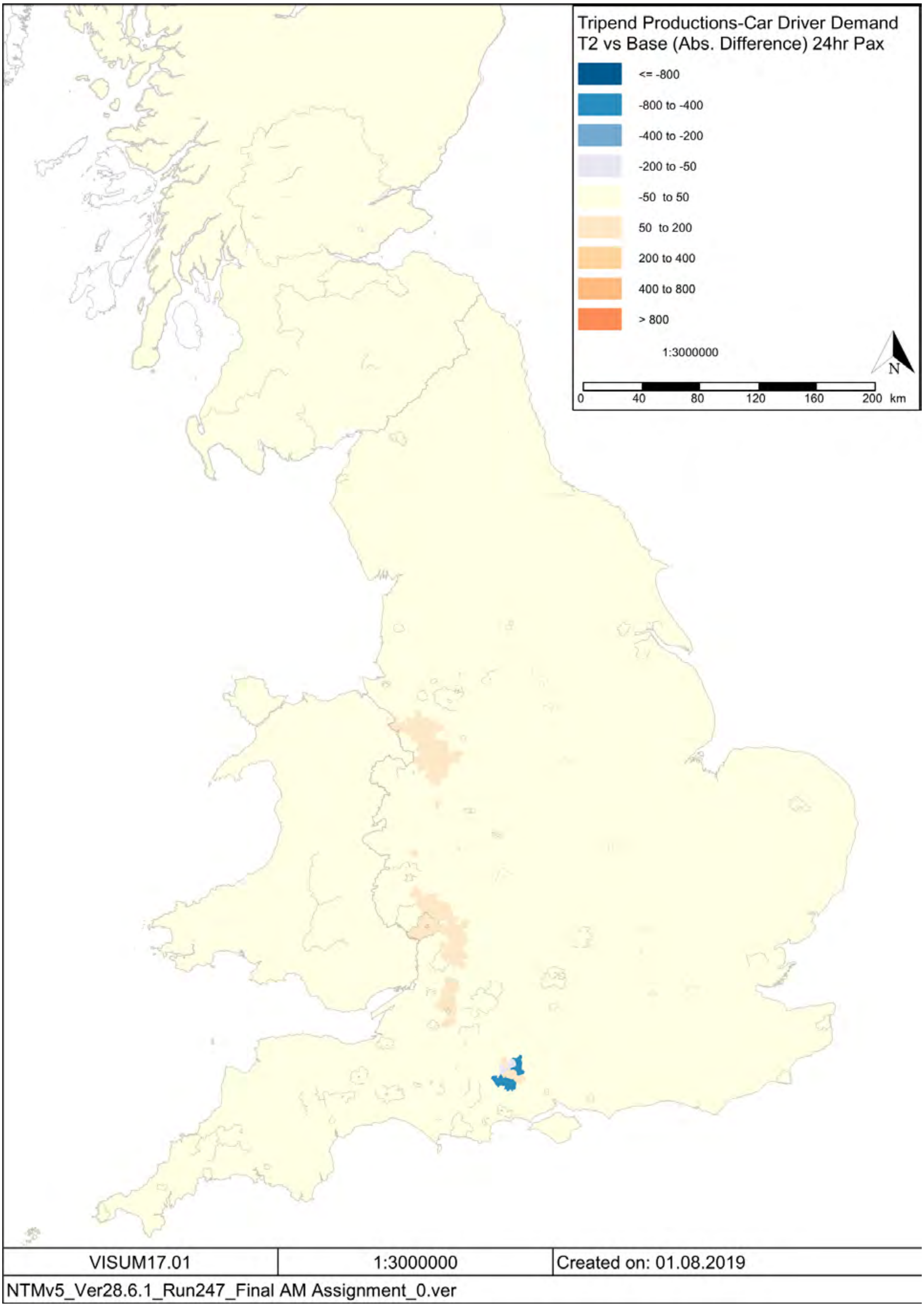


Figure 15.7 - Change in Car Driver 24hr trip productions; Test 2 - Base

In line with this, highway trips increase along the corridor in the expected manner, with some evidence of re-routing on local roads either side of the new highway corridor, as would be expected (see Figure 15.8). Due to the increased capacity, volume/capacity checks show little significant additional congestion along the new route beyond a couple of junctions in Hereford and Salisbury.

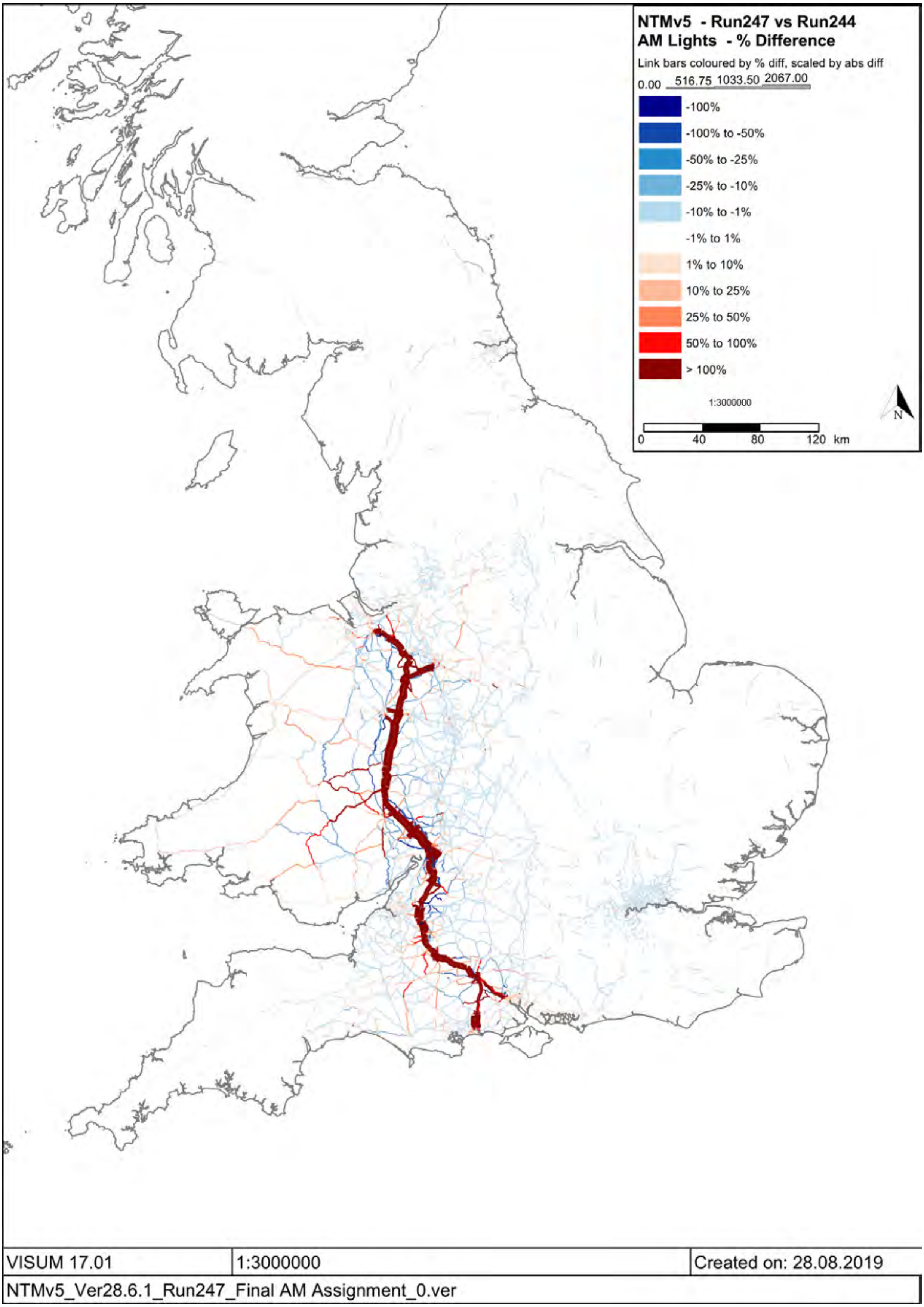


Figure 15.8 - Flow change from Base to Test 2, Light Vehicles, AM

Routing checks were conducted along the length of the new route, and these showed routing to be sensible along and across the new road. Bournemouth to Hereford and Chester to Bournemouth routes show near complete use of the new highway for the length of the route, for both light and heavy vehicles. Leominster to Southampton, and Chester to Southampton routes show partial use of the new highway; using it through Cheshire and Shropshire before deviating south of Gloucester to take a more direct route than the new highway. Some routes, such as Southampton to Telford and Stoke-on-Trent to Southampton do not use the new highway at all, but this is largely sensible, given that the route of the new highway is largely further west than these routes, and hence features a greater distance than the new route.

Some differences are seen between light and heavy routes; Southampton to Telford in particular shows light vehicles choosing to route via motorways, whereas heavies, as expected are taking a more direct route.

15.3.4. Summary

Overall, this test has demonstrated the functionality of NTMv5 in testing significant changes to infrastructure on a national scale. Whilst the specification for this particular test was likely to be less detailed than future tests conducted in NTMv5, with existing local roads connected into the new highway where necessary as opposed to based upon a fully detailed plan, the test has helped to establish and confirm that the highway coding rules for NTMv5 are sufficiently clear to capably implement significant new infrastructure. This coding guidance is further detailed in the NTMv5 User Guide. The test has also shown that NTMv5 functions well with the addition of significant lengths of new highway, and that the responses of the model are largely intuitive. The addition of the new highway saw an increase in highway trips in the affected regions, with the impacts on local roads displaying the expected patterns along the corridor. Routing checks have shown that highway routing in the model has responded in accordance with the geographic location, size and speed of the new infrastructure.

15.4. Test 3: Public transport connectivity

15.4.1. Test objectives

The specification agreed with the DfT sets out the aims of this test as follows:

1. Demonstrate and test the functionality for modifying the exogenously specified public transport attributes;
2. Investigate the responsiveness of the model to changes in public transport supply;
3. Ensure guidance for making changes to public transport attributes is accurate and adequate.

15.4.2. Outline specification

This test investigates the impact of a downgrading of rail services between the northernmost regions in the model (NE, NW and Y&H) and London (in both directions). The impacted areas are highlighted in Figure 15.9. The proposed approach for this test was to halve the frequency of services, and increase rail travel times by 30 minutes.

The change in travel times was implemented via ride times (plus 30 minutes for all zone pairs within the selected areas). The change in frequency were implemented via changes, for the relevant zone pairs, to the matrices of wait times. The wait time matrices are the sum of three components:

- Initial wait time for the first service capped at a maximum of 7.5 minutes;
- Initial parking time if access is not close enough to walk of 5 minutes; and
- Intermediate wait times when interchanging.

If there are no interchanges the wait time is capped at a maximum of 12.5 minutes in the base year model. For this test, the journeys will be long distance and hence many of the zone pair combinations will involve interchanges and hence relatively high wait times in the base year. Reducing the frequencies would certainly increase the initial wait time, but may have less impact where many interchanges are already involved. The proposed approach is therefore to double the wait times (reflecting the reduction in frequency) up to a maximum of 30 additional minutes. Further details on how changes are made to PT cost matrices can be found in the NTMv5 User Guide.

Ride time modification

The inputs for the ride time modification is simply an additive Region-Region matrix to increase ride times between the affected regions and retain the base values elsewhere.

It is not possible within the Visum procedure sequence to combine both zone and main zone matrices in a calculation and hence it is necessary to create a zonal matrix from the sector matrix. This can be done using the ‘matrix disaggregation’ procedure, which takes the values in a main zone matrix and uses them to populate a zonal matrix.

Wait time modification

The wait time modification has been coded as a multiplicative Region-Region matrix that is applied to the zonal base values.

The change required is:

$$wait^F_{o,d} = wait^B_{o,d} + \min(wait^B_{o,d}, 30) = \begin{cases} 2 \times wait^B_{o,d}, & wait^B_{o,d} \leq 30 \\ wait^B_{o,d} + 30, & wait^B_{o,d} > 30 \end{cases}$$ for the affected pairs and

$$wait^F_{o,d} = wait^B_{o,d}$$ otherwise

This has been coded in Visum as follows:

$$wait^F_{o,d} = IF(wait^B_{o,d} > 30 \; \& \; wait\_multiply^F_{x,y} = 2, wait^B_{o,d} + 30, wait^B_{o,d} \times wait\_multiply^F_{x,y}),$$

where $wait\_multiply^F_{x,y}$ is a regional matrix taking value 2 for the affected regional pairs and 1 otherwise.

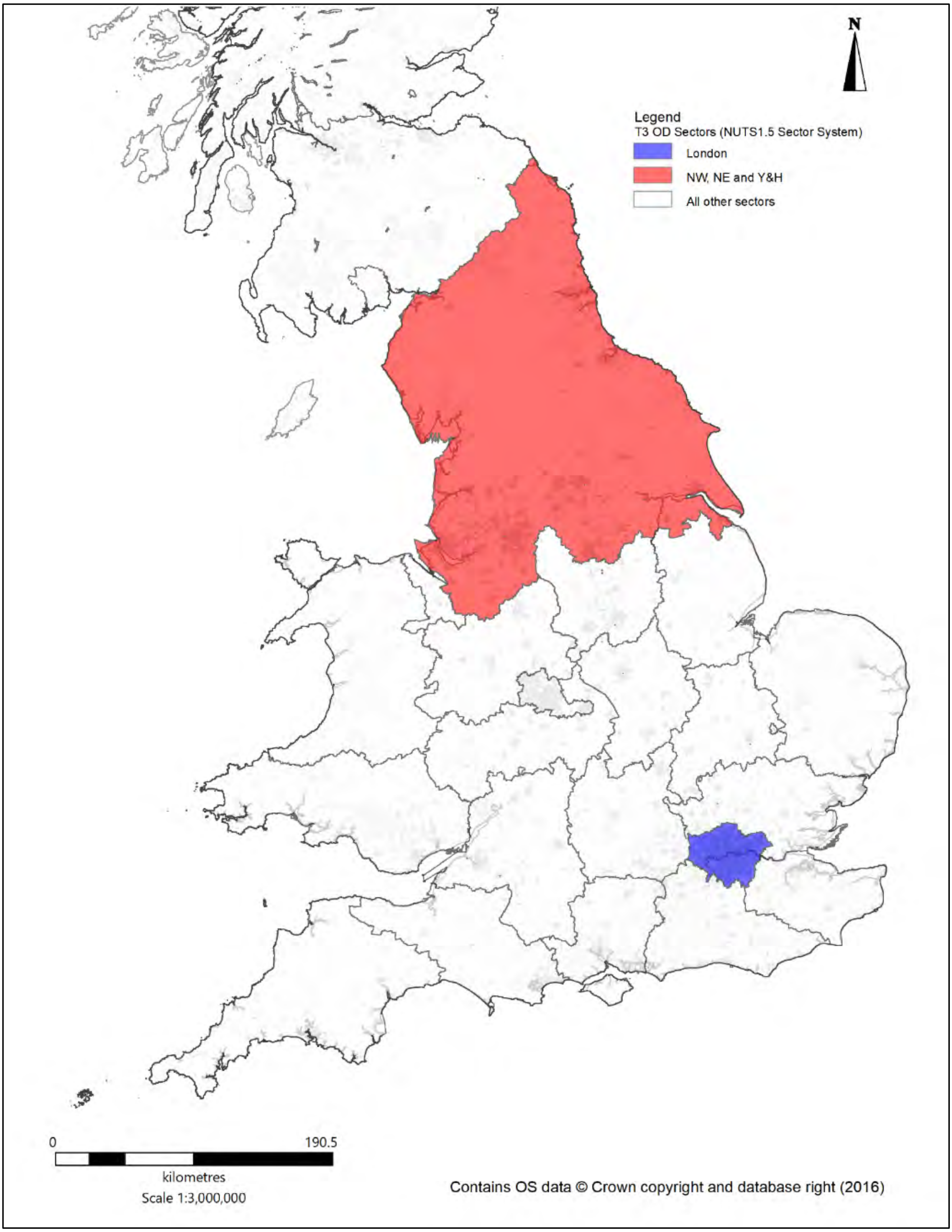


Figure 15.9 – Test 3 test zone pairings

15.4.3. Test results

Examining P/A trips for Test 3 shows that, as expected given the nature of Test 3, the significant changes to trips are exclusive to public transport modes.

Analysis of the distribution of the change in travel times (see Table 15.6) in the model suggest that Test 3 was implemented successfully, with no changes in travel time internally, either in the North of England or in London, but large (~ 60 minute) changes between the North of England and London. A distribution of the changes in trips also confirm the large decreases witnessed between the sectors chosen for the test, with particularly large (absolute) decreases in trips from Inner London to Cumbria and Lancashire, and from South Yorkshire to Inner London. In relative terms, the results show a symmetry in the input between trips to, and from, the impacted sectors, with roughly 60% decreases in trip productions.

Table 15.6 - Travel time changes between selected sectors; T3 Test 3 - Base, Rail (mins)

	Nbria+Tees	Cbria+Lancs	Manchester	Cshire+Mers	NEYrk+NLinc	SYorks	WYorks	InnerLdn	OuterLdn
Nbria+Tees	-0	-1	0	0	0	0	0	54	60
Cbria+Lancs	1	0	0	0	0	0	0	52	64
Manchester	0	0	-0	0	0	0	0	57	60
Cshire+Mers	0	0	-0	-0	0	0	0	55	60
NEYrk+NLinc	0	0	0	0	0	0	0	58	60
SYorks	-0	-0	0	0	-0	-0	-0	60	60
WYorks	-0	0	-0	0	0	-0	-0	58	59
InnerLdn	53	41	55	54	57	61	56	0	-0
OuterLdn	57	53	59	59	60	59	58	-0	-0

Examining the region-to-region patterns of rail productions, similar magnitudes of changes are visible, with roughly 60% decreases in rail productions between the three northern England regions, and London (and vice-versa). There are a few significant percentage region-to-region changes outside those with implemented changes, between the North West and East of England/South East (and vice-versa), although these are likely due to small changes in already minor values, given the absolute changes are equal to or less than 100.

Changes in rail trips appear to match the expected pattern (see Table 15.7 and Table 15.8), with the North East, North West and Yorkshire and Humber being the only regions with decreases in rail trips of a (relatively) significant magnitude: there are 1,950 fewer rail trips starting in Yorkshire & Humber, a fall of 1.3% from the base. All other regions display small increases in rail trips. This includes London, which, despite the increased costs of rail travel to the North of England, displays a small overall increase in trips. This appears to be related to the decrease in car driver trips, which is a very small percentage shift but causes an increase in non-car mode trips from London.

Table 15.7 – Changes in 24hr trip productions between regions; T3 Test 3 - Base, Rail

	NE	NW	Y&H	EM	WM	EoE	Lon	SE	SW	IWa	EWa	Sc	Grand Total
NE	68	32	4	1	1	1	-468	1	0	-0	0	6	**-353**
NW	-10	333	-1	4	30	10	-1,357	33	1	37	1	-11	**-930**
Y&H	15	56	261	38	8	5	-2,352	3	1	0	1	14	**-1,950**
EM	0	6	-8	25	10	8	135	1	0	1	0	-2	**176**
WM	0	1	0	7	117	1	102	8	3	0	2	-0	**240**
EoE	0	101	-0	-0	1	33	546	8	0	0	0	0	**690**
Lon	-8	-1,222	-29	2	2	57	2,270	66	2	-0	0	21	**1,161**
SE	0	572	0	0	-0	3	442	-30	0	-1	-0	3	**990**
SW	0	1	0	1	2	0	76	9	101	-5	-3	-0	**181**
IWa	0	42	0	0	5	0	1	0	0	8	2	0	**59**
EWa	0	33	1	1	5	0	15	2	34	5	0	0	**98**
Sc	-1	1	-0	-0	-0	-0	6	-0	-0	-0	0	0	**6**
Grand Total	**64**	**-44**	**230**	**79**	**181**	**118**	**-582**	**101**	**143**	**46**	**2**	**31**	**369**

Table 15.8 – Percentage changes in 24hr trip productions between regions; Test 3 - Base, Rail

	NE	NW	Y&H	EM	WM	EoE	Lon	SE	SW	IWa	EWa	Sc	Grand Total
NE	0.1%	2.7%	0.1%	1.7%	2.6%	3.1%	-59.9%	6.2%	5.4%	-4.2%	3.8%	0.1%	**-0.5%**
NW	-1.0%	0.2%	0.0%	0.3%	0.6%	21.0%	-65.0%	29.4%	2.2%	0.5%	0.1%	-0.2%	**-0.4%**
Y&H	0.5%	0.6%	0.2%	0.5%	1.6%	2.3%	-68.7%	4.9%	4.2%	0.2%	1.9%	1.3%	**-1.3%**
EM	0.2%	0.2%	-0.1%	0.0%	0.1%	0.2%	1.0%	0.0%	0.1%	1.1%	0.3%	-0.3%	**0.2%**
WM	0.3%	0.0%	0.0%	0.1%	0.1%	0.3%	1.0%	0.3%	0.1%	0.0%	0.1%	-0.2%	**0.1%**
EoE	0.2%	58.0%	0.0%	0.0%	0.2%	0.0%	0.3%	0.2%	0.5%	0.2%	0.2%	0.3%	**0.3%**
Lon	-61.4%	-75.3%	-60.7%	1.2%	1.1%	0.4%	0.2%	0.3%	1.2%	-2.6%	0.9%	3.8%	**0.1%**
SE	0.3%	70.1%	0.4%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	-1.8%	-0.1%	2.1%	**0.3%**
SW	0.4%	0.5%	0.4%	0.4%	0.1%	0.3%	0.6%	0.1%	0.1%	-9.1%	-0.1%	-0.3%	**0.2%**
IWa	1.3%	0.8%	1.1%	1.1%	0.4%	2.0%	2.1%	1.7%	1.1%	0.5%	0.3%	0.6%	**0.7%**
EWa	0.5%	1.6%	1.2%	0.9%	0.2%	0.8%	0.9%	0.6%	0.5%	1.9%	n/a	n/a	**0.7%**
Sc	0.0%	0.0%	-0.1%	-0.1%	0.0%	-0.3%	0.6%	-0.5%	-0.7%	-0.1%	n/a	n/a	**0.1%**
Grand Total	**0.1%**	**0.0%**	**0.2%**	**0.1%**	**0.1%**	**0.1%**	**0.0%**	**0.1%**	**0.1%**	**0.4%**	**0.0%**	**0.2%**	**0.0%**

The decrease in rail use is also visible in the average trip length and duration results, with largely stable results across purpose for car, bus, cycle and walk modes, but an overall decrease in rail trip lengths. In particular, there is a significant decrease for NHbEB rail trips; this applies to only a small proportion of trips, and appears a logical result, given that the small volume of trips between London and northern England are likely to be business trips, and the difference in elasticity between these and trips of other purposes.

This change in NHbEB rail trips is the only small change visible in the trip length distribution analysis, with a 1% decrease in 100-200 mile NHbEB trips. However, this applies to a very small proportion of trips.

15.4.4. Summary

Overall, this test has helped to demonstrate the functionality of NTMv5 in implementing changes in PT characteristics. The test has shown that these exogenously defined characteristics can be edited easily and in a bespoke manner to implement tests of changes in PT costs and supply. In addition, this test has helped to confirm the guidance around editing these characteristics, more detail on which can be found in the NTMv5 User Guide. The impact and results of the test confirms that NTMv5 responds in the expected manner to changes in PT characteristics, with changes in rail trips restricted to those regions directly impacted by the input changes, and that these have a proportionate impact on rail trips in the model.

15.5. Test 4: Highway travel costs

15.5.1. Test objectives

The specification agreed with DfT set the following objectives for this test:

1. Demonstrate and test the functionality for introducing a distance based cost to a subset of the highway network;
2. Investigate the responsiveness of the model to spatially variable charges for road travel; and
3. Ensure guidance for introducing distance based costs in the model is accurate and adequate.

15.5.2. Outline specification

This test investigates the impact of introducing a distance based cost of 10p per kilometre (in 2015 prices) implemented across all vehicle types (Cars, LGVs and HGVs). The network selected for this implementation is based on the following criteria:

- Regions: South East, East of England, South West and Wales; and
- Road type: all dual carriageway roads that are not part of the SRN.

The distance based cost is implemented based upon distance travelled on the selected links as specified above. This charge is applied consistently to all time periods modelled.

The Test 4 required identification of SRN links from the NTMv5 network. QGIS tools were used to undertake this task. Buffers were drawn for each of the SRN links. These buffers were intersected with the NTMv5 network to identify the SRN links matching the NTMv5 network. There are 28,836 SRN links out of a total 135,962 links (21%) within the NTMv5 network. Having obtained this information, link level UDAs have been added to the NTMv5 network to identify whether each link is SRN or not.

Based on the defined specification, the Visum network file was filtered using the UDAs for SRN, UK_Region attribute and link type. This process identified 5,417 dual carriageway non-SRN links for introducing distance based costs in the South East, East of England, South West and Wales regions under the current test.

The link type attribute denotes whether the links in the highway network are dual carriageway or not. For the links in urban areas which are coded as fixed speed, these have their own link type which does not differentiate the road type. No tolls have therefore been applied to any roads in the fixed speed areas. It is to be noted that, the highway network in Wales region is mainly categorised as fixed speed links. This implies that, application of distance based costs will not have any impact on these links.

The actual value of distance based costs on the links identified have been calculated in a spreadsheet external to Visum based on the link length and the charge of 10 pence per kilometre. The tolls calculated were added to existing charges where this was relevant (one link has both tolls). The resulting charges were coded as an updated toll attribute in the Visum highway network. This approach was adopted rather than new UDAs because the link toll attributes are automatically included in the route choice and skimmed and included in the utility calculations for the VDM within the full model.

The highway network with distance based costs by region are presented in Table 15.9.

Table 15.9 – Network components to be tolled by Region

Region	No. of Links	Network length in kms	% of network length
South East	2,592	1,522.62	8.3%
East of England	1,719	1,223.71	8.5%
South West	1,002	670.82	3.4%
Wales	104	113.56	2.5%
Network Tolled under Test 4 Scenario	5,417	3,530.71	6.2% (charged region) 2.8% (all regions)

The charges implemented are shown in Figure 15.10. Note that existing tolls such as the M6 are also shown.

The charges from the network are combined with other vehicle operating costs and parking charges when skimmed and input to the utility functions in the VDM. It should be noted that because income segmentation was excluded from the VDM for reasons of scale and efficiency the variation and levels of response in NTMv5 in response to scenarios varying costs in this way will be more limited and in practice travellers with different incomes in different locations and with different trip lengths will respond in more varied ways.

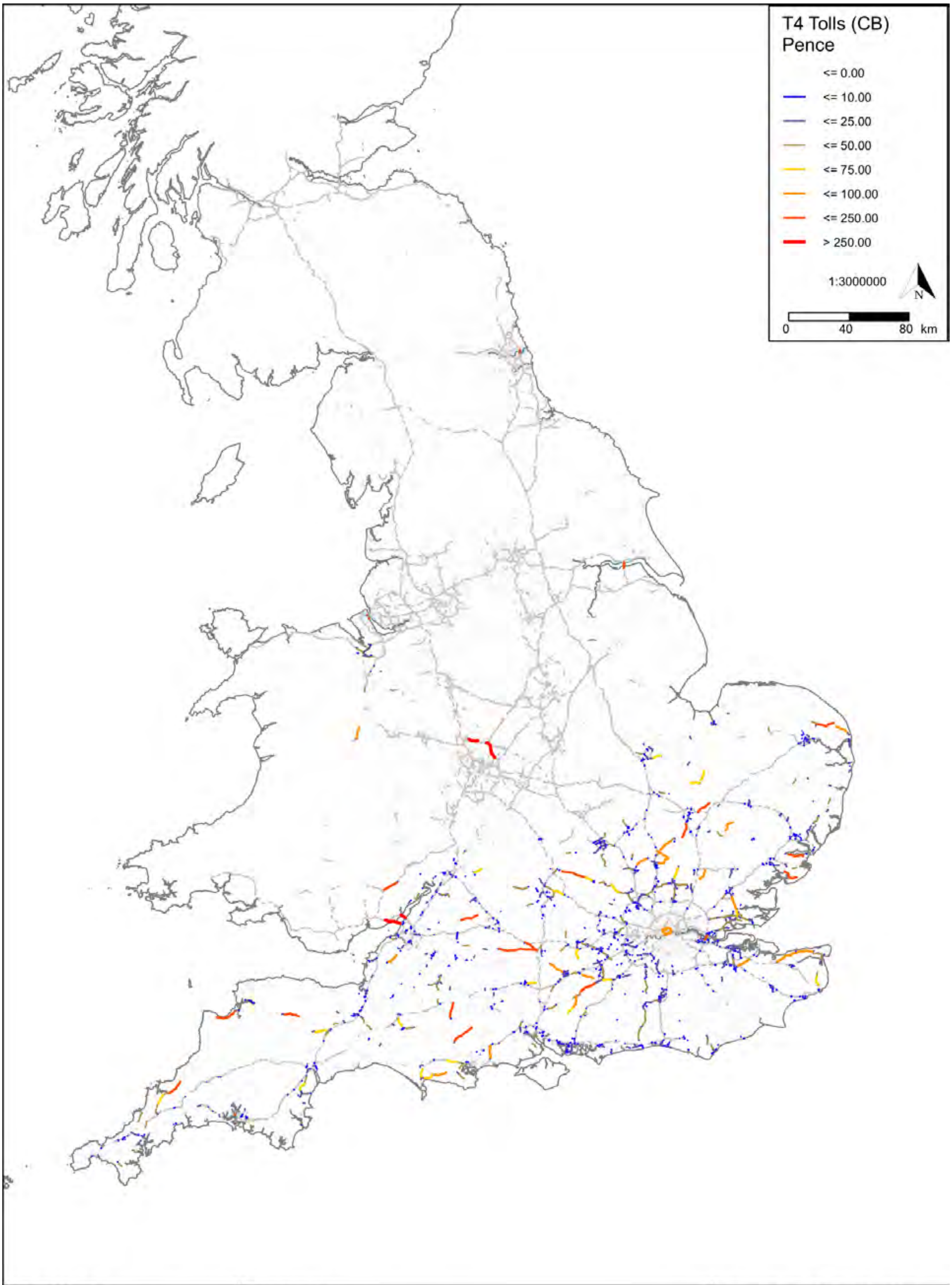


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Figure 15.10 – Test 4 user charges on links (pence)

15.5.3. Test results

Regional differences in person trips show the expected patterns in trip changes. Car driver and passenger trip in the East of England, South East, South West and Wales show 0.5-1.5% decreases in trips, compared with the base, whilst other regions show no change. The same regions display percentage increases (2-3%) in public transport and active modes, as would be expected given the user changes imposed on driving. The analysis of changes by trip purpose shows that this response is strongest for education and shopping/personal business trips, and weakest for business trips, which is logical in relation to values of time. Table 15.10 and Table 15.11 show car driver and bus example tables of trip changes resulting from Test 4.

Table 15.10 - Regional summary of difference in 24hr trip productions from Test 4 to base run - Car driver

Region	Base trips	Diff. from base	% diff. from base
NE	1,509,556	-116	-0.00%
NW	4,241,227	-1,432	-0.03%
Y&H	3,118,019	-20	-0.00%
EM	2,822,977	-110	-0.00%
WM	3,456,088	-732	-0.02%
EoE	3,644,239	-53,453	-1.46%
Lon	3,543,262	-6,386	-0.18%
SE	5,356,628	-77,941	-1.45%
SW	3,290,066	- 17,634	-0.53%
IWa	179,065	-944	-0.52%
Ewa	48,702	-736	-1.51%
Sc	2,444	-1	-0.05%
Total	**31,212,270**	**-159,504**	**-0.51%**

Table 15.11 - Regional summary of difference in 24hr trip productions from Test 4 to base run - Bus

Region	Base trips	Diff. from base	% diff. from base
NE	250,029	48	0.01%
NW	668,320	390	0.05%
Y&H	514,786	28	0.00%
EM	396,831	275	0.06%
WM	498,417	323	0.06%
EoE	486,873	15,802	3.24%
Lon	1,015,316	3,422	0.33%
SE	721,866	23,322	3.23%
SW	518,597	6,208	1.19%
IWa	24,534	529	2.15%
Ewa	1,407	50	3.56%
Sc	184	0	0.01%
Total	**5,097,159**	**50,397**	**0.98%**

Average trip lengths and journey times decrease for car driver and car passenger, while rail sees small increases, in line with the implemented user charges, In terms of average speeds, by purpose, HbEB and NHbEB are the only purposes that feature an increase in speed, which suggests that due to their higher VoT, they are taking advantage of reduced congestion when other purposes change routes or mode. Average costs have increased for car driver and passenger across purposes.

Vehicle kilometres appear to confirm the expected impact of charging on non-SRN dual carriageways, with decreases across the impacted regions, particularly impacting A Roads, smaller decreases for B Roads and other roads, and largely static results for Motorways. Decreases in vehicle kilometres for A Roads in the East of England, South East, South West and Wales were of the magnitude 3-6%. Outside these regions, decreases were under 1%. The test appears to have had very little impact on trip length distributions, with all changes in percentage share at each distance band less than 0.5% across all modes and purposes.

Figure 15.11 and Figure 15.12 show the zonal changes in productions resulting from Test 4, for car driver productions, car driver attractions respectively. As can be seen, car driver trips generally display decreases in the tolled areas, with some areas of increase, likely resulting from reduced congestion on the network. In terms of overall demand however, productions feature small increases in many areas, which is due to changes in trip distribution and therefore in the pattern of non-home-based trips.

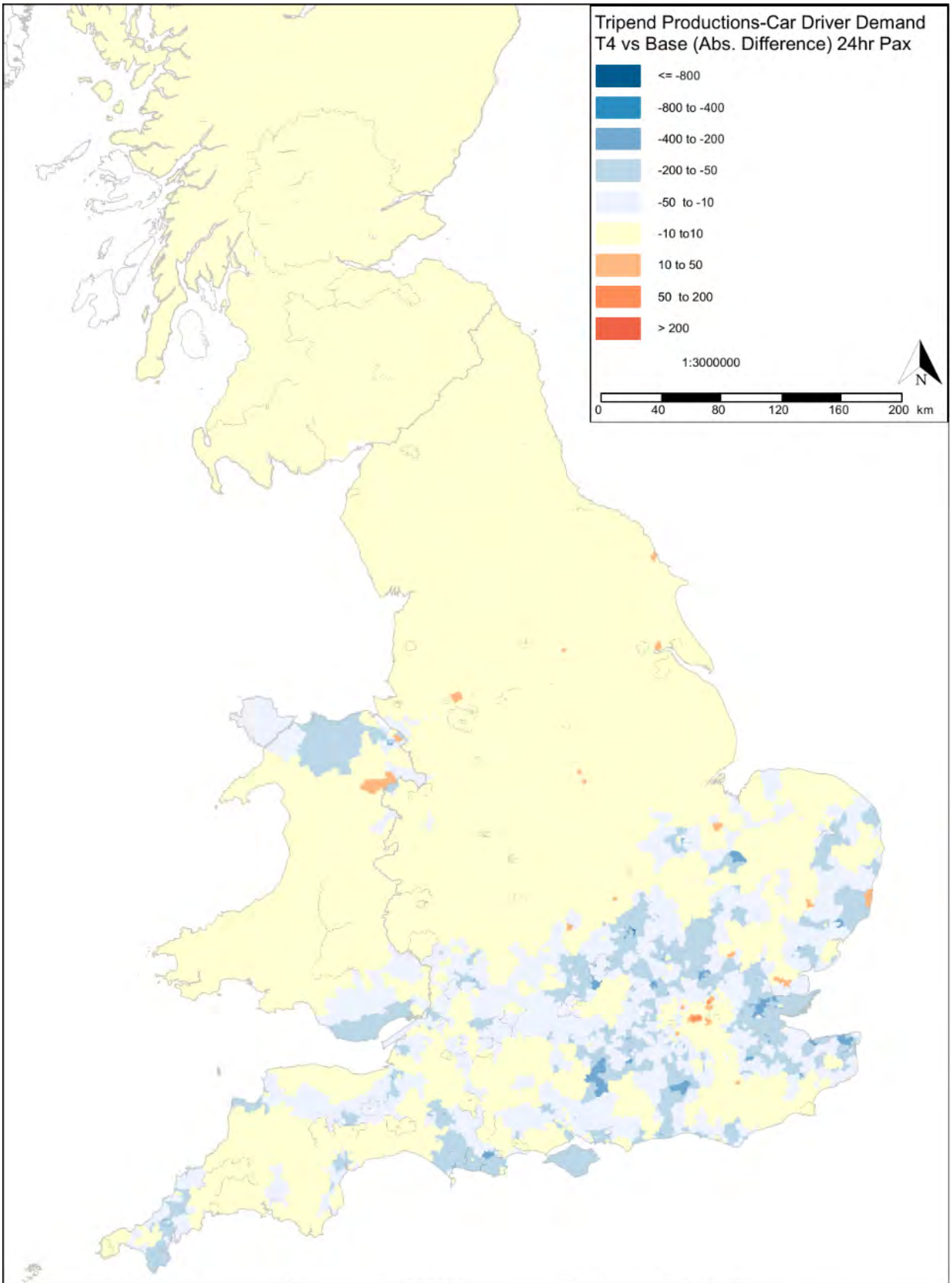

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Figure 15.11 - Change in Car Driver 24hr trip productions; Test 4 - Base

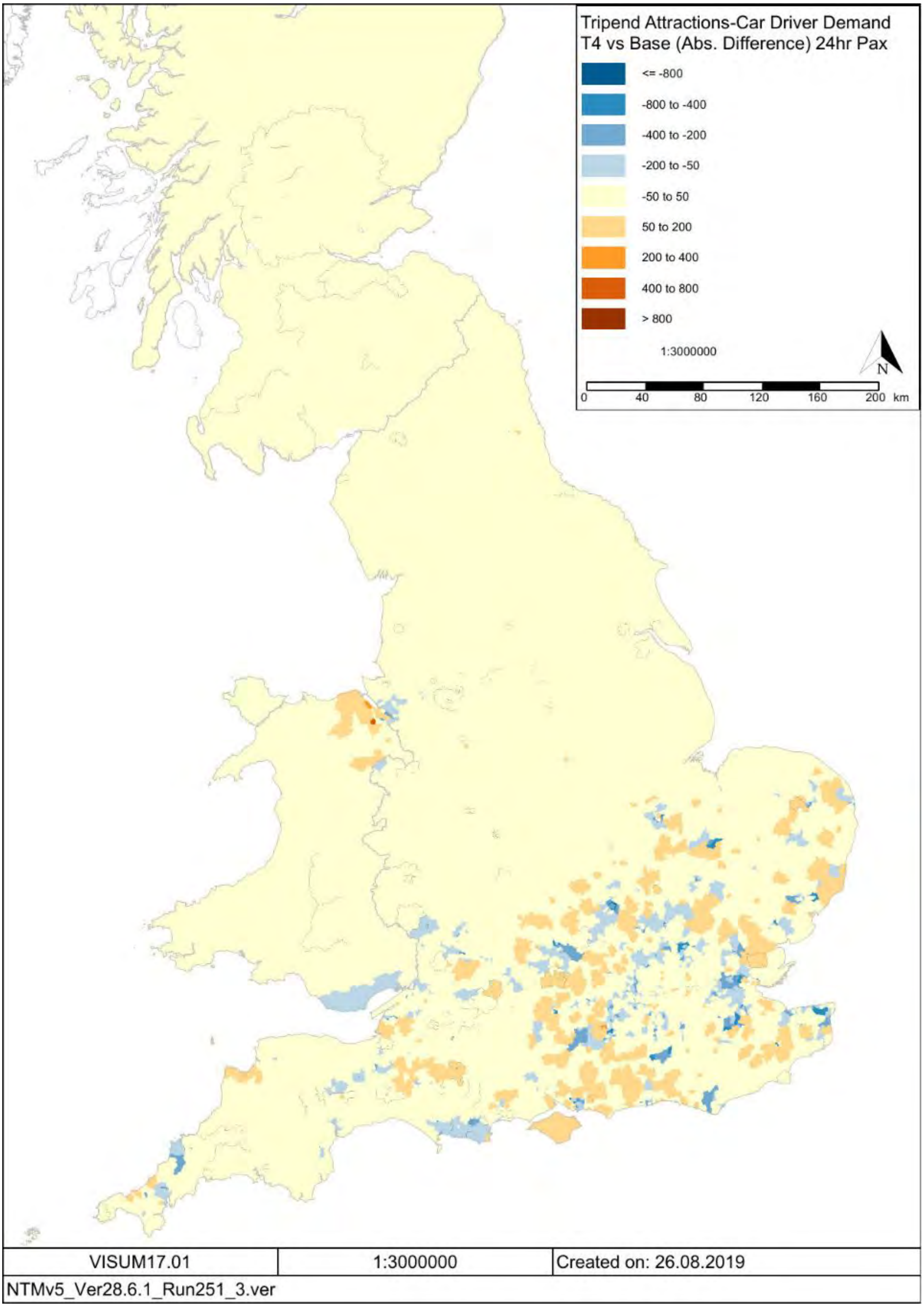


Figure 15.12 - Change in Car Driver 24hr trip attractions; Test 4 - Base

On the highway network, the user charges cause significant decreases in trips across the affected regions, as shown in Figure 15.13, for the AM period, light vehicles. There are decreases in flow observed along the links where road user cost charges are implemented and increases observed in adjacent links caused by re-routing. The flow differences however are often not major, due to the sparsity of the links impacted. The pattern is similar across the time periods. Across the rest of the network, there are minor changes observed, which generally indicate a decrease in car traffic related to the longer distance trips to/from the areas where increased charges apply.

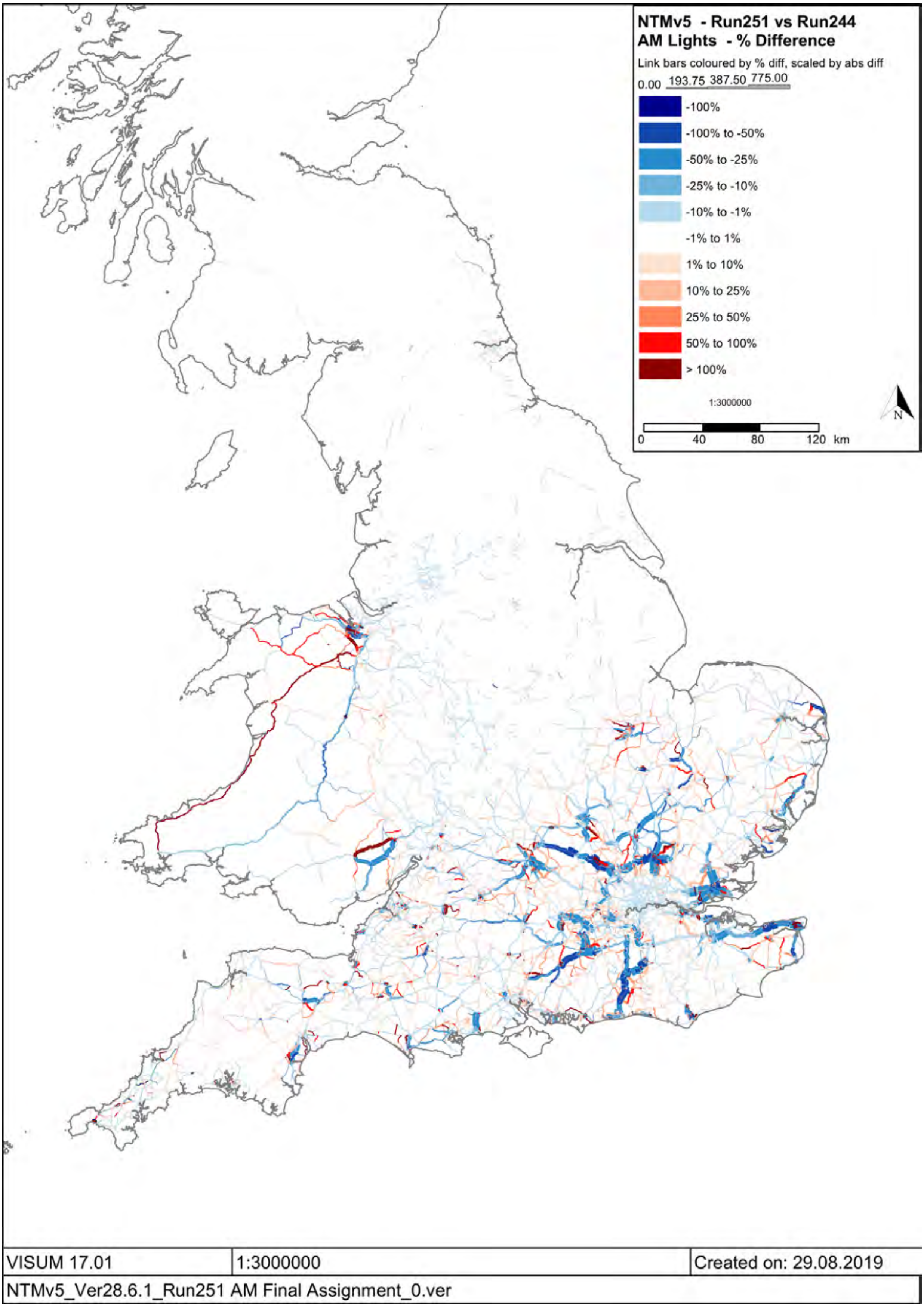


Figure 15.13 - Flow change from Base to Test 4, Light Vehicles, AM

15.5.4. Summary

Overall, this test has met the objectives set out in Section 15.5.1. It has demonstrated that distance-based user charges can be introduced in NTM, and tailored to specific regions, road types, and charge levels. The lessons from this implementation has fed into user guidance for the model, which will enable clear and consistent future tests of user charging in the model. The test has also shown how the model responds to spatially-variable charging of this type. Responsiveness has been intuitive, with modal, purpose and regional results fitting the expected pattern, of a move away from car driver and car passenger trips towards public transport and active modes, some increases in trips on alternative routes, and in average speeds for certain purposes, and spatially, little impact outside of the affected regions. The translation from test inputs to outputs is clear, and results logical.

15.6. Test 5: Urban area strategy

15.6.1. Test objectives

The specification agreed with the DfT describes the objectives of this test as to:

1. Demonstrate functionality / tools are available to make changes to groups of urban areas not just one location;
2. Test changes to a range of interventions that are applicable to urban area;
3. Demonstrate the mechanisms introduced to address the limited spatial detail available in urban areas are sufficient to provide realistic responses within the model;
4. Check user guidance is sufficient for the user to introduce changes for urban areas; and
5. Show how the model responds to interventions in urban (rather than rural) areas where there is likely to be more competition between alternative modes of travel

15.6.2. Outline specification

This test makes a range of changes to urban areas in specific subsets of the network, with the overall aim of making car travel less attractive and/or making other modes of travel more attractive, in the model. The proposed changes will be implemented in the following areas:

- Region: East Midlands, Yorkshire and Humber, and North East
- Urban Area: Those with the NTS definition of ‘urban medium’ or above (a population of greater than 25,000)

The changes proposed for this test are:

- All single carriageway roads (including those with several lanes) within the defined urban areas to have a 20mph (32kph) speed limit imposed. Any strategic routes into/through the urban area which are dual carriageways are to have speed limits no greater than 50mph.
- Centroid connector speeds will remain unchanged as they are set to 30kph i.e., less than 20mph in the base year;
- Parking charges to be increased by changing the proportion of trips paying to park. Parking charges and the area (zones) to which the charges apply would be unchanged.
- Access and egress times for car travel to be increased by 2 minutes.
- Cycling for trips within the identified urban areas would be made more attractive (representing a cycle safety/awareness strategy).

Based on the urban area definition by region, the network and zonal attributes are amended for the links and zones falling within the combination of East Midlands, Yorkshire and the Humber and North East regions, and those urban areas with population greater than 25,000. A map of the zones identified for the test is provided in Figure 15.14.

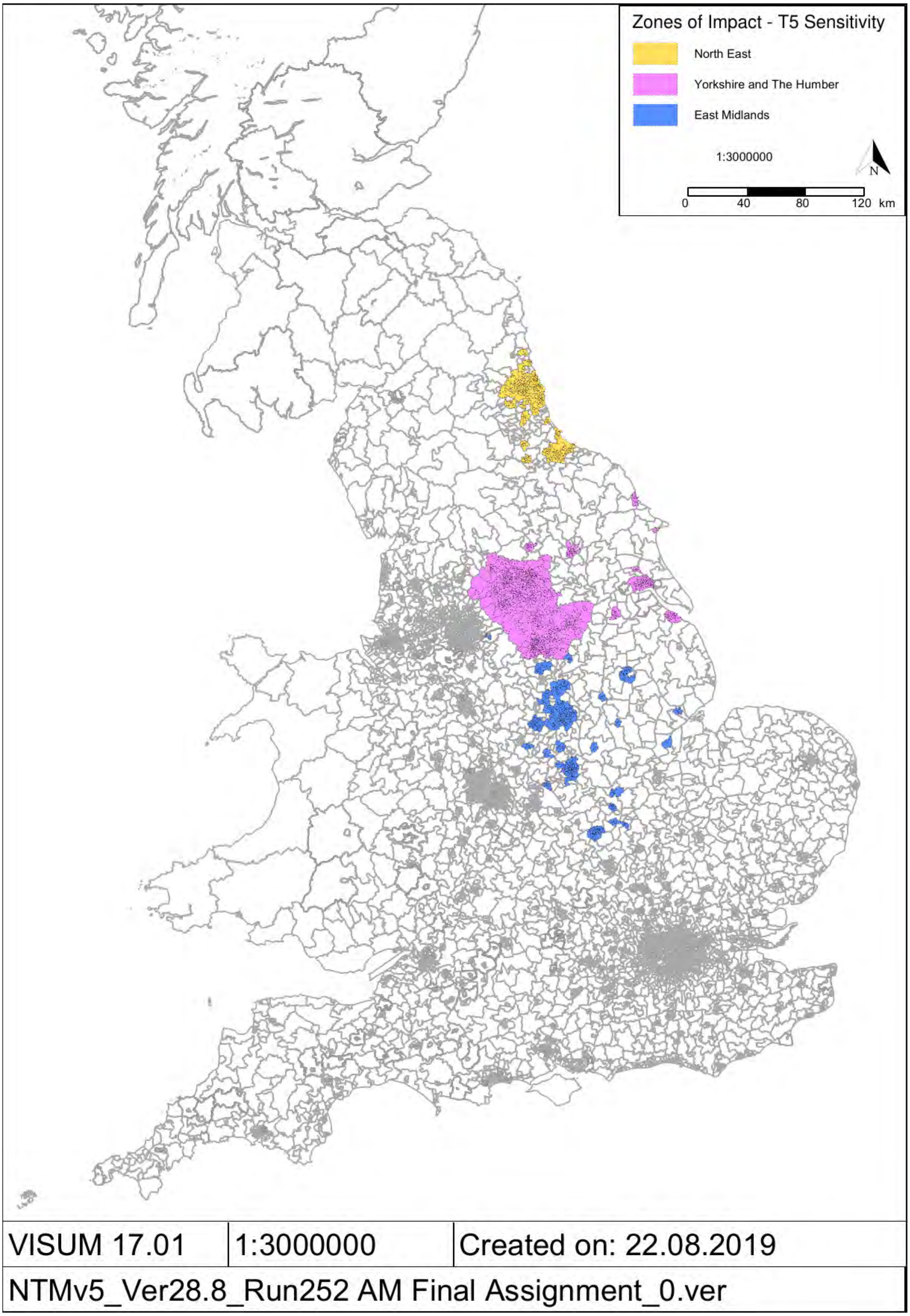


Figure 15.14 - Zones of Impact for Test 5 sensitivity testing

Speed limits on Highway Network

The following steps were followed to apply the speed limit changes to the links within the urban areas as defined in the specification:

- The links that need speed limits changed have been identified with an intersect query with the zoning layer, and then filtered by the zones that are part of the defined urban areas and regions. 17,252 links have been identified for speed reduction which includes 13,138 VDF links and 4,114 fixed speed links;
- For the VDF links,
  - the link type has been used to identify single and dual carriageway links (that are not in urban fixed speed areas);
  - the free-flow speed (v0-PrT) on these links have been reduced to 32kph (single carriageway) or 80kph (dual carriageway). So, they use the same link types and hence VDF curves as previously;
- For the fixed speed links, there are no separate link types for dual or single carriageway. However, the attribute named “Link_Type” contains information on the link, including single/dual carriageway for a large number of roads, and junction types where exploded junctions have been coded. This attribute was used for the fixed speed links, with anything marked as dual having an 80kph limit and everything else assumed to be single carriageway and hence given a speed limit of 32kph. However, there are a significant number of links where the speed coded in the base is lower than this speed limit, and therefore a minimum has been taken between the new speed limit and the existing speeds; and
- The combined link list generated from VDF and fixed speed links is loaded into Visum as an attribute file (*.att) along with the link identifier as a UDA.

Parking charges

There are three underlying tables that provide the calculation of parking charges in NTMv5. These are:

- Parking Charges – Average charge for those paying to park in pence;
- % paying to park – Percentage of people paying the parking fee; and
- Parking cost paid – Average parking fees paid. This is derived using the formula below.

*Parking Cost Paid = Average parking charge for an individual * % people paying the parking charge*

For this test, the percentage paying the parking charges has been doubled for the zones in the specified regions and urban areas. As the parking charges are developed at NTMv2R area level, it implies that the parking charges remain constant for the zones within the combination of specified regions and urban areas.

Access and egress times

In order to make car less attractive, car travel times by purpose for OD pairs for defined urban areas have been increased by 2 minutes. 1204 zones were identified to fall within the defined urban areas under this test. Thus, 1204 x 1204 OD pairs are subjected to an increase in travel times by 2 minutes for each of the purposes.

Cycling

Following advice from RAND Europe, adjustments to the calibrated constants in the VDM to reflect safety and other interventions that are expected to improve the perception of travel without necessarily changing the actual attributes, are best achieved through modifying the perceived travel times with an appropriate amount of equivalent travel time savings. Analysis was therefore carried out on the Base Year model cycle times to determine by what amount these should be adjusted for Test 5.

Analysis of the base cycle attribute matrix shows that 66% of the cycle trips have less than 20mins travel time and 99% of the trips are less than 40mins. Also, response of time savings was checked for absolute (-10mins), percentage (-50%) and combined changes (absolute = -5mins; Percentage = -25%) in cycle times.

The response check provided an indication to test reducing the perceived cycle time by 10 minutes for specific OD pairs as per the specification for the purpose of this test.

For the Test 5, the actual cycle times have been reduced for the 1204 x 1204 OD pairs identified for defined urban areas. It is to be noted that there are 4,420 OD pairs in the base year matrix where the cycle time is less than or equal to 10minutes which results in times less than or equal to zero minutes.

15.6.3. Test results

The range of input changes appear to filter through to trip end changes in the expected manner. In terms of a difference from the base run, the test sees a significant (~10%) decrease in car driver and passenger trips in the affected regions, paired with significant increases in bus and rail trips (10-17%). There are also ~10% changes in walking trips in these regions, and the most significant modal increases are in cycling, which features a more than doubling of trips in the three affected regions. Outside of these regions, results are almost static across mode. Table 15.12 to Table 15.14 show trip end changes results for car driver, bus and cycling modes.

Table 15.12 - Regional difference in 24hr trip productions from Test 5 to base run - Car driver

Region	Base trips	Diff. from base	% diff. from base
NE	1,509,556	-121,226	-8.03%
NW	4,241,227	-2,124	-0.05%
Y&H	3,118,019	-286,770	-9.19%
EM	2,822,977	-173,644	-6.15%
WM	3,456,088	-283	-0.00%
EoE	3,644,239	405	0.01%
Lon	3,543,262	-5,451	-0.15%
SE	5,356,628	71	0.00%
SW	3,290,066	-492	-0.01%
IWa	179,065	-210	-0.11%
Ewa	48,702	-41	-0.08%
Sc	2,444	34	1.38%
Total	**31,212,270**	**-589,731**	**-1.88%**

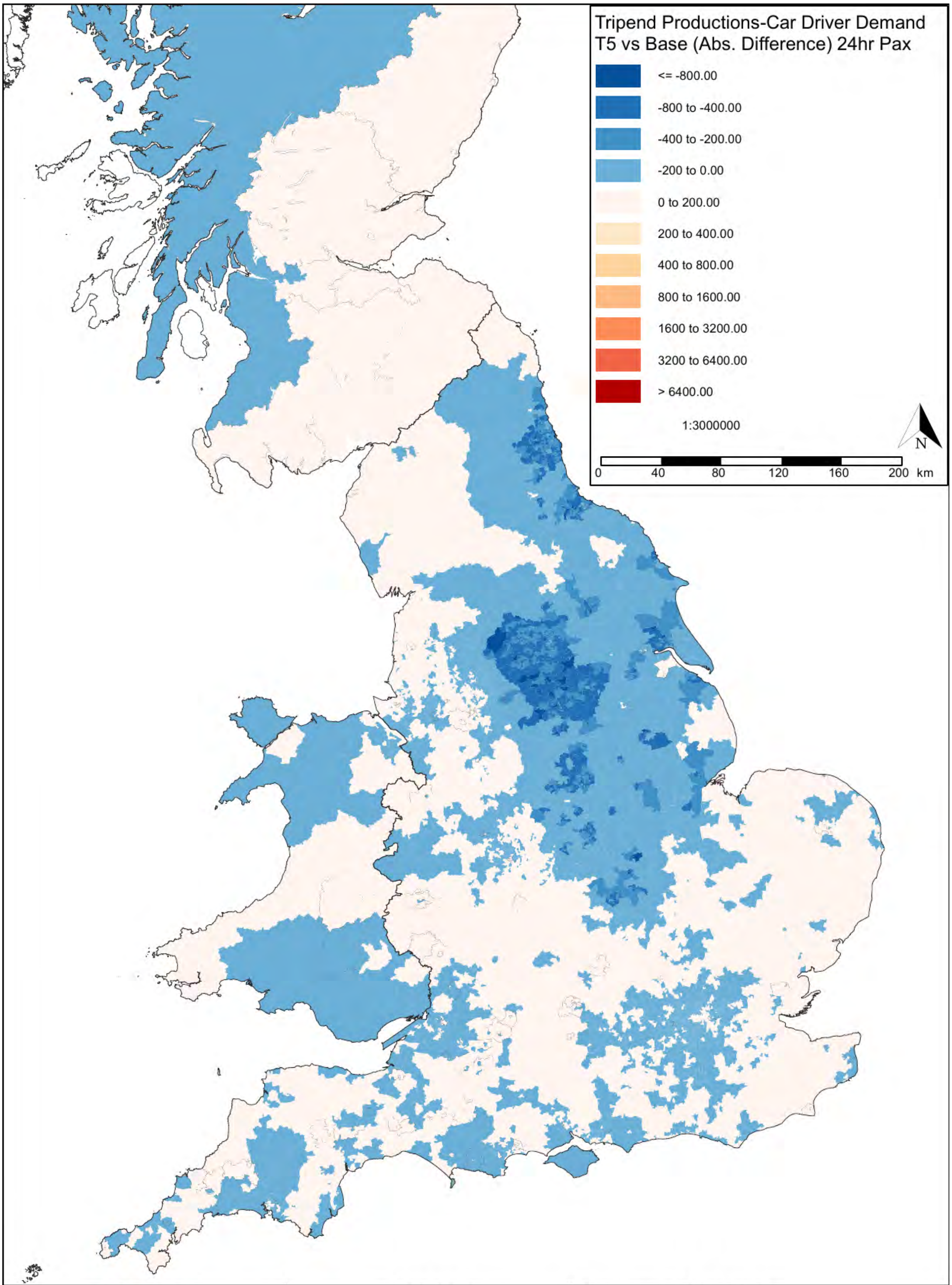
Table 15.13 - Regional difference in 24hr trip productions from Test 5 to base run - Bus

Region	Base trips	Diff. from base	% diff. from base
NE	250,029	31,530	12.61%
NW	668,320	1,669	0.25%
Y&H	514,786	69,757	13.55%
EM	396,831	38,874	9.79%
WM	498,417	1,066	0.21%
EoE	486,873	533	0.10%
Lon	1,015,316	1,513	0.14%
SE	721,866	307	0.04%
SW	518,597	260	0.05%
IWa	24,534	88	0.35%
Ewa	1,407	4	0.27%
Sc	184	2	0.82%
Total	**5,097,159**	**145,602**	**2.85%**

Table 15.14 - Regional difference in 24hr trip productions from Test 5 to base run - Cycle

Region	Base trips	Diff. from base	% diff. from base
NE	50,152	71,081	141.73%
NW	146,071	762	0.52%
Y&H	111,630	180,090	161.32%
EM	86,329	105,506	122.21%
WM	111,546	414	0.37%
EoE	101,228	199	0.19%
Lon	295,523	708	0.24%
SE	160,161	127	0.07%
SW	113,592	98	0.08%
IWa	3,405	18	0.51%
Ewa	94	0	0.44%
Sc	2	0	1.77%
Total	**1,179,732**	**359,004**	**30.43%**

Examining the spatial impact of the input changes shows a significant reduction in production and attraction car driver trips within the urban areas of the North East, Yorkshire and the Humber and East Midlands. These correspond with the zones impacted, as shown in Figure 15.15 to Figure 15.17. Car driver trip productions reduce across a wide area, relating to trips both from and within the impacted urban areas. Reductions in trip attractions are understandably more focused on the urban areas, with increases in attractions in adjacent areas. This is evidence of trip re-distribution from the impacted urban areas, with inbound trips re-distributing. It is notable that total trip attractions (all modes) also rise across adjacent areas, which reflects an increase in public transport travel out of the study area.



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NTMv5_Ver28.8_Run252 AM Final Assignment_0.ver		

Figure 15.15 - Change in Car Driver 24hr trip productions; Test 5 - Base

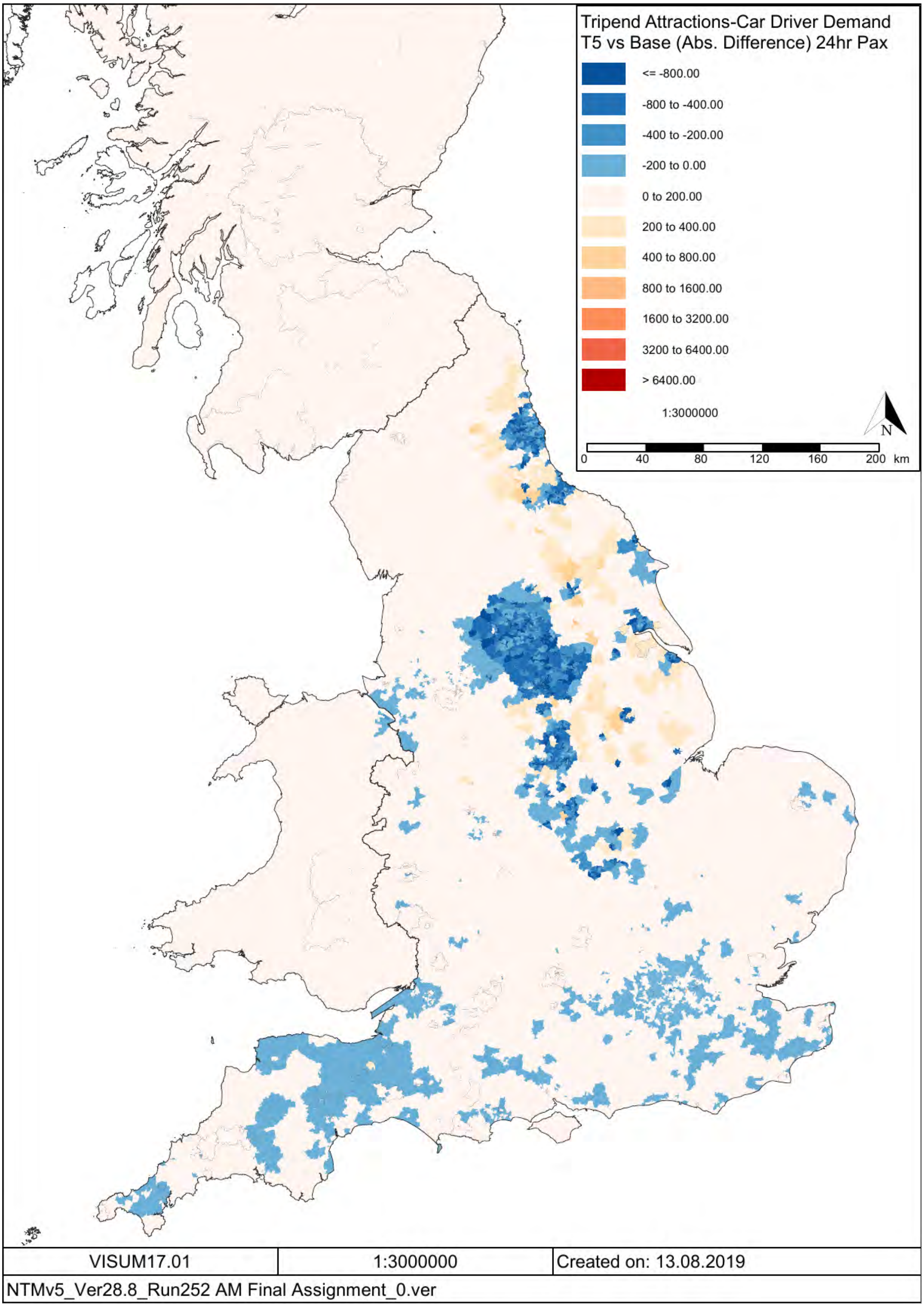


Figure 15.16 - Change in Car Driver 24hr trip attractions; Test 5 - Base

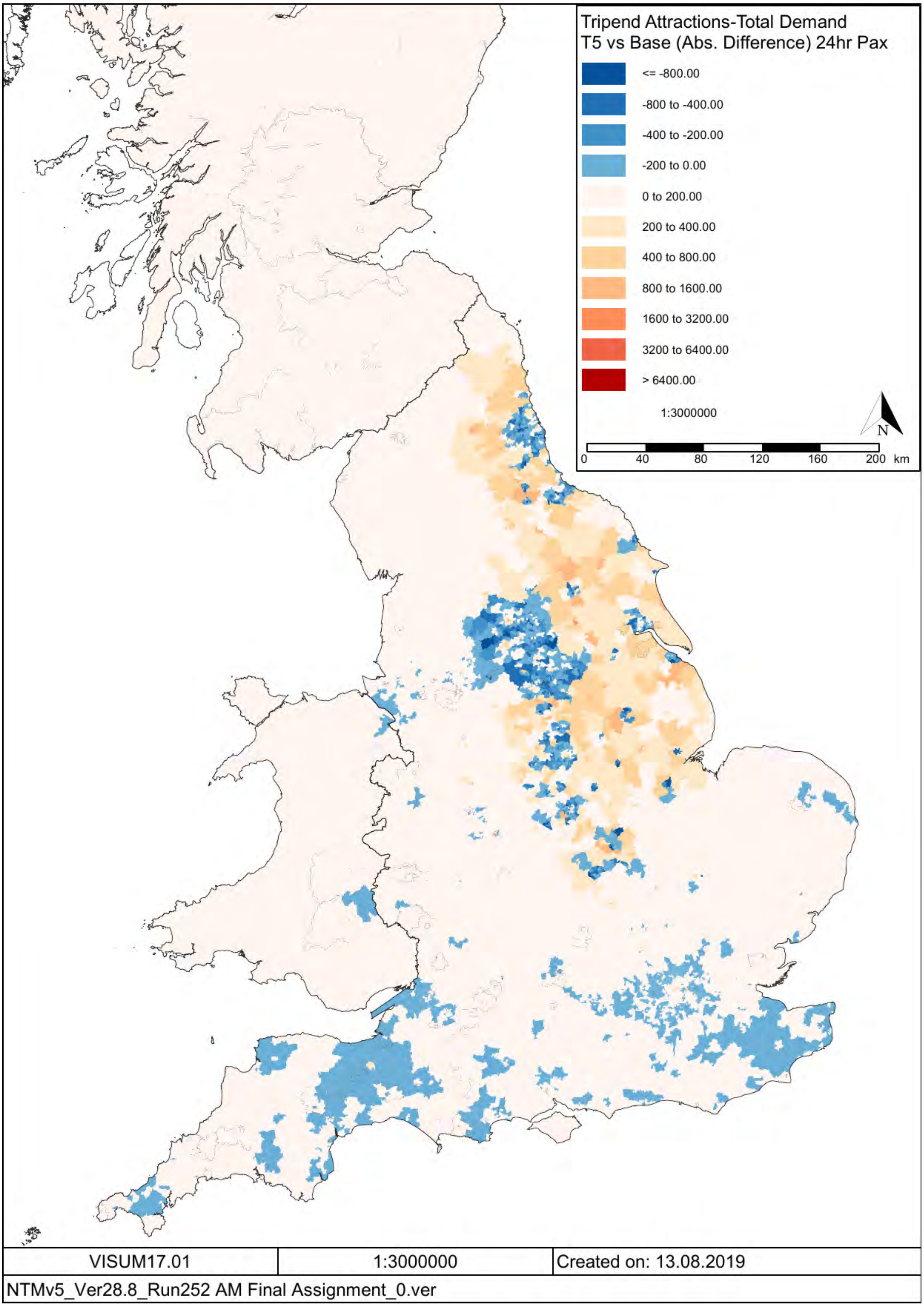


Figure 15.17 - Change in Total 24hr trip attractions (all modes); Test 5 - Base

Vehicle kilometres also appear to have responded in the expected manner to Test 5. Given the minor changes in trip length, the changes in total vehicle kilometres largely reflect the changes in trip volume in the regions of impact amongst light vehicles, with 10-20% decrease in all three time periods. The other regions show very minimal changes in vehicle kilometres. The breakdown by road type for the three regions shows that, in total across the model, the reduction in vehicle kilometres is greater on the A Roads compared to motorway and B Roads. These patterns appear to be consistent with the basis of the test, given changes were focused around urban areas. Table 15.15 shows the AM, light vehicle summary of vehicle kilometre changes.

Table 15.15 - Change in vehicle kilometres; Test 5 – Base, light vehicles, AM (Mil. kms)

Region	All Roadtypes + Connectors + Intrazonals		Motorway		A Road		B Roads + other roads	
	Diff. from base	% diff. from base	Diff. from base	% diff. from base	Diff. from base	% diff. from base	Diff. from base	% diff. from base
NE	-0.33	-11.79%	-0.03	-18.65%	-0.25	-12.98%	-0.03	-8.60%
NW	-0.02	-0.28%	0.00	-0.08%	-0.02	-0.51%	0.00	-0.42%
Y+H	-1.25	-19.11%	-0.33	-20.95%	-0.73	-21.29%	-0.16	-22.60%
EM	-0.80	-11.57%	-0.18	-14.95%	-0.55	-12.92%	-0.06	-8.33%
WM	-0.01	-0.14%	0.00	-0.09%	-0.01	-0.32%	0.00	0.34%
EoE	-0.02	-0.21%	-0.01	-0.87%	-0.01	-0.17%	0.00	0.17%
Lon	-0.03	-0.72%	0.00	-0.58%	-0.02	-0.79%	0.00	-0.99%
SE	-0.01	-0.07%	0.00	-0.03%	-0.01	-0.11%	0.00	-0.10%
SW	-0.01	-0.09%	0.00	-0.08%	0.00	-0.09%	0.00	-0.18%
Eng	**-2.48**	**-3.68%**	**-0.56**	**-3.74%**	**-1.61**	**-4.40%**	**-0.25**	**-3.24%**
Wal	-0.01	-0.26%	0.00	0.09%	-0.01	-0.57%	0.00	-1.75%
Sco	-0.01	-0.22%	0.00	0.51%	0.00	-8.46%	-0.01	-0.67%
GB	**-2.50**	**-3.41%**	**-0.56**	**-3.67%**	**-1.61**	**-4.31%**	**-0.26**	**-2.98%**

In terms of changes in average distance, car driver and car passenger trip lengths have decreased from base, whilst bus and rail journey distances increase, relative to the base trip length. Matching journey distances closely, average speeds also decrease for car driver and car passenger and increase for bus and rail modes. Journey times on the other hand increase for the car modes and decrease for the non-car modes whilst average cost feature small changes across both car and PT modes, with cycle and walk being static. Trip length distributions change little as a result of Test 5, with all changes from the base distance band share of trips smaller than 1.0%. Cycling trip lengths feature a small shift (1%) towards shorter trips across all purposes.

In line with the reduction in car driver and passenger trips in the urban areas already detailed, analysis of highway flows showed decreases in flows on the highway network in all time periods. Matching the reduction in trip volumes, A Roads and B Roads in particular saw decreases, with the Leeds area within the Yorkshire and the Humber region showing slightly greater decrease than those from North East and East Midlands. This reduction in trip volumes may be also attributed to the link speed reduction in the urban areas.

Regarding link speeds, Figure 15.18 shows the changes in link speeds from the base, for the AM time period. As would be expected from this test, with the reduction in free flow link speeds in the urban areas for specific regions, there is a decrease in speeds observed in the network. Matching the patterns seen in the flow volume change analysis, A Roads and B Roads within North East, East Midlands and Yorkshire and the Humber, see significant decreases in average link speed. Major impacts are observed with the cities of Leeds, Newcastle upon Tyne and York. All three time periods experience similar decreases in average speed.

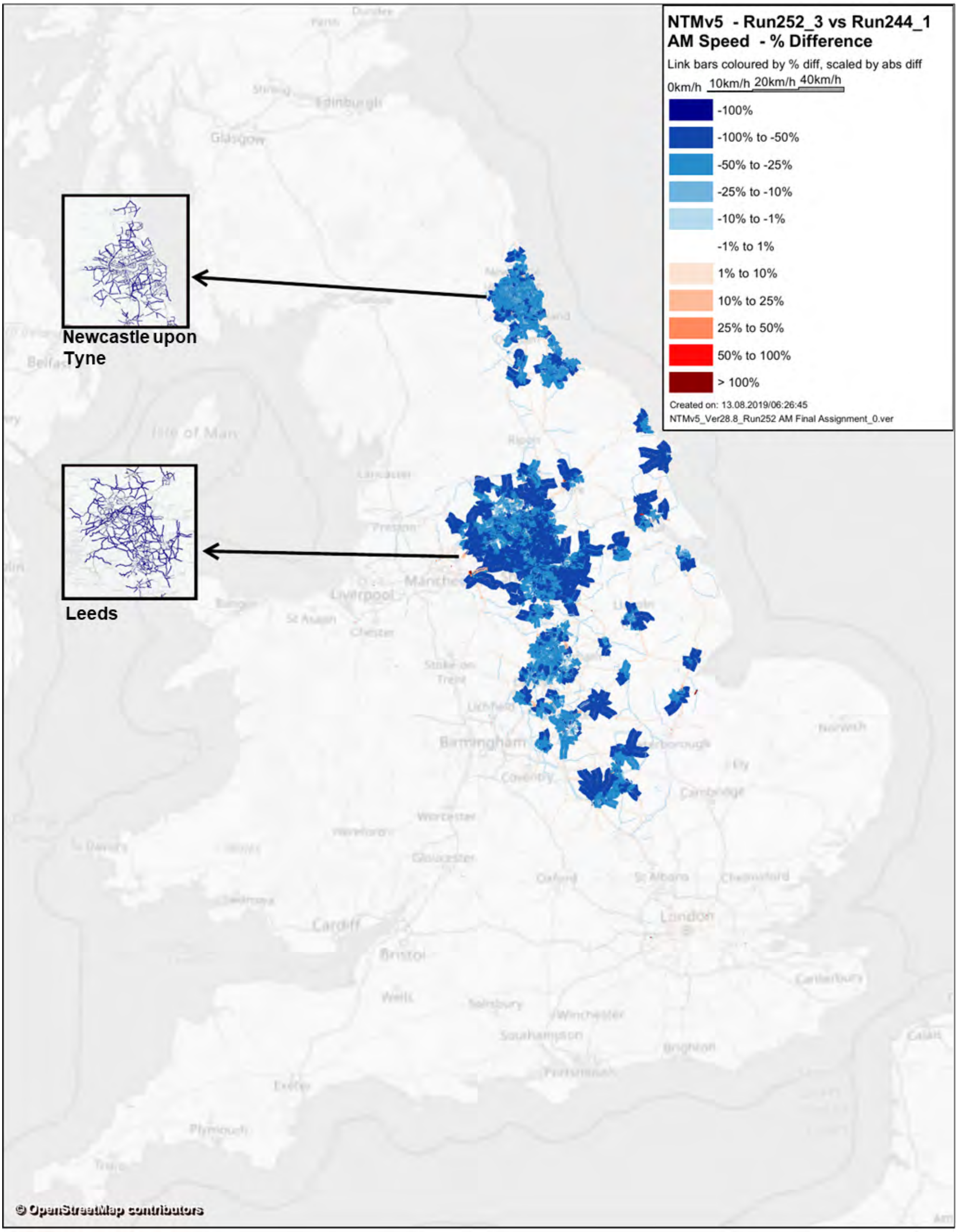


Figure 15.18 - Link speed changes from Base to Test 5, AM

15.6.4. Test 5 Summary

Overall, Test 5 has shown that it is possible to introduce and test policy changes to groups of urban areas in NTMv5. The test has demonstrated that changes can be made to both a group of urban areas and a set of different interventions (including parking, cycling etc.) at once, in a clear and systematic manner. The methods for changing the model inputs has been established as part of Test 5, and has been documented in the NTMv5 User Guide. In terms of the response of the model, this has been largely logical given the input changes. A general shift in the affected urban areas from car to public transport and active modes, and particularly cycling, reflect the full range of the policies tested. The regions impacted are those intended, with other regions experiencing no or little change. The trip length and volumes patterns are also intuitive, given the test inputs. In particular, it should be noted that the spatial analysis presented demonstrates that competition between different modes of travel and fluctuations in commuting behaviour, that is of greater focus in urban areas than rural areas, are both present in the results of the test.

15.7. Overall summary

The NTMv5 sensitivity tests have demonstrated how the model responds to user-specified input changes, and that these input changes can be implemented in a controlled and clear manner, in-line with potential DfT future uses for the model.

The testing process has enabled checking and updating of input processes to ensure the model runs correctly and as intended when changes are made by the user. In addition, the development of input processes have fed into documentation of user guidance, and have been documented in the NTMv5 User Guide.

In terms of model responses, the five tests have all shown largely logical and intuitive responses to the input changes. In some cases, these input changes have been too minor in a national context to have a significant impact, but the results of the model have reflected the magnitude of the changes in all tests. Close monitoring of changes across purpose, mode and region has allowed detailed analysis of changes from the base model, and it is recommended that these checks along with other appropriate analysis are used for future tests. These changes have been sensible and suggest a model that can be used to test a wide range of policy changes.

Part 4: Quality Assurance

16. Quality Assurance in NTMv5

16.1. Introduction

In line with the DfT's *Quality Assurance for Analytical Modelling* guidelines[8] and given the 'Impact' and 'Complexity' of both the overall NTMv5 project, and the model itself, there has been a correspondingly rigorous and comprehensive approach to quality assurance in NTMv5. Following the DfT's own Quality Assurance Framework, 'Output Specification and Quality Assurance' (OSQA) Plans at each phase of model development have provided clear governance on quality assurance, tailored to the unique challenges that the development of NTMv5 would bring. The OSQA documents set out for each stage:

- Specification: Objectives, required inputs, responsibilities and final deliverables required; and
- QA plan: Details of any internal and external review and audit, a review of risks and mitigation plans, and criteria for determining whether the output meets the required standards of accuracy and reliability.

In addition, a comprehensive approach to quality assurance was embedded in every step of the project, with important principles such as clear internal documentation, version control, and progress updates agreed with the DfT.

The DfT's *Quality Assurance for Analytical Modelling* defines a model as typically having three main parts:

- Inputs;
- A processing component; and
- Outputs.

As a result, QA on these areas has been broken down into:

- **Inputs:** Checks on the quality and reliability of raw data and other inputs, as well as their appropriateness for NTMv5;
- **Processing:** Checks on the importing, manipulation and formatting of data, robustness of processes and replicability once model is transferred to DfT;
- **Validity of model:** Checks on the quality of outputs against observed data and general assurance on quality of the model as a whole;
- **Checks on functionality:** Ensuring that the model, either as a whole or specific components, functions to the required standard, in terms of implementation, modelling processes and run times; and
- **Checks against scope:** Ensuring that all elements of the model, including inputs, processing stages and final outputs, meet the standard set out and agreed with the DfT.

This section features a table setting out the QA undertaken throughout the development of NTMv5, covering the areas set out above. Given the scale of the project, it is not possible to list full details of every check conducted by the project team throughout the project. For example, the range of checks embedded in spreadsheets used during the HAM calibration process are not listed. Instead, the table focuses on significant QA steps documented throughout the project, and the table contents are designed to demonstrate both the breadth, and type of checks undertaken to ensure quality in all elements of the model.

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350904/qa-modelling-guidance_pdf.pdf

16.2. NTMv5 Quality assurance summary tables

Table 16.1 - Quality assurance conducted on model design and software capability

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Treatment of urban areas	Refinement of approach to modelling urban areas	Against scope	N/A	Details of documentation and agreement with DfT on strategy for modelling urban areas.
Linking of base year demand and VDM	Discussion of potential pivoting approaches	Against scope	N/A	Consideration of pivoting approach.
Use cases	Critical questions related to use cases	Against scope	N/A	Qualitative discussion of technical impact of use cases.
Choice of incremental approach	Comparison of AMAI and IPP approaches	Against scope	N/A	Detailed documentation of pivoting approach, plus table comparing AMAI and IPP methods.
Software Capability	Testing of overall model run times	Functionality	Whole model	Details of tests carried out on the highway and demand models to ascertain model run times and confirm software capability.
User Interface Design	Review of VISUM functionality for each UI	Against scope and functionality	N/A	Review of Visum capability for each element of the User Interface in tabular format. Demonstrates planning ahead of implementation in Visum.
Weekend peak analysis	Checks on ATC sample size	Against scope	Full dataset	Details of exploratory analysis into weekend peak periods from a Highways England set of ATC count data.
Technical specification	Documentation	Against scope	Whole model	Documentation and agreement with DfT through iterations of drafts of Technical Specification document

Table 16.2 - Quality assurance conducted throughout model implementation

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Mathematical implementation of NTMv5	Mathematical specification of VDM and model supply-demand loop	Functionality	Whole model	Table of different stages of Procedure Sequence, with mathematical specification and notes on progress, issues and questions. Recorded in Technical Notes and reviewed at each stage.
NTM Visum Implementation	Details of run time testing	Functionality	Whole model	Table setting out model run times from testing, regular review.
	Review of Visum functionality	Functionality	Whole model	Review of Visum 17 functionality and Procedure Sequence ahead of model implementation.
	Procedure Sequence Review	Functionality	Procedure Sequence	Reviews of the control script for the model running were carried out by an independent internal Visum expert, and separately by PTV.
AMAI Pivoting Process	Implementation and testing of pivoting process	Functionality	Whole model	Details of mathematical and Visum implementation of AMAI pivoting, plus detailed results of testing, comparing synthetic and post-processing forecast growth.
Documentation	User Guidance Tests	Against Scope, Functionality	Whole model	User Guidance and appropriate model files provided to DfT prior to model finalisation to enable user guidance feedback.
	Final documentation	Against scope	Whole model	Full set of checks, reviews and authorisation procedures conducted on all deliverables and final documentation provided to DfT.

Table 16.3 - Quality assurance conducted on model zoning

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Initial zoning	Review of RTM zones	Input	Whole model	Review of RTM zoning systems and boundaries, compatibility with LSOAs and MSOAs.
Reviewing of bespoke zones	Urban Area MSOA Aggregation	Input	Whole model	Requirements and consideration of urban area MSOA aggregation.
	Review of bespoke and problem zones	Processing	Whole model	Detailed approach taken for bespoke zones; requirements, definition, creation, plus issues encountered.
Final zone definition	Changes from interim to detailed zoning	Processing	Whole model	Testing of interim zoning including run time testing, plus a summary of changes from interim to detailed zoning system.
	Review of zoning by DfT	Against scope	Whole model	Documentation and agreement with DfT on principles of zoning, and on final zoning system,

Table 16.4 - Quality assurance on highway network development

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
NTMv5 link types	Converting SATURN SFC to Visum VDF	Processing	Whole model	Detailed write-up of methodology used for converting SATURN SFC to Visum VDF.
Network importing methodology	Comparison of network importing methodology	Processing	Whole model	Table comparing method for importing SATURN network to Visum; via shapefile vs directly importing the SATURN network file to Visum.
Process of network conversion	Network QA	Processing	Whole model	Flowchart showing network import process, and text describing QA to be conducted during RTM network stitching process.
Testing of network conversion	Testing of importing into Visum	Processing	Whole model	Tables showing how link, node and turn attributes are converted from SATURN to Visum, and any loss of information/issues.
Junction modelling methods	Consideration of other coding techniques	Processing	Whole model	Description of proposed junction modelling method, with tables of test results.
Pilot testing in Oxford Visum model	Comparisons of SATURN and Visum results	Processing	Sample	Results of a pilot test of the proposed junction modelling parameters, examining journey times against observed.
Modelling in urban areas	Review of approach in RTMs	Input	N/A	Review of fixed speed urban area approach in RTMs, plus comparison of two methods for forecasting urban area speeds.
Analysis of speed-flow relationships in urban areas	Plotting of speed-flow relationships	Input	Sample	Demonstration of speed-flow relationship from a sample of TrafficMaster locations in London, and justification for using fixed-speed approach in NTMv5.
Review of fixed-speed coding	Outline of fixed-speed urban area coding	Input	Whole model	Method used to select fixed-speed links in NTMv5, from the RTMs, plus summary of resulting number of links, location etc.

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
HAM calibration and validation	Ongoing development of network during calibration.	Validity	Sample	Continued development and checks on highway network during calibration process, including reviews of connectors crossing screenlines and motorways, HGV restrictions, reviewing Midlands RTM area, and examining links with high volume/capacity
HAM Quality Assurance	QA checks on network, as well as network statistics	Validity, against scope	Whole model	Complete set of checks on the fulfilment of quality assurance exercises during network development, covering completeness, compilation, routing, consistency and run time tests. Also includes showing overall network statistics and link consistency checks, see Developer Guide Volume 1, Chapter 3 for more information.

Table 16.5 - Quality assurance conducted on base matrix construction

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Overview of HSL data	Checks on HSL data	Input	Whole model, sample	Regional and LAD completeness checks on HSL-provided data, plus spot-checks and scatter plots of data.
Technical specification for AYC data	Specification for AYC data	Input	Whole model	Description of requirements for AYC data.
Processing of AYC Data	Checks throughout processing	Processing	Full dataset	Details of processing applied to the AYC property data, and checks on this process.
Processing of AYC Data (technical detail)	QA throughout on AYC data processing	Processing	Full dataset	Details of checks applied to each of the six steps of processing for obtaining the 2015 population per property type per NTM zone from the AYC data.
Status of matrix construction tasks	Overview of progress (Sept. 2017)	Processing	N/A	Summary table of status of tasks, with indication of QA conducted.
Determining airport trips - methodology	Checks on airport data processing	Processing	Full dataset	Summary statistics and summary of checks conducted on CAA airport data.
HGV/LGV Matrices	Checks on implied vehicle kilometres	Processing	Full dataset	Checks on implied annual vehicle kilometres by assigning prior HGV/LGV matrices and comparing with observed annual traffic data.
Creating synthetic P/A matrices (Gravity model)	QA on Kalibri process	Processing	Full dataset	Details of Kalibri runs conducted, and comparison of resulting trip length distributions against observed NTS data.
Census JTW data	QA on Census JTW data	Processing	Full dataset	Trip length distribution comparison of HbW matrix vs NTS data, after processing of census JTW data.
School Census Education data	QA on education data	Processing	Full dataset	For education trips, comparison between final P/A matrices and School Census inputs (overall totals, TLDs).

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
External trips	Checks on external trips	Processing	Full dataset	Checks setting out the impact of using NTS ratios of other purposes trip length to HbW and the resulting external matrix trip length distributions.
Status of matrix construction	Overview of progress (March 2018)	Processing	N/A	Summary table of status of tasks, with indication of QA conducted.
Collating matrices for HAM	Checks on matrix totals	Processing	Whole model	Tables showing the checks on totals at each stage in the construction of the base HAM matrices, for each user class and time period.
NHb Trip matrices	Checks on NHB matrices (Distributions etc.)	Processing	N/A	Tables and figures showing checks conducted on the spatial distribution resulting from the building of NHb matrices.
Port matrices	Testing of different alpha values for trip distribution	Processing	N/A	Details of testing of different distributions of demand to/from ports across country (graphical).
Bus preload processing	QA throughout on bus preloads	Processing	Full dataset	Checks conducted during processing of TRACC bus data, and tabular summary of coverage of the bus preload on the NTM network.
Matrix rezoning	Tests of matrix rezoning Python tool	Processing	Whole model	Full details of tests conducted on the Python tool used to convert matrices from intermediate zoning systems, plus results.
TIS data summary	Initial sense checks on TIS data	Input	Full dataset	Details and results of checks conducted on TIS data.
Interim matrix	DfT review of matrix deliverables	Against scope	N/A	Documentation and agreement with DfT of developed base car matrices, port and HGV matrices following DfT review.

Table 16.6 - Quality assurance conducted on trip end and trip rate development

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
TravelEstimator Trip Rate process	QA throughout on trip rate calculations	Processing	Full dataset	Details of checks applied to each of the six steps of importing and processing the NTM trip rates
TravelEstimator HB Trip Production Process	QA on HB trip productions processing	Processing	Full dataset	Summary of checks on the processing of trip productions, plus findings of checks.
TravelEstimator Trip Attraction Process	QA on trip attractions processing	Processing	Full dataset	Summary of checks on the processing of trip attractions from HSL data, plus findings of checks
Splitting of Car-LGV matrices	QA Checks on Car-LGV Splitting	Processing	Whole model	Tables of checks on totals, and that ratios between car and LGV have been applied accurately.
Interim matrix	DfT review of matrix deliverables	Against scope	N/A	Documentation and agreement with DfT of developed base car trip ends.
P/A trip ends	Checks against TEMRPO	Validity	Whole model	Checks comparing regional P/A trip end totals against values from TEMPRO.

Table 16.7 - Quality assurance conducted on HAM implementation

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Software capability	PTV HAM speed tests	Functionality	Whole model	Details of PTV tests of highway assignment methods, along with results and conclusions for HAM implementation, including hardware requirements.
Assignment model (GAP) convergence	QA on convergence	Functionality	Sample	Details of checks on a sample of network areas causing instability.
	Zero flow links	Functionality	Whole model	Summary of location of zero-flow links in the network.
Link convergence (stability)	Review of link convergence during calibration	Functionality	Whole model, sample	Detailed check of link convergence during early stages of calibration to monitor progress and stability of assignment.
	Review of link convergence after calibration complete	Functionality	Whole model	Review of link convergence of validated HAM assignment.
HAM Implementation QA	QA in HAM implementation	Against scope	N/A	QA checks conducted as part of HAM implementation, incl. run times, VoT/VOC, assignment algorithm.

Table 16.8 - Quality assurance conducted on HAM calibration and validation

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Count data provenance	Review of RTM counts, ranking of quality	Input	Full dataset	Count quality checks conducted on the count data obtained from the RTMs.
Journey time data processing	Journey time data review	Processing	Full dataset	Summary of infilling applied to journey time routes, plus comparison of TrafficMaster data journey times against Google Maps.
Proposed screenlines	QA on screenlines	Processing	Whole model	Assessment of gaps in initial screenlines, and steps taken to reduce these gaps.
Calibration and validation	Calibration iteration 1	Validity	Whole model	Results and details of calibration steps provided to DfT for feedback into second iteration of calibration. Included initial connector reviews and matrix estimation strategy.
	Calibration iteration 2	Validity	Whole model	Results and details of calibration steps provided to DfT for feedback into third iteration of calibration. Included link type reviews and network snags.
	Calibration iteration 3	Validity	Whole model	Results and details of calibration steps provided to DfT for feedback into final iteration of calibration. Included Midlands RTM update and connectors connecting to motorways review.
	Calibration iteration 4	Validity	Whole model	Results and details of final calibration steps provided to DfT for review. Included final link type updates and changes to HGV VoT weighting.
Key data and tasks for validation	QA in NTM HAM Validation	Validity	N/A	QA checks conducted as part of HAM calibration, incl. checks on journey time, data provenance and preparations for validation.
Calibration and validation	Documentation of standards achieved.	Validity, against scope	Whole model	Detailed documentation provided to DfT of calibration and validation process, and model standards achieved.

Table 16.9 - Quality assurance conducted on non-car attributes

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Checks on sample Basemap PT matrices	Checks on attributes, PT times, walk and cycle	Input	Sample datasets	Details (both qualitative and quantitative) of a series of checks conducted on two sample PT matrices provided by Basemap. Totals of matrices, checks on distances, times, interchanges etc.
Checks on Basemap PT databases	Checks on attributes, PT times, walk and cycle	Input	Full dataset	Detailed results of checks conducted on the full databases provided by Basemap; Matrix totals, checks on distances, times, interchanges, for both PT and Walk/Cycle.
Creating non-car attribute matrices	Post-processing as a result of previous checks	Processing	Full dataset	Post-processing and checks conducted during the combining and creation of non-car attributes matrices.
QA conducted by Basemap	Checks conducted by Basemap	Input	Full dataset	Checks conducted by Basemap on the non-car attributes provided to Atkins. Figures and tables describing accuracy of PT matrices and cycle/walk speeds.
Creating Non-Car Cost Input Matrices (Monetary Costs)	Calculation of bus/rail fares and parking charges	Processing	N/A	Details of the process for calculating rail fares, bus fares and parking charges, with summary statistics provided and references to checks undertaken.
Creating Non-Car Cost Input Matrices	Checks on imported matrices	Processing	N/A	Qualitative summary of the checks conducted on importing the non-car input matrices to Visum (Matrix totals etc.)

Table 16.10 - Quality assurance on VDM estimation

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
NTS trip processing	Analysis of NTS data (distance band analysis, sample size, time period)	Processing	Full dataset	Detailed analysis of NTS input data processed for VDM, with summaries of distance profiles and variation by time period, as well as sample sizes in the data.
Set-up of singly constrained choice structure	Development and testing of an example singly-constrained mode-destination model	Processing	Sample	Results of an initial test run for singly constrained HbEB trips.
Set up of doubly-constrained choices	Test run results, and a comparison of test with singly-constrained test results.	Functionality	N/A	Qualitative documentation of run results and implications for run times. Also a comparison of doubly-constrained runs with singly-constrained runs, to provide gauge of accuracy.
Assessment of doubly-constrained run time options	Documentation and agreement of potential solutions to doubly-constrained run time issues	Functionality	Whole model (VDM)	Detailed discussion of the options considered in tackling excessive doubly-constrained run times and the potential impacts and risks of these options.
Analysis of highway skims provided to RAND	QA record on network	Processing	N/A	Record of QA conducted on the prior network used for the highway skims provided to RAND for VDM estimation.
Analysis of highway skims provided to RAND	Comparison of JTs with Google Maps	Validity	N/A	Analysis of the highway skims provided to RAND for VDM estimation; specifically, comparison of average journey times (Figures and sectoral table) against Google Maps.
NTM Visum Implementation	Details of QA conducted on replication tests	Validity, against scope	Whole model (VDM)	Details of replication runs, plus results tables comparing against RAND runs.

Table 16.11 - Quality assurance on realism testing

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Realism test implementation	Testing of model	Functionality, against scope	Whole model	Checks that model responsiveness to changes was appropriate, and model was functioning as intended (assignment stability).
Realism test implementation	Check of inputs	Processing	Whole model	Checks that changes in input costs and times were accurately input and correctly carried through to model.
Realism test update	Check on results stability	Validity	Whole model	Analysis of re-run of fuel cost realism test following updated base run, checking continued validity of results.

Table 16.12 - Quality assurance conducted on sensitivity testing

Model area	Sub-task	Check… (On input, on processing, on validity, of functionality, against scope)	Scale (Whole model, full dataset, sample…)	Details of QA undertaken
Sensitivity test specification	Checks on implementation of sensitivity tests	Processing	Whole model	Details of checks carried out throughout the planning and coding of the five sensitivity tests, including checks against observed data and Visum network checks
Sensitivity test implementation	Processes for making changes to model	Processing	Whole model	Checks and documentation of processes followed in sensitivity testing, to ensure quality of inputs to tests, and accuracy in future guidance. Includes demand forecasting, making changes to highway network, PT characteristics.
	Testing of model	Functionality	Whole model	Checks that model responsiveness to input changes was appropriate.
Sensitivity test results	Documentation of sensitivity test implementation and results	Validity, against scope	Whole model	Documentation and agreement with DfT on outcomes of sensitivity tests, and review against objectives of the individual tests.

Appendices

Appendix A. Glossary and abbreviations

A.1. Glossary

The table below provides a glossary of terms used in the NTMv5 reports, including the Quality Report, Developer Guide and User Guide.

Term	Definition / meaning
Active mode	Trips by walk or (bi)cycle modes.
Activity pair	PTV Visum term for trip purpose (ie reason for travel between a pair of activities).
Absolute model applied incrementally (AMAI)	A method using a VDM to create absolute (total) forecasts of travel demand and then use two VDM forecasts to apply changes to the base validated matrices.
Assignment	The process of loading a matrix of trips on to a network to establish the routes used and the resulting traffic levels, as used in the Highway Assignment Model.
Assignment user class	A segmentation of highway demand by trip purpose and/or vehicle type. Used to differentiate trips in the highway assignment model typically with different preferences affecting route choice, e.g. value of time.
Automatic traffic count (ATC)	A method of surveying traffic volumes normally identified by two rubber tubes laid across the carriageway link to a road-side recorder box.
Base Year	Year selected for model development, calibration and (usually) validation. For NTMv5 the Base Year is 2015.
Base Year Matrices	Matrices of trips developed and fed into the highway assignment model in the Base Year (see also Prior and Post Matrices).
Four-stage transport model	Description of a transport model with which includes trip generation, distribution, mode choice and assignment.
Calibration	The process of adjusting model coding assumptions, data and parameters to improve the fit of the model with observed data / empirical evidence.
Capacity	Amount of space on road links for vehicles. For road links this is usually measured in vehicles or cars (pcus) per hour.
Census journey to work data	Data from the 2011 UK Census of Population on the individual's usual journey to work (usual mode: method of travel to work), home location and usual workplace location.
Centroid	See Zone Centroid.
Centroid connector	The link(s) carrying trips to / from the zone (zone centroid) and the point(s) on network represented in the model.
Cost	Monetary cost (unless otherwise specified).
Cost damping	Cost damping reduces the sensitivity of demand responses to changes in generalised cost with increasing trip length.
Cost sharing	Car drivers and passengers are represented separately in NTMv5. This is the functionality to spread the car travel money costs between the drivers and occupants when determining the utility for choice modelling in the VDM.
Demand model	See VDM.

Term	Definition / meaning
Demand strata	PTV Visum term to define categories of travel demand (trips) input to (represented in) the demand model. Demand strata are the combination of trip purpose and traveller type segmentation.
Disaggregate data	Information on individual choices / trips eg interview data on people and / or their trip making rather than aggregate (counts) observations.
Discrete choice model	A discrete choice model is an econometric model that predicts a decision made by an individual (choice of mode, choice of route, etc.) as a function of any number of variables. The model can be used to estimate the total number of people who change their behaviour in response to an action. The model can also be used to derive elasticities.
Distribution	The process of estimating the pattern of destination or attraction zones for a given origin or production zone.
Estimation	Statistical process of setting model structure and / or parameters to fit observed data. Estimation techniques used in NTMv5 for demand model form and for improving fit of base year trip matrices.
Elasticity	A measure of response to change. Defined as the ratio of the proportional change resulting from an effect to the proportional change causing the effect. This statistic is normally used as a measure of model response in Realism tests.
FORGE	Department for Transport tool to handle capacity constraint of car traffic at a regional level.
Generalised cost	The total measure of the inconvenience of a journey combining (money) cost and time combined using the traveller's value of time. Can be measured in units of money or (preferably) time. Note PTV Visum uses the term Impedance.
Generalised journey time	The total perceived journey time including time spent waiting and accessing modes for different stages of a journey weighted according to the perceived inconvenience of that stage (eg people don't like waiting for buses). Differs from generalised cost / generalised time as it excludes monetary cost. Measure typically used for public transport trips.
Generalised time	As generalised cost but measured in time units.
Gravity model	Gravity models are used to predict and describe certain behaviours that mimic gravitational interaction as described in Isaac Newton's law of gravity. The models contain some elements of mass (activity) and distance (generalised cost), which lends them to the metaphor of physical gravity.
Highway assignment model (HAM)	A model that assigns origin-destination matrices of highway trips to a network of links and nodes representing the road network.
Home-based (Hb)	Referring to a type of trip which is generated at the traveller's home. These are always Production/Attraction trips.
Impedance function	PTV Visum term for utility or generalised cost used in assignment and VDM.
Incremental model	A forecasting model which applies changes to a base year model. These changes can be forecast directly (pivot-point model) or from a pair of forecasts for the base and scenario (absolute model applied incrementally).
Intrazonal	A trip or characteristic for travel which starts and ends within the sample model zone.
Kalibri	Gravity modelling functionality within PTV Visum.
LENNON	National rail ticket database, providing records of ticket sales in Great Britain by station pair and ticket type, see also MOIRA.

Term	Definition / meaning
Level of Service	Term used to denote the ease of travel between two locations based on the specific attributes of cost and time for that trip.
Link type	Attribute in Visum used to categorise links in the highway network and associate other attributes (eg volume delay functions) with each link.
Logit model	A standard form of choice formula used in a Variable Demand Model (VDM). Logit models are used to model a relationship between a dependent variable Y and one or more independent variables X. The dependent variable, Y, is a discrete variable that represents a choice, or category, from a set of mutually exclusive choices or categories (such as mode and destination).
LUCE	Linear User Cost Equilibrium: Origin based highway assignment algorithm within PTV Visum used for NTMv5.
Main zone	PTV Visum term for groups of model zones forming a larger area.
Matrix estimation	The adjustment of prior trip matrices so that, when assigned, the resulting flows accord more closely with counts used as constraints in the estimation process.
Matrix sparsity	Proportion of matrix cells containing attributes (typically trips).
Maximum Likelihood (MLE)	A method of estimating the parameters of a probability distribution by maximizing a likelihood function, so that under the assumed statistical model the observed data is most probable.
MOIRA	A rail timetable planning package which is often used as the direct source of LENNON data, which is therefore sometimes referred to as ‘MOIRA data’.
National Trip End Model (NTEM)	DfT’s national trip end model providing forecasts of personal travel demand (trip ends) from 2011 to 2051.
NTMv2R	Spatially aggregate version of national transport model including statistics road capacity and costs model (FORGE).
National Travel Survey	National Travel Survey (NTS) is a continuous household survey designed to monitor long-term trends in personal travel and to inform the development of policy. It includes a seven day travel diary and is the primary source of data on personal travel patterns by residents of England within Great Britain.
Non-home-based (NHb)	A type of trip which does not start at the traveller’s home. These are normally views as starting at the Attraction end of a Home-based Production/Attraction trip, and are represented as a single Origin-Destination trip.
Origin-Destination (O-D)	A matrix of one-way trip legs without direction, see Production/Attraction (P/A).
Pivot process	A process of scaling the Base Year Matrix (e.g. to a future year) using the change forecast by the Variable Demand Model (VDM) - pivoting from the Base Year. See Absolute Model Applied Incrementally.
Post matrix	Matrix of trips after matrix estimation is applied, see Prior matrix.
Pre-load	Loads (typically vehicles or pcus) allocated by the user to specific model links to represent unmodelled activity. NTMv5 uses public service bus pre-loads.
Prior matrix	Matrix of trips before calibration (matrix estimation) is applied, see Post matrix.
Procedure Sequence	The Visum procedure sequence is the control script which provides the full set of steps covering all elements of the model running.
Production/Attraction	A matrix of trips by direction from a trip generator (normally a home location) to attraction location (the reason for travelling – to work / shop etc). Note that

Term	Definition / meaning
	one home-based Production/Attraction trip corresponds to two Origin-Destination trips.
PTV Visum	A software package for transport modelling, traffic analyses, forecasts, and GIS-based data management. Software package used to implement NTMv5.
Realism test	A type of test specified in DfT TAG Unit M2 to test the elasticity response of a Variable Demand Model to changes in various cost and time components.
Regions	Formerly known as the government office regions. Highest tier of sub-national division in England. For NTMv5 nine English regions, plus Wales and Scotland.
Regional Traffic Models (RTMs)	Five regional highway models developed for Highways England in the SATURN modelling software, that cover the South West, South East, Midlands, Transpennine and North regions of England.
Road Traffic forecasts (RTF)	DfT forecasts of road traffic, congestion and emissions in England and Wales up to 2050 under a number of plausible scenarios. RTF 2018 produced using NTMv2R and NTEM trip ends.
SATURN	Simulation and Assignment of Traffic in Urban Road Networks – A suite of highway traffic modelling computer programs used for the RTMs and source of NTMv5 highway networks.
Screenline	A user defined line / series of points cutting across (intersecting) a number of roads / routes. The exact location of a screenline is typically determined by the data collection locations. Screenlines are often defined to divide up the study area into a number of sectors.
Sectors	Groups of zones forming larger areas for scenario definition or analysis.
Speed flow curve	Function that determines how speed of travel varies with level of flow. See also Volume delay function (equivalent Visum term used in NTMv5).
Supply-demand iteration	The iteration of the Variable Demand Model (VDM) and Highway Assignment Model (HAM) used to feedback congestion impacts to the VDM. A four-stage model is typically be iterated in this fashion until the cost and demand changes converge to a solution.
TEMPro	Software (Trip End Model Presentation Program) for viewing results in NTEM dataset (https://www.gov.uk/government/publications/tempro-downloads).
TModel	PTV Visum functionality used to represent turning movement delays at intersections in NTMv5.
TRACC	A multi-modal accessibility and travel time analysis tool, provided by Basemap. TRACC contains bus and rail timetables along with travel networks allowing end-to-end journey times and travel distances to be calculated, including numbers of interchanges, and access.
TrafficMaster	GPS data providing details of vehicle speeds across the UK Ordnance Survey ITN link layer and Origin-Destination trips, distances and times for a sample of vehicles
Trip Attraction	Number of trips from home or non-home-based trips to the location determining the reason for travel (shopping, education etc)
Trip Destination	Number of trips ending at the location (irrespective of their reason / direction)
Trip Ends	Trip productions or trip attractions. These terms are often used to refer to the quantity of trips starting or ending at a given location.
Trip Generation	Process of estimating the demand for travel (number of trips) from population and economic activity data

Term	Definition / meaning
Trip Information System (TIS)	A database of trip information and a web based interface developed by Highways England in collaboration with Telefonica covering the whole of Great Britain containing data for the whole of 2016.
Trip Origin	Number of trips starting at the location (irrespective of their reason / direction)
Trip Production	A type of Trip End, the generation of an home or non-home-based trip at the location where the decision to travel is made
Trip purpose	The primary activity for which an individual makes a trip, such as commuting, shopping or leisure, see Activity Pair
Urban Area Speeds	Special treatment of NTMv5 links in urban areas with speeds defined as input and not adjusted (fixed) during model runs
Use Case	An application of a software tool or model, in respect of NTMv5 an area of traffic forecasting and/or policy making for which the DfT intends to use the model to inform model design and functionality requirements
User class	See Assignment User Class (AUC)
User defined attribute	Any attributes attached to different model components in Visum (eg links / zones) , e.g. for a zone the number of trip productions for a single trip purpose, or for a highway link the link type.
(Dis)Utility	The measure (sometimes defined in terms of generalised costs), that a transport user seeks to maximise (minimise) across a set of choices. Note PTV Visum uses the term Impedance.
Validation	Process of comparing model outputs with (independent) observations to determine how well the model performs at that level
Value of time	A measure of the perceived equivalent monetary cost to an individual of unit time spent travelling
Variable Demand Model (VDM)	A model used to determine the personal choices of travel mode and destination for each user in the model, determined by utility
Version file	Visum file containing model implementation (files have a suffix .ver)
Visum	See PTV Visum
Volume Delay Function (VDF)	Function that specifies how speed of travel on link varies based on level of demand using the link.
Weekday	Average of Monday to Friday inclusive (24 hours)
Zone	A spatial area or point containing or representing land use / economic activity to / from which trips are generated and attracted.
Zone centroid	A zone centroid is the point in a zone from which all flows (trips) are assumed to start and at which all flows end.

A.2. Abbreviations

The table below provides a list of common abbreviations used in the NTMv5 reports, including the Quality Report, Developer Guide and User Guide.

Abbreviation	Meaning
%Gap	Demand-supply measure of convergence as defined in TAG M2 Section 6.3
AM	The morning peak period represented in NTMv5. Average weekday 0700-1000
AMAI	Absolute model applied incrementally
ATC	Automatic Traffic Count
AUC	Assignment User Class
DfT	Department for Transport
FORGE	Department for Transport tool to handle capacity constraint of car traffic at a regional level. (Abbreviation for Fitting On of Regional Growth and Elasticities or Effects).
GBFM	Great Britain Freight Model owned and operated by MDS Transmodal.
GIS	Geographical Information System
HAM	Highway assignment model
IP	The interpeak period represented in NTMv5. Average weekday 1000-1600
JTW	Census Journey to Work
LOS	Level of service
LUCE	Linear User Cost Equilibrium: Origin base assignment algorithm within PTV Visum used for NTMv5
MSOA	Middle Super Output Area (Census of Population geographical unit)
NTEM	DfT's National Trip End Model
NTM	DfT's National Transport Model
NTS	National Travel Survey
O-D	Origin-Destination (trip matrix)
OP	The off peak period represented in NTMv5. Average weekday 0000-0700 and 1900-0000
P/A	Production / attraction (trip matrix)
PM	The evening peak period represented in NTMv5. Average weekday 1600-1900
PSeq	(Visum) Procedure Sequence
RTF	DfT's Road Traffic Forecasts (current version RTF 2018)
RTM	Highways England's five Regional Traffic Models
TAG	DfT's Transport Appraisal Guidance. https://www.gov.uk/guidance/transport-analysis-guidance-webtag
TEMPro	Trip End Model Presentation Program
TIS	Trip Information System
UAS	Urban Area Speeds (set of links with assumed speeds of travel in urban areas)
UDA	User Defined Attribute (Visum term)
VDF	Volume delay function

Abbreviation	Meaning
VDM	Variable demand model
VOC	Vehicle operating cost
VoT	Value of time

Appendix B. Base year VDM trip length distributions

B.1. Trip length distributions; Base vs NTS observed data

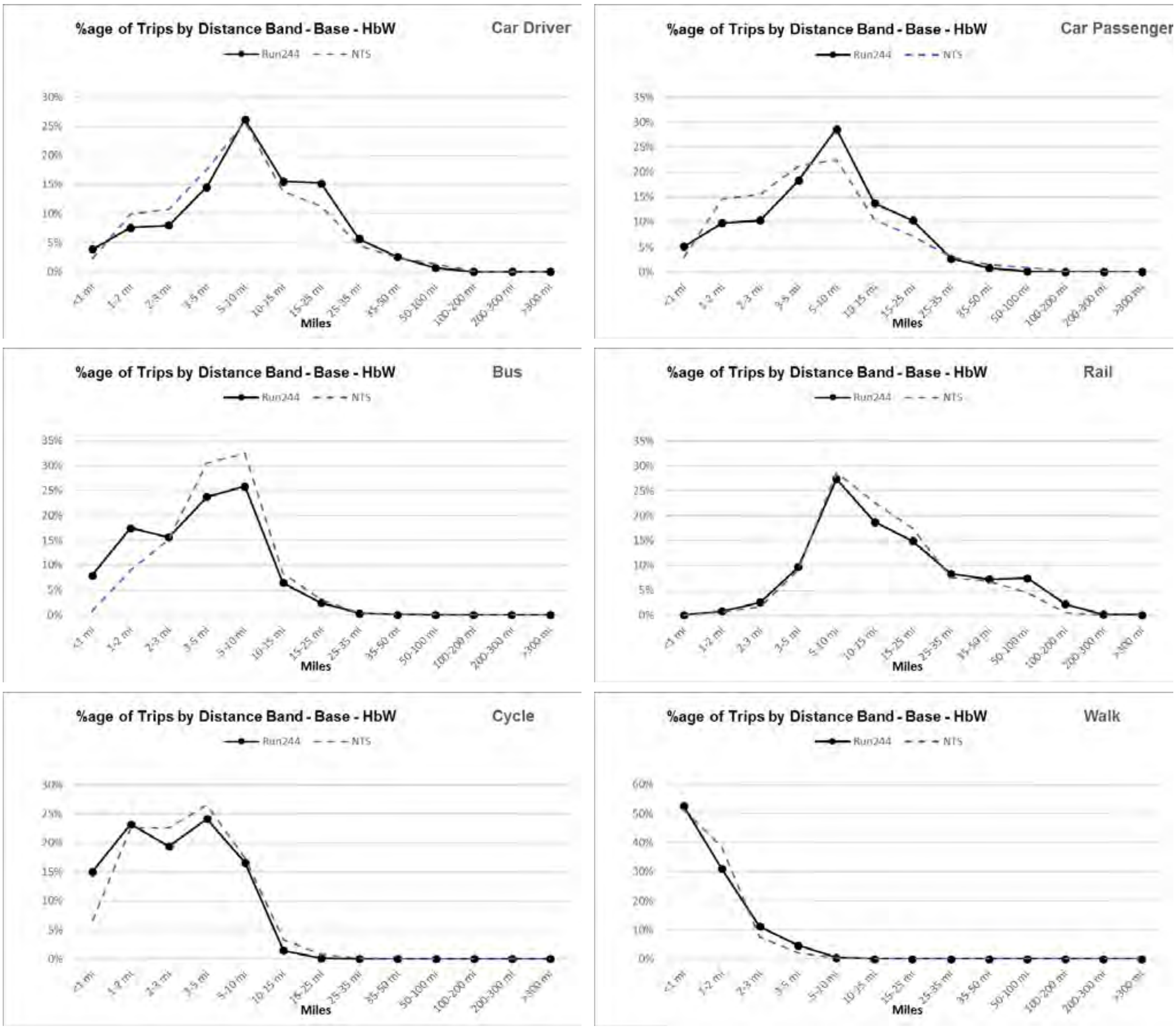


Figure A.1 - Trip length distributions by mode for Hb Work trips versus NTS

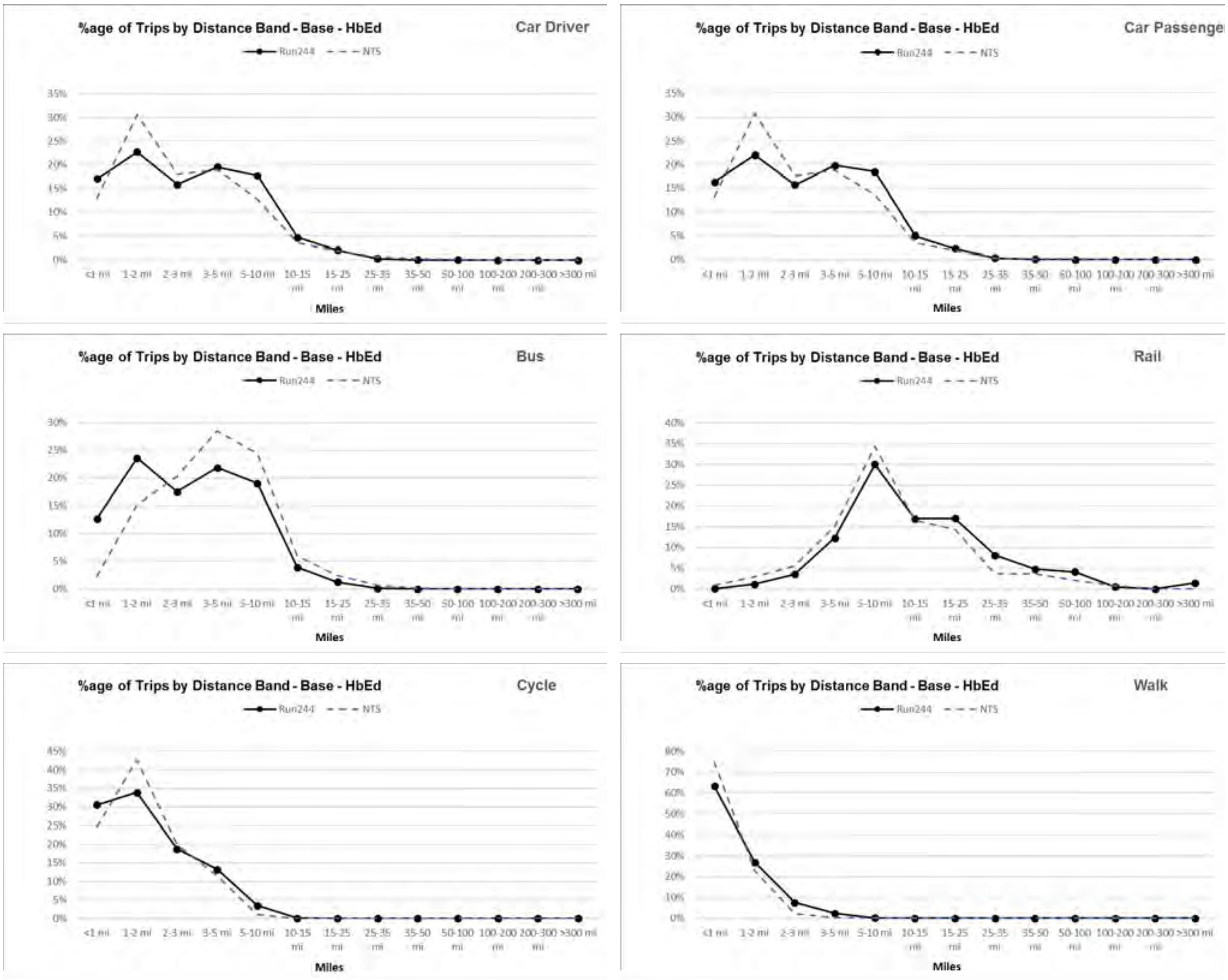


Figure A.2 - Trip length distributions by mode for Hb Education trips versus NTS

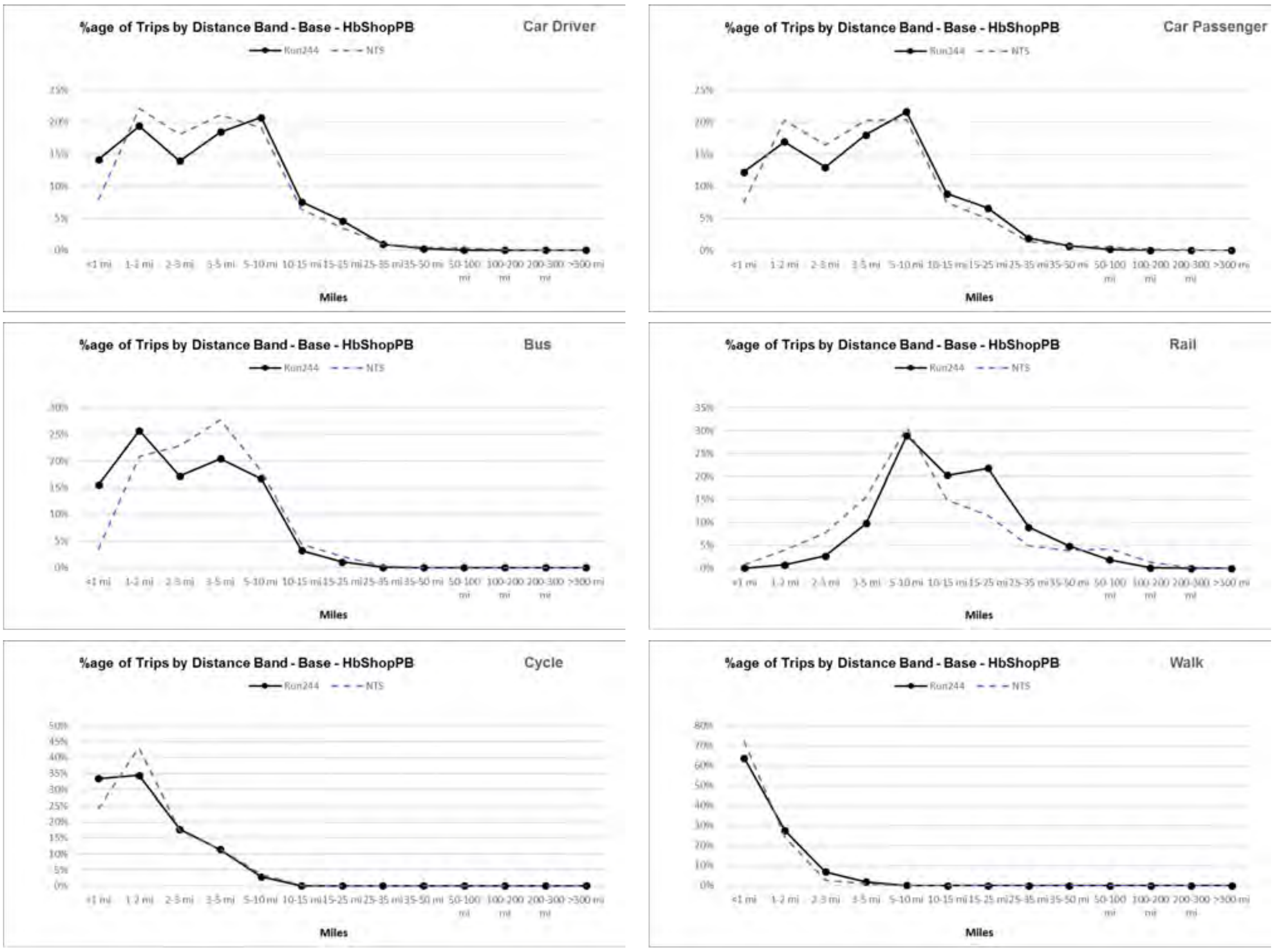


Figure A.3 - Trip length distributions by mode for Hb shopping and personal business trips versus NTS

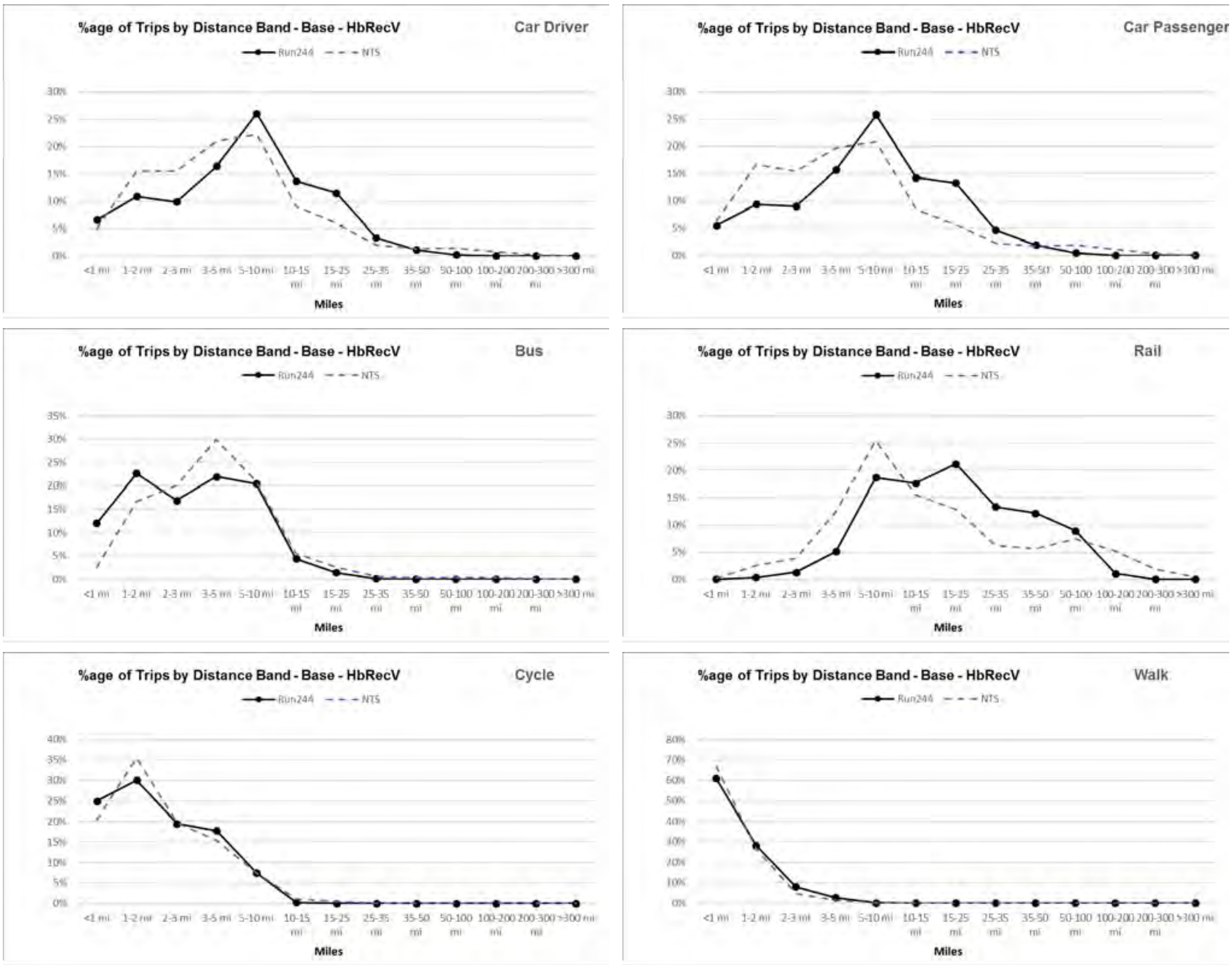


Figure A.4 - Trip length distributions by mode for Hb recreation and visiting friends trips versus NTS

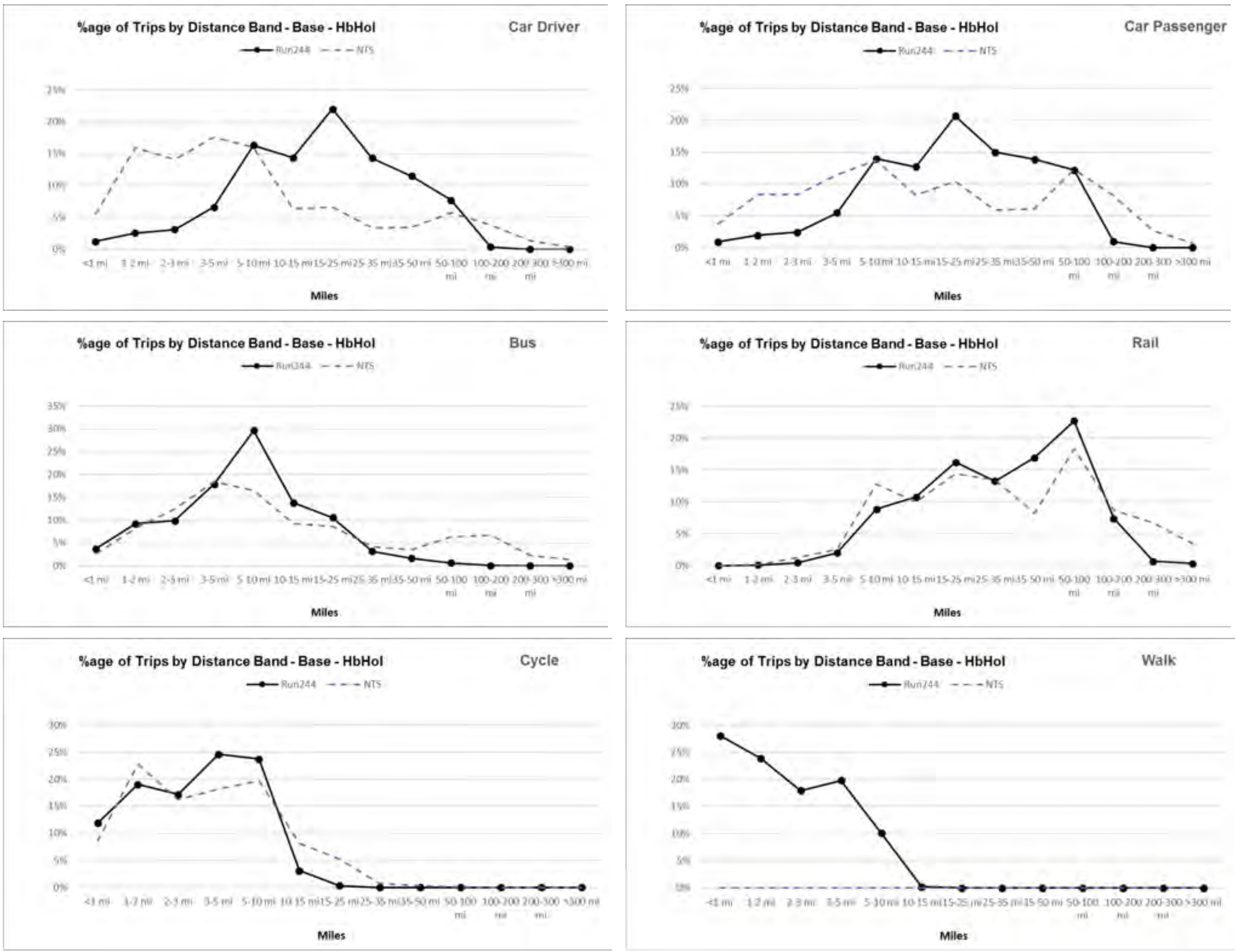


Figure A.5 - Trip length distributions by mode for Hb holiday and day trips versus NTS

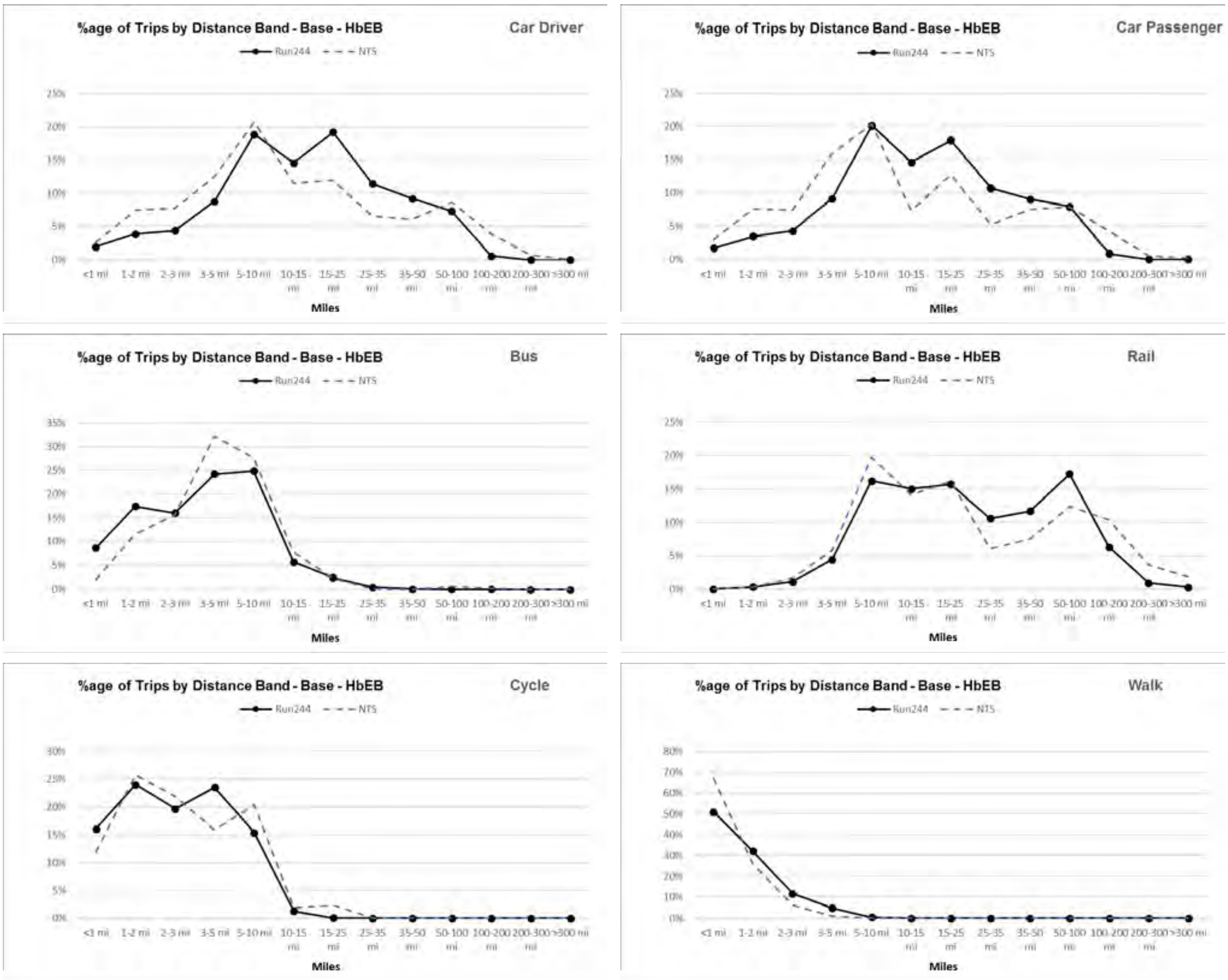


Figure A.6 - Trip length distributions by mode for Hb employer's business trips versus NTS

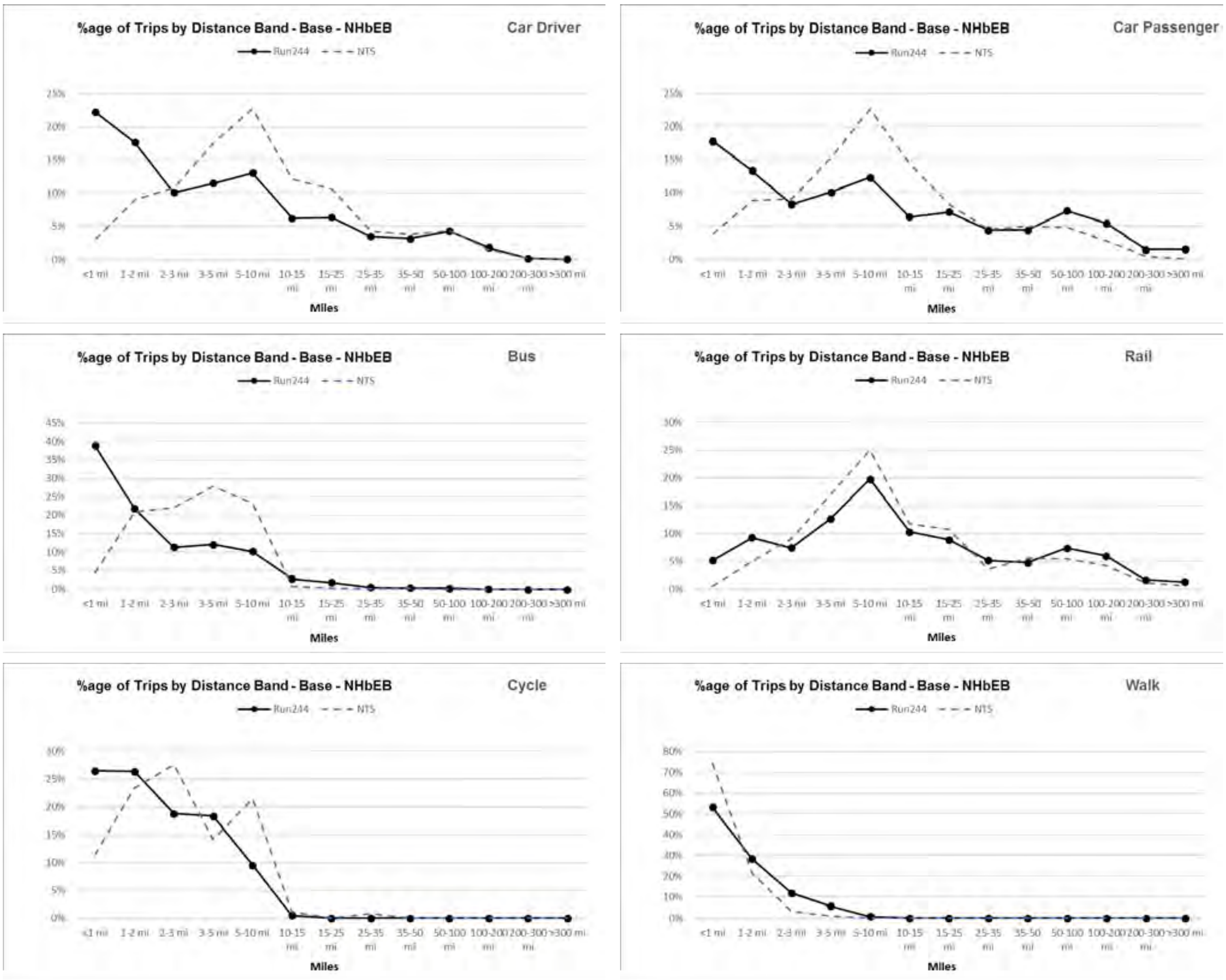


Figure A.7 - Trip length distributions by mode for NHb employer's business trips versus NTS

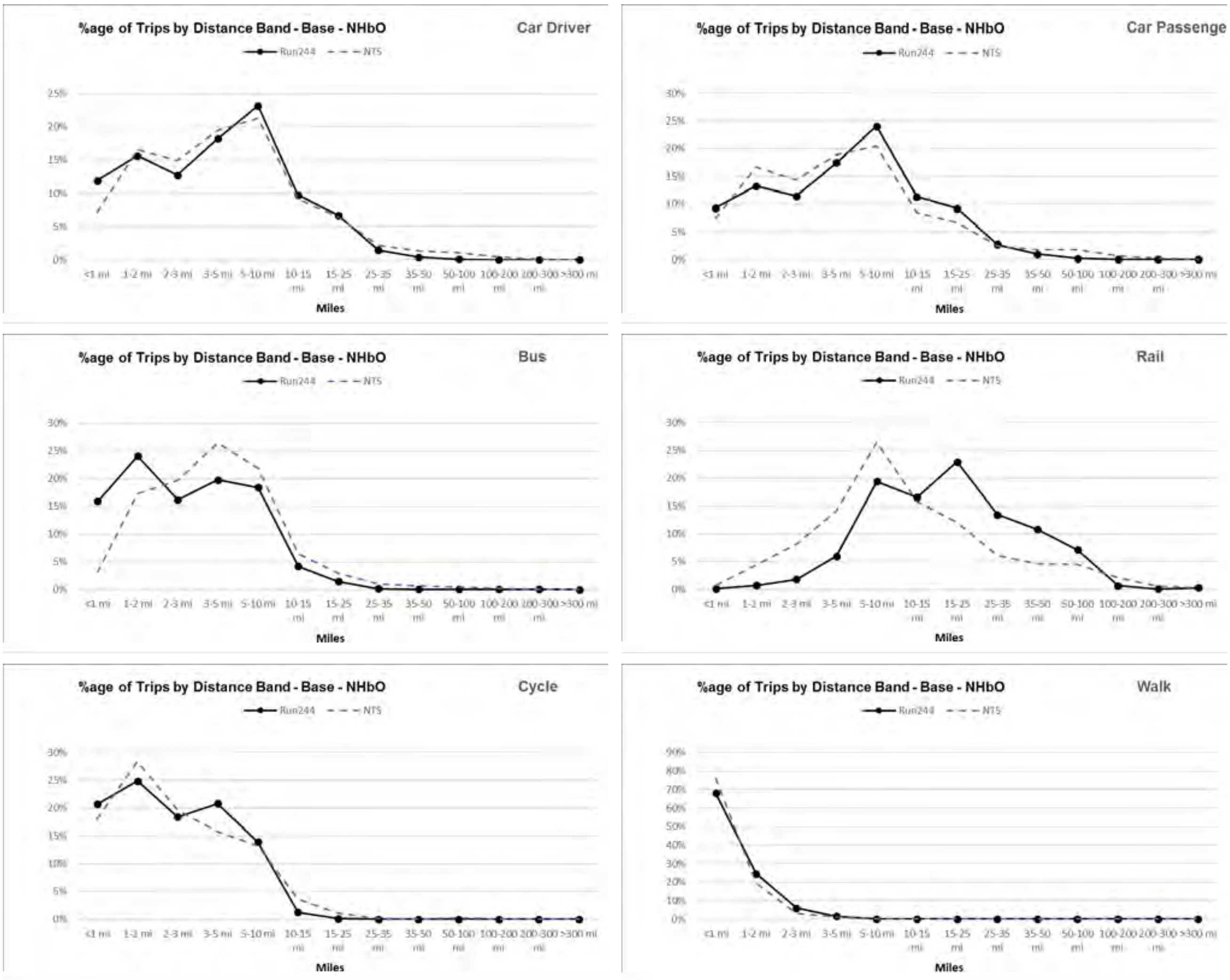


Figure A.8 - Trip length distributions by mode for NHb other trips versus NTS

Appendix C. Journey time routes

Table C.1 - Journey time validation routes with observed times

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
1	1_NB	A1/ A1(M)	Scotch Corner - Newcastle	79	57	53	56
1	1_SB	A1/ A1(M)	Newcastle - Scotch Corner	79	56	55	58
2	2_NB	A1/A1(M)	Barnet - Peterborough	107	74	73	77
2	2_SB	A1/A1(M)	Peterborough - Barnet	106	73	68	67
3	3_NB_1	A1/A1(M)	Peterborough - Pontefract (M62)	70	40	42	41
3	3_NB_2	A1/A1(M)	Peterborough - Pontefract (M62)	84	52	53	53
3	3_SB_1	A1/A1(M)	Pontefract (M62) - Peterborough	84	53	53	53
3	3_SB_2	A1/A1(M)	Pontefract (M62) - Peterborough	71	42	41	41
4	4_NB	A1	Newcastle - Berwick	95	64	65	62
4	4_SB	A1	Berwick - Newcastle	96	63	65	63
5	5_NB	A11	Duxford (M11) - Norwich	99	61	61	60
5	5_SB	A11	Norwich - Duxford (M11)	99	59	59	58
6	6_EB	A12	Brentwood - Ipswich	84	54	54	57
6	6_WB	A12	Ipswich - Brentwood	84	59	54	54
7	7_WB	A120	Harwich - Bishops Stortford	84	62	57	56
7	7_EB	A120	Bishops Stortford - Harwich	84	58	58	64
8	8_EB_1	A14	Felixstowe - Brampton Hut (A1)	78	52	49	49
8	8_EB_2	A14	Felixstowe - Brampton Hut (A1)	63	38	38	37
8	8_WB_1	A14	Brampton Hut (A1) - Felixstowe	64	39	38	38
8	8_WB_2	A14	Brampton Hut (A1) - Felixstowe	78	50	49	50
9	9_WB	A14	Brampton Hut (A1) - Rugby (M1)	69	46	42	42
9	9_EB	A14	Rugby (M1) - Brampton Hut (A1)	69	40	40	39
10	10_NB_1	A168/A19	Harrogate (A1(M)) - Newcastle	63	37	38	37
10	10_NB_2	A168/A19	Harrogate (A1(M)) - Newcastle	56	46	39	42

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
10	10_SB_1	A168/A19	Newcastle - Harrogate (A1(M))	56	39	38	41
10	10_SB_2	A168/A19	Newcastle - Harrogate (A1(M))	63	38	37	37
11	11_EB	A2/M2	Dartford - Dover	99	64	63	66
11	11_WB	A2/M2	Dover - Dartford	98	68	65	66
12	12_EB	A21	Sevenoaks - Hastings	59	51	49	52
12	12_WB	A21	Hastings - Sevenoaks	59	48	48	47
13	13_NB	A23/M23	Brighton - Croydon	55	40	38	38
13	13_SB	A23/M23	Croydon - Brighton	56	40	36	39
14	14_EB	A259/ A2070	Eastbourne - Ashford	69	77	79	77
14	14_WB	A259/ A2070	Ashford - Eastbourne	69	69	70	68
15	15_EB_1	A27/A24	Portsmouth - Eastbourne	63	64	60	69
15	15_EB_2	A27/A24	Portsmouth - Eastbourne	48	37	36	42
15	15_WB_1	A27/A24	Eastbourne - Portsmouth	49	38	36	37
15	15_WB_2	A27/A24	Eastbourne - Portsmouth	61	60	58	62
16	16_AntiClockwise	A282 M25	Dartford - Purfleet	4	4	4	4
16	16_Clockwise	A282 M25	Purfleet - Dartford	4	4	3	4
17	17_EB	A3/A3(M)	Portsmouth - Epsom	88	56	52	53
17	17_WB	A3/A3(M)	Epsom - Portsmouth	88	53	52	60
18	18_EB_1	A30	Penzance - Exeter	98	64	65	65
18	18_EB_2	A30	Penzance - Exeter	76	41	41	40
18	18_WB_1	A30	Exeter - Penzance	76	42	42	40
18	18_WB_2	A30	Exeter - Penzance	98	66	66	66
19	19_NB_1	A303	Honiton - Basingstoke (M3)	95	65	66	64
19	19_NB_2	A303	Honiton - Basingstoke (M3)	64	39	40	38
19	19_SB_1	A303	Basingstoke (M3) - Honiton	72	44	47	45
19	19_SB_2	A303	Basingstoke (M3) - Honiton	87	59	60	59
20	20_EB_1	A31/A35/ A30	Exeter - Southampton	88	69	73	69
20	20_EB_2	A31/A35/ A30	Exeter - Southampton	65	48	48	47
20	20_WB_1	A31/A35/ A30	Southampton - Exeter	69	52	53	56

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
20	20_WB_2	A31/A35/ A30	Southampton - Exeter	84	65	69	66
21	21_NB	A34	Winchester (M3) - Bicester (M40)	101	62	63	64
21	21_SB	A34	Bicester (M40) - Winchester (M3)	100	65	61	66
22	22_NB	A36/A46	Southampton - Bristol (M4)	103	101	102	111
22	22_SB	A36/A46	Bristol (M4) - Southampton	104	103	105	107
23	23_NB	A38	Lichfield (M6 Toll) - Mansfield (M1)	66	43	42	43
23	23_SB	A38	Mansfield (M1) -Lichfield (M6 Toll)	65	44	42	41
24	24_EB	A38	Bodmin - Exeter	109	75	75	74
24	24_WB	A38	Exeter - Bodmin	109	76	76	75
25	25_NB_1	A40/A49	Gloucester - Shrewsbury	72	75	75	74
25	25_NB_2	A40/A49	Gloucester - Shrewsbury	66	55	57	55
25	25_SB_1	A40/A49	Shrewsbury - Gloucester	61	52	53	51
25	25_SB_2	A40/A49	Shrewsbury - Gloucester	77	75	76	76
26	26_EB_1	A40/M40	Redditch (M42) - Uxbridge	75	43	42	41
26	26_EB_2	A40/M40	Redditch (M42) - Uxbridge	68	43	41	42
26	26_WB_1	A40/M40	Uxbridge - Redditch (M42)	70	47	46	47
26	26_WB_2	A40/M40	Uxbridge - Redditch (M42)	72	39	40	41
27	27_NB	A419/A41 7	Swindon - Gloucester	53	34	34	37
27	27_SB	A419/A41 7	Gloucester - Swindon	53	35	32	32
28	28_NB	A421	Milton Keynes (M1) - Black Cat (A1)	28	16	16	19
28	28_SB	A421	Black Cat (A1) - Milton Keynes (M1)	28	17	16	16
29	29_EB	A428	St Neots (A1) - Cambridge	26	20	19	20
29	29_WB	A428	Cambridge - St Neots (A1)	27	20	19	20
30	30_NB	A43	Bicester (M40) - Northampton	38	34	35	41
30	30_SB	A43	Northampton - Bicester (M40)	38	35	32	32
31	31_NB	A45	Northampton (M1) - Thrapston (A14)	39	28	27	28
31	31_SB	A45	Thrapston (A14) - Northampton (M1)	39	29	28	28

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
32	32_EB	A46/M69	Tewkesbury - Leicester	108	82	80	88
32	32_WB	A46/M69	Leicester - Tewkesbury	108	85	83	84
33	33_EB	A46	Leicester (M1) - Lincoln	88	66	65	68
33	33_WB	A46	Lincoln - Leicester (M1)	89	67	65	65
34	34_EB_1	A47/A12	Wansford - Lowestoft	80	62	62	65
34	34_EB_2	A47/A12	Wansford - Lowestoft	106	83	81	81
34	34_WB_1	A47/A12	Lowestoft - Wansford	90	71	70	72
34	34_WB_2	A47/A12	Lowestoft - Wansford	97	75	74	75
35	35_EB_1	A5/M54/ A449/A458	Welsh Border - Tamworth (M42)	70	51	51	50
35	35_EB_2	A5/M54/ A449/A458	Welsh Border - Tamworth (M42)	54	49	49	52
35	35_WB_1	A5/M54/ A449/A458	Tamworth (M42) - Welsh Border	44	40	39	42
35	35_WB_2	A5/M54/ A449/A458	Tamworth (M42) - Welsh Border	81	58	59	59
36	36_EB_1	A5	Tamworth (M42) - Luton (M1)	61	54	52	53
36	36_EB_2	A5	Tamworth (M42) - Luton (M1)	67	65	65	64
36	36_WB_1	A5	Luton (M1) - Tamworth (M42)	55	59	59	64
36	36_WB_2	A5	Luton (M1) - Tamworth (M42)	72	62	62	64
37	37_EB	M6	Stoke-On-Trent (M6) - Nottingham (M1)	82	56	53	53
37	37_WB	M6	Nottingham (M1) - Stoke-On-Trent (M6)	82	55	52	54
38	38_EB	A52/A453/ A5111/A6	Derby (A50) - Grantham	64	58	53	55
38	38_WB	A52/A453/ A5111/A6	Grantham - Derby (A50)	64	59	55	59
39	39_EB	A55/M53	Welsh Border - Wallasey(Liverpool)	44	27	27	27
39	39_WB	A55/M53	Wallasey(Liverpool) - Welsh Border	44	28	27	27

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
40	40_EB	A590	Dalton-in-Furness - Kendal (M6)	48	36	37	37
40	40_WB	A590	Kendal (M6) - Dalton-in-Furness	48	37	37	36
41	41_EB	A616/A628/A57/M67	Manchester (M67) - Barnsley	49	49	49	53
41	41_WB	A616/A628/A57/M67	Barnsley - Manchester (M67)	49	45	44	46
42	42_EB	A64	Wetherby (A1(M)) - Scarborough	86	60	61	59
42	42_WB	A64	Scarborough - Wetherby (A1(M))	86	61	61	60
43	43_EB	A66(M)/A66	Darlington - Middlesbrough	28	20	20	20
43	43_WB	A66(M)/A66	Middlesbrough - Darlington	28	20	20	20
44	44_EB	A66/A595	Egremont - Penrith	85	66	68	70
44	44_WB	A66/A595	Penrith - Egremont	84	67	67	66
45	45_EB	A66	Penrith - Scotch Corner	79	50	51	51
45	45_WB	A66	Scotch Corner - Penrith	80	53	54	53
46	46_EB	A69	Carlisle - Newcastle (A1)	84	61	62	60
46	46_WB	A69	Newcastle (A1) - Carlisle	84	59	60	58
47	47_NB	M1	Brent Cross - Northampton	90	59	59	64
47	47_SB	M1	Northampton - Brent Cross	90	63	55	55
48	48_NB_1	M1	Northampton - Chesterfield	59	40	40	40
48	48_NB_2	M1	Northampton - Chesterfield	82	50	51	53
48	48_SB_1	M1	Chesterfield - Northampton	74	48	47	46
48	48_SB_2	M1	Chesterfield - Northampton	68	47	44	44
49	49_NB	M1	Chesterfield - Leeds (A1(M))	80	58	56	57
49	49_SB	M1	Leeds (A1(M)) - Chesterfield	80	56	54	58
50	50_NB	M11	Walthamstow - Cambridge	81	54	54	56
50	50_SB	M11	Cambridge - Walthamstow	80	61	54	55
51	51_NB	M18	Rotherham (M1) - Goole (M62)	45	28	28	28
51	51_SB	M18	Goole (M62) - Rotherham (M1)	44	28	28	28
52	52_EB	M180/A180	Hatfield (M18) - Grimsby	62	37	37	36

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
52	52_WB	M180/ A180	Grimsby - Hatfield (M18)	62	39	38	38
53	53_AntiClockwise	M25	South Mimms - Uxbridge	35	35	24	24
53	53_Clockwise	M25	Uxbridge - South Mimms	35	23	23	24
54	54_AntiClockwise	M25	Nutfield - Dartford	40	27	28	33
54	54_Clockwise	M25	Dartford - Nutfield	40	30	27	26
55	55_AntiClockwise	M25	Purfleet - South Mimms	54	44	42	43
55	55_Clockwise	M25	South Mimms - Purfleet	54	41	40	42
56	56_AntiClockwise	M25	Uxbridge - Nutfield	58	48	44	60
56	56_Clockwise	M25	Nutfield - Uxbridge	58	48	45	62
57	57_EB	M26/M20/ A20	Bromley - Dover	101	63	63	65
57	57_WB	M26/M20/ A20	Dover - Bromley	101	62	61	60
58	58_EB	M27	Southampton - Portsmouth	46	30	26	27
58	58_WB	M27	Portsmouth - Southampton	45	29	27	28
59	59_EB	M3	Southampton - Twickenham	95	62	59	58
59	59_WB	M3	Twickenham - Southampton	95	58	58	64
60	60_EB_1	M4	Swindon - Brentford	59	36	35	35
60	60_EB_2	M4	Swindon - Brentford	53	40	37	42
60	60_WB_1	M4	Brentford - Swindon	46	33	31	38
60	60_WB_2	M4	Brentford - Swindon	66	39	39	39
61	61_EB	M4	Severn Bridge - Swindon	70	40	38	38
61	61_WB	M4	Swindon - Severn Bridge	70	38	38	38
62	62_EB	M42/A42	Birmingham (M6) - Loughborough (M1)	50	29	30	30
62	62_WB	M42/A42	Loughborough (M1) - Birmingham (M6)	50	30	29	29
63	63_EB	M42	Bromsgrove - Birmingham (M6)	38	24	23	25
63	63_WB	M42	Birmingham (M6) - Bromsgrove	38	24	23	25
64	64_EB	M45/A45	Coventry - Daventry (M1)	24	16	16	15
64	64_WB	M45/A45	Daventry (M1) - Coventry	24	18	16	17
65	65_NB_1	M5	Exeter - Bristol (M4)	66	35	35	35

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
65	65_NB_2	M5	Exeter - Bristol (M4)	64	35	35	34
65	65_SB_1	M5	Bristol (M4) - Exeter	58	31	32	32
65	65_SB_2	M5	Bristol (M4) - Exeter	73	39	40	40
66	66_NB_1	M5	Bristol (M4) - Birmingham (M6)	69	37	38	37
66	66_NB_2	M5	Bristol (M4) - Birmingham (M6)	63	38	39	41
66	66_SB_1	M5	Birmingham (M6) - Bristol (M4)	51	31	31	31
66	66_SB_2	M5	Birmingham (M6) - Bristol (M4)	81	45	45	44
67	67_EB	M50/A449/ A40	Welsh Border - Tewkesbury	52	32	32	31
67	67_WB	M50/A449/ A40	Tewkesbury - Welsh Border	53	33	33	32
68	68_EB	M55/A585	Fleetwood - Preston	32	28	28	28
68	68_WB	M55/A585	Preston - Fleetwood	32	27	27	27
69	69_EB	M56/ A5117	Manchester (M56) - Welsh Border	57	36	35	35
69	69_WB	M56/ A5117	Welsh Border - Manchester (M56)	58	37	35	40
70	70_EB	M58/ A5036	Liverpool - Wigan	25	20	20	21
70	70_WB	M58/ A5036	Wigan - Liverpool	25	21	20	21
71	71_EB_1	M6/A74	Carlisle (A74) - Preston	72	40	40	40
71	71_EB_2	M6/A74	Carlisle (A74) - Preston	76	42	42	42
71	71_WB_1	M6/A74	Preston - Carlisle (A74)	63	38	37	38
71	71_WB_2	M6/A74	Preston - Carlisle (A74)	86	49	48	48
72	72_EB	M6	Warrington - Wolverhampton (M6 Toll)	88	54	54	54
72	72_WB	M6	Wolverhampton (M6 Toll) - Warrington	88	55	55	56
73	73_EB	M6	Preston - Warrington	61	38	37	38
73	73_WB	M6	Warrington - Preston	60	38	37	42
74	74_EB	M6	Wolverhampton (M6 Toll) - Rugby (M1)	79	67	60	66
74	74_WB	M6	Rugby (M1) - Wolverhampton (M6 Toll)	77	51	48	50

Route details					Observed JT (Mins)		
Route No	Route ID and Direction	Road name(s)	Route description	Distance (km)	AM	IP	PM
75	75_AntiClockwise	M60	Manchester (M56) - Manchester (M66) via Stockport	29	18	17	19
75	75_clockwise	M60	Manchester (M66) - Manchester (M56) via Stockport	28	21	19	19
76	76_AntiClockwise	M60	Manchester (M66) - Manchester (M56)	27	25	20	21
76	76_clockwise	M60	Manchester (M56) - Manchester (M66)	28	21	21	25
77	77_EB	M602/M62/M57	Liverpool (M58) - Manchester	54	41	34	34
77	77_WB	M602/M62/M57	Manchester - Liverpool (M58)	54	36	35	36
78	78_NB	M61	Manchester (M60) - Preston (M6)	35	22	21	22
78	78_SB	M61	Preston (M6) - Manchester (M60)	35	24	21	21
79	79_EB	M62/A63/A1033	Wakefield (M1) - Hull	90	62	59	61
79	79_WB	M62/A63/A1033	Hull - Wakefield (M1)	90	64	60	63
80	80_EB	M62	Manchester (M60) - Wakefield (M1)	63	42	40	40
80	80_WB	M62	Wakefield (M1) - Manchester (M60)	64	43	40	44
81	81_EB	M65	Preston (M6) - Burnley	32	19	19	19
82	82_NB	M66	Manchester (M60) - Burnley	28	19	18	19
82	82_SB	M66	Burnley - Manchester (M60)	28	18	17	17
81	81_WB	M65	Burnley - Preston (M6)	32	19	19	19
83	83_NB	A1/A1(M)	Pontefract (M62) - Scotch Corner	97	59	59	58
83	83_SB	A1/A1(M)	Scotch Corner - Pontefract (M62)	96	59	58	58
84	84_EB	M6 Toll	Birmingham (M42) - Wolverhampton (M6)	43	24	23	23
84	84_WB	M6 Toll	Wolverhampton (M6) - Birmingham (M42)	41	23	24	24

Appendix D. Impact of matrix estimation

D.1. Matrix totals

The change in total number of trips by vehicle type and time period is shown in Table D.1. When looking at the whole matrix it can be seen that all car and LGV matrices generally reduce in total size as a result of matrix estimation, changing by less than 1%, with the exception of LGV in the PM peak which decreases by 1.05%. The HGV matrices increase by between 4% and 6.5%. This is as anticipated and is due to the availability of quality data used to construct the matrices. All these changes are considered to be within acceptable levels.

Table D.1 - Change in matrix totals (total vehicle trips)

	AM			IP			PM		
	Prior	Post	% Diff. Post-Prior	Prior	Post	% Diff. Post-Prior	Prior	Post	% Diff. Post-Prior
Car	3,625,808	3,609,971	-0.44%	3,229,401	3,209,941	-0.60%	3,993,149	3,997,843	0.12%
LGV	968,890	967,886	-0.10%	910,054	908,015	-0.22%	937,054	927,208	-1.05%
HGV	105,186	111,025	5.55%	103,186	107,228	3.92%	54,900	58,500	6.56%

D.2. Matrix zonal cell values

Table D.2 provides the matrix zonal cell value regression statistics by time period comparing the prior and post matrix estimation matrices.

Table D.2 - Matrix zonal cell value changes – prior vs. post ME

Measure	Significance Criteria	AM		IP		PM	
		Lights	HGV	Lights	HGV	Lights	HGV
Matrix Zonal Cell Values	Slope within 0.98 and 1.02	0.9998	1.0000	1.0000	0.9999	0.9999	0.9997
	Intercept near zero	-0.0003	0.0001	-0.0004	0.0001	-0.0001	0.0001
	R^2 in excess of 0.95	0.9992	0.9977	0.9993	0.9972	0.9991	0.9906

When looking at the whole matrix the regression statistics for Lights and HGV vehicles meet the TAG criteria in all time periods.

In addition to the standard TAG zonal cell value checks the sparsity of the NTMv5 matrices has been reviewed. The impact of matrix estimation on matrix sparsity has been reviewed by grouping the share of O-D cells and the volume of trips by the number of O-D trips in the cell and comparing the change after matrix estimation. This ensures that matrix estimation process is not disproportionately inflating small cell values in order to satisfy the matrix estimation targets. Table D.3 to Table D.8 present the results by time period for Lights and HGV vehicles.

Table D.3 - Matrix sparsity, light vehicles in AM peak

O-D Trips Lights	Share of O-D cells			% Volume of trips		
	Prior Lights	Post Lights	Change	Prior Lights	Post Lights	Change
0	26.0%	26.0%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	9.0%	11.4%	2.4%	0.002%	0.002%	0.0%
0.00001 to 0.0001	25.3%	25.1%	-0.1%	0.05%	0.05%	0.0%
0.0001 to 0.001	24.0%	22.4%	-1.6%	0.4%	0.4%	0.0%
0.001 to 0.01	10.6%	10.0%	-0.6%	1.5%	1.5%	-0.1%
0.01 to 0.1	3.4%	3.3%	-0.1%	4.7%	4.7%	0.0%
0.1 to 1	1.4%	1.3%	0.0%	18.3%	18.0%	-0.3%
1 to 3	0.2%	0.2%	0.0%	14.6%	14.7%	0.0%
3 to 5	0.05%	0.05%	0.0%	8.1%	8.2%	0.0%
5 to 10	0.04%	0.04%	0.0%	11.8%	11.8%	0.1%
10 to MAX	0.03%	0.03%	0.0%	40.6%	40.8%	0.3%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Table D.4 - Matrix sparsity, HGVs in AM peak

O-D Trips HGV	Share of O-D cells			% Volume of trips		
	Prior HGV	Post HGV	Change	Prior HGV	Post HGV	Change
0	2.2%	2.2%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	38.5%	42.7%	4.2%	0.1%	0.0%	0.0%
0.00001 to 0.0001	28.8%	26.6%	-2.2%	0.5%	0.5%	-0.1%
0.0001 to 0.001	19.8%	18.2%	-1.6%	3.3%	2.9%	-0.4%
0.001 to 0.01	8.3%	7.9%	-0.4%	12.7%	11.5%	-1.2%
0.01 to 0.1	2.1%	2.1%	0.0%	28.5%	27.8%	-0.7%
0.1 to 1	0.3%	0.3%	0.0%	30.7%	32.7%	2.0%
1 to 3	0.01%	0.01%	0.0%	8.7%	9.3%	0.7%
3 to 5	0.001%	0.001%	0.0%	2.1%	2.3%	0.2%
5 to 10	0.001%	0.001%	0.0%	2.3%	2.4%	0.1%
10 to MAX	0.001%	0.001%	0.0%	11.2%	10.6%	-0.6%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Table D.5 - Matrix sparsity, light vehicles in Inter-peak

O-D Trips Lights	Share of O-D cells			% Volume of trips		
	Prior Lights	Post Lights	Change	Prior Lights	Post Lights	Change
0	26.0%	26.0%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	10.1%	13.0%	2.9%	0.002%	0.002%	0.0%
0.00001 to 0.0001	21.2%	22.2%	1.0%	0.04%	0.05%	0.0%
0.0001 to 0.001	24.8%	22.4%	-2.3%	0.4%	0.4%	0.0%
0.001 to 0.01	12.4%	11.2%	-1.3%	2.0%	1.8%	-0.2%
0.01 to 0.1	4.1%	3.8%	-0.3%	6.2%	5.9%	-0.3%
0.1 to 1	1.1%	1.0%	0.0%	15.7%	15.5%	-0.1%
1 to 3	0.2%	0.2%	0.0%	13.0%	13.0%	0.0%
3 to 5	0.04%	0.04%	0.0%	7.1%	7.2%	0.1%
5 to 10	0.03%	0.03%	0.0%	10.1%	10.2%	0.1%
10 to MAX	0.03%	0.03%	0.0%	45.5%	46.0%	0.4%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Table D.6 - Matrix sparsity, HGVs in Inter-peak

O-D Trips HGV	Share of O-D cells			% Volume of trips		
	Prior HGV	Post HGV	Change	Prior HGV	Post HGV	Change
0	2.2%	2.2%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	35.4%	41.1%	5.7%	0.1%	0.1%	0.0%
0.00001 to 0.0001	30.4%	27.7%	-2.7%	0.6%	0.5%	-0.1%
0.0001 to 0.001	21.1%	18.8%	-2.3%	3.6%	3.1%	-0.5%
0.001 to 0.01	8.5%	7.8%	-0.7%	13.1%	11.8%	-1.3%
0.01 to 0.1	2.1%	2.1%	0.0%	28.7%	27.9%	-0.8%
0.1 to 1	0.3%	0.3%	0.0%	30.4%	32.3%	1.9%
1 to 3	0.01%	0.01%	0.0%	8.5%	9.2%	0.7%
3 to 5	0.001%	0.001%	0.0%	2.1%	2.3%	0.2%
5 to 10	0.001%	0.001%	0.0%	2.3%	2.5%	0.2%
10 to MAX	0.001%	0.001%	0.0%	10.8%	10.4%	-0.4%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Table D.7 - Matrix sparsity, light vehicles in PM peak

O-D Trips Lights	Share of O-D cells			% Volume of trips		
	Prior Lights	Post Lights	Change	Prior Lights	Post Lights	Change
0	26.0%	26.0%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	8.6%	11.7%	3.1%	0.002%	0.002%	0.0%
0.00001 to 0.0001	21.2%	21.5%	0.2%	0.04%	0.04%	0.0%
0.0001 to 0.001	25.6%	23.4%	-2.1%	0.4%	0.4%	0.0%
0.001 to 0.01	13.0%	11.9%	-1.1%	1.7%	1.6%	-0.1%
0.01 to 0.1	3.9%	3.8%	-0.1%	5.2%	5.1%	-0.1%
0.1 to 1	1.4%	1.4%	0.0%	17.0%	16.9%	-0.1%
1 to 3	0.2%	0.2%	0.0%	14.1%	14.1%	0.0%
3 to 5	0.05%	0.05%	0.0%	7.9%	8.0%	0.0%
5 to 10	0.04%	0.04%	0.0%	11.5%	11.6%	0.1%
10 to MAX	0.03%	0.03%	0.0%	42.1%	42.4%	0.3%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Table D.8 - Matrix sparsity, HGVs in PM peak

O-D Trips HGV	Share of O-D cells			% Volume of trips		
	Prior HGV	Post HGV	Change	Prior HGV	Post HGV	Change
0	2.2%	2.2%	0.0%	0.0%	0.0%	0.0%
0 to 0.00001	36.8%	45.4%	8.7%	0.1%	0.1%	0.0%
0.00001 to 0.0001	31.9%	27.4%	-4.5%	1.1%	0.9%	-0.2%
0.0001 to 0.001	20.6%	17.0%	-3.6%	6.4%	5.0%	-1.4%
0.001 to 0.01	7.1%	6.4%	-0.7%	19.7%	17.1%	-2.6%
0.01 to 0.1	1.3%	1.4%	0.1%	33.0%	33.0%	0.0%
0.1 to 1	0.1%	0.1%	0.0%	24.7%	28.0%	3.3%
1 to 3	0.003%	0.0%	0.0%	4.4%	5.5%	1.1%
3 to 5	0.0004%	0.0005%	0.0%	1.3%	1.5%	0.1%
5 to 10	0.0002%	0.0003%	0.0%	1.5%	1.6%	0.1%
10 to MAX	0.0002%	0.0002%	0.0%	7.6%	7.2%	-0.4%
Total	**100%**	**100%**	**0.0%**	**100%**	**100%**	**0.0%**

Although there are no specific TAG acceptability criteria relating to the changes in matrix sparsity the analysis shows that matrix estimation is not overly distorting the distribution of O-D cell values in the matrix. The largest changes in the share of O-D cells are for those cells with very small O-D trips and represent a small proportion of the overall trip matrix volume therefore these changes are considered acceptable.

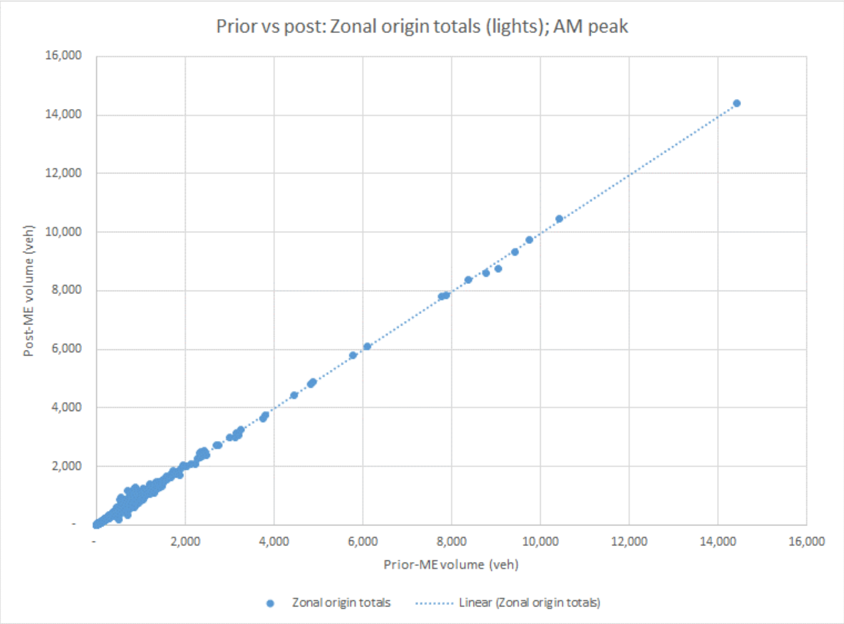
D.3. Matrix zonal trip ends

Table D.9 presents the matrix zonal trip end regression statistics for origins and destinations comparing the prior and post matrix estimation matrices.

Table D.9 - Matrix zonal trip end value changes – prior vs. post-ME

Measure	Significance Criteria	AM		IP		PM	
		Lights	HGV	Lights	HGV	Lights	HGV
Matrix Zonal Trip Ends – Origin (Rows)	Slope within 0.99 and 1.01	1.00	0.98	0.99	0.97	1.00	0.92
	Intercept near zero	0.23	1.05	2.12	1.02	2.52	1.09
	R^2 in excess of 0.98	0.99	0.98	1.00	0.98	1.00	0.95
Matrix Zonal Trip Ends – Destination (Columns)	Slope within 0.99 and 1.01	0.99	1.00	0.99	0.97	1.00	0.94
	Intercept near zero	3.77	0.89	0.84	1.02	0.23	0.96
	R^2 in excess of 0.98	1.00	0.98	1.00	0.98	0.99	0.96

For the entire Light vehicles matrix, the slope and R^2 criterion was met for origins and destinations in all time periods and intercept values are near zero. For HGV matrices the slope criteria were close to meeting the criteria in all time periods with values between 0.92 and 0.99. the HGV R^2 values were close to meeting the criteria with values between 0.94 and 0.98. In all cases these results are considered acceptable. Further analysis of the changes to zonal trip end values are presented in the following scatterplots.



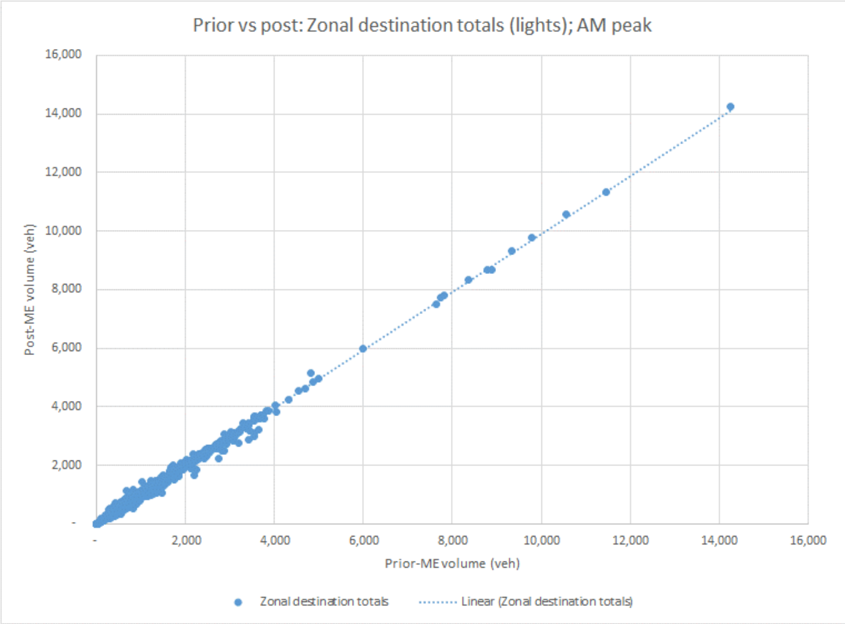
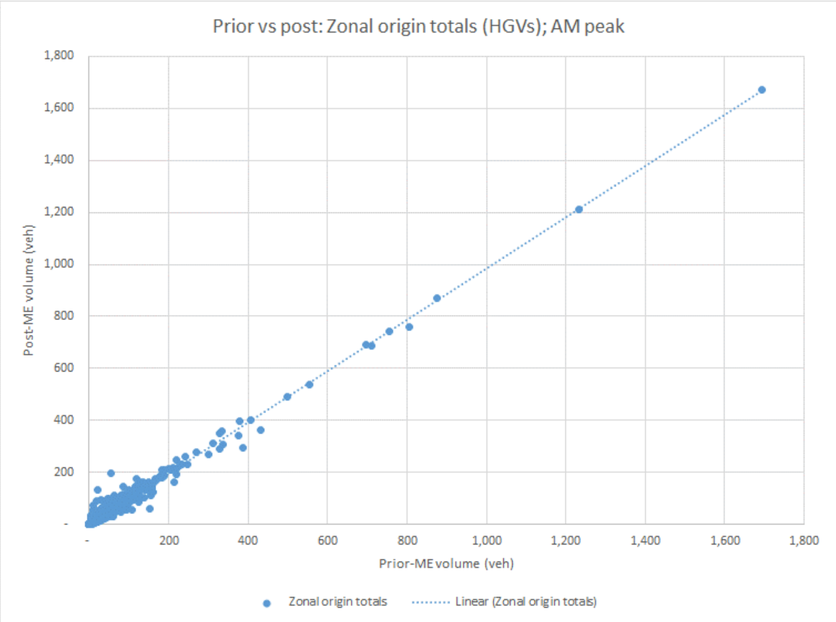


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (light vehicles, AM)



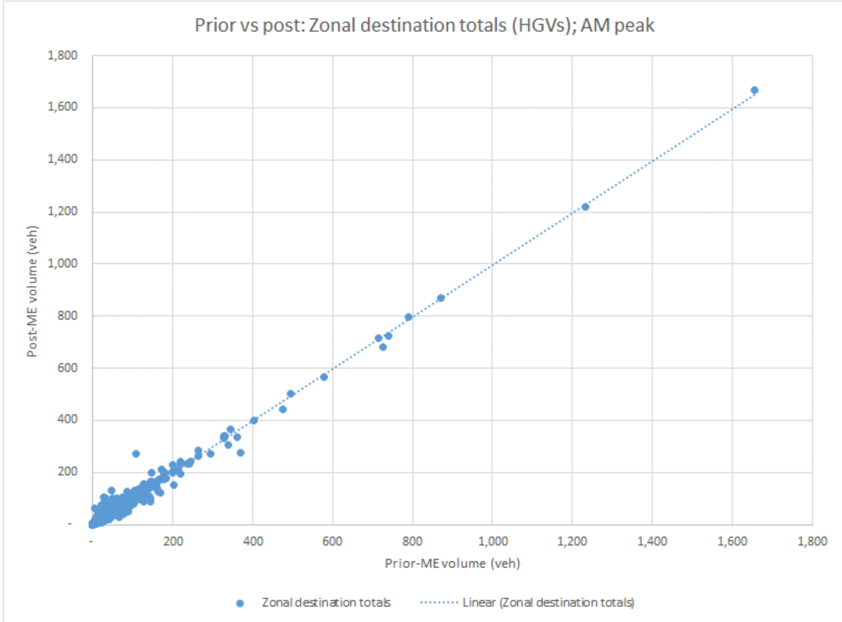
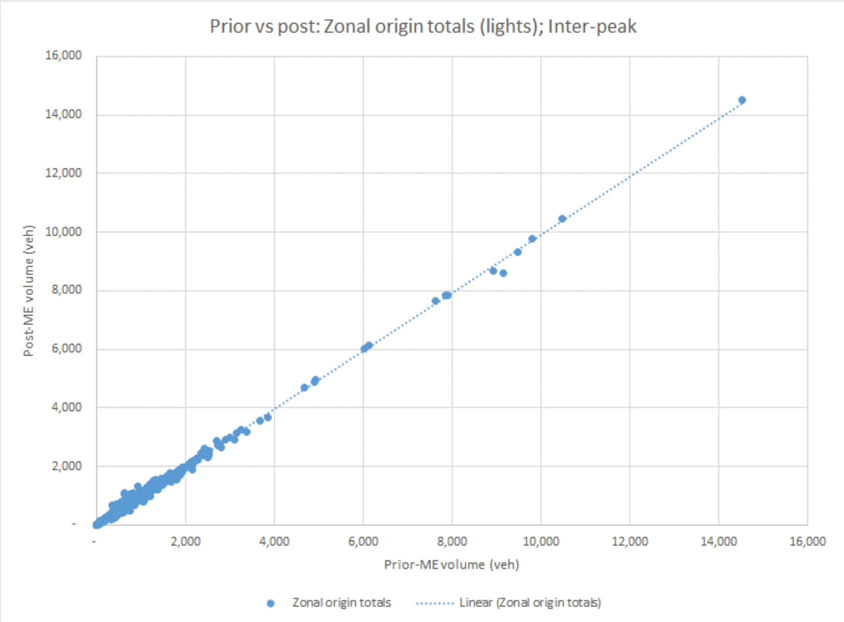


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (HGVs, AM)



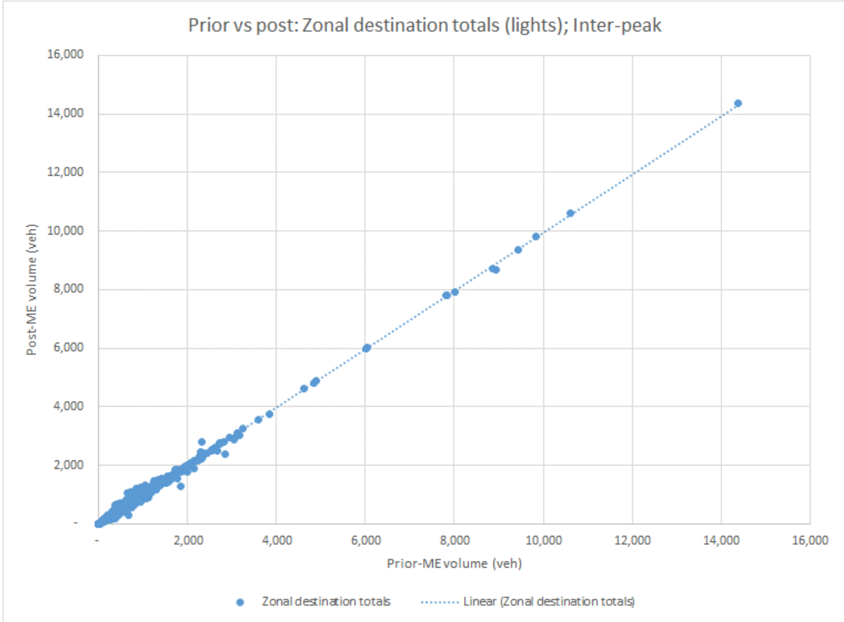


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (light vehicles, IP)

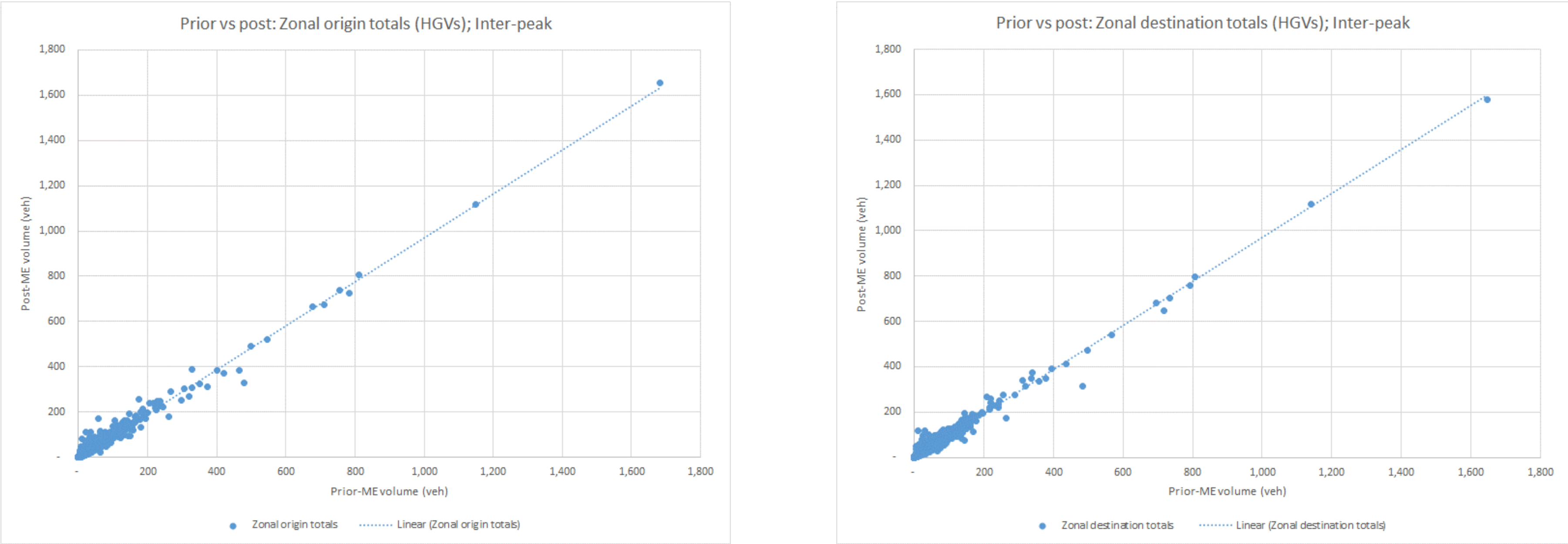


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (HGVs, IP)

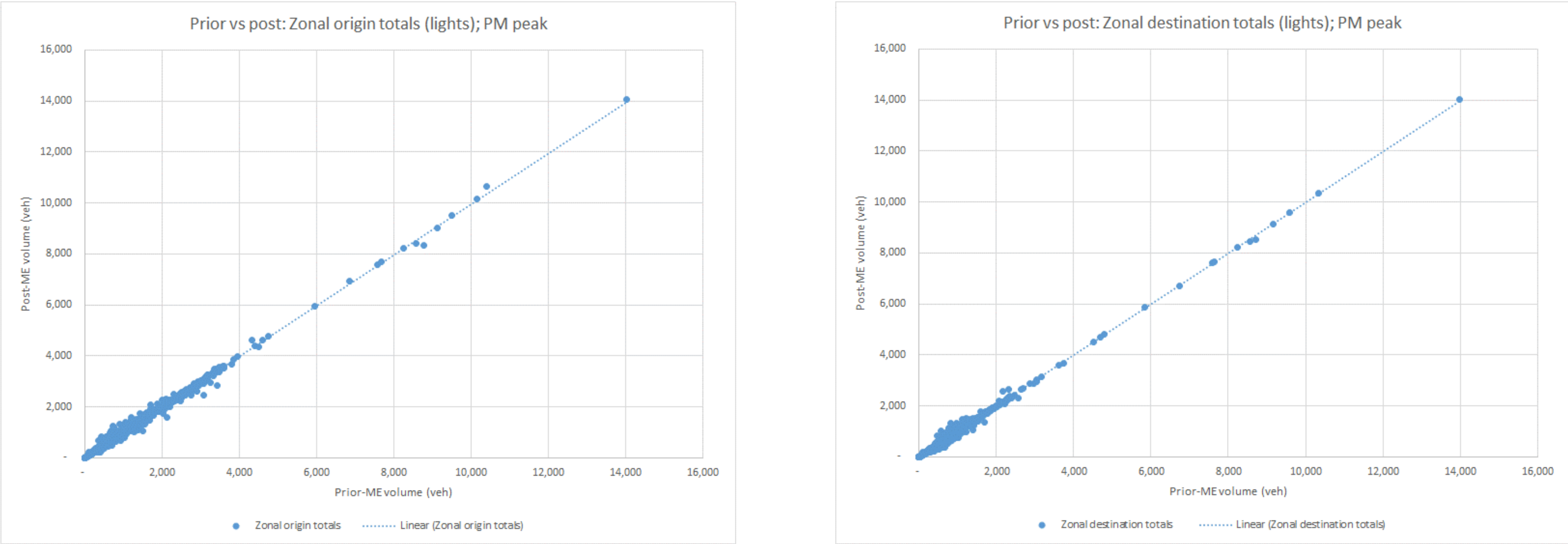


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (light vehicles, PM)

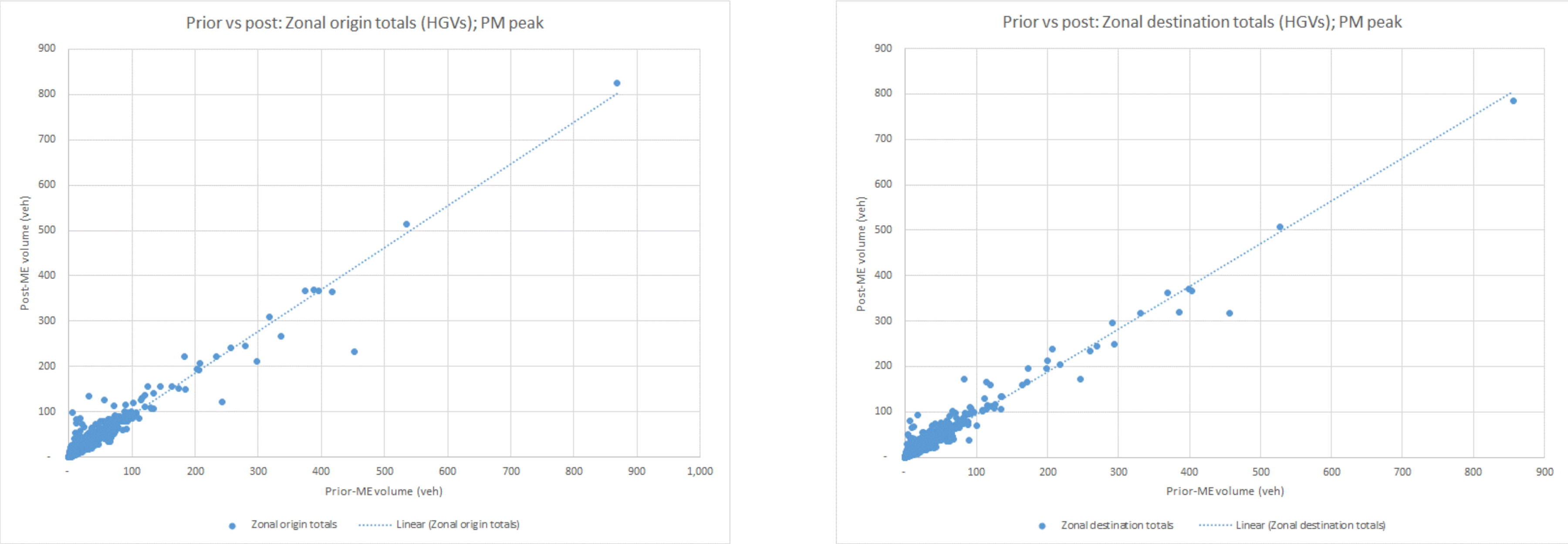


Figure A.6 – Origin and destination total vehicle trips, prior vs post matrix estimation (HGVs, PM)

D.4. Matrix trip length distribution

A comparison of the trip length distribution statistics for all trips between the prior and post matrix estimation matrices has been undertaken. Table D.10 presents the results of the TAG criteria for changes in trip length distributions statistics.

Table D.10 – Trip length distribution

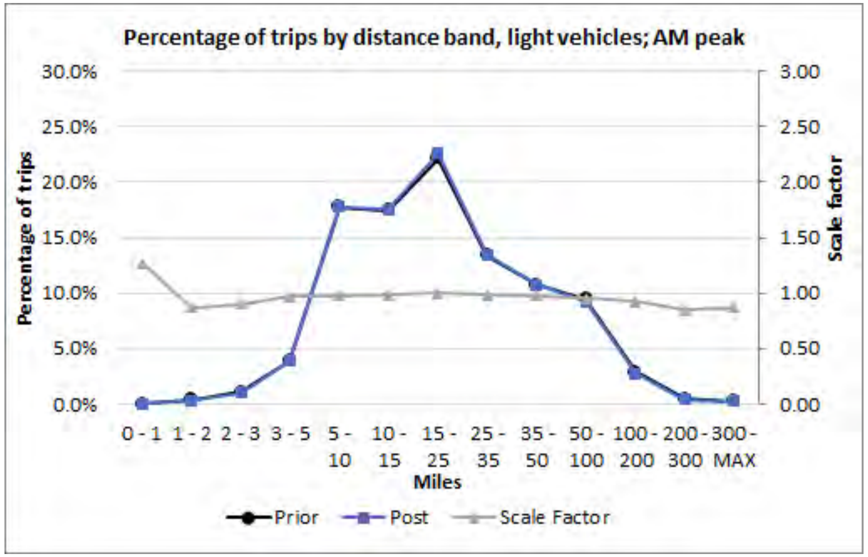
Measure	Significance Criteria	AM		IP		PM	
		Lights	HGV	Lights	HGV	Lights	HGV
Trip length distribution	Means within 5%	-1.6%	-2.9%	-5.1%	-8.0%	-1.8%	-17.3%
	Standard Deviations within 5%	-2.9%	-6.0%	-7.4%	-11.3%	-3.7%	-18.7%

The results in Table D.10 show that for Light vehicles the mean and standard deviation trip length distribution changes are within or very close to the 5% TAG criteria, with the IP recorded at a -5.1% and -7.4% change respectively. The HGV differences pass the mean criteria in the AM peak but exceed both criteria in the IP and PM peak.

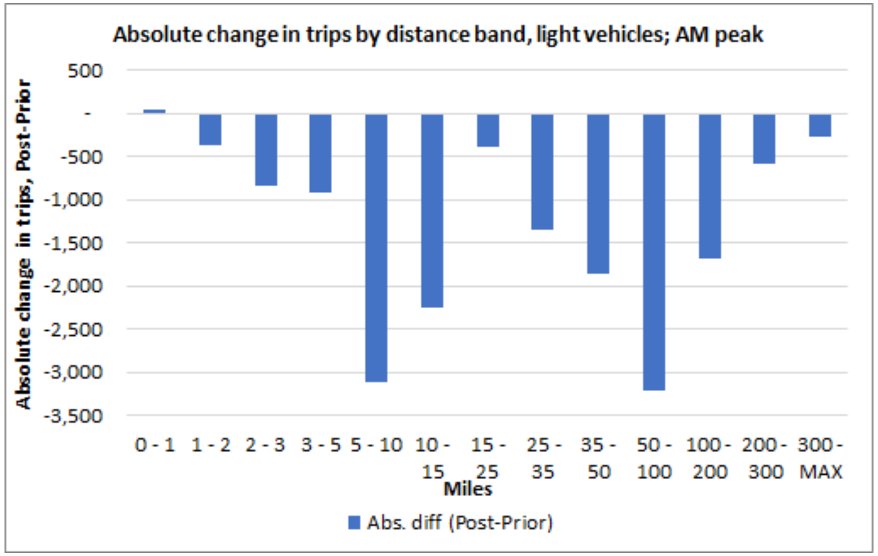
More detailed analysis of the matrix estimation impact on trip length distribution is presented in the following charts. The charts on the left present, for the cells of the matrix changed by matrix estimation, the change in the percentage of trips and the scale factor between the prior and post trips in each distance band. The charts on the right present, for the cells of the matrix changed by matrix estimation, the absolute change in trips in each distance band between the prior and post matrices. These charts show the general trend to the change in trip length distribution by time period for Lights and HGV vehicles.

For Light vehicles the left-hand charts show that the matrix estimation process is not overly distorting the trip length distribution with scale factors generally between 5% and 15% of trips, with acceptable distortion in the short distance trips. The absolute change in trips charts show that the IP has the largest change in trips in the 50 to 100 miles distance band.

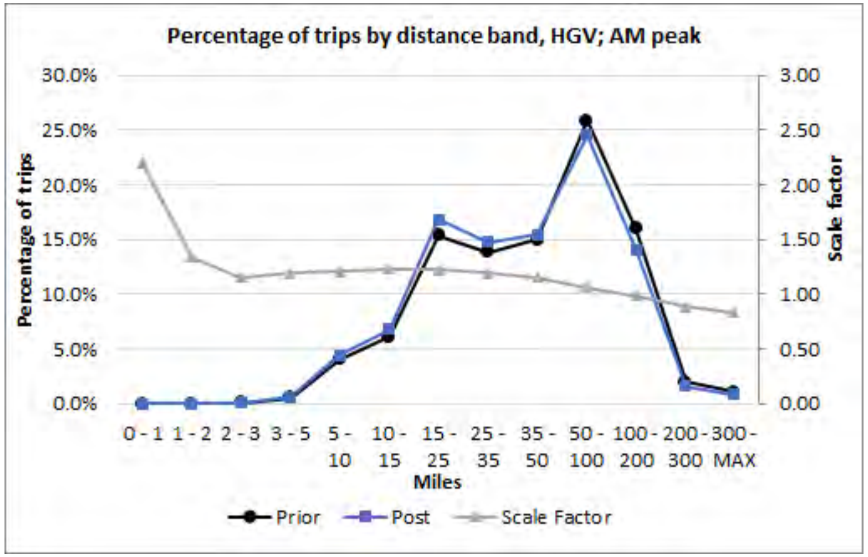
For HGVs, the left-hand charts show that the matrix estimation process is having a slightly greater impact than for lights but is still not overly distorting the trip length distribution, with scale factors generally between 5% and 25% of trips. The absolute change in trips charts show that the 15-25 miles distance band has the largest change in all time periods.



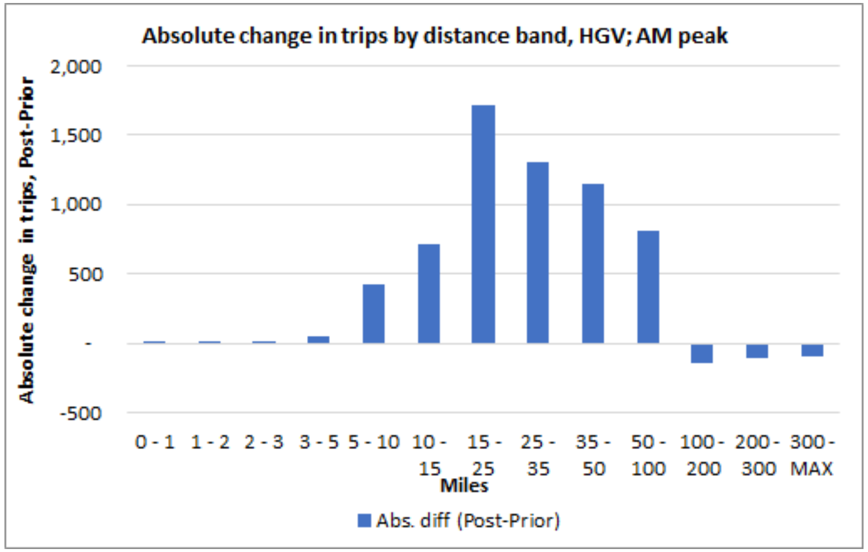
Percentage of trips by distance band, light vehicles; AM peak
Percentage of trips
Scale factor
Miles
0 - 1
1 - 2
2 - 3
3 - 5
5 - 10
10 - 15
15 - 25
25 - 35
35 - 50
50 - 100
100 - 200
200 - 300
300 - MAX
Prior
Post
Scale Factor



Absolute change in trips by distance band, light vehicles; AM peak
Absolute change in trips, Post-Prior
Miles
Abs. diff (Post-Prior)

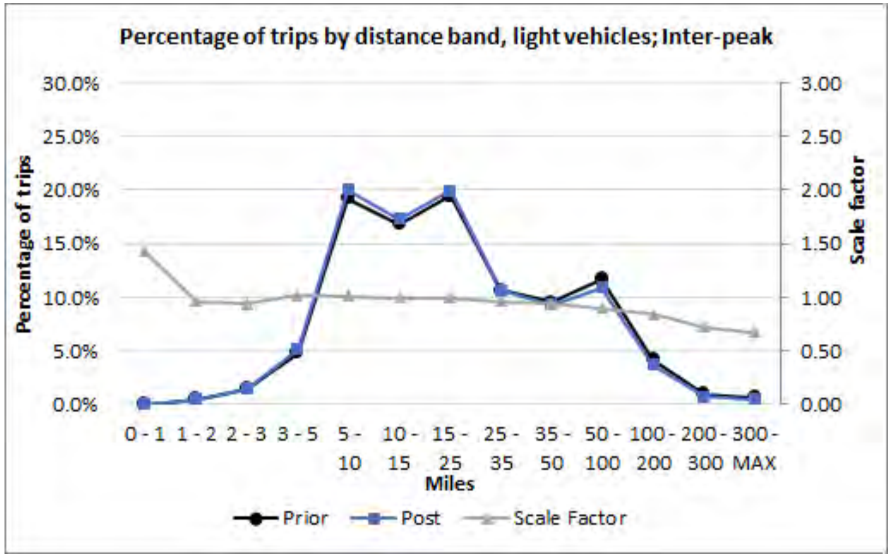


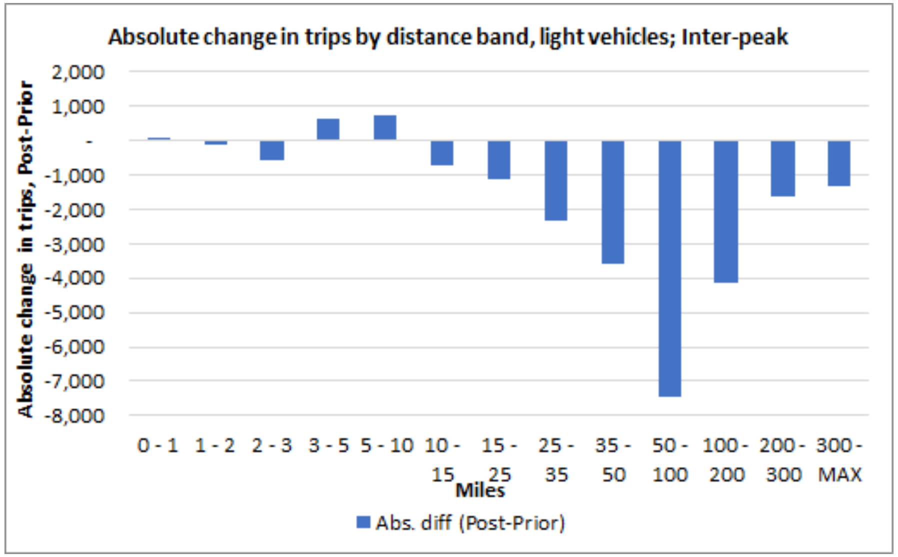
Percentage of trips by distance band, HGV; AM peak
Percentage of trips
Scale factor
Miles
Prior
Post
Scale Factor

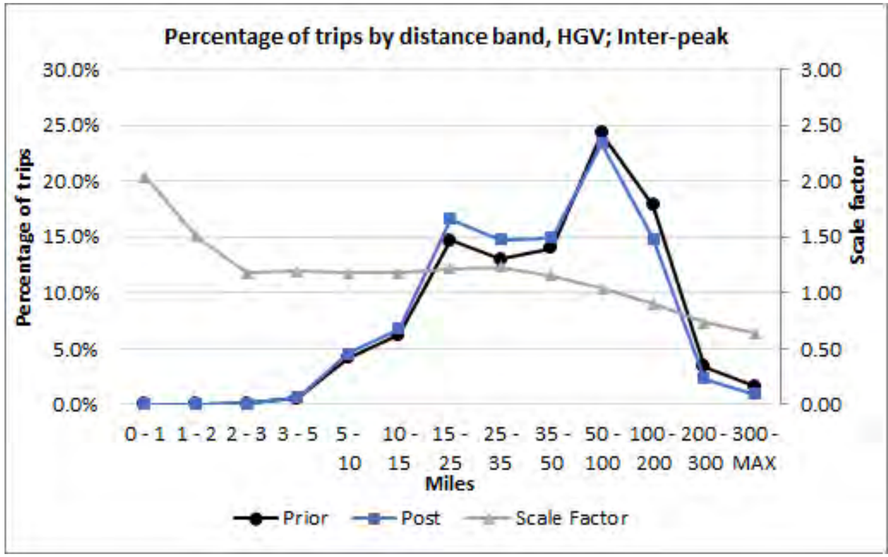


Absolute change in trips by distance band, HGV; AM peak
Absolute change in trips, Post-Prior
Miles
Abs. diff (Post-Prior)

Figure A.6 – Impact of matrix estimation on trips by distance band (AM)







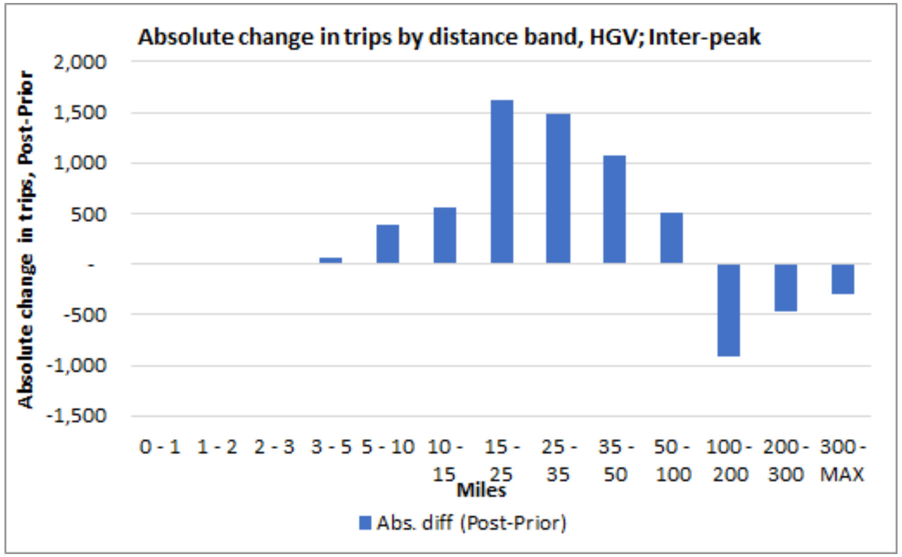
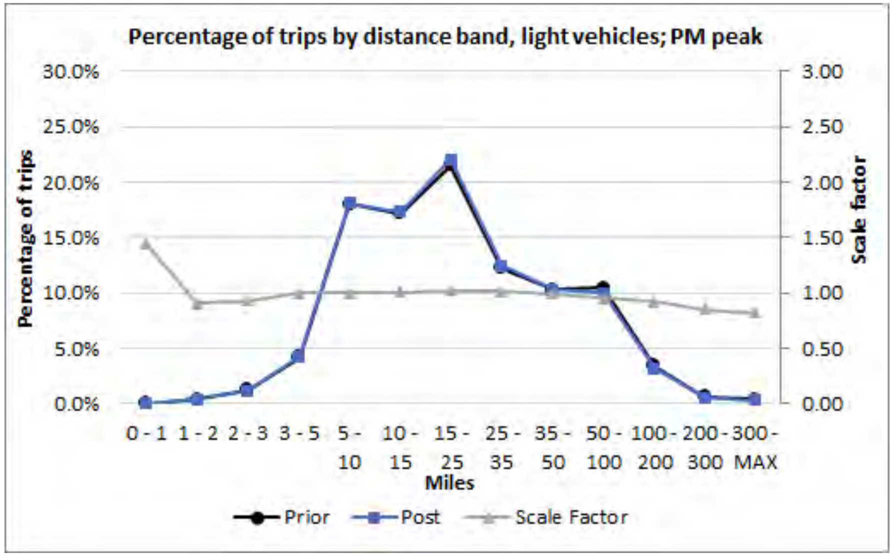
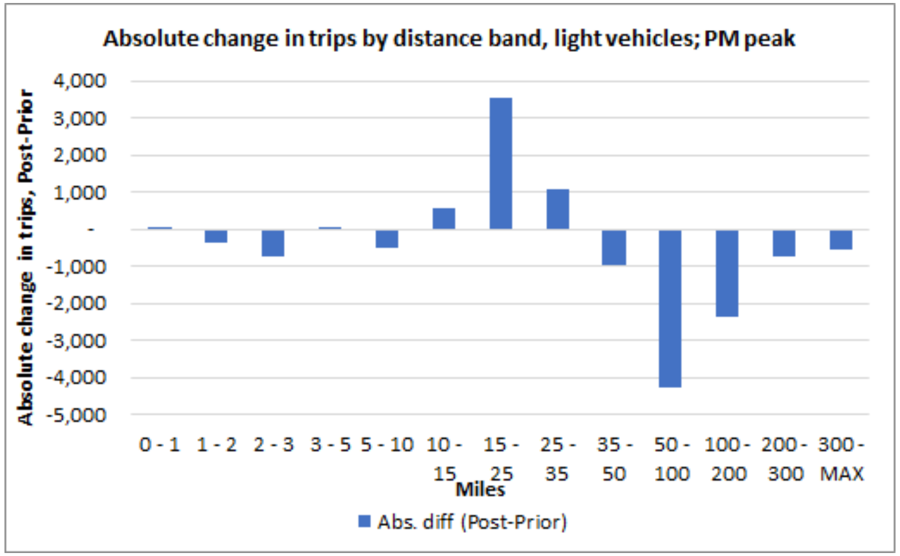
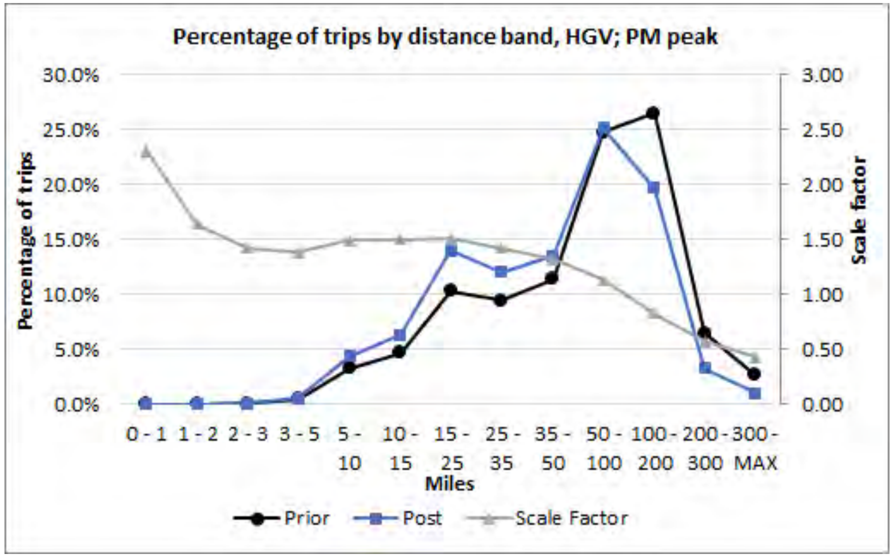


Figure A.6 – Impact of matrix estimation on trips by distance band (IP)







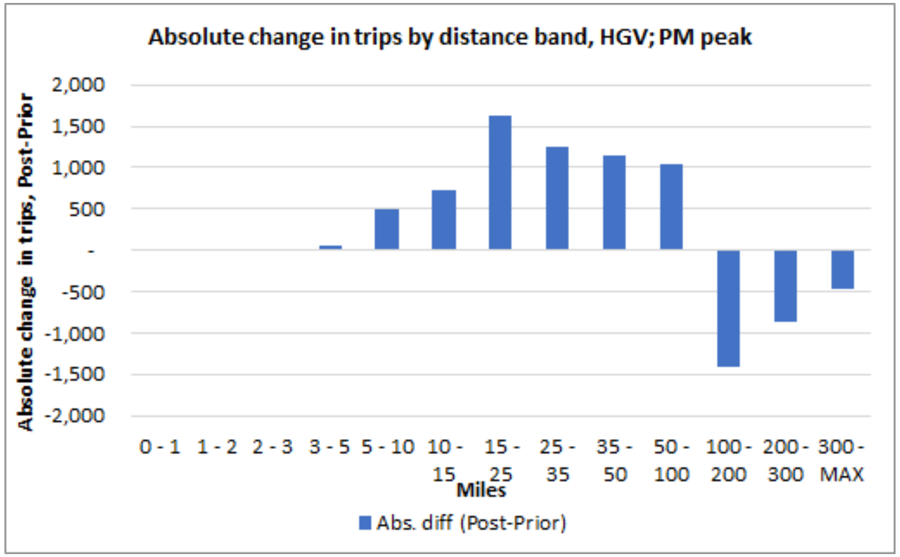


Figure A.6 – Impact of matrix estimation on trips by distance band (PM)

D.5. Matrix sectoring

This section reviews the spatial impact of matrix estimation using the 26-sector system shown in Figure 14.4 of Section 14.7. TAG criteria states that sector to sector differences should be within 5% when comparing the prior and post matrices. This criterion has been assessed firstly considering all sector to sector movement pairs and secondly considering sector to sector pairs with significant flows. Table D.11 shows the results.

Table D.11 – Sector to sector differences

Measure	Significance Criteria	AM		IP		PM	
		Lights	HGV	Lights	HGV	Lights	HGV
Sector to Sector Differences	All sector pairs differences <5%	20% of sector pairs	11% of sector pairs	15% of sector pairs	12% of sector pairs	20% of sector pairs	8% of sector pairs
	Sector pairs with significant flow (>1000 for lights) (>500 for HGV)	124	44	118	44	128	24
	No of Significant sector pairs <5%	52	15	49	18	62	9
	Significant sector pairs differences <5%	42% of sector pairs	34% of sector pairs	42% of sector pairs	41% of sector pairs	48% of sector pairs	38% of sector pairs

Although the overall impact of matrix estimation has been shown to be low, the results in Table D.11 show that a high proportion of sector to sector pairs change by more than 5%. Of the 676 sector pairs analysed over 50% have trip totals less than 100. When considering sector to sector pairs with significant flows the results improve and are considered acceptable.

Further analysis has been undertaken to understand the impact of matrix estimation on the sector origin and destination trip totals. Figure D.1 to Figure D.6 present the total change in sector destination and origin trips where the absolute change in sector pairs is either less than or greater than 100 trips along with the percentage change in relation to the sector total. This highlights the impact that changes to small and large sector to sector movements is having on the sector total. Given that there is some sector to sector pairs with large absolute changes in trips the change as a percentage of the sector total rarely exceeds 10%.

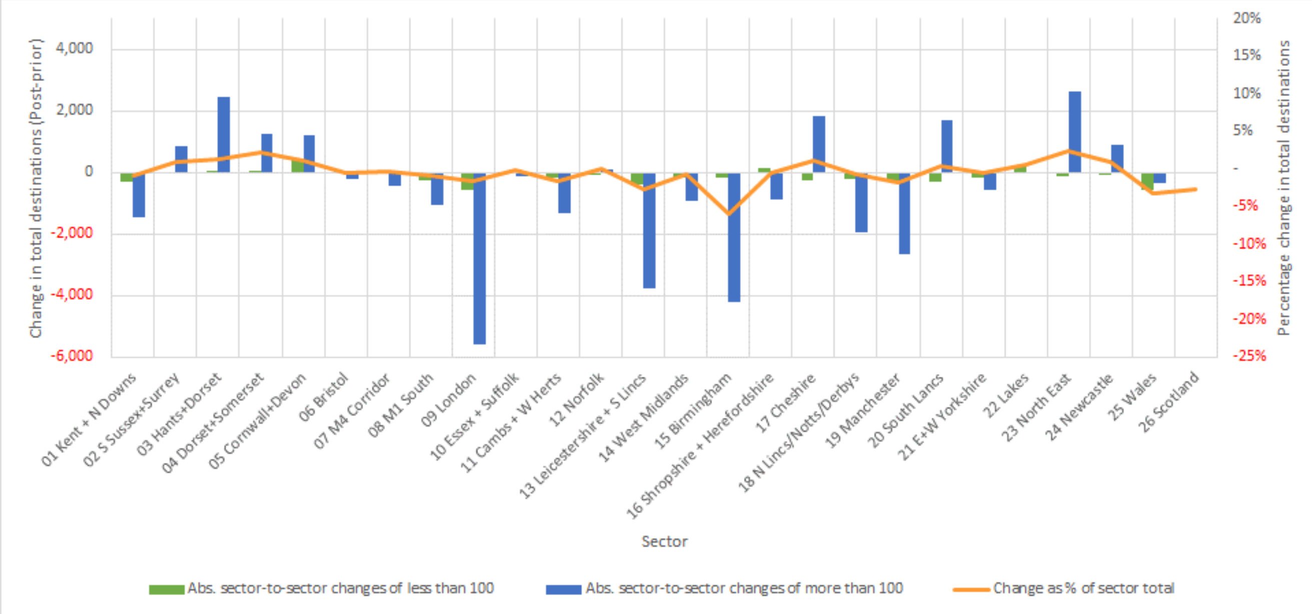


Figure D.1 - Post-Prior change in total car destinations by sector, AM peak

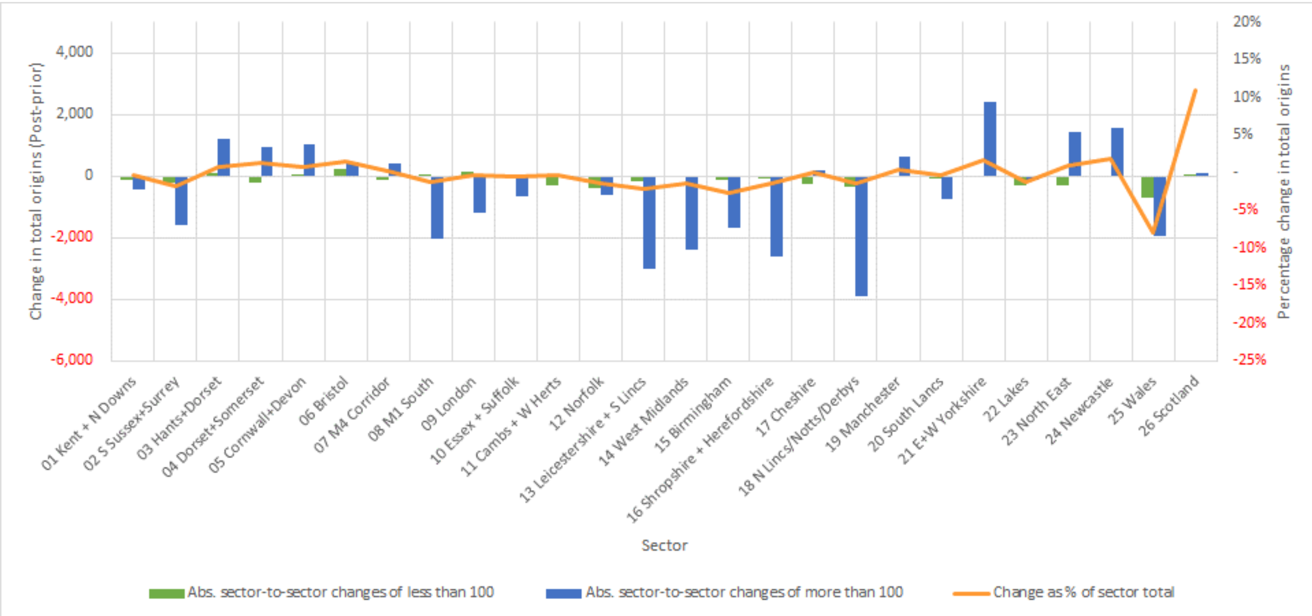


Figure D.2 - Post-Prior change in total car origins by sector, AM peak

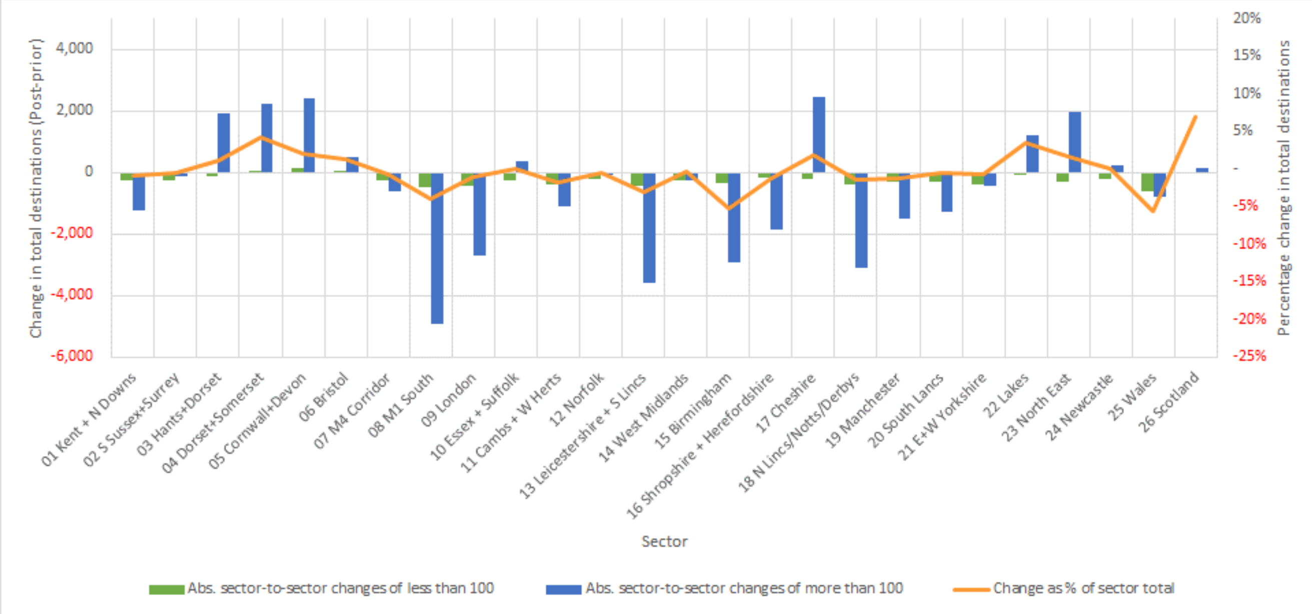


Figure D.3 - Post-Prior change in total car destinations by sector, Inter-peak

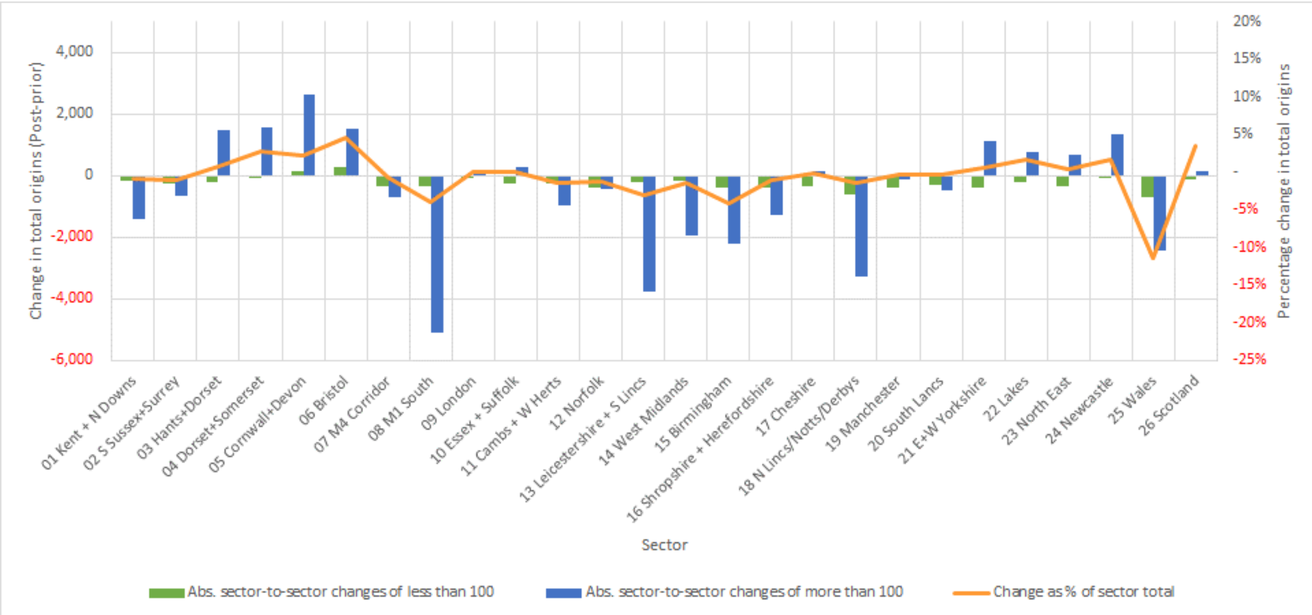


Figure D.4 - Post-Prior change in total car origins by sector, Inter-peak

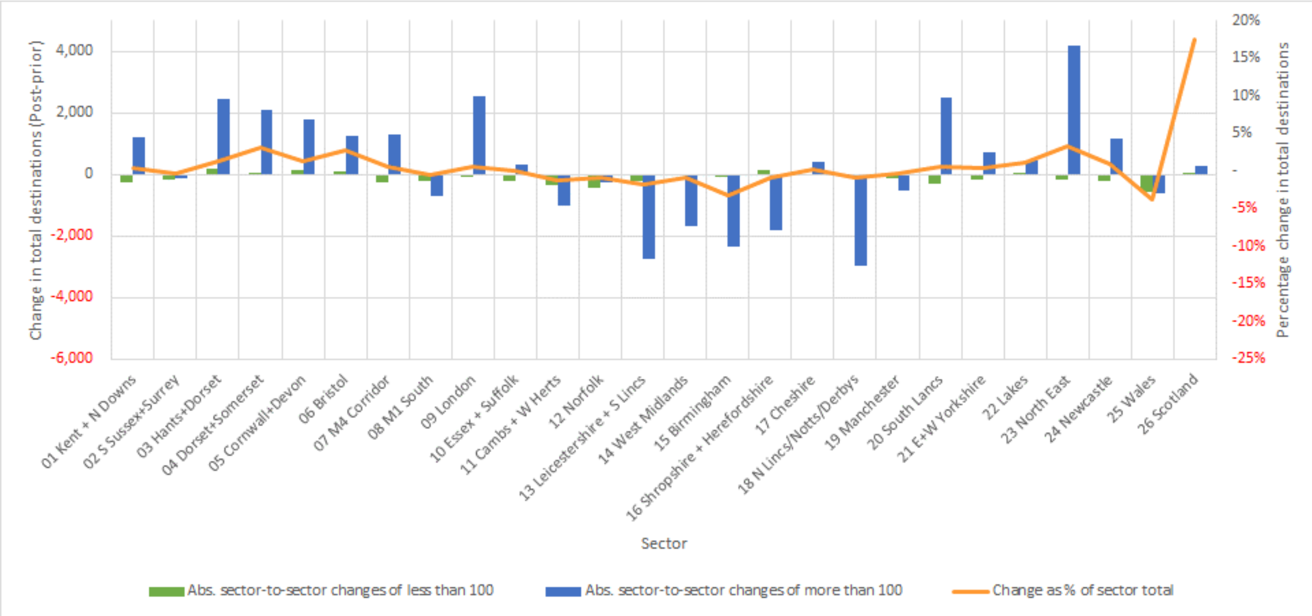


Figure D.5 - Post-Prior change in total car destinations by sector, PM peak

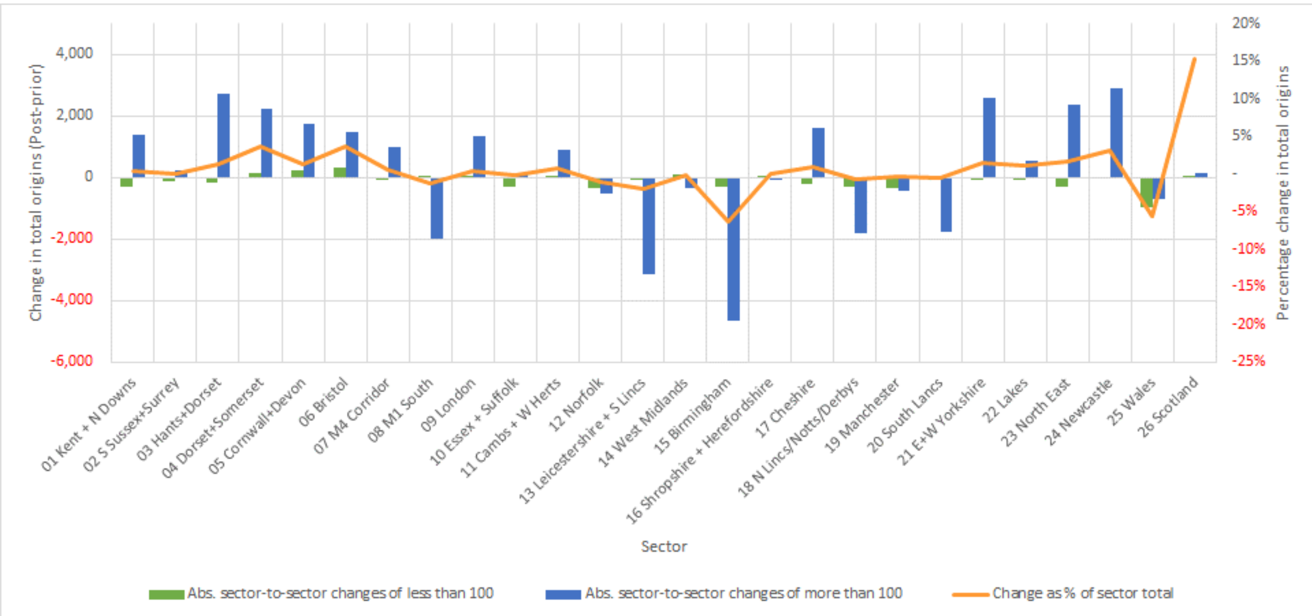


Figure D.6 - Post-Prior change in total car origins by sector, PM peak

Appendix E. HAM calibration results

E.1. Screenline and link flows

Table E.1 to Table E.3 provide a more detailed summary of the proportion of links, screenlines and mini-screenlines meeting the flow criteria following matrix calibration using these counts.

Table E.1 - Link/Screenline Calibration Summary; AM peak

% Pass		Lights	HGV	Total
Links (1901)	Flow Difference	85%	99%	83%
	GEH (<5)	77%	96%	76%
	GEH (<7)	87%	99%	86%
	GEH (<5) or Flow Diff	86%	99%	85%
Screenlines (68)	Flow Difference (5%)	96%	96%	96%
	GEH (<4)	88%	100%	88%
	GEH (<7)	99%	100%	99%
Mini-Screenlines (134)	Flow Difference (5%)	91%	89%	91%
	GEH (<4)	90%	100%	90%
	GEH (<7)	98%	100%	98%

Table E.2 - Link/Screenline Calibration Summary; Inter-peak

% Pass		Lights	HGV	Total
Links (1901)	Flow Difference	91%	99%	90%
	GEH (<5)	84%	95%	82%
	GEH (<7)	92%	99%	91%
	GEH (<5) or Flow Diff	92%	99%	90%
Screenlines (68)	Flow Difference (5%)	97%	93%	97%
	GEH (<4)	93%	100%	91%
	GEH (<7)	99%	100%	99%
Mini-Screenlines (134)	Flow Difference (5%)	89%	86%	90%
	GEH (<4)	94%	100%	91%
	GEH (<7)	100%	100%	100%

Table E.3 - Link/Screenline Calibration Summary; PM peak

% Pass		Lights	HGV	Total
Links (1901)	Flow Difference	84%	97%	83%
	GEH (<5)	77%	96%	75%
	GEH (<7)	87%	99%	87%
	GEH (<5) or Flow Diff	86%	97%	84%
Screenlines (68)	Flow Difference (5%)	96%	90%	96%
	GEH (<4)	87%	100%	85%

% Pass		Lights	HGV	Total
	GEH (<7)	99%	100%	99%
Mini-Screenlines (134)	Flow Difference (5%)	87%	83%	88%
	GEH (<4)	87%	100%	87%
	GEH (<7)	97%	100%	97%

E.2. Link flows by Region

Table E.4 presents the individual link count calibration summary by region, while Table E.5 shows the total calibration counts in each region.

Table E.4 - Regional calibration summary: All vehicles

		NE	NW	Y&H	EM	WM	EoE	Lon	SE	SW
AM peak - % pass	Flow Difference	88%	82%	88%	82%	74%	85%	76%	82%	88%
	GEH (<5)	78%	74%	83%	74%	63%	80%	73%	79%	79%
	GEH (<7)	84%	83%	92%	90%	77%	90%	79%	86%	90%
	GEH (<5) or Flow Diff	88%	84%	89%	84%	75%	86%	76%	85%	89%
Inter-peak - % pass	Flow Difference	89%	88%	93%	92%	83%	91%	73%	90%	95%
	GEH (<5)	82%	79%	89%	79%	71%	85%	73%	82%	87%
	GEH (<7)	83%	88%	96%	94%	85%	95%	91%	92%	95%
	GEH (<5) or Flow Diff	89%	88%	94%	92%	84%	91%	73%	90%	95%
PM peak - % pass	Flow Difference	86%	84%	88%	86%	74%	85%	64%	79%	88%
	GEH (<5)	79%	76%	84%	70%	60%	79%	64%	73%	80%
	GEH (<7)	83%	88%	91%	88%	77%	89%	82%	87%	90%
	GEH (<5) or Flow Diff	87%	86%	89%	87%	75%	86%	67%	80%	89%

Table E.5 - Number of calibration counts in each region

Region	Number of calibration counts
North East	112
North West	294
Yorkshire and The Humber	228
East Midlands	214
West Midlands	231
East of England	184
London	33
South East	345
South West	260
Total	**1901**

Appendix F. Routing check table

The table below summarises observations from the route checking process, as outlined in Section 14.8 of the main document. The commentary below relates to the final checks of the routing, using the final post-ME HAM assignment in NTM v5 Run A203.

Images related to each check have been supplied to DfT, showing the overall route in each direction for light vehicles and HGVs, in each direction. Sense-checks were carried out using Google Maps, the links for which are also supplied. It should be noted however that Google Maps is a dynamic system and will not necessarily return identical results for a specific route and travel time.

The information below is organised into 'Sets' which relate to the spreadsheets in which the images are stored. Set 1 contains the 10 priority routes agreed with DfT for early checking, with the remainder being in numerical order.

Table F.1 - Routing check comments

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
1 /4	560	7271	Doncaster 003	Newcastle upon Tyne 024	OK	OK	OK
	7271	560	Newcastle upon Tyne 024	Doncaster 003	OK	OK	OK
1 /11	5081	2668	Sefton 030	Copeland 001	Slight variation - NTM takes A591 instead of continuing along M6. A591 is significantly shorter, similar time on Google	OK	OK
	2668	5081	Copeland 001	Sefton 030	Slight variation - NTM takes A591 instead of continuing along A66. A591 is significantly shorter, similar time on Google	OK	OK
1 /16	477	1844	Ashford 005	West Devon 003	OK	OK	OK
	1844	477	West Devon 003	Ashford 005	OK	OK	OK
1 /20	5244	6470	Cheshire West and Chester 047	Peterborough 017	Variation - NTM routes along A525 instead of A41. Google	OK	OK

Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Comments: Overall Route	Journey Start	Journey End
					chooses x-country route, very similar times + distance		
	6470	5244	Peterborough 017	Cheshire West and Chester 047	Variation - NTM routes along the A1, A47 instead of A1139. NTM route reasonable	OK	Slight variation
1 /27	1225	2549	West Devon 003	Herefordshire 001	OK	OK	OK
	2549	1225	Herefordshire 001	West Devon 003	OK	OK	OK
1 /28	6470	2453	University Hospital of North Durham	Bolton 015	Matches with one of the plausible routes, similar results for IP and PM.	OK	OK
	2453	6470	Bolton 015	University Hospital of North Durham	Matches with one of the plausible routes, similar results for IP and PM.	OK	OK
1 /37	7243	66	Winchester 007	Gloucester 006	OK	OK	OK
	66	7243	Gloucester 006	Winchester 007	OK	OK	OK
1 /38	4189	2501	Sutton 024	Stoke-on-Trent 003	Slight Variation - Opts M1 instead of M25. Uses M1 which is plausible route, but then through London which is shorter in distance terms, but longer duration.	Variation - NTM routes along minor roads through London	OK
	2501	4189	Stoke-on-Trent 003	Sutton 024	A proportion of NTM routes matches with the Google route. Different routing to outbound, more similar to Google.	OK	OK
1 /41	3658	5499	Enfield 032	Norwich 003	Variation - NTM routes along M25 instead of A406	OK	OK

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
	5499	3658	Norwich 003	Enfield 032	Slight variation - NTM routes along M25 instead of A406	OK	Slight variation
1 /45	4024	851	Merton 003	Leeds 010	Variation - NTM routes along the local roads to access M1 instead of taking M4&M40. As with Ref 38 cutting through London. This is similar to routing in previous route check.	OK	Slight variation
	851	4024	Leeds 010	Merton 003	Variation - NTM routes along M1 instead of M25	Slight variation	Variation - NTM routes along the local roads from M1 through London
2 /1	5541	4703	Oxford 008	Cambridge 005	OK	OK	OK
	4703	5541	Cambridge 005	Oxford 008	OK	OK	OK
2 /2	5870	5081	Crawley 005	Winchester 007	Variation - NTM routes along minor roads (shorter) instead of M25 & M3 (longer)	Variation -routes along minor roads	Variation-routes along minor roads
	5081	5870	Winchester 007	Crawley 005	Variation - NTM routes along minor roads (shorter) instead of M25 & M3 (longer)	Variation - routes along minor roads	Variation - routes along minor roads
2 /3	3658	5795	Enfield 032	Tandridge 008	Variation – NTM takes direct route along the minor roads via London instead of M25. Additional checks show that this is not the case in the IP and PM assignment.	Variation - routes along minor roads	Variation - routes along minor roads
	5795	3658	Tandridge 008	Enfield 032	Variation - NTM takes direct route along the minor roads via London instead of M25	Variation - routes along minor roads	Variation - routes along minor roads

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
2 /5	1091	1841	Kingston upon Hull 024	Carlisle 011	OK	OK	OK
	1841	1091	Carlisle 011	Kingston upon Hull 024	OK	OK	OK
2 /6	5139	103	East Hertfordshire 018	Manchester 020	Variation - NTM routes along M1 to move to A52 & A523 instead of taking M6. IP and PM similar to AM.	Slight variation - routes along A414 to access M1 instead of M25	OK
	103	5139	Manchester 020	East Hertfordshire 018	Variation - each proportion of NTM routes along A52 & A6	OK	Slight variation - routes along A414 instead of M25
2 /7	6533	7488	Cotswold 009	Blaby 006	Matches with one of the plausible routes	Slight variation due to model network detail	Matches with one of the plausible routes
	7488	6533	Blaby 006	Cotswold 009	Minor Variation - NTM continues along minor (B4455) instead of moving to A423	Variation - routes along minor roads (B4114) instead of M69/M1	OK
2 /8	2453	560	Herefordshire 001	Doncaster 003	Matches with one of the plausible routes	OK	OK
	560	2453	Doncaster 003	Herefordshire 001	OK	OK	OK
2 /9	2229	4189	Sandwell 017	Sutton 024	OK	OK	Slight variation - NTM routes along minor to access M25
	4189	2229	Sutton 024	Sandwell 017	OK	Slight variation - NTM routes along minor roads from M25	OK

Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Comments: Overall Route	Journey Start	Journey End
2 /10	791	2453	Kirklees 009	Herefordshire 001	Matches with one of the plausible routes	OK	Slight variation - NTM routes along minor road instead of A49
	2453	791	Herefordshire 001	Kirklees 009	Variation - NTM routes along the minor roads (B4365)	Slight variation - NTM routes along minor road instead of A49	OK
2 /12	1841	7097	Carlisle 011	Stockton-on-Tees 003	OK	OK	OK
	7097	1841	Stockton-on-Tees 003	Carlisle 011	OK	OK	OK
3 /13	5822	6508	Woking 008	West Dorset 001	OK	OK	Slight variation due to model network detail
	6508	5822	West Dorset 001	Woking 008	OK	OK	OK
3 /14	1091	791	Kingston upon Hull 024	Kirklees 009	OK	OK	OK
	791	1091	Kirklees 009	Kingston upon Hull 024	OK	OK	OK
3 /15	7020	4189	Newham 033	Sutton 024	Model uses a more direct route	Different route (uses A205)	Different route (uses minor routes)
	4189	7020	Sutton 024	Newham 033	Model uses a more direct route	Slight variation	Different route (uses A205)
3 /23	4017	5139	Lewisham 030	East Hertfordshire 018	Slight variation as NTM opts minor roads in Walthamstow	Variation (uses A21 instead of Whitefoot lane)	Matches with one of the plausible routes
	5139	4017	East Hertfordshire 018	Lewisham 030	Variation - NTM routes along A10 through Enfield instead of M25/M11	Matches with one of the plausible routes	Slight variation

Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Comments		
					Overall Route	Journey Start	Journey End
3 /17	2229	5499	Sandwell 017	Norwich 003	OK	OK	OK
	5499	2229	Norwich 003	Sandwell 017	OK	OK	Slight variation - turns to A4041 instead of continuing along M6
3 /18	851	7075	Leeds 010	Sunderland 016	OK	OK	OK
	7075	851	Sunderland 016	Leeds 010	OK	OK	OK
3 /19	66	2444	Bolton 015	Nottingham 028	Model uses a more direct route	OK	Variation - continues along M1 instead of taking A610
	2444	66	Nottingham 028	Bolton 015	Model uses more direct route	Variation - NTM routing continues along A610 instead of diverting to M1	Matches with one of the plausible routes
3 /21	2444	2156	Nottingham 028	Coventry 028	OK	Slight variation - Routes along Ilkeston Road instead of A6200	OK
	2156	2444	Coventry 028	Nottingham 028	Slight variation - Major routing along M1 in the model	OK	Variation - routes along A52 instead of Clifton Blvd
3 /22	2453	2668	Herefordshire 001	Gloucester 006	OK	OK	Slight variation - NTM Routes along Estcourt Road instead of A417
	2668	2453	Gloucester 006	Herefordshire 001	OK	Slight variation - NTM Routes along Estcourt Road instead of A417	OK

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
3 /24	7112	4024	Dover Port	Merton 003	Matches with one of the plausible routes	OK	OK
	4024	7112	Merton 003	Dover Port	Matches with one of the plausible routes	Slight variation - NTM routes along B237	OK
4 /25	1091	7687	Kingston upon Hull 024	Heathrow T5	Aligns with one of the plausible routes	OK	OK
	7687	1091	Heathrow T5	Kingston upon Hull 024	Aligns with one of the plausible routes	OK	OK
4 /26	6508	6302	West Dorset 001	Cornwall 025	OK	Slight variation - NTM routes along W Coker Rd instead of Lysander Rd	Slight variation - NTM shifts from A38 to Callington Rd instead of going along B3271
	6302	6508	Cornwall 025	West Dorset 001	OK	Slight variation - NTM uses Callington Rd instead of going along B3271	Slight variation due to network detail
4 /29	5389	7488	Thanet 017	Blaby 006	OK	OK	Variation - NTM enters the local roads instead of continuing along M1
	7488	5389	Blaby 006	Thanet 017	OK	OK	OK
4 /30	5541	477	Oxford 008	Sefton 030	Slight variation - NTM routes along M6 instead of taking M6 Toll.	OK	OK
	477	5541	Sefton 030	Oxford 008	OK	OK	OK

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
4 /31	4703	5081	Cambridge 005	Winchester 007	Aligns with one of the plausible routes	OK	OK
	5081	4703	Winchester 007	Cambridge 005	Aligns with one of the plausible routes	OK	OK
4 /32	6212	5822	Swindon 010	Woking 008	OK	OK	OK
	5822	6212	Woking 008	Swindon 010	OK	OK	Slight variation - NTM routes along Drakesway instead of A259
4 /33	5139	6466	East Hertfordshire 018	Torridge 008	OK	OK	OK
	6466	5139	Torridge 008	East Hertfordshire 018	OK	OK	OK
4 /34	197	1841	Salford 021	Carlisle 011	OK	OK	OK
	1841	197	Carlisle 011	Salford 021	OK	OK	OK
4 /35	7075	7271	Sunderland 016	Newcastle upon Tyne 024	OK	OK	Variation - NTM has a Rail bridge coded as Link (No.47506)
	7271	7075	Newcastle upon Tyne 024	Sunderland 016	OK	OK	Slight variation - NTM routes along B1539 to access A1231 rather than taking A1231 directly from Wessington Way
4 /36	7488	5541	Blaby 006	Oxford 008	Aligns with one of the plausible routes	OK	OK

Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Comments		
					Overall Route	Journey Start	Journey End
	5541	7488	Oxford 008	Blaby 006	OK	OK	Variation - NTM routes along A5 instead of entering M1
5 /39	1225	7097	Cheshire West and Chester 047	Stockton-on-Tees 003	Slight variation - at the start and end of journey	Variation - NTM opts A49 to access M62 instead of A41	Slight variation - NTM routes along B1275 to access A19 rather than Central Ave
	7097	1225	Stockton-on-Tees 003	Cheshire West and Chester 047	Slight variation - at the start and end of journey	Slight variation - NTM routes along B1275 to access A19 rather than Central Ave	Variation - NTM opts A49 to access M62 instead of A41
5 /40	103	791	Manchester 020	Kirklees 009	OK	NTM aligns with one of the plausible routes	HGV routes match but Lights routes along A643 to reach the destination
	791	103	Kirklees 009	Manchester 020	Variation on approaching Manchester (routing along inner ring as compared to outer)	OK	Variation - NTM routes through inner ring (A610) of Manchester as compared to outer ring (M60)
5 /42	5870	5244	Crawley 005	Ashford 005	OK	OK	OK
	5244	5870	Ashford 005	Crawley 005	OK	OK	OK
5 /43	2453	4703	Herefordshire 001	Cambridge 005	OK	OK	OK
	4703	2453	Cambridge 005	Herefordshire 001	OK	OK	OK

					Comments		
Set /Ref	Orig Zone	Dest Zone	Origin	Destination	Overall Route	Journey Start	Journey End
5 /44	6212	7020	Swindon 010	Newham 033	Aligns with one of the plausible routes	OK	Slight variation - NTM routes along A1020 instead of Newham Way
	7020	6212	Newham 033	Swindon 010	Aligns with one of the plausible routes	Slight variation - NTM routes along A1020 instead of Newham Way	Slight variation - routes along A4313 instead of A4259

Appendix G. Journey time validation results

G.1. AM peak

Table G.1 - AM peak journey time validation

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
1_A1/ A1(M)_Scotch Corner - Newcastle_NB	1_NB	78.56	00:56:41	01:05:11	00:48:11	00:52:30	✓
1_A1/ A1(M)_Newcastle - Scotch Corner_SB	1_SB	78.73	00:55:55	01:04:19	00:47:32	00:53:08	✓
2_A1/A1(M)_Barnet - Peterborough_NB	2_NB	106.54	01:13:53	01:24:58	01:02:48	01:07:23	✓
2_A1/A1(M)_Peterborough - Barnet_SB	2_SB	106.29	01:13:18	01:24:18	01:02:19	01:11:36	✓
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_1	70.33	00:40:13	00:46:15	00:34:11	00:52:22	✗
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_2	84.44	00:52:17	01:00:07	00:44:26	00:59:29	✓
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_1	84.28	00:53:26	01:01:26	00:45:25	01:00:16	✓
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_2	70.65	00:42:14	00:48:34	00:35:54	00:54:17	✗
4_A1_Newcastle - Berwick_NB	4_NB	95.46	01:03:31	01:13:03	00:53:59	01:03:44	✓
4_A1_Berwick - Newcastle_SB	4_SB	95.53	01:02:43	01:12:08	00:53:19	01:03:36	✓
5_A11_Duxford (M11) - Norwich_NB	5_NB	99.15	01:01:05	01:10:15	00:51:56	00:58:05	✓
5_A11_Norwich - Duxford (M11)_SB	5_SB	99.46	00:59:20	01:08:14	00:50:26	00:58:43	✓
6_A12_Brentwood - Ipswich_EB	6_EB	83.60	00:53:51	01:01:55	00:45:46	00:55:07	✓
6_A12_Ipswich - Brentwood _WB	6_WB	83.56	00:59:08	01:08:00	00:50:15	00:59:24	✓
7_A120_Bishops Stortford - Harwich_EB	7_EB	84.02	00:57:32	01:06:10	00:48:55	00:58:13	✓
7_A120_Harwich - Bishops Stortford_WB	7_WB	83.91	01:01:37	01:10:52	00:52:22	01:01:45	✓
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_1	77.61	00:52:23	01:00:15	00:44:32	00:52:20	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_2	63.34	00:37:44	00:43:24	00:32:04	00:38:46	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_1	63.82	00:38:34	00:44:21	00:32:47	00:39:57	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_2	77.55	00:50:06	00:57:37	00:42:35	00:55:28	✓
9_A14_Rugby (M1) - Brampton Hut (A1)_EB	9_EB	69.32	00:40:17	00:46:20	00:34:15	00:42:11	✓
9_A14_Brampton Hut (A1) - Rugby (M1)_WB	9_WB	69.38	00:45:41	00:52:32	00:38:50	00:43:26	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_1	63.07	00:37:11	00:42:46	00:31:37	00:38:13	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_2	56.21	00:45:55	00:52:48	00:39:01	00:42:26	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_1	55.56	00:39:04	00:44:56	00:33:13	00:42:46	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_2	63.12	00:37:41	00:43:20	00:32:02	00:39:28	✓
11_A2/M2_Dartford - Dover_EB	11_EB	98.52	01:03:53	01:13:28	00:54:18	01:03:06	✓
11_A2/M2_Dover - Dartford_WB	11_WB	98.23	01:07:47	01:17:57	00:57:37	01:08:50	✓
12_A21_Sevenoaks - Hastings_EB	12_EB	59.09	00:51:12	00:58:53	00:43:32	00:44:54	✓
12_A21_Hastings - Sevenoaks_WB	12_WB	59.01	00:48:26	00:55:42	00:41:10	00:52:09	✓
13_A23/M23_Brighton - Croydon_NB	13_NB	55.03	00:39:31	00:45:26	00:33:35	00:43:37	✓
13_A23/M23_Croydon - Brighton_SB	13_SB	55.59	00:39:46	00:45:44	00:33:48	00:45:58	×
14_A259/A2070_Eastbourne - Ashford_EB	14_EB	69.09	01:16:50	01:28:22	01:05:19	01:06:38	✓
14_A259/A2070_Ashford - Eastbourne_WB	14_WB	68.77	01:09:25	01:19:49	00:59:00	01:06:12	✓
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_1	62.88	01:04:18	01:13:57	00:54:39	00:58:26	✓
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_2	47.68	00:36:38	00:42:08	00:31:08	00:36:18	✓
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_1	49.36	00:38:18	00:44:03	00:32:33	00:39:26	✓
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_2	60.93	00:59:48	01:08:46	00:50:50	00:57:50	✓
16_A282 M25_Dartford - Purfleet_AntiClockwise	16_AntiClockwise	3.83	00:04:10	00:04:48	00:03:33	00:03:39	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
16_A282 M25_Purfleet - Dartford_Clockwise	16_Clockwise	3.92	00:04:16	00:04:54	00:03:37	00:03:23	✓
17_A3/A3(M)_Portsmouth - Epsom_EB	17_EB	87.72	00:56:08	01:04:33	00:47:43	01:01:22	✓
17_A3/A3(M)_Epsom - Portsmouth_WB	17_WB	87.61	00:52:48	01:00:43	00:44:53	00:56:11	✓
18_A30_Penzance - Exeter_EB	18_EB_1	98.21	01:04:00	01:13:36	00:54:24	01:14:11	×
18_A30_Penzance - Exeter_EB	18_EB_2	76.30	00:40:50	00:46:58	00:34:43	00:44:13	✓
18_A30_Exeter - Penzance_WB	18_WB_1	76.26	00:41:43	00:47:58	00:35:28	00:43:41	✓
18_A30_Exeter - Penzance_WB	18_WB_2	98.16	01:05:44	01:15:36	00:55:53	01:13:37	✓
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_1	94.56	01:04:31	01:14:12	00:54:50	01:20:14	×
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_2	64.41	00:39:10	00:45:02	00:33:17	00:47:09	×
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_1	72.25	00:44:12	00:50:50	00:37:35	00:51:00	×
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_2	86.84	00:58:45	01:07:34	00:49:56	01:15:20	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_1	88.00	01:09:18	01:19:41	00:58:54	01:24:54	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_2	64.85	00:48:26	00:55:42	00:41:10	01:02:15	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_1	68.75	00:52:18	01:00:09	00:44:28	01:07:10	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_2	83.74	01:05:18	01:15:05	00:55:30	01:17:52	×
21_A34_Winchester (M3) - Bicester (M40)_NB	21_NB	101.01	01:02:29	01:11:52	00:53:07	01:05:33	✓
21_A34_Bicester (M40) - Winchester (M3)_SB	21_SB	100.39	01:05:04	01:14:49	00:55:18	01:04:23	✓
22_A36/A46_Southampton - Bristol (M4)_NB	22_NB	103.44	01:40:55	01:56:03	01:25:47	01:58:33	×
22_A36/A46_Bristol (M4) - Southampton_SB	22_SB	103.52	01:42:49	01:58:14	01:27:23	02:00:05	×
23_A38_Lichfield (M6 Toll) - Mansfield (M1)_NB	23_NB	65.96	00:43:08	00:49:36	00:36:40	01:00:26	×
23_A38_Mansfield (M1) -Lichfield (M6 Toll)_SB	23_SB	65.10	00:44:25	00:51:05	00:37:46	01:01:44	×
24_A38_Bodmin - Exeter_EB	24_EB	109.22	01:14:40	01:25:52	01:03:28	01:29:27	×

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
24_A38_Exeter - Bodmin_WB	24_WB	109.36	01:15:38	01:26:59	01:04:17	01:26:59	✗
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_1	72.32	01:14:36	01:25:48	01:03:25	01:11:27	✓
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_2	65.59	00:54:59	01:03:14	00:46:44	00:58:00	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_1	61.02	00:51:40	00:59:24	00:43:55	00:52:03	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_2	77.45	01:15:29	01:26:49	01:04:10	01:11:18	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_1	75.08	00:43:03	00:49:30	00:36:35	00:46:16	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_2	67.69	00:43:08	00:49:36	00:36:40	00:44:26	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_1	70.13	00:47:22	00:54:29	00:40:16	00:42:41	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_2	72.17	00:38:30	00:44:17	00:32:44	00:42:44	✓
27_A419/A417_Swindon - Gloucester_NB	27_NB	53.36	00:33:50	00:38:55	00:28:46	00:41:55	✗
27_A419/A417_Gloucester - Swindon_SB	27_SB	53.42	00:35:09	00:40:26	00:29:53	00:41:36	✗
28_A421_Milton Keynes (M1) - Black Cat (A1)_NB	28_NB	27.84	00:15:57	00:18:21	00:13:33	00:16:23	✓
28_A421_Black Cat (A1) - Milton Keynes (M1)_SB	28_SB	27.76	00:16:40	00:19:10	00:14:10	00:17:24	✓
29_A428_St Neots (A1) - Cambridge_EB	29_EB	26.39	00:20:24	00:23:28	00:17:20	00:20:21	✓
29_A428_Cambridge - St Neots (A1)_WB	29_WB	26.98	00:19:58	00:22:58	00:16:59	00:20:28	✓
30_A43_Bicester (M40) - Northampton_NB	30_NB	38.29	00:34:01	00:39:07	00:28:55	00:31:04	✓
30_A43_Northampton - Bicester (M40)_SB	30_SB	38.22	00:35:24	00:40:42	00:30:05	00:31:54	✓
31_A45_Northampton (M1) - Thrapston (A14)_NB	31_NB	38.85	00:27:33	00:31:41	00:23:25	00:28:00	✓
31_A45_Thrapston (A14) - Northampton (M1)_SB	31_SB	38.86	00:29:10	00:33:32	00:24:47	00:30:53	✓
32_A46/M69_Tewkesbury - Leicester_EB	32_EB	108.46	01:22:24	01:34:46	01:10:02	01:31:37	✓
32_A46/M69_Leicester - Tewkesbury_WB	32_WB	108.39	01:24:37	01:37:18	01:11:55	01:33:37	✓
33_A46_Leicester (M1) - Lincoln_EB	33_EB	87.55	01:05:50	01:15:42	00:55:57	01:12:13	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
33_A46_Lincoln - Leicester (M1)_WB	33_WB	88.75	01:06:51	01:16:52	00:56:49	01:12:13	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_1	80.00	01:02:06	01:11:25	00:52:47	01:01:35	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_2	105.94	01:22:53	01:35:19	01:10:27	01:25:03	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_1	89.66	01:11:13	01:21:54	01:00:32	01:12:31	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_2	96.55	01:15:11	01:26:28	01:03:55	01:15:55	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_1	70.20	00:51:12	00:58:53	00:43:31	00:55:19	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_2	54.15	00:49:00	00:56:21	00:41:39	00:57:24	✗
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_1	43.74	00:40:29	00:46:33	00:34:25	00:49:16	✗
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_2	80.77	00:58:29	01:07:15	00:49:43	00:59:45	✓
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_1	61.17	00:54:08	01:02:15	00:46:00	01:03:22	✗
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_2	67.19	01:05:02	01:14:47	00:55:16	00:58:59	✓
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_1	55.49	00:58:33	01:07:20	00:49:46	00:50:58	✓
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_2	72.12	01:02:04	01:11:22	00:52:45	01:09:58	✓
37_M6_Stoke-On-Trent (M6) - Nottingham (M1)_EB	37_EB	81.89	00:55:47	01:04:09	00:47:25	01:03:46	✓
37_M6_Nottingham (M1) - Stoke-On-Trent (M6)_WB	37_WB	82.42	00:55:06	01:03:21	00:46:50	01:03:34	✗
38_A52/A453/A5111/A6_Derby (A50) - Grantham_EB	38_EB	64.09	00:58:00	01:06:42	00:49:18	01:12:01	✗
38_A52/A453/A5111/A6_Grantham - Derby (A50)_WB	38_WB	64.34	00:58:57	01:07:47	00:50:06	01:09:21	✗
39_A55/M53_Welsh Border - Wallasey(Liverpool)_EB	39_EB	44.45	00:27:13	00:31:18	00:23:08	00:28:26	✓
39_A55/M53_Wallasey(Liverpool) - Welsh Border_WB	39_WB	44.46	00:28:05	00:32:18	00:23:52	00:28:11	✓
40_A590_Dalton-in-Furness - Kendal (M6)_EB	40_EB	47.72	00:36:23	00:41:50	00:30:55	00:38:11	✓
40_A590_Kendal (M6) - Dalton-in-Furness_WB	40_WB	47.64	00:36:44	00:42:15	00:31:13	00:38:54	✓
41_A616/A628/A57/M67_Manchester (M67) - Barnsley_EB	41_EB	49.14	00:48:46	00:56:05	00:41:27	00:46:23	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
41_A616/A628/A57/M67_Barnsley - Manchester (M67)_WB	41_WB	49.00	00:44:34	00:51:15	00:37:53	00:48:12	✓
42_A64_Wetherby (A1(M)) - Scarborough_EB	42_EB	85.85	01:00:15	01:09:18	00:51:13	01:02:18	✓
42_A64_Scarborough - Wetherby (A1(M))_WB	42_WB	85.88	01:00:42	01:09:48	00:51:36	01:10:12	×
43_A66(M)/A66_Darlington - Middlesbrough_EB	43_EB	28.27	00:20:29	00:23:34	00:17:25	00:20:50	✓
43_A66(M)/A66_Middlesbrough - Darlington_WB	43_WB	27.64	00:20:18	00:23:20	00:17:15	00:19:46	✓
44_A66/A595_Egremont - Penrith_EB	44_EB	84.90	01:06:14	01:16:10	00:56:18	01:07:30	✓
44_A66/A595_Penrith - Egremont_WB	44_WB	83.92	01:07:15	01:17:21	00:57:10	01:12:25	✓
45_A66_Penrith - Scotch Corner_EB	45_EB	78.85	00:50:24	00:57:58	00:42:51	00:51:32	✓
45_A66_Scotch Corner - Penrith_WB	45_WB	79.85	00:52:43	01:00:37	00:44:48	00:53:30	✓
46_A69_Carlisle - Newcastle (A1)_EB	46_EB	84.34	01:00:45	01:09:52	00:51:38	01:01:32	✓
46_A69_Newcastle (A1) - Carlisle_WB	46_WB	84.37	00:59:09	01:08:01	00:50:17	01:01:23	✓
47_M1_Brent Cross - Northampton_NB	47_NB	89.75	00:59:26	01:08:21	00:50:31	00:58:18	✓
47_M1_Northampton - Brent Cross_SB	47_SB	89.93	01:03:22	01:12:52	00:53:52	01:04:20	✓
48_M1_Chesterfield - Northampton_SB	48_SB_1	73.53	00:47:52	00:55:03	00:40:41	00:56:05	×
48_M1_Chesterfield - Northampton_SB	48_SB_2	67.73	00:47:03	00:54:07	00:40:00	00:43:11	✓
48_M1_Northampton - Chesterfield_NB	48_NB_1	59.35	00:39:43	00:45:41	00:33:46	00:37:36	✓
48_M1_Northampton - Chesterfield_NB	48_NB_2	81.64	00:49:59	00:57:29	00:42:29	00:57:10	✓
49_M1_Chesterfield - Leeds (A1(M))_NB	49_NB	80.31	00:57:39	01:06:18	00:49:00	01:00:50	✓
49_M1_Leeds (A1(M)) - Chesterfield_SB	49_SB	80.46	00:55:34	01:03:54	00:47:14	01:01:09	✓
50_M11_Walthamstow - Cambridge_NB	50_NB	81.20	00:54:22	01:02:31	00:46:12	00:50:06	✓
50_M11_Cambridge - Walthamstow_SB	50_SB	80.45	01:00:36	01:09:41	00:51:30	00:51:39	✓
51_M18_Rotherham (M1) - Goole (M62)_NB	51_NB	44.74	00:28:17	00:32:32	00:24:03	00:30:15	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
51_M18_Goole (M62) - Rotherham (M1)_SB	51_SB	44.17	00:28:13	00:32:27	00:23:59	00:31:29	✓
52_M180/A180_Hatfield (M18) - Grimsby_EB	52_EB	62.40	00:37:14	00:42:49	00:31:39	00:35:58	✓
52_M180/A180_Grimsby - Hatfield (M18)_WB	52_WB	62.41	00:38:36	00:44:23	00:32:48	00:36:00	✓
53_M25_South Mimms - Uxbridge_AntiClockwise	53_AntiClockwise	34.82	00:34:59	00:40:13	00:29:44	00:24:10	×
53_M25_Uxbridge - South Mimms_Clockwise	53_Clockwise	34.99	00:22:53	00:26:19	00:19:27	00:24:19	✓
54_M25_Nutfield - Dartford_AntiClockwise	54_AntiClockwise	39.82	00:26:57	00:31:00	00:22:54	00:26:14	✓
54_M25_Dartford - Nutfield_Clockwise	54_Clockwise	40.03	00:30:05	00:34:36	00:25:34	00:26:52	✓
55_M25_Purfleet - South Mimms_AntiClockwise	55_AntiClockwise	53.66	00:44:19	00:50:58	00:37:40	00:35:28	×
55_M25_South Mimms - Purfleet_Clockwise	55_Clockwise	53.67	00:40:34	00:46:39	00:34:29	00:34:45	✓
56_M25_Uxbridge - Nutfield_AntiClockwise	56_AntiClockwise	58.34	00:48:30	00:55:46	00:41:13	00:41:21	✓
56_M25_Nutfield - Uxbridge_Clockwise	56_Clockwise	58.24	00:47:39	00:54:48	00:40:30	00:42:05	✓
57_M26/M20/A20_Bromley - Dover_EB	57_EB	101.19	01:03:28	01:12:59	00:53:57	01:00:43	✓
57_M26/M20/A20_Dover - Bromley_WB	57_WB	101.24	01:01:59	01:11:17	00:52:41	01:04:01	✓
58_M27_Southampton - Portsmouth_EB	58_EB	45.52	00:29:35	00:34:02	00:25:09	00:29:37	✓
58_M27_Portsmouth - Southampton_WB	58_WB	45.45	00:29:20	00:33:44	00:24:56	00:30:30	✓
59_M3_Southampton - Twickenham_EB	59_EB	95.48	01:01:50	01:11:07	00:52:34	01:09:53	✓
59_M3_Twickenham - Southampton_WB	59_WB	95.06	00:58:01	01:06:43	00:49:19	01:00:12	✓
60_M4_Swindon - Brentford_EB	60_EB_1	59.48	00:36:12	00:41:38	00:30:46	00:40:17	✓
60_M4_Swindon - Brentford_EB	60_EB_2	52.55	00:39:46	00:45:44	00:33:48	00:37:57	✓
60_M4_Brentford - Swindon_WB	60_WB_1	46.01	00:33:06	00:38:04	00:28:08	00:35:25	✓
60_M4_Brentford - Swindon_WB	60_WB_2	65.91	00:38:42	00:44:30	00:32:53	00:39:01	✓
61_M4_Severn Bridge - Swindon_EB	61_EB	70.17	00:39:53	00:45:52	00:33:54	00:41:25	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
61_M4_Swindon - Severn Bridge_WB	61_WB	70.26	00:37:52	00:43:33	00:32:12	00:41:20	✓
62_M42/A42_Birmingham (M6) - Loughborough (M1)_EB	62_EB	50.09	00:29:14	00:33:37	00:24:51	00:33:47	×
62_M42/A42_Loughborough (M1) - Birmingham (M6)_WB	62_WB	49.68	00:30:16	00:34:49	00:25:44	00:35:32	×
63_M42_Bromsgrove - Birmingham (M6)_EB	63_EB	37.83	00:23:56	00:27:32	00:20:21	00:27:54	×
63_M42_Birmingham (M6) - Bromsgrove_WB	63_WB	38.41	00:23:59	00:27:35	00:20:23	00:27:47	×
64_M45/A45_Coventry - Daventry (M1)_EB	64_EB	24.21	00:16:05	00:18:30	00:13:41	00:16:16	✓
64_M45/A45_Daventry (M1) - Coventry_WB	64_WB	24.09	00:17:45	00:20:25	00:15:05	00:15:59	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_1	66.21	00:35:02	00:40:17	00:29:47	00:38:03	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_2	64.08	00:34:34	00:39:45	00:29:23	00:38:06	✓
65_M5_Bristol (M4) - Exeter_SB	65_SB_1	57.50	00:31:17	00:35:59	00:26:35	00:35:07	✓
65_M5_Bristol (M4) - Exeter_SB	65_SB_2	73.08	00:39:25	00:45:19	00:33:30	00:41:52	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_1	68.60	00:37:27	00:43:05	00:31:50	00:41:57	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_2	63.12	00:37:57	00:43:38	00:32:15	00:42:21	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_1	50.82	00:31:09	00:35:50	00:26:29	00:34:14	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_2	81.05	00:44:38	00:51:20	00:37:57	00:49:07	✓
67_M50/A449/A40_Welsh Border - Tewkesbury_EB	67_EB	52.28	00:31:56	00:36:43	00:27:08	00:34:01	✓
67_M50/A449/A40_Tewkesbury - Welsh Border_WB	67_WB	52.54	00:33:01	00:37:58	00:28:04	00:34:07	✓
68_M55/A585_Fleetwood - Preston_EB	68_EB	31.77	00:28:22	00:32:37	00:24:07	00:37:23	×
68_M55/A585_Preston - Fleetwood_WB	68_WB	31.78	00:27:23	00:31:29	00:23:16	00:32:25	×
69_M56/A5117_Manchester (M56) - Welsh Border_EB	69_EB	56.86	00:35:51	00:41:13	00:30:28	00:39:54	✓
69_M56/A5117_Welsh Border - Manchester (M56)_WB	69_WB	57.69	00:37:06	00:42:39	00:31:32	00:43:18	×
70_M58/A5036_Liverpool - Wigan_EB	70_EB	25.11	00:20:13	00:23:15	00:17:11	00:20:58	✓

			Time (hh:mm:ss)				
Journey time route	ID	Length (km)	Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
70_M58/A5036_Wigan - Liverpool_WB	70_WB	24.99	00:21:21	00:24:34	00:18:09	00:20:47	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_1	72.35	00:40:24	00:46:28	00:34:20	00:40:25	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_2	75.95	00:42:02	00:48:20	00:35:44	00:46:18	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_1	62.86	00:38:00	00:43:42	00:32:18	00:38:17	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_2	86.15	00:48:45	00:56:04	00:41:26	00:48:03	✓
72_M6_Warrington - Wolverhampton (M6 Toll)_EB	72_EB	88.36	00:54:23	01:02:32	00:46:13	00:58:34	✓
72_M6_Wolverhampton (M6 Toll) - Warrington_WB	72_WB	88.25	00:55:12	01:03:29	00:46:55	00:59:32	✓
73_M6_Preston - Warrington_EB	73_EB	60.51	00:38:25	00:44:11	00:32:39	00:45:42	×
73_M6_Warrington - Preston_WB	73_WB	60.20	00:38:25	00:44:11	00:32:39	00:45:29	×
74_M6_Wolverhampton (M6 Toll) -Rugby (M1)_EB	74_EB	78.81	01:06:46	01:16:47	00:56:45	00:59:25	✓
74_M6_Rugby (M1) - Wolverhampton (M6 Toll)_WB	74_WB	76.89	00:50:35	00:58:10	00:43:00	00:56:59	✓
75_M60_Manchester (M56) - Manchester (M66) via Stockport_AntiClockwise	75_AntiClockwise	28.59	00:17:45	00:20:24	00:15:05	00:20:55	×
75_M60_Manchester (M66) - Manchester (M56) via Stockport_clockwise	75_clockwise	28.47	00:20:51	00:23:58	00:17:43	00:25:02	×
76_M60_Manchester (M66) - Manchester (M56)_AntiClockwise	76_AntiClockwise	27.11	00:24:56	00:28:40	00:21:11	00:33:54	×
76_M60_Manchester (M56) - Manchester (M66)_clockwise	76_clockwise	27.63	00:20:50	00:23:58	00:17:43	00:32:31	×
77_M602/M62/M57_Liverpool (M58) - Manchester_EB	77_EB	53.61	00:40:38	00:46:44	00:34:32	00:39:37	✓
77_M602/M62/M57_Manchester - Liverpool (M58)_WB	77_WB	53.88	00:35:52	00:41:15	00:30:29	00:39:47	✓
78_M61_Manchester (M60) - Preston (M6)_NB	78_NB	35.13	00:21:37	00:24:52	00:18:23	00:22:06	✓
78_M61_Preston (M6) - Manchester (M60)_SB	78_SB	34.62	00:23:49	00:27:23	00:20:15	00:21:59	✓
79_M62/A63/A1033_Wakefield (M1) - Hull_EB	79_EB	89.72	01:01:41	01:10:56	00:52:26	01:11:02	×

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
79_M62/A63/A1033_Hull - Wakefield (M1)_WB	79_WB	89.72	01:03:36	01:13:08	00:54:03	01:14:12	✗
80_M62_Manchester (M60) - Wakefield (M1)_EB	80_EB	63.23	00:41:40	00:47:54	00:35:25	00:47:18	✓
80_M62_Wakefield (M1) - Manchester (M60)_WB	80_WB	63.71	00:42:30	00:48:53	00:36:08	00:46:38	✓
81_M65_Preston (M6) - Burnley_EB	81_EB	32.06	00:19:28	00:22:23	00:16:32	00:20:30	✓
82_M66_Manchester (M60) - Burnley_NB	82_NB	28.04	00:18:50	00:21:39	00:16:00	00:18:38	✓
82_M66_Burnley - Manchester (M60)_SB	82_SB	28.12	00:17:42	00:20:21	00:15:03	00:22:57	✗
81_M65_Burnley - Preston (M6)_WB	81_WB	31.96	00:19:10	00:22:03	00:16:18	00:20:56	✓
83_A1/A1(M)_Pontefract (M62) - Scotch Corner_NB	83_NB	96.51	00:58:45	01:07:33	00:49:56	01:03:11	✓
83_A1/A1(M)_Scotch Corner - Pontefract (M62)_SB	83_SB	95.82	00:58:32	01:07:19	00:49:45	01:03:07	✓
84_M6 Toll_Birmingham (M42) - Wolverhampton (M6)_EB	84_EB	42.99	00:23:36	00:27:09	00:20:04	00:24:50	✓
84_M6 Toll_Wolverhampton (M6) - Birmingham (M42)_WB	84_WB	41.24	00:22:41	00:26:05	00:19:17	00:24:22	✓

G.2. Inter-peak

Table G.2 - Inter-peak journey time validation

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
1_A1/ A1(M)_Scotch Corner - Newcastle_NB	1_NB	78.56	00:53:30	01:01:31	00:45:28	00:50:22	✓
1_A1/ A1(M)_Newcastle - Scotch Corner_SB	1_SB	78.73	00:54:52	01:03:06	00:46:39	00:50:59	✓
2_A1/A1(M)_Barnet - Peterborough_NB	2_NB	106.54	01:12:58	01:23:55	01:02:01	01:07:30	✓
2_A1/A1(M)_Peterborough - Barnet_SB	2_SB	106.29	01:07:41	01:17:50	00:57:32	01:05:26	✓
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_1	70.33	00:41:49	00:48:05	00:35:33	00:55:16	✗

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_2	84.44	00:53:00	01:00:57	00:45:03	00:59:30	✓
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_1	84.28	00:52:54	01:00:50	00:44:58	01:00:31	✓
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_2	70.65	00:41:08	00:47:18	00:34:58	00:51:37	×
4_A1_Newcastle - Berwick_NB	4_NB	95.46	01:05:04	01:14:50	00:55:18	01:03:17	✓
4_A1_Berwick - Newcastle_SB	4_SB	95.53	01:04:42	01:14:25	00:55:00	01:03:53	✓
5_A11_Duxford (M11) - Norwich_NB	5_NB	99.15	01:01:22	01:10:35	00:52:10	00:58:12	✓
5_A11_Norwich - Duxford (M11)_SB	5_SB	99.46	00:59:03	01:07:54	00:50:12	00:57:36	✓
6_A12_Brentwood - Ipswich_EB	6_EB	83.60	00:53:35	01:01:38	00:45:33	00:54:57	✓
6_A12_Ipswich - Brentwood _WB	6_WB	83.56	00:54:00	01:02:05	00:45:54	00:55:08	✓
7_A120_Bishops Stortford - Harwich_EB	7_EB	84.02	00:57:49	01:06:29	00:49:08	00:57:40	✓
7_A120_Harwich - Bishops Stortford_WB	7_WB	83.91	00:57:29	01:06:07	00:48:52	00:57:44	✓
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_1	77.61	00:49:02	00:56:23	00:41:41	00:51:03	✓
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_2	63.34	00:37:53	00:43:34	00:32:12	00:38:08	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_1	63.82	00:37:45	00:43:25	00:32:05	00:38:17	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_2	77.55	00:48:49	00:56:08	00:41:29	00:51:50	✓
9_A14_Rugby (M1) - Brampton Hut (A1)_EB	9_EB	69.32	00:40:12	00:46:14	00:34:11	00:41:38	✓
9_A14_Brampton Hut (A1) - Rugby (M1)_WB	9_WB	69.38	00:42:24	00:48:45	00:36:02	00:42:29	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_1	63.07	00:37:35	00:43:13	00:31:57	00:37:24	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_2	56.21	00:38:45	00:44:34	00:32:56	00:38:45	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_1	55.56	00:37:41	00:43:20	00:32:02	00:39:22	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_2	63.12	00:36:57	00:42:30	00:31:25	00:38:28	✓
11_A2/M2_Dartford - Dover_EB	11_EB	98.52	01:03:18	01:12:47	00:53:48	01:03:29	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
11_A2/M2_Dover - Dartford_WB	11_WB	98.23	01:05:17	01:15:05	00:55:30	01:02:38	✓
12_A21_Sevenoaks - Hastings_EB	12_EB	59.09	00:49:30	00:56:55	00:42:04	00:45:12	✓
12_A21_Hastings - Sevenoaks_WB	12_WB	59.01	00:47:52	00:55:03	00:40:41	00:44:15	✓
13_A23/M23_Brighton - Croydon_NB	13_NB	55.03	00:37:41	00:43:20	00:32:02	00:37:00	✓
13_A23/M23_Croydon - Brighton_SB	13_SB	55.59	00:36:30	00:41:58	00:31:01	00:38:36	✓
14_A259/A2070_Eastbourne - Ashford_EB	14_EB	69.09	01:18:37	01:30:25	01:06:49	01:04:39	×
14_A259/A2070_Ashford - Eastbourne_WB	14_WB	68.77	01:10:08	01:20:39	00:59:36	01:04:14	✓
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_1	62.88	01:00:06	01:09:07	00:51:05	00:53:12	✓
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_2	47.68	00:35:56	00:41:20	00:30:33	00:35:16	✓
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_1	49.36	00:35:57	00:41:20	00:30:33	00:35:22	✓
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_2	60.93	00:57:56	01:06:37	00:49:15	00:52:18	✓
16_A282 M25_Dartford - Purfleet_AntiClockwise	16_AntiClockwise	3.83	00:04:12	00:04:50	00:03:34	00:03:34	✓
16_A282 M25_Purfleet - Dartford_Clockwise	16_Clockwise	3.92	00:03:30	00:04:01	00:02:58	00:03:19	✓
17_A3/A3(M)_Portsmouth - Epsom_EB	17_EB	87.72	00:52:02	00:59:50	00:44:13	00:56:18	✓
17_A3/A3(M)_Epsom - Portsmouth_WB	17_WB	87.61	00:52:07	00:59:56	00:44:18	00:55:27	✓
18_A30_Penzance - Exeter_EB	18_EB_1	98.21	01:05:11	01:14:57	00:55:24	01:11:57	✓
18_A30_Penzance - Exeter_EB	18_EB_2	76.30	00:41:20	00:47:32	00:35:08	00:43:53	✓
18_A30_Exeter - Penzance_WB	18_WB_1	76.26	00:41:46	00:48:02	00:35:30	00:43:39	✓
18_A30_Exeter - Penzance_WB	18_WB_2	98.16	01:06:18	01:16:14	00:56:21	01:11:56	✓
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_1	94.56	01:05:59	01:15:53	00:56:05	01:20:24	×
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_2	64.41	00:39:37	00:45:33	00:33:40	00:45:45	×
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_1	72.25	00:46:38	00:53:37	00:39:38	00:53:09	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_2	86.84	01:00:18	01:09:20	00:51:15	01:14:38	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_1	88.00	01:12:34	01:23:28	01:01:41	01:24:03	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_2	64.85	00:47:55	00:55:07	00:40:44	00:59:08	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_1	68.75	00:53:06	01:01:04	00:45:08	01:04:14	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_2	83.74	01:08:33	01:18:50	00:58:16	01:18:18	✓
21_A34_Winchester (M3) - Bicester (M40)_NB	21_NB	101.01	01:03:03	01:12:30	00:53:35	01:03:16	✓
21_A34_Bicester (M40) - Winchester (M3)_SB	21_SB	100.39	01:01:18	01:10:30	00:52:07	01:02:21	✓
22_A36/A46_Southampton - Bristol (M4)_NB	22_NB	103.44	01:42:22	01:57:43	01:27:01	01:52:53	✓
22_A36/A46_Bristol (M4) - Southampton_SB	22_SB	103.52	01:44:33	02:00:14	01:28:52	01:53:42	✓
23_A38_Lichfield (M6 Toll) - Mansfield (M1)_NB	23_NB	65.96	00:41:57	00:48:14	00:35:39	00:58:20	×
23_A38_Mansfield (M1) -Lichfield (M6 Toll)_SB	23_SB	65.10	00:41:56	00:48:13	00:35:39	00:57:57	×
24_A38_Bodmin - Exeter_EB	24_EB	109.22	01:14:42	01:25:54	01:03:29	01:23:04	✓
24_A38_Exeter - Bodmin_WB	24_WB	109.36	01:15:56	01:27:19	01:04:33	01:23:40	✓
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_1	72.32	01:14:59	01:26:14	01:03:44	01:09:19	✓
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_2	65.59	00:56:43	01:05:13	00:48:13	00:57:03	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_1	61.02	00:52:42	01:00:37	00:44:48	00:51:44	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_2	77.45	01:16:02	01:27:26	01:04:37	01:10:18	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_1	75.08	00:41:43	00:47:58	00:35:27	00:44:38	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_2	67.69	00:41:20	00:47:32	00:35:08	00:40:40	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_1	70.13	00:45:59	00:52:52	00:39:05	00:43:20	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_2	72.17	00:39:33	00:45:29	00:33:37	00:43:12	✓
27_A419/A417_Swindon - Gloucester_NB	27_NB	53.36	00:33:41	00:38:44	00:28:38	00:40:56	×

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
27_A419/A417_Gloucester - Swindon_SB	27_SB	53.42	00:31:48	00:36:34	00:27:02	00:37:55	✗
28_A421_Milton Keynes (M1) - Black Cat (A1)_NB	28_NB	27.84	00:16:08	00:18:33	00:13:42	00:16:12	✓
28_A421_Black Cat (A1) - Milton Keynes (M1)_SB	28_SB	27.76	00:16:25	00:18:53	00:13:57	00:16:17	✓
29_A428_St Neots (A1) - Cambridge_EB	29_EB	26.39	00:19:09	00:22:01	00:16:16	00:19:32	✓
29_A428_Cambridge - St Neots (A1)_WB	29_WB	26.98	00:19:05	00:21:57	00:16:13	00:19:31	✓
30_A43_Bicester (M40) - Northampton_NB	30_NB	38.29	00:35:20	00:40:38	00:30:02	00:31:04	✓
30_A43_Northampton - Bicester (M40)_SB	30_SB	38.22	00:32:03	00:36:52	00:27:15	00:31:10	✓
31_A45_Northampton (M1) - Thrapston (A14)_NB	31_NB	38.85	00:27:08	00:31:13	00:23:04	00:27:10	✓
31_A45_Thrapston (A14) - Northampton (M1)_SB	31_SB	38.86	00:28:06	00:32:19	00:23:53	00:27:58	✓
32_A46/M69_Tewkesbury - Leicester_EB	32_EB	108.46	01:20:28	01:32:32	01:08:24	01:29:37	✓
32_A46/M69_Leicester - Tewkesbury_WB	32_WB	108.39	01:23:15	01:35:44	01:10:46	01:31:06	✓
33_A46_Leicester (M1) - Lincoln_EB	33_EB	87.55	01:05:00	01:14:45	00:55:15	01:11:04	✓
33_A46_Lincoln - Leicester (M1)_WB	33_WB	88.75	01:04:50	01:14:33	00:55:06	01:10:06	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_1	80.00	01:02:12	01:11:32	00:52:52	00:58:47	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_2	105.94	01:21:23	01:33:35	01:09:11	01:22:59	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_1	89.66	01:09:59	01:20:29	00:59:29	01:11:21	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_2	96.55	01:14:05	01:25:11	01:02:58	01:12:58	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_1	70.20	00:51:03	00:58:43	00:43:24	00:53:26	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_2	54.15	00:48:37	00:55:54	00:41:19	00:54:31	✓
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_1	43.74	00:39:18	00:45:12	00:33:25	00:48:30	✗
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_2	80.77	00:58:59	01:07:49	00:50:08	00:58:54	✓
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_1	61.17	00:52:02	00:59:50	00:44:14	00:59:41	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_2	67.19	01:04:47	01:14:30	00:55:04	00:51:53	✗
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_1	55.49	00:59:02	01:07:53	00:50:10	00:44:32	✗
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_2	72.12	01:02:30	01:11:52	00:53:07	01:08:00	✓
37_M6_Stoke-On-Trent (M6) - Nottingham (M1)_EB	37_EB	81.89	00:52:33	01:00:26	00:44:40	01:00:13	✓
37_M6_Nottingham (M1) - Stoke-On-Trent (M6)_WB	37_WB	82.42	00:51:56	00:59:43	00:44:09	01:01:48	✗
38_A52/A453/A5111/A6_Derby (A50) - Grantham_EB	38_EB	64.09	00:53:17	01:01:17	00:45:18	01:08:45	✗
38_A52/A453/A5111/A6_Grantham - Derby (A50)_WB	38_WB	64.34	00:54:45	01:02:58	00:46:32	01:05:11	✗
39_A55/M53_Welsh Border - Wallasey(Liverpool)_EB	39_EB	44.45	00:26:48	00:30:49	00:22:47	00:27:44	✓
39_A55/M53_Wallasey(Liverpool) - Welsh Border_WB	39_WB	44.46	00:26:58	00:31:01	00:22:55	00:27:36	✓
40_A590_Dalton-in-Furness - Kendal (M6)_EB	40_EB	47.72	00:37:11	00:42:45	00:31:36	00:37:32	✓
40_A590_Kendal (M6) - Dalton-in-Furness_WB	40_WB	47.64	00:37:16	00:42:51	00:31:40	00:37:18	✓
41_A616/A628/A57/M67_Manchester (M67) - Barnsley_EB	41_EB	49.14	00:48:59	00:56:20	00:41:38	00:45:09	✓
41_A616/A628/A57/M67_Barnsley - Manchester (M67)_WB	41_WB	49.00	00:44:21	00:51:00	00:37:42	00:45:55	✓
42_A64_Wetherby (A1(M)) - Scarborough_EB	42_EB	85.85	01:00:57	01:10:05	00:51:48	01:00:33	✓
42_A64_Scarborough - Wetherby (A1(M))_WB	42_WB	85.88	01:01:09	01:10:19	00:51:58	01:05:31	✓
43_A66(M)/A66_Darlington - Middlesbrough_EB	43_EB	28.27	00:19:58	00:22:57	00:16:58	00:19:57	✓
43_A66(M)/A66_Middlesbrough - Darlington_WB	43_WB	27.64	00:20:18	00:23:21	00:17:15	00:19:14	✓
44_A66/A595_Egremont - Penrith_EB	44_EB	84.90	01:08:07	01:18:20	00:57:54	01:06:42	✓
44_A66/A595_Penrith - Egremont_WB	44_WB	83.92	01:07:24	01:17:30	00:57:17	01:05:45	✓
45_A66_Penrith - Scotch Corner_EB	45_EB	78.85	00:51:02	00:58:41	00:43:23	00:51:45	✓
45_A66_Scotch Corner - Penrith_WB	45_WB	79.85	00:54:01	01:02:07	00:45:55	00:52:25	✓
46_A69_Carlisle - Newcastle (A1)_EB	46_EB	84.34	01:01:31	01:10:45	00:52:18	01:00:38	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
46_A69_Newcastle (A1) - Carlisle_WB	46_WB	84.37	01:00:03	01:09:03	00:51:03	01:00:43	✓
47_M1_Brent Cross - Northampton_NB	47_NB	89.75	00:59:13	01:08:06	00:50:20	00:58:26	✓
47_M1_Northampton - Brent Cross_SB	47_SB	89.93	00:55:25	01:03:44	00:47:07	00:58:00	✓
48_M1_Chesterfield - Northampton_SB	48_SB_1	73.53	00:46:31	00:53:30	00:39:32	00:53:33	×
48_M1_Chesterfield - Northampton_SB	48_SB_2	67.73	00:44:26	00:51:06	00:37:46	00:41:34	✓
48_M1_Northampton - Chesterfield_NB	48_NB_1	59.35	00:40:13	00:46:15	00:34:11	00:38:07	✓
48_M1_Northampton - Chesterfield_NB	48_NB_2	81.64	00:50:44	00:58:20	00:43:07	00:57:18	✓
49_M1_Chesterfield - Leeds (A1(M))_NB	49_NB	80.31	00:55:42	01:04:03	00:47:20	00:58:51	✓
49_M1_Leeds (A1(M)) - Chesterfield_SB	49_SB	80.46	00:54:19	01:02:27	00:46:10	00:59:17	✓
50_M11_Walthamstow - Cambridge_NB	50_NB	81.20	00:53:54	01:01:59	00:45:49	00:53:16	✓
50_M11_Cambridge - Walthamstow_SB	50_SB	80.45	00:54:09	01:02:17	00:46:02	00:50:59	✓
51_M18_Rotherham (M1) - Goole (M62)_NB	51_NB	44.74	00:27:47	00:31:57	00:23:37	00:29:33	✓
51_M18_Goole (M62) - Rotherham (M1)_SB	51_SB	44.17	00:27:43	00:31:52	00:23:33	00:30:42	✓
52_M180/A180_Hatfield (M18) - Grimsby_EB	52_EB	62.40	00:36:45	00:42:15	00:31:14	00:35:29	✓
52_M180/A180_Grimsby - Hatfield (M18)_WB	52_WB	62.41	00:38:03	00:43:46	00:32:21	00:35:35	✓
53_M25_South Mimms - Uxbridge_AntiClockwise	53_AntiClockwise	34.82	00:24:13	00:27:51	00:20:35	00:23:37	✓
53_M25_Uxbridge - South Mimms_Clockwise	53_Clockwise	34.99	00:22:56	00:26:22	00:19:29	00:24:06	✓
54_M25_Nutfield - Dartford_AntiClockwise	54_AntiClockwise	39.82	00:28:05	00:32:18	00:23:52	00:26:06	✓
54_M25_Dartford - Nutfield_Clockwise	54_Clockwise	40.03	00:26:33	00:30:32	00:22:34	00:25:50	✓
55_M25_Purfleet - South Mimms_AntiClockwise	55_AntiClockwise	53.66	00:42:18	00:48:38	00:35:57	00:34:49	×
55_M25_South Mimms - Purfleet_Clockwise	55_Clockwise	53.67	00:40:15	00:46:18	00:34:13	00:35:18	✓
56_M25_Uxbridge - Nutfield_AntiClockwise	56_AntiClockwise	58.34	00:44:11	00:50:49	00:37:34	00:40:46	✓

			Time (hh:mm:ss)				
Journey time route	ID	Length (km)	Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
56_M25_Nutfield - Uxbridge_Clockwise	56_Clockwise	58.24	00:44:33	00:51:14	00:37:52	00:39:45	✓
57_M26/M20/A20_Bromley - Dover_EB	57_EB	101.19	01:03:12	01:12:41	00:53:43	01:00:36	✓
57_M26/M20/A20_Dover - Bromley_WB	57_WB	101.24	01:01:11	01:10:22	00:52:01	01:01:05	✓
58_M27_Southampton - Portsmouth_EB	58_EB	45.52	00:26:26	00:30:24	00:22:28	00:28:15	✓
58_M27_Portsmouth - Southampton_WB	58_WB	45.45	00:27:03	00:31:06	00:22:59	00:28:38	✓
59_M3_Southampton - Twickenham_EB	59_EB	95.48	00:58:33	01:07:20	00:49:46	01:01:27	✓
59_M3_Twickenham - Southampton_WB	59_WB	95.06	00:58:17	01:07:02	00:49:33	00:59:11	✓
60_M4_Swindon - Brentford_EB	60_EB_1	59.48	00:34:50	00:40:04	00:29:37	00:38:03	✓
60_M4_Swindon - Brentford_EB	60_EB_2	52.55	00:36:42	00:42:13	00:31:12	00:34:20	✓
60_M4_Brentford - Swindon_WB	60_WB_1	46.01	00:31:03	00:35:42	00:26:23	00:32:32	✓
60_M4_Brentford - Swindon_WB	60_WB_2	65.91	00:38:57	00:44:47	00:33:06	00:39:02	✓
61_M4_Severn Bridge - Swindon_EB	61_EB	70.17	00:37:35	00:43:13	00:31:57	00:41:05	✓
61_M4_Swindon - Severn Bridge_WB	61_WB	70.26	00:38:27	00:44:13	00:32:41	00:41:02	✓
62_M42/A42_Birmingham (M6) - Loughborough (M1)_EB	62_EB	50.09	00:29:34	00:34:01	00:25:08	00:33:37	✓
62_M42/A42_Loughborough (M1) - Birmingham (M6)_WB	62_WB	49.68	00:29:23	00:33:48	00:24:59	00:33:15	✓
63_M42_Bromsgrove - Birmingham (M6)_EB	63_EB	37.83	00:22:38	00:26:02	00:19:14	00:27:11	✗
63_M42_Birmingham (M6) - Bromsgrove_WB	63_WB	38.41	00:22:53	00:26:19	00:19:27	00:26:59	✗
64_M45/A45_Coventry - Daventry (M1)_EB	64_EB	24.21	00:16:08	00:18:34	00:13:43	00:16:05	✓
64_M45/A45_Daventry (M1) - Coventry_WB	64_WB	24.09	00:16:27	00:18:55	00:13:59	00:15:53	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_1	66.21	00:34:51	00:40:05	00:29:37	00:37:59	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_2	64.08	00:34:55	00:40:10	00:29:41	00:37:50	✓
65_M5_Bristol (M4) - Exeter_SB	65_SB_1	57.50	00:31:55	00:36:42	00:27:08	00:34:35	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
65_M5_Bristol (M4) - Exeter_SB	65_SB_2	73.08	00:39:31	00:45:27	00:33:35	00:41:29	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_1	68.60	00:37:35	00:43:13	00:31:57	00:41:49	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_2	63.12	00:38:42	00:44:31	00:32:54	00:42:48	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_1	50.82	00:31:07	00:35:47	00:26:27	00:33:43	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_2	81.05	00:44:32	00:51:13	00:37:51	00:47:40	✓
67_M50/A449/A40_Welsh Border - Tewkesbury_EB	67_EB	52.28	00:32:16	00:37:06	00:27:25	00:33:44	✓
67_M50/A449/A40_Tewkesbury - Welsh Border_WB	67_WB	52.54	00:32:57	00:37:54	00:28:01	00:33:58	✓
68_M55/A585_Fleetwood - Preston_EB	68_EB	31.77	00:28:08	00:32:22	00:23:55	00:31:16	✓
68_M55/A585_Preston - Fleetwood_WB	68_WB	31.78	00:27:03	00:31:07	00:23:00	00:30:40	✓
69_M56/A5117_Manchester (M56) - Welsh Border_EB	69_EB	56.86	00:34:35	00:39:46	00:29:24	00:37:35	✓
69_M56/A5117_Welsh Border - Manchester (M56)_WB	69_WB	57.69	00:35:29	00:40:48	00:30:10	00:38:46	✓
70_M58/A5036_Liverpool - Wigan_EB	70_EB	25.11	00:20:01	00:23:01	00:17:01	00:20:27	✓
70_M58/A5036_Wigan - Liverpool_WB	70_WB	24.99	00:20:02	00:23:02	00:17:02	00:20:14	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_1	72.35	00:40:12	00:46:13	00:34:10	00:40:38	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_2	75.95	00:42:08	00:48:27	00:35:49	00:46:37	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_1	62.86	00:37:21	00:42:57	00:31:45	00:37:59	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_2	86.15	00:48:13	00:55:27	00:40:59	00:48:00	✓
72_M6_Warrington - Wolverhampton (M6 Toll)_EB	72_EB	88.36	00:54:16	01:02:24	00:46:07	00:59:01	✓
72_M6_Wolverhampton (M6 Toll) - Warrington_WB	72_WB	88.25	00:55:24	01:03:42	00:47:05	01:00:20	✓
73_M6_Preston - Warrington_EB	73_EB	60.51	00:36:50	00:42:22	00:31:19	00:43:39	✗
73_M6_Warrington - Preston_WB	73_WB	60.20	00:37:24	00:43:00	00:31:47	00:42:41	✓
74_M6_Wolverhampton (M6 Toll) -Rugby (M1)_EB	74_EB	78.81	01:00:23	01:09:26	00:51:20	00:56:50	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
74_M6_Rugby (M1) - Wolverhampton (M6 Toll)_WB	74_WB	76.89	00:47:56	00:55:08	00:40:45	00:56:44	×
75_M60_Manchester (M56) - Manchester (M66) via Stockport_AntiClockwise	75_AntiClockwise	28.59	00:17:21	00:19:57	00:14:45	00:20:04	×
75_M60_Manchester (M66) - Manchester (M56) via Stockport_clockwise	75_clockwise	28.47	00:18:44	00:21:33	00:15:56	00:20:49	✓
76_M60_Manchester (M66) - Manchester (M56)_AntiClockwise	76_AntiClockwise	27.11	00:19:51	00:22:50	00:16:53	00:27:32	×
76_M60_Manchester (M56) - Manchester (M66)_clockwise	76_clockwise	27.63	00:20:33	00:23:38	00:17:28	00:30:25	×
77_M602/M62/M57_Liverpool (M58) - Manchester_EB	77_EB	53.61	00:34:01	00:39:07	00:28:55	00:37:25	✓
77_M602/M62/M57_Manchester - Liverpool (M58)_WB	77_WB	53.88	00:34:56	00:40:10	00:29:41	00:39:05	✓
78_M61_Manchester (M60) - Preston (M6)_NB	78_NB	35.13	00:21:08	00:24:18	00:17:58	00:21:19	✓
78_M61_Preston (M6) - Manchester (M60)_SB	78_SB	34.62	00:20:45	00:23:52	00:17:38	00:21:22	✓
79_M62/A63/A1033_Wakefield (M1) - Hull_EB	79_EB	89.72	00:59:05	01:07:57	00:50:14	01:03:54	✓
79_M62/A63/A1033_Hull - Wakefield (M1)_WB	79_WB	89.72	00:59:33	01:08:29	00:50:37	01:05:24	✓
80_M62_Manchester (M60) - Wakefield (M1)_EB	80_EB	63.23	00:39:35	00:45:31	00:33:38	00:46:06	×
80_M62_Wakefield (M1) - Manchester (M60)_WB	80_WB	63.71	00:40:20	00:46:23	00:34:17	00:45:08	✓
81_M65_Preston (M6) - Burnley_EB	81_EB	32.06	00:18:58	00:21:48	00:16:07	00:20:01	✓
82_M66_Manchester (M60) - Burnley_NB	82_NB	28.04	00:18:13	00:20:57	00:15:29	00:18:20	✓
82_M66_Burnley - Manchester (M60)_SB	82_SB	28.12	00:17:04	00:19:38	00:14:31	00:19:52	×
81_M65_Burnley - Preston (M6)_WB	81_WB	31.96	00:18:37	00:21:24	00:15:49	00:20:01	✓
83_A1/A1(M)_Pontefract (M62) - Scotch Corner_NB	83_NB	96.51	00:58:31	01:07:18	00:49:44	01:02:26	✓
83_A1/A1(M)_Scotch Corner - Pontefract (M62)_SB	83_SB	95.82	00:58:20	01:07:05	00:49:35	01:03:21	✓
84_M6 Toll_Birmingham (M42) - Wolverhampton (M6)_EB	84_EB	42.99	00:22:55	00:26:21	00:19:29	00:24:44	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
84_M6 Toll_Wolverhampton (M6) - Birmingham (M42)_WB	84_WB	41.24	00:23:41	00:27:15	00:20:08	00:24:20	✓

G.3. PM peak

Table G.3 - PM peak journey time validation

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
1_A1/ A1(M)_Scotch Corner - Newcastle_NB	1_NB	78.56	00:56:02	01:04:26	00:47:38	00:51:53	✓
1_A1/ A1(M)_Newcastle - Scotch Corner_SB	1_SB	78.73	00:58:02	01:06:45	00:49:20	00:52:31	✓
2_A1/A1(M)_Barnet - Peterborough_NB	2_NB	106.54	01:17:06	01:28:40	01:05:32	01:12:05	✓
2_A1/A1(M)_Peterborough - Barnet_SB	2_SB	106.29	01:07:18	01:17:24	00:57:12	01:06:34	✓
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_1	70.33	00:41:10	00:47:21	00:35:00	00:57:47	×
3_A1/A1(M)_Peterborough - Pontefract (M62)_NB	3_NB_2	84.44	00:52:38	01:00:32	00:44:44	01:00:21	✓
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_1	84.28	00:53:16	01:01:15	00:45:17	01:01:17	×
3_A1/A1(M)_Pontefract (M62) - Peterborough_SB	3_SB_2	70.65	00:40:43	00:46:50	00:34:37	00:51:51	×
4_A1_Newcastle - Berwick_NB	4_NB	95.46	01:02:13	01:11:33	00:52:53	01:03:27	✓
4_A1_Berwick - Newcastle_SB	4_SB	95.53	01:02:46	01:12:11	00:53:21	01:03:37	✓
5_A11_Duxford (M11) - Norwich_NB	5_NB	99.15	01:00:02	01:09:03	00:51:02	00:59:34	✓
5_A11_Norwich - Duxford (M11)_SB	5_SB	99.46	00:57:41	01:06:20	00:49:02	00:57:49	✓
6_A12_Brentwood - Ipswich_EB	6_EB	83.60	00:56:58	01:05:31	00:48:25	00:58:51	✓
6_A12_Ipswich - Brentwood _WB	6_WB	83.56	00:53:30	01:01:32	00:45:29	00:55:04	✓
7_A120_Bishops Stortford - Harwich_EB	7_EB	84.02	01:03:53	01:13:28	00:54:18	01:00:26	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
7_A120_Harwich - Bishops Stortford_WB	7_WB	83.91	00:56:24	01:04:51	00:47:56	00:58:33	✓
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_1	77.61	00:48:55	00:56:15	00:41:35	00:54:54	✓
8_A14_Felixstowe - Brampton Hut (A1)_EB	8_EB_2	63.34	00:37:26	00:43:03	00:31:49	00:39:21	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_1	63.82	00:37:36	00:43:14	00:31:57	00:38:47	✓
8_A14_Brampton Hut (A1) - Felixstowe_WB	8_WB_2	77.55	00:49:47	00:57:15	00:42:19	00:53:55	✓
9_A14_Rugby (M1) - Brampton Hut (A1)_EB	9_EB	69.32	00:39:23	00:45:18	00:33:29	00:42:18	✓
9_A14_Brampton Hut (A1) - Rugby (M1)_WB	9_WB	69.38	00:41:43	00:47:58	00:35:27	00:43:01	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_1	63.07	00:36:55	00:42:27	00:31:23	00:38:29	✓
10_A168/A19_Harrogate (A1(M)) - Newcastle_NB	10_NB_2	56.21	00:41:54	00:48:11	00:35:37	00:40:55	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_1	55.56	00:41:13	00:47:24	00:35:02	00:41:37	✓
10_A168/A19_Newcastle - Harrogate (A1(M))_SB	10_SB_2	63.12	00:36:52	00:42:23	00:31:20	00:38:47	✓
11_A2/M2_Dartford - Dover_EB	11_EB	98.52	01:05:48	01:15:40	00:55:56	01:06:45	✓
11_A2/M2_Dover - Dartford_WB	11_WB	98.23	01:05:36	01:15:26	00:55:45	01:01:53	✓
12_A21_Sevenoaks - Hastings_EB	12_EB	59.09	00:52:27	01:00:19	00:44:35	00:51:37	✓
12_A21_Hastings - Sevenoaks_WB	12_WB	59.01	00:47:23	00:54:30	00:40:17	00:44:29	✓
13_A23/M23_Brighton - Croydon_NB	13_NB	55.03	00:37:57	00:43:39	00:32:15	00:42:35	✓
13_A23/M23_Croydon - Brighton_SB	13_SB	55.59	00:39:02	00:44:53	00:33:10	00:45:21	✗
14_A259/A2070_Eastbourne - Ashford_EB	14_EB	69.09	01:16:51	01:28:22	01:05:19	01:06:25	✓
14_A259/A2070_Ashford - Eastbourne_WB	14_WB	68.77	01:08:07	01:18:21	00:57:54	01:06:08	✓
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_1	62.88	01:09:20	01:19:44	00:58:56	00:58:46	✗
15_A27/A24_Portsmouth - Eastbourne_EB	15_EB_2	47.68	00:41:50	00:48:07	00:35:34	00:38:19	✓
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_1	49.36	00:36:46	00:42:17	00:31:15	00:36:24	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
15_A27/A24_Eastbourne - Portsmouth_WB	15_WB_2	60.93	01:02:11	01:11:31	00:52:51	00:57:01	✓
16_A282 M25_Dartford - Purfleet_AntiClockwise	16_AntiClockwise	3.83	00:04:26	00:05:06	00:03:46	00:03:38	✓
16_A282 M25_Purfleet - Dartford_Clockwise	16_Clockwise	3.92	00:03:38	00:04:11	00:03:05	00:03:25	✓
17_A3/A3(M)_Portsmouth - Epsom_EB	17_EB	87.72	00:52:53	01:00:48	00:44:57	00:58:08	✓
17_A3/A3(M)_Epsom - Portsmouth_WB	17_WB	87.61	00:59:49	01:08:48	00:50:51	00:58:51	✓
18_A30_Penzance - Exeter_EB	18_EB_1	98.21	01:04:31	01:14:12	00:54:51	01:13:06	✓
18_A30_Penzance - Exeter_EB	18_EB_2	76.30	00:40:11	00:46:13	00:34:10	00:43:49	✓
18_A30_Exeter - Penzance_WB	18_WB_1	76.26	00:40:28	00:46:32	00:34:24	00:43:52	✓
18_A30_Exeter - Penzance_WB	18_WB_2	98.16	01:05:55	01:15:48	00:56:02	01:13:34	✓
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_1	94.56	01:03:50	01:13:24	00:54:15	01:20:50	×
19_A303_Honiton - Basingstoke (M3)_NB	19_NB_2	64.41	00:38:14	00:43:58	00:32:30	00:45:49	×
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_1	72.25	00:44:59	00:51:44	00:38:14	00:59:13	×
19_A303_Basingstoke (M3) - Honiton_SB	19_SB_2	86.84	00:58:54	01:07:44	00:50:04	01:15:05	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_1	88.00	01:09:29	01:19:54	00:59:03	01:24:21	×
20_A31/A35/A30_Exeter - Southampton_EB	20_EB_2	64.85	00:47:10	00:54:14	00:40:05	01:00:23	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_1	68.75	00:56:15	01:04:42	00:47:49	01:08:59	×
20_A31/A35/A30_Southampton - Exeter_WB	20_WB_2	83.74	01:06:19	01:16:16	00:56:22	01:18:15	×
21_A34_Winchester (M3) - Bicester (M40)_NB	21_NB	101.01	01:03:58	01:13:33	00:54:22	01:05:28	✓
21_A34_Bicester (M40) - Winchester (M3)_SB	21_SB	100.39	01:05:48	01:15:40	00:55:56	01:05:29	✓
22_A36/A46_Southampton - Bristol (M4)_NB	22_NB	103.44	01:51:04	02:07:44	01:34:25	01:57:44	✓
22_A36/A46_Bristol (M4) - Southampton_SB	22_SB	103.52	01:46:41	02:02:41	01:30:41	01:57:52	✓
23_A38_Lichfield (M6 Toll) - Mansfield (M1)_NB	23_NB	65.96	00:43:11	00:49:39	00:36:42	01:00:53	×

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
23_A38_Mansfield (M1) -Lichfield (M6 Toll)_SB	23_SB	65.10	00:41:26	00:47:39	00:35:13	00:59:37	✗
24_A38_Bodmin - Exeter_EB	24_EB	109.22	01:13:32	01:24:34	01:02:30	01:24:55	✗
24_A38_Exeter - Bodmin_WB	24_WB	109.36	01:15:04	01:26:20	01:03:48	01:27:43	✗
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_1	72.32	01:13:44	01:24:48	01:02:40	01:10:09	✓
25_A40/A49_Gloucester - Shrewsbury_NB	25_NB_2	65.59	00:55:06	01:03:22	00:46:51	00:57:12	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_1	61.02	00:50:43	00:58:19	00:43:06	00:52:30	✓
25_A40/A49_Shrewsbury - Gloucester_SB	25_SB_2	77.45	01:15:37	01:26:58	01:04:17	01:12:25	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_1	75.08	00:40:55	00:47:04	00:34:47	00:44:54	✓
26_A40/M40_Redditch (M42) - Uxbridge_EB	26_EB_2	67.69	00:41:43	00:47:59	00:35:28	00:41:55	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_1	70.13	00:47:04	00:54:08	00:40:01	00:45:00	✓
26_A40/M40_Uxbridge - Redditch (M42)_WB	26_WB_2	72.17	00:40:55	00:47:03	00:34:47	00:44:31	✓
27_A419/A417_Swindon - Gloucester_NB	27_NB	53.36	00:36:43	00:42:13	00:31:12	00:43:46	✗
27_A419/A417_Gloucester - Swindon_SB	27_SB	53.42	00:31:49	00:36:35	00:27:02	00:39:41	✗
28_A421_Milton Keynes (M1) - Black Cat (A1)_NB	28_NB	27.84	00:18:54	00:21:44	00:16:04	00:16:49	✓
28_A421_Black Cat (A1) - Milton Keynes (M1)_SB	28_SB	27.76	00:16:14	00:18:40	00:13:48	00:16:32	✓
29_A428_St Neots (A1) - Cambridge_EB	29_EB	26.39	00:20:05	00:23:05	00:17:04	00:20:19	✓
29_A428_Cambridge - St Neots (A1)_WB	29_WB	26.98	00:19:34	00:22:30	00:16:38	00:20:23	✓
30_A43_Bicester (M40) - Northampton_NB	30_NB	38.29	00:41:20	00:47:32	00:35:08	00:31:35	✗
30_A43_Northampton - Bicester (M40)_SB	30_SB	38.22	00:31:45	00:36:31	00:26:59	00:31:26	✓
31_A45_Northampton (M1) - Thrapston (A14)_NB	31_NB	38.85	00:28:03	00:32:15	00:23:50	00:29:14	✓
31_A45_Thrapston (A14) - Northampton (M1)_SB	31_SB	38.86	00:28:01	00:32:13	00:23:49	00:28:54	✓
32_A46/M69_Tewkesbury - Leicester_EB	32_EB	108.46	01:27:37	01:40:45	01:14:28	01:31:56	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
32_A46/M69_Leicester - Tewkesbury_WB	32_WB	108.39	01:23:33	01:36:05	01:11:01	01:33:04	✓
33_A46_Leicester (M1) - Lincoln_EB	33_EB	87.55	01:08:03	01:18:15	00:57:50	01:13:45	✓
33_A46_Lincoln - Leicester (M1)_WB	33_WB	88.75	01:04:40	01:14:22	00:54:58	01:12:06	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_1	80.00	01:05:17	01:15:04	00:55:29	01:01:07	✓
34_A47/A12_Wansford - Lowestoft_EB	34_EB_2	105.94	01:20:33	01:32:38	01:08:28	01:24:10	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_1	89.66	01:11:45	01:22:31	01:01:00	01:11:57	✓
34_A47/A12_Lowestoft - Wansford_WB	34_WB_2	96.55	01:14:58	01:26:12	01:03:43	01:15:50	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_1	70.20	00:50:16	00:57:49	00:42:44	00:54:12	✓
35_A5/M54/A449/A458_Welsh Border - Tamworth (M42)_EB	35_EB_2	54.15	00:51:44	00:59:29	00:43:58	00:54:54	✓
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_1	43.74	00:41:45	00:48:01	00:35:29	00:51:04	✗
35_A5/M54/A449/A458_Tamworth (M42) - Welsh Border_WB	35_WB_2	80.77	00:58:52	01:07:42	00:50:02	01:00:50	✓
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_1	61.17	00:53:25	01:01:26	00:45:24	01:01:23	✓
36_A5_Tamworth (M42) - Luton (M1)_EB	36_EB_2	67.19	01:04:20	01:13:59	00:54:41	00:58:03	✓
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_1	55.49	01:03:39	01:13:12	00:54:06	00:51:57	✗
36_A5_Luton (M1) - Tamworth (M42)_WB	36_WB_2	72.12	01:03:43	01:13:17	00:54:10	01:10:56	✓
37_M6_Stoke-On-Trent (M6) - Nottingham (M1)_EB	37_EB	81.89	00:52:56	01:00:53	00:45:00	01:02:04	✗
37_M6_Nottingham (M1) - Stoke-On-Trent (M6)_WB	37_WB	82.42	00:54:06	01:02:12	00:45:59	01:03:10	✗
38_A52/A453/A5111/A6_Derby (A50) - Grantham_EB	38_EB	64.09	00:55:05	01:03:21	00:46:49	01:12:33	✗
38_A52/A453/A5111/A6_Grantham - Derby (A50)_WB	38_WB	64.34	00:58:33	01:07:20	00:49:46	01:07:58	✗
39_A55/M53_Welsh Border - Wallasey(Liverpool)_EB	39_EB	44.45	00:26:54	00:30:57	00:22:52	00:28:33	✓
39_A55/M53_Wallasey(Liverpool) - Welsh Border_WB	39_WB	44.46	00:26:49	00:30:51	00:22:48	00:28:09	✓
40_A590_Dalton-in-Furness - Kendal (M6)_EB	40_EB	47.72	00:36:59	00:42:32	00:31:26	00:37:56	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss) Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
40_A590_Kendal (M6) - Dalton-in-Furness_WB	40_WB	47.64	00:35:47	00:41:09	00:30:25	00:37:57	✓
41_A616/A628/A57/M67_Manchester (M67) - Barnsley_EB	41_EB	49.14	00:52:44	01:00:39	00:44:50	00:45:53	✓
41_A616/A628/A57/M67_Barnsley - Manchester (M67)_WB	41_WB	49.00	00:45:48	00:52:40	00:38:56	00:45:49	✓
42_A64_Wetherby (A1(M)) - Scarborough_EB	42_EB	85.85	00:59:20	01:08:14	00:50:26	01:02:40	✓
42_A64_Scarborough - Wetherby (A1(M))_WB	42_WB	85.88	00:59:48	01:08:46	00:50:50	01:07:00	✓
43_A66(M)/A66_Darlington - Middlesbrough_EB	43_EB	28.27	00:20:05	00:23:06	00:17:05	00:20:17	✓
43_A66(M)/A66_Middlesbrough - Darlington_WB	43_WB	27.64	00:20:30	00:23:34	00:17:25	00:19:48	✓
44_A66/A595_Egremont - Penrith_EB	44_EB	84.90	01:09:39	01:20:06	00:59:12	01:10:40	✓
44_A66/A595_Penrith - Egremont_WB	44_WB	83.92	01:05:45	01:15:37	00:55:53	01:06:29	✓
45_A66_Penrith - Scotch Corner_EB	45_EB	78.85	00:50:56	00:58:34	00:43:17	00:52:31	✓
45_A66_Scotch Corner - Penrith_WB	45_WB	79.85	00:53:26	01:01:27	00:45:25	00:52:55	✓
46_A69_Carlisle - Newcastle (A1)_EB	46_EB	84.34	00:59:43	01:08:41	00:50:46	01:00:59	✓
46_A69_Newcastle (A1) - Carlisle_WB	46_WB	84.37	00:58:10	01:06:54	00:49:27	01:01:32	✓
47_M1_Brent Cross - Northampton_NB	47_NB	89.75	01:04:09	01:13:46	00:54:31	01:03:20	✓
47_M1_Northampton - Brent Cross_SB	47_SB	89.93	00:54:39	01:02:51	00:46:27	01:00:28	✓
48_M1_Chesterfield - Northampton_SB	48_SB_1	73.53	00:45:50	00:52:43	00:38:58	00:53:51	✗
48_M1_Chesterfield - Northampton_SB	48_SB_2	67.73	00:44:12	00:50:49	00:37:34	00:41:57	✓
48_M1_Northampton - Chesterfield_NB	48_NB_1	59.35	00:40:19	00:46:22	00:34:16	00:38:58	✓
48_M1_Northampton - Chesterfield_NB	48_NB_2	81.64	00:52:45	01:00:40	00:44:50	01:00:05	✓
49_M1_Chesterfield - Leeds (A1(M))_NB	49_NB	80.31	00:56:48	01:05:20	00:48:17	01:00:22	✓
49_M1_Leeds (A1(M)) - Chesterfield_SB	49_SB	80.46	00:57:37	01:06:15	00:48:58	01:01:48	✓
50_M11_Walthamstow - Cambridge_NB	50_NB	81.20	00:56:06	01:04:31	00:47:41	00:55:45	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
50_M11_Cambridge - Walthamstow_SB	50_SB	80.45	00:55:26	01:03:45	00:47:07	00:52:12	✓
51_M18_Rotherham (M1) - Goole (M62)_NB	51_NB	44.74	00:27:58	00:32:10	00:23:46	00:30:13	✓
51_M18_Goole (M62) - Rotherham (M1)_SB	51_SB	44.17	00:27:47	00:31:57	00:23:37	00:31:03	✓
52_M180/A180_Hatfield (M18) - Grimsby_EB	52_EB	62.40	00:36:01	00:41:25	00:30:37	00:35:29	✓
52_M180/A180_Grimsby - Hatfield (M18)_WB	52_WB	62.41	00:37:53	00:43:33	00:32:12	00:35:42	✓
53_M25_South Mimms - Uxbridge_AntiClockwise	53_AntiClockwise	34.82	00:24:19	00:27:57	00:20:40	00:24:39	✓
53_M25_Uxbridge - South Mimms_Clockwise	53_Clockwise	34.99	00:24:02	00:27:39	00:20:26	00:26:16	✓
54_M25_Nutfield - Dartford_AntiClockwise	54_AntiClockwise	39.82	00:33:08	00:38:06	00:28:10	00:29:32	✓
54_M25_Dartford - Nutfield_Clockwise	54_Clockwise	40.03	00:26:17	00:30:13	00:22:20	00:26:26	✓
55_M25_Purfleet - South Mimms_AntiClockwise	55_AntiClockwise	53.66	00:42:48	00:49:13	00:36:23	00:34:36	×
55_M25_South Mimms - Purfleet_Clockwise	55_Clockwise	53.67	00:42:00	00:48:17	00:35:42	00:36:14	✓
56_M25_Uxbridge - Nutfield_AntiClockwise	56_AntiClockwise	58.34	00:59:44	01:08:42	00:50:46	00:46:04	×
56_M25_Nutfield - Uxbridge_Clockwise	56_Clockwise	58.24	01:01:33	01:10:47	00:52:19	00:42:29	×
57_M26/M20/A20_Bromley - Dover_EB	57_EB	101.19	01:05:00	01:14:45	00:55:15	01:02:38	✓
57_M26/M20/A20_Dover - Bromley_WB	57_WB	101.24	01:00:20	01:09:23	00:51:17	01:01:12	✓
58_M27_Southampton - Portsmouth_EB	58_EB	45.52	00:27:26	00:31:33	00:23:19	00:29:45	✓
58_M27_Portsmouth - Southampton_WB	58_WB	45.45	00:28:06	00:32:19	00:23:53	00:30:08	✓
59_M3_Southampton - Twickenham_EB	59_EB	95.48	00:57:56	01:06:38	00:49:15	01:03:55	✓
59_M3_Twickenham - Southampton_WB	59_WB	95.06	01:03:38	01:13:10	00:54:05	01:03:54	✓
60_M4_Swindon - Brentford_EB	60_EB_1	59.48	00:34:37	00:39:49	00:29:26	00:38:34	✓
60_M4_Swindon - Brentford_EB	60_EB_2	52.55	00:41:51	00:48:08	00:35:35	00:36:37	✓
60_M4_Brentford - Swindon_WB	60_WB_1	46.01	00:37:48	00:43:28	00:32:08	00:35:37	✓

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
60_M4_Brentford - Swindon_WB	60_WB_2	65.91	00:39:28	00:45:24	00:33:33	00:40:59	✓
61_M4_Severn Bridge - Swindon_EB	61_EB	70.17	00:37:51	00:43:32	00:32:11	00:41:20	✓
61_M4_Swindon - Severn Bridge_WB	61_WB	70.26	00:38:03	00:43:45	00:32:20	00:41:42	✓
62_M42/A42_Birmingham (M6) - Loughborough (M1)_EB	62_EB	50.09	00:29:35	00:34:02	00:25:09	00:34:36	×
62_M42/A42_Loughborough (M1) - Birmingham (M6)_WB	62_WB	49.68	00:28:45	00:33:03	00:24:26	00:34:22	×
63_M42_Bromsgrove - Birmingham (M6)_EB	63_EB	37.83	00:25:22	00:29:10	00:21:34	00:27:58	✓
63_M42_Birmingham (M6) - Bromsgrove_WB	63_WB	38.41	00:24:43	00:28:26	00:21:01	00:28:34	×
64_M45/A45_Coventry - Daventry (M1)_EB	64_EB	24.21	00:15:25	00:17:44	00:13:06	00:16:14	✓
64_M45/A45_Daventry (M1) - Coventry_WB	64_WB	24.09	00:17:04	00:19:37	00:14:30	00:15:59	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_1	66.21	00:35:15	00:40:32	00:29:57	00:38:00	✓
65_M5_Exeter - Bristol (M4)_NB	65_NB_2	64.08	00:34:14	00:39:23	00:29:06	00:39:00	✓
65_M5_Bristol (M4) - Exeter_SB	65_SB_1	57.50	00:32:05	00:36:53	00:27:16	00:36:17	✓
65_M5_Bristol (M4) - Exeter_SB	65_SB_2	73.08	00:40:18	00:46:21	00:34:15	00:41:57	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_1	68.60	00:37:15	00:42:51	00:31:40	00:42:09	✓
66_M5_Bristol (M4) - Birmingham (M6)_NB	66_NB_2	63.12	00:41:24	00:47:37	00:35:12	00:42:28	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_1	50.82	00:30:34	00:35:10	00:25:59	00:34:34	✓
66_M5_Birmingham (M6) - Bristol (M4)_SB	66_SB_2	81.05	00:43:32	00:50:04	00:37:01	00:48:19	✓
67_M50/A449/A40_Welsh Border - Tewkesbury_EB	67_EB	52.28	00:31:04	00:35:44	00:26:25	00:33:36	✓
67_M50/A449/A40_Tewkesbury - Welsh Border_WB	67_WB	52.54	00:32:28	00:37:20	00:27:35	00:34:01	✓
68_M55/A585_Fleetwood - Preston_EB	68_EB	31.77	00:28:24	00:32:39	00:24:08	00:33:08	×
68_M55/A585_Preston - Fleetwood_WB	68_WB	31.78	00:26:57	00:31:00	00:22:54	00:34:18	×
69_M56/A5117_Manchester (M56) - Welsh Border_EB	69_EB	56.86	00:35:11	00:40:27	00:29:54	00:40:59	×

Journey time route	ID	Length (km)	Time (hh:mm:ss)				TAG Compliant
			Observed	Observed +15%	Observed -15%	Modelled	
69_M56/A5117_Welsh Border - Manchester (M56)_WB	69_WB	57.69	00:39:44	00:45:42	00:33:47	00:41:10	✓
70_M58/A5036_Liverpool - Wigan_EB	70_EB	25.11	00:21:30	00:24:43	00:18:16	00:21:00	✓
70_M58/A5036_Wigan - Liverpool_WB	70_WB	24.99	00:20:59	00:24:07	00:17:50	00:20:28	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_1	72.35	00:39:58	00:45:57	00:33:58	00:40:35	✓
71_M6/A74_Carlisle (A74) - Preston_EB	71_EB_2	75.95	00:41:35	00:47:49	00:35:21	00:46:36	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_1	62.86	00:37:36	00:43:14	00:31:57	00:38:09	✓
71_M6/A74_Preston - Carlisle (A74)_WB	71_WB_2	86.15	00:48:10	00:55:24	00:40:57	00:47:59	✓
72_M6_Warrington - Wolverhampton (M6 Toll)_EB	72_EB	88.36	00:54:11	01:02:19	00:46:04	00:58:53	✓
72_M6_Wolverhampton (M6 Toll) - Warrington_WB	72_WB	88.25	00:56:28	01:04:56	00:48:00	00:59:41	✓
73_M6_Preston - Warrington_EB	73_EB	60.51	00:38:00	00:43:43	00:32:18	00:46:19	×
73_M6_Warrington - Preston_WB	73_WB	60.20	00:42:11	00:48:31	00:35:51	00:44:42	✓
74_M6_Wolverhampton (M6 Toll) -Rugby (M1)_EB	74_EB	78.81	01:06:16	01:16:12	00:56:20	00:57:08	✓
74_M6_Rugby (M1) - Wolverhampton (M6 Toll)_WB	74_WB	76.89	00:50:28	00:58:02	00:42:54	01:00:17	×
75_M60_Manchester (M56) - Manchester (M66) via Stockport_AntiClockwise	75_AntiClockwise	28.59	00:19:10	00:22:02	00:16:17	00:22:24	×
75_M60_Manchester (M66) - Manchester (M56) via Stockport_clockwise	75_clockwise	28.47	00:19:17	00:22:10	00:16:23	00:23:14	×
76_M60_Manchester (M66) - Manchester (M56)_AntiClockwise	76_AntiClockwise	27.11	00:21:25	00:24:38	00:18:12	00:30:46	×
76_M60_Manchester (M56) - Manchester (M66)_clockwise	76_clockwise	27.63	00:24:48	00:28:31	00:21:05	00:36:35	×
77_M602/M62/M57_Liverpool (M58) - Manchester_EB	77_EB	53.61	00:34:23	00:39:33	00:29:14	00:37:20	✓
77_M602/M62/M57_Manchester - Liverpool (M58)_WB	77_WB	53.88	00:36:20	00:41:47	00:30:53	00:40:57	✓
78_M61_Manchester (M60) - Preston (M6)_NB	78_NB	35.13	00:21:37	00:24:51	00:18:22	00:22:10	✓

			Time (hh:mm:ss)				
Journey time route	ID	Length (km)	Observed	Observed +15%	Observed -15%	Modelled	TAG Compliant
78_M61_Preston (M6) - Manchester (M60)_SB	78_SB	34.62	00:20:55	00:24:03	00:17:47	00:21:51	✓
79_M62/A63/A1033_Wakefield (M1) - Hull_EB	79_EB	89.72	01:01:22	01:10:34	00:52:10	01:06:55	✓
79_M62/A63/A1033_Hull - Wakefield (M1)_WB	79_WB	89.72	01:03:12	01:12:41	00:53:43	01:07:11	✓
80_M62_Manchester (M60) - Wakefield (M1)_EB	80_EB	63.23	00:40:25	00:46:28	00:34:21	00:45:55	✓
80_M62_Wakefield (M1) - Manchester (M60)_WB	80_WB	63.71	00:44:19	00:50:58	00:37:40	00:46:31	✓
81_M65_Preston (M6) - Burnley_EB	81_EB	32.06	00:19:00	00:21:51	00:16:09	00:20:39	✓
82_M66_Manchester (M60) - Burnley_NB	82_NB	28.04	00:18:41	00:21:30	00:15:53	00:19:14	✓
82_M66_Burnley - Manchester (M60)_SB	82_SB	28.12	00:16:42	00:19:12	00:14:12	00:20:31	✗
81_M65_Burnley - Preston (M6)_WB	81_WB	31.96	00:18:57	00:21:48	00:16:07	00:20:39	✓
83_A1/A1(M)_Pontefract (M62) - Scotch Corner_NB	83_NB	96.51	00:58:13	01:06:56	00:49:29	01:03:13	✓
83_A1/A1(M)_Scotch Corner - Pontefract (M62)_SB	83_SB	95.82	00:58:08	01:06:51	00:49:25	01:03:17	✓
84_M6 Toll_Birmingham (M42) - Wolverhampton (M6)_EB	84_EB	42.99	00:23:16	00:26:45	00:19:47	00:24:46	✓
84_M6 Toll_Wolverhampton (M6) - Birmingham (M42)_WB	84_WB	41.24	00:24:15	00:27:53	00:20:37	00:24:32	✓

Appendix H. HAM validation results

H.1. Vehicle kilometres by road type and time period

Table H.1 - AM summary - Motorways

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	0.2	-14%	0.0	-8%	0.2	-13%
NW	3.3	-9%	0.4	7%	3.7	-7%
Y&H	1.8	-13%	0.4	6%	2.2	-9%
EM	1.1	9%	0.2	18%	1.3	10%
WM	2.2	-14%	0.4	-10%	2.6	-14%
EoE	1.6	-9%	0.2	-19%	1.9	-11%
Lon	0.4	1%	0.1	8%	0.5	1%
SE	4.1	-9%	0.4	7%	4.6	-8%
SW	1.6	1%	0.2	7%	1.8	1%
Eng	**16.4**	**-8%**	**2.4**	**2%**	**18.7**	**-7%**

Table H.2 - AM summary – A Roads

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	1.9	1%	0.1	31%	2.0	3%
NW	3.6	7%	0.2	50%	3.8	9%
Y&H	3.1	11%	0.2	50%	3.3	13%
EM	3.8	10%	0.4	26%	4.2	12%
WM	3.4	14%	0.2	64%	3.6	17%
EoE	4.9	3%	0.4	13%	5.3	4%
Lon	3.0	7%	0.1	27%	3.1	8%
SE	6.5	6%	0.3	21%	6.9	7%
SW	4.1	-3%	0.2	23%	4.4	-1%
Eng	**34.5**	**6%**	**2.2**	**31%**	**36.6**	**8%**

Table H.3 - AM summary - All road types, connectors and intrazonals

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	3.5	-21%	0.1	26%	3.6	-19%
NW	10.2	-17%	0.6	20%	10.9	-14%
Y&H	7.7	-16%	0.6	21%	8.3	-13%
EM	7.6	-10%	0.6	22%	8.3	-8%
WM	8.9	-18%	0.7	20%	9.6	-15%
EoE	10.6	-16%	0.7	3%	11.3	-15%
Lon	5.3	-18%	0.2	26%	5.6	-17%
SE	16.0	-15%	0.8	15%	16.8	-13%
SW	9.4	-17%	0.5	16%	9.9	-15%
Eng	**79.3**	**-16%**	**5.0**	**17%**	**84.3**	**-14%**

Table H.4 - IP summary - Motorways

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	0.2	-27%	0.0	-11%	0.2	-25%
NW	2.9	-16%	0.4	4%	3.4	-13%
Y&H	1.6	-20%	0.4	5%	2.0	-15%
EM	1.0	6%	0.2	24%	1.2	9%
WM	2.0	-16%	0.4	-3%	2.4	-13%
EoE	1.5	-15%	0.2	-3%	1.7	-13%
Lon	0.4	-7%	0.1	18%	0.4	-4%
SE	3.7	-19%	0.5	8%	4.2	-16%
SW	1.4	3%	0.2	3%	1.6	3%
Eng	**14.7**	**-14%**	**2.4**	**5%**	**17.1**	**-11%**

Table H.5 - IP summary – A Roads

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	1.7	-11%	0.1	22%	1.8	-9%
NW	3.2	-3%	0.2	44%	3.4	0%
Y&H	2.8	-1%	0.2	42%	3.0	2%
EM	3.4	-3%	0.4	22%	3.8	0%
WM	3.0	5%	0.2	56%	3.3	9%
EoE	4.4	-9%	0.4	15%	4.8	-7%
Lon	2.7	-6%	0.2	21%	2.8	-5%
SE	5.9	-10%	0.3	15%	6.2	-9%
SW	3.7	-14%	0.2	6%	3.9	-12%
Eng	**30.9**	**-6%**	**2.2**	**25%**	**33.1**	**-4%**

Table H.6 - IP summary - All road types, connectors and intrazonals

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	3.1	-29%	0.2	17%	3.3	-27%
NW	9.2	-23%	0.7	16%	9.8	-21%
Y&H	6.9	-24%	0.6	16%	7.5	-20%
EM	6.8	-19%	0.7	21%	7.5	-15%
WM	8.0	-22%	0.7	21%	8.7	-19%
EoE	9.5	-24%	0.7	9%	10.2	-22%
Lon	4.8	-27%	0.2	23%	5.0	-25%
SE	14.3	-26%	0.9	12%	15.2	-24%
SW	8.4	-23%	0.5	5%	8.9	-21%
Eng	**71.1**	**-24%**	**5.1**	**15%**	**76.2**	**-21%**

Table H.7 - PM summary - Motorways

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	0.2	-26%	0.0	-13%	0.3	-25%
NW	3.7	-12%	0.3	13%	4.0	-10%
Y&H	2.0	-13%	0.3	11%	2.3	-10%
EM	1.2	9%	0.2	34%	1.4	12%
WM	2.5	-17%	0.3	4%	2.8	-15%
EoE	1.9	-9%	0.2	2%	2.0	-8%
Lon	0.5	-4%	0.0	29%	0.5	-2%
SE	4.7	-14%	0.3	28%	5.0	-11%
SW	1.8	-2%	0.1	14%	1.9	-1%
Eng	**18.6**	**-11%**	**1.6**	**15%**	**20.2**	**-9%**

Table H.8 - PM summary – A Roads

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	2.2	-6%	0.1	14%	2.3	-6%
NW	4.1	-1%	0.1	36%	4.2	0%
Y&H	3.5	3%	0.1	35%	3.7	4%
EM	4.4	4%	0.3	21%	4.6	5%
WM	3.9	7%	0.1	55%	4.0	8%
EoE	5.6	-4%	0.3	20%	5.9	-3%
Lon	3.4	-1%	0.1	3%	3.5	-1%
SE	7.4	-3%	0.2	13%	7.7	-2%
SW	4.7	-10%	0.2	-2%	4.9	-10%
Eng	**39.2**	**-2%**	**1.5**	**22%**	**40.7**	**-1%**

Table H.9 - PM summary - All road types, connectors and intrazonals

Region	Lights		Heavies		Total	
	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff	Observed (million kms)	Modelled % Diff
NE	4.0	-27%	0.1	8%	4.1	-26%
NW	11.6	-22%	0.4	19%	12.1	-20%
Y&H	8.7	-20%	0.4	17%	9.2	-19%
EM	8.7	-15%	0.4	23%	9.1	-13%
WM	10.2	-22%	0.5	24%	10.6	-20%
EoE	12.1	-21%	0.5	13%	12.6	-19%
Lon	6.1	-24%	0.1	12%	6.2	-23%
SE	18.2	-21%	0.6	21%	18.8	-20%
SW	10.7	-22%	0.3	4%	11.0	-21%
Eng	**90.2**	**-21%**	**3.4**	**17%**	**93.7**	**-20%**

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