1-1012 – NTMv5 AUDIT

Audit Status Report

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This is a controlled document.

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Glossary

AMAI	Absolute Models Applied Incrementally
AUC	Assignment User Class
BPR	Bureau of Public Roads (name of a Volume Delay Function in Vissum)
FH	From Home
GAP	An indicator of overall model convergence.
GDP	Gross Domestic Product
GIS	Geographic Information System
HAM	Highway Assignment Model
HB	Home Based
HGV	Heavy Goods Vehicle
HSL	Health and Safety Laboratory (HSL). They maintain The National Population Database (NPD)
ICA	Intersection Capacity Analysis
IPP	Incremental Pivot-Point Models
ITN	Integrated Transport Network
JTW	Journey to Work
LA	Local Authority
LAD	Local Authority District
LENNON	Latest Earnings Networked Nationally Over Night (Rail ticket database)
LGV	Light Goods Vehicle
LoHAM	London Highway Assignment Model
LOS	Level of Service
LUCE	Linear User Cost Equilibrium, an algorithm to solve traffic assignment with deterministic route choice available in VISUM
ME	Matrix Estimation
MOIRA	Rail forecasting software and database. Maintained on behalf of ATOC members for rail demand and revenue forecasting
MoLS	Method of Least Squares
MRN	Major Road Network
MRTM	Midlands Regional Traffic Model
MSOA	Middle layer Super Output Area
NHB	Non Home-Based Business
NRTM	Northern Regional Traffic Model
NTS	National Travel Survey
OD	Origin Destination

ONS	Office for National Statistics
OTP	Open Trip Planner
PA	Production Attraction
PCU	Passenger Car Unit
PLANET	National rail forecasting model
PSV	Public Service Vehicle
RTM	Regional Traffic Model
RUC	Road User Charging
SATURN	Congested highway assignment software
SATVIEW	A tool to adapt and code SATURN model networks
SERTM	South Eastern Regional Traffic Model
SFC	Speed Flow Curve
SRN	Strategic Road Network
SWRTM	South West Regional Traffic Model
TAG	Transport Analysis Guidance
TLD	Trip Length Distribution
TPSRTM	Trans Pennine South Regional Traffic Model
TRACC	Multi modal travel time tool developed by Basemap
TRADS	Highways England legacy traffic count sites
UAS	Urban Area Speed
VDF	Volume Delay Function
VDM	Variable Demand Model
VOC	Value of Cost
VOT	Value of Time
WebTRIS	Highways England Web based Traffic Reporting Information System

1. INTRODUCTION

1.1. Background

Arup AECOM have been awarded a commission for Specialist Professional and Technical Services (SPaTS) Task 1-1012 'National Transport Model Version 5 Audit'. The purpose of conducting the NTMv5 Audit is to provide clear, independent evidence of the quality of the NTMv5 model. Taken together with DfT advice and peer review comments the audit will inform the Department and their stakeholders about the extent to which the model is fit for purpose, and further inform future development of the model to improve its robustness and quality assurance.

1.2. Purpose of Document

This document provides a final draft of the of the Audit Status Report. The purpose of this document is to identify to what extent the model is developed to the agreed specification. Improvements needed have been identified and their merits and any challenges will be clearly set out.

The first chapters provide a review of the documentation. The following three documents have been reviewed:

- NTMv5 quality report
- NTMv5 user guides, and
- NTMv5 developer guides

The review process has considered both model use and implementation aspects and describes the areas of higher importance where the reports can be improved.

The remaining chapters provide details of the model audit. The audit considers the following three areas in turn:

- model implementation
- data processing, and
- model use

The final chapter provides our summary and recommendations. The chapter summarises the main outcome of the audit and sets out recommended model enhancements.

2. Documentation Review - Quality Report

2.1. Overview: Quality Report

This chapter sets out findings from a detailed review of the NTMv5 Quality Report and describes the areas of higher importance where the report can be improved. The review process has considered both model use and implementation aspects. Recommendations are provided to improve robustness, suitability and usability of the report for model users.

In terms of structure and completeness of the document, it is observed that there is no concluding section that summarises the extent to which the model can be used for the defined use cases. This is considered to be an important gap and should be added to the document.

2.2. Chapter 1: Introductory Topics

This section provides the context to build NTMv5 (Section 1.1), introduces the project team, and sets out overall content and structure of the report. The contents of this section are considered proportionate and appropriate.

2.3. Chapter 2: Intended Uses and Applications of NTMv5

This chapter provides general information about model components, inputs and the main outputs. It provides a description of model use cases, including some examples, and highlights limitations associated with each use case that should be considered.

The high-level overview of model structure provided in Figure 2.1 is considered appropriate with sufficient details for the intended non-technical reader of this chapter.

In general, Section 2.4 does not provide enough information on the use cases for the users to understand the model limitations. As described, the generic purpose of the use cases expressed are inadequate for the users to understand how specific cases should be linked with model capabilities and risks, and how to use the model correctly for the intended purposes.

- It is recommended that a more detailed and accurate description of the intended uses is developed, clearly explaining the type of questions within each use case that the model should and should not be used for to answer. These should be described independent of, and prior to, reporting the model capabilities.

2.4. Chapter 3: NTMv5 Scope and Structure

The chapter starts by describing model aspects that are included in the scope, and those that are excluded. The overall model structure and geographical coverage of the model is then defined. This is followed by discussing each model component in more detail.

Section 3.3 states that travel between England and Scotland / Wales is constrained and may understate improvements in cross border infrastructure and / or policies affecting longer distance travel. This should be explained and linked to relevant model use cases.

- It is recommended that possible consequences of the limitation in representing cross border movements are explained and linked with affected use cases.

Section 3.5 describes the VDM broadly for a non-technical reader. It however refers to technical terms such as Production / Attraction and trip utility.

- ➢ It is recommended that for a non-technical person, as the intended reader of this section, references to standard definition of these terms are added to this section of the report.

The highway assignment model and base year highway matrices are then introduced briefly in relatively non-technical terms. Section 3.8 summarises the interface between the VDM and the HAM. The brief summary given in these sections is considered appropriate given the objective of this section.

The next section (3.9) sets out the main model outputs for both VDM and highway assignment model and gives a few examples of how these can be used. The content and language of this section is considered appropriate. However, some of the example outputs given are potentially subject to significant uncertainty, for example % HGVs on links, which the user should be made aware of.

- ➢ It is recommended that advice is given to the users about the uncertainty in some of model outputs (e.g. %HGVs on links) and include a discussion of the granularity at which outputs can be relied on for different purposes.

Section 3.10 provides a brief overview of the wider model suite and interfaces between different model components. The description given and in particular the diagram included (Figure 3.3) is considered appropriate and sufficient. References are also given to model user guide where more details on different model aspects can be found.

2.5. Chapter 4: Technical Overview

This chapter aims to provide technical details on overall model structure and its components, and to explain the rational for the current design of the model.

- Section 4.2 and Figure 4.1 summarise the overall structure of the model and the key data transformations that take place when the model is run. The details included in Figure 4.1 are considered to be sufficient for the users.
- The definition of model zoning system is described in Section 4.4, with Figure 4.3 giving an overview of the model zones and Table 4.1 providing a breakdown of zones by type and region. One of the zone types included in this table is called “enterprise” but no description of this zone type is provided in the accompanying text. Also, the table title refers to v6.5 of the zoning system, but no description of different versions of the model zones is provided.
    - ➢ It is recommended that a brief description of enterprise zones is included in the paragraph before Table 4.1.
    - ➢ It is recommended that either reference to v6.5 is removed from the title of Table 4.1, or different versions of the zoning system are defined for the user.
- Section 4.5 explains the different interpretation of 2015 base year for the VDM and HAM, resulting from underpinning data sourced from different months in 2015. Whilst the document notes that it was accepted to have slightly incompatible months for the demand and supply data, no information is given to the user of any potential consequence this may have and if any consideration should be given to the interpretation of model results.

- It is recommended that a clarification sentence explaining the nature and scale of differences is added to confirm if any consideration is needed to be given by the model users to model outputs because of the use of slightly incompatible months for the demand and supply data.

- The time period definitions for the VDM and HAM provided in Table 4.2 is considered informative and appropriate.
- Section 4.7 summarises the approach to coding of urban areas and deriving urban link speeds in base and forecast years, with references given to more details provided in later chapters.
- This chapter ends with providing a brief description of the approach used within NTMv5 to model freight and, in particular, LGVs. The level of detail provided here is considered appropriate, and references are given to later chapters where more details can be found.

2.6. Chapter 5: Variable Demand Model Structure

This chapter describes the structure and demand segmentation of the VDM.

Sections 5.2 to 5.5 introduce the VDM structure, approach to define demand segmentation, trip purpose definitions, and travel modes considered within VDM. The rationale to defining these is also provided to a sufficient degree of technical detail. The contents of these sections and the technical information provided are considered appropriate.

Section 5.4 introduces travel modes in the model; these exclude air and park and ride. Modelling domestic air relates to some specific areas of policy. Park and ride is important for strategic traffic management in a number of urban areas and as parkways for rail services. There is no discussion of the possible consequences of these limitation with respect to specific use cases.

- Possible consequences of lack of representation of domestic air and park and ride in the model on model use cases should be discussed.

Section 5.5 discusses demand inputs to the VDM, namely trip productions and trip attractions. These sections read reasonably well and clarify the type and nature of inputs to the VDM with references given to later chapters with more details.

Section 5.6 discusses the specification of utility functions used within the VDM. In general, this section is slightly difficult to follow and could be strengthened with technical detail and references to other chapters or documentation where more details can be found. While chapter 10 later quotes coefficients and parameters for utility functions, neither chapter describes the functions themselves sufficiently.

- It is recommended that further details are added to Section 5.6 to better explain the role of segmentation specific utility terms and cost damping, and to give references to where more detail can be found on the specification of utility functions.

2.7. Chapter 6: Base Year Demand

This section summarises the process used to derive base year demand. The introductory paragraph states that use of synthetic matrices is the best way to achieve demand forecasts. This statement expresses an opinion, potentially related to context and is not expressed correctly, there are different forecasting methodologies, based on base year travel demand that is estimated using various methods, and the synthetic approach is one of them. Different methods have different strengths and limitations.

- ➢ It is recommended that the introductory paragraph is revised to set out the advantages of the synthetic approach used instead of regarding it as the best way of achieving demand forecast in general.

Section 6.2 summarises the main outputs and Section 6.3 provides a comprehensive list of all data sources that have been used for base year matrix development.

Section 6.4 summarises the process to develop demand matrices for personal trips; this is illustrated in Figure 6.1 in detail. Some of the terms used in this figure are not clearly defined for the reader and can therefore benefit from clarification. This includes the term “travel estimator” and abbreviations used to define trip purposes.

- ➢ It is recommended that some of the terms used in Figure 6.1 are better defined to add clarity, either directly in this section or in other places (e.g. appendix A) with references included in this section. These include the term “travel estimator” or abbreviations used for trip purposes.

There are biases and definitional differences in census and (ageing) school census data sets in comparison with the NTS. The definition of demand is fundamental to interpretation of outputs and this section does not provide information on these and how these have been addressed.

- ➢ Supplementary detailed documentation or suitable references should be added to explain interpretation of different definitions that are inconsistent between data sources e.g. how tertiary education is included to align with planning data, or how JTW is related to the definition of average weekday commuting trips in NTS.

Development of freight matrices is covered in Section 6.5. A brief summary is given for HGV matrix development process, with references given to an external document produced by MDS Transmodal where more details can be found. This is considered appropriate provided that this document can be supplied to the users upon individual request. Section 6.5.2 summarise the process for LGV matrix development. This relies heavily on use of DfT’s 2002 to 2005 surveys, including for the expansion of Trafficmaster data. Given the age of this survey, it is not made clear in the report whether there has been any process to allow for growth between 2002-2005 and 2015.

- ➢ It is recommended that clarification is added to explain whether any adjustment is made to account for the age of van surveys used to inform development of a 2015 van matrix and if not, the reasoning behind and potential implications of this.

2.8. Chapter 7: Travel Costs and Characteristics

The general formulation of the highway assignment generalised costs and utilities used in the demand choice models are introduced in Sections 7.2 and 7.3, respectively. Sections 7.3 and 7.4 set out the assumptions and parameters used to calculate vehicle operating costs and values of time. The parameters reported in these sections are consistent with those in the associated TAG (Transport Analysis Guidance) books that the text refers to.

Section 7.5 explains derivation of parking cost assumptions. It explains that due to the complexities involved, the assumptions used in NTMv2R are implemented directly, which are sourced from the NTS. It is not made clear however which year of NTS data this relates to and, if this is old data, why these are not updated using more recent

NTS data. Tables 7.4 to 7.6 summarise these assumptions by trip purpose and area types, no reference has been given however to the numbers used in these tables for different area types. This is reducing the values of these tables as it is difficult to interpret these and compare the values given between different area types.

- It is recommended that this section is expanded to clarify what year of NTS data has been used to derive parking costs, and to define the area type numbers used in Tables 7.4 to 7.6.

Section 7.6 explains how tolls and road charges are collated and coded, and these are summarised with references given to their source in Table 7.7.

Section 7.7 discusses derivation of public transport fares. The key assumptions to derive rail fares are described in Section 7.7.1 and more details are provided in two accompanying tables. The level of detail provided is considered proportionate and appropriate. Regarding bus fares (Section 7.7.2), reference is given to the approach used for NTMv2R and the bus fare functions used are described while their parameters are introduced in Table 7.10. However, it is not entirely clear how these parameters are estimated and what the source of information in this table is.

- It is recommended that the source of data and parameters used to calculate bus fares are introduced and explained.

Derivation of bus, rail, walk, and cycle time and distances using TRACC software is covered in Sections 7.8 and 7.9. Calculation of intrazonal costs and the assumptions used are sufficiently described in Section 7.10. The second paragraph in this section refers to the TAG guidance, stating that:

"*A common approach has been to consider half the interzonal cost as representative of the intrazonal cost*."

This statement is not entirely clear and should be further clarified. It probably intends to say considering half of the *minimum* interzonal cost. Furthermore, there are other assumptions adopted in some models, so an explanation of why this particular assumption is used is needed.

- It is recommended that this statement is revised to clarify the common approach used and explain why this is preferred.

2.9. Chapter 8: Highway Assignment Model

This chapter provides an overview of the development and assumptions behind each component of the highway network.

Section 8.1 provides an introduction and clear structure to the chapter. Section 8.2 describes the user classes defined in the HAM model. Both sections present appropriate level of detail.

Section 8.3 introduces components of the highway network consisting of road links and nodes, centroid connectors and volume delay functions for links. A component representative of junction coding seems to be missing on this list, which is covered later in the chapter. This section also covers the methodology for developing the highway network based on inherited networks from Regional Transport Models (RTMs) which documents the sources clearly and provides an appropriate level of detail.

- It is recommended that the list of highway network components in Section 8.3.1 is updated and accounts for all network components covered in the chapter e.g. junction coding.

Section 8.4 and 8.5 describe the travel delay mechanisms deployed in the model to evaluate the journey times in congested conditions which are composed of volume delay functions and a simplified junction model.

The methodology for development of volume delay functions is easy to follow and contains an appropriate level of detail. The documentation describes that the free flow speeds (by mode) are based on a minimum value of the speed limits defined in the model and a free-flow speed for a particular link type. However, it was noticed that the maximum speeds set in the model are above legal speed limits without further explanation on this assumption and implication on the model use cases. For example, for economic appraisal, speeds should be capped for skimming to avoid inappropriate economic valuation of illegal behaviour.

- It is recommended that additional comment is included in Section 8.4 to explain the choice of maximum speeds and their impact on the model results.

The junction modelling section is vague and does not provide any detail on the extent of the junction modelling and types of junctions covered in the model. For example, the volume delay functions on grade separated roads in the RTM models were developed in conjunction with detailed merge node modelling. In this instance, the report mentions that the volume delay functions were replicated but modelling of merge nodes is not considered in the report.

- It is recommended that further detail is provided in relation to the junction modelling approach undertaken, specifying the extent of the junction modelling and junction types that are or are not represented in the model.

Section 8.6 describes the process applied to account for bus demands taking up capacity on the network using bus pre-loads. Within this section it is stated that bus flows calculated are lower than DfT PSV counts in almost all cases for a small sample used for comparison. This statement cannot be fully commented on, as the scale of issue is not quantified but the explanation provided by the model developer seems reasonable.

- It is recommended that further detail is provided to inform the user of the scale of disproportion between bus preload flows and DfT PSV counts.

Section 8.7 describes the assignment procedure selected for this model and contains appropriate level of detail for this report.

While the intention of this report is mainly to provide a summary of the NTMv5, throughout the chapter there are no references to other reports/sections with additional detail on the topics for the reader to explore further if required.

- It is recommended that references are added within the chapter to relevant sections of this or other reports that contain further detail on the modelling approach for topics discussed in this chapter.

2.10. Chapter 9: Linking VDM and HAM

This chapter summarises the forecasting approach and the conversion of demand matrices between HAM and VDM within VISUM.

Section 9.1 states that it is common for future-year forecasts to be developed based on '*accurate'* base year flows. This statement is misleading as no representation of the base year demand can be truly accurate. This is particularly the case for NTM as the base year demand matrix is developed using synthetic methods.

- It is recommended that the wording in Section 9.1 is revised to clarify that the forecasting approach is using the best *estimate* of the base year condition and this is not necessarily *accurate*. Alternatively, define precision implied when using words like accurate.

Section 9.2 introduces the incremental modelling approach used, Section 9.3 explains the conversion of VDM matrices to those required by the HAM, and Section 9.4 outlines the approach to demand and supply iterations. These sections generally read well, and their length is considered proportionate.

2.11. Chapter 10: Demand Model Estimation

This chapter sets out the estimation process to identify demand segmentation and estimate sensitivity parameters and modal constants.

The description of the overall approach, the model validation, and diagnostic tests as summarised in Sections 10.1 and 10.2 are considered to provide sufficient clarity and details. It is noted that the calibration process has made use of national data, which is consistent with the scope and definition of the model. However, there may be some particular applications of the models to test specific policies that may be affected if local travel behaviours are different. Further benchmarking and verification may be appropriate in these circumstances to understand if there are likely to be any material impacts.

- It is recommended that a caveat is added to explain that where travel behaviour might be different for a subset of demand, such as for a remote local area where distances travelled differ significantly from the national average, some specific model use cases may be affected, and additional verification of model responses may be needed.

Section 10.3 and Table 10.1 describe the final demand segmentation used in the model, with refinements made to the segmentation suggested by the estimation process colour coded in the table. Whilst different colours are explained in the paragraph prior to the table, it will be helpful for the reader to also add these as footnote under the table. The title of the table is not also accurate: it refers to this as the “final” segmentation but later the text explains how gender was removed from the final segmentation.

- It is recommended that Table 10.1 is revised to either remove gender from the list of segmentation variables or remove the word “final” from the title. It is also suggested that the key to cell colours is added as footnote to the table for added clarity.

2.12. Chapter 11: Forecasting Model

This chapter outlines the forecasting process and requirements in NTMv5. The overall approach to forecasting is summarised in Section 11.1 and Figure 11.1.

Section 11.2 sets out how growth factors are calculated based on NTEM and implemented within NTM. It highlights the need for two correspondences between NTEM and NTM: demand segments and model zones. Section 11.2.1 explains how NTEM segments correspond to those in NTM. There is no discussion of correspondence between the two zoning systems and how growth factors are converted from NTEM zoning to NTM zoning when these are not identical.

- ➢ It is recommended that a section is added similar to 11.2.1 to describe the process of developing the correspondence between NTEM and NTM zoning systems and conversion of data between them when they differ.

Adjustment of urban area speeds for future-year forecasts is discussed in Section 11.4. Whilst the main principles are set out here, this section is lacking more detail on how the changes in speed are calculated as a result of demand changes. i.e. how speed reduction factors are adjusted based on trip end growth.

- ➢ It is recommended that either more detail is added to Section 11.4 to explain how speed changes are related to demand changes, by providing the formula applied, or references are given to other documents where this can be found.

The remainder of this chapter covers forecasting assumptions with regards to costs and values of time, public transport and active modes, freight demand, and behavioural changes. It is considered that the contents of these sections are appropriate, with sufficient detail and appropriate references given to other documents where applicable.

2.13. Chapter 12: Model Standards

This chapter sets out the standards and guidelines used to build and assess performance of the model, referring to TAG Units M2 and M3.1, but noting that there have been deviations from these given the national scope of the model.

In general, this chapter provides a comprehensive summary of the key model standards used and the differences with those in TAG when they exist. Where there are deviations from TAG, the note says these have been 'agreed' with DfT, but no information is provided for the basis of new standards defined and possible consequence on use cases and uncertainty of model forecasts.

- ➢ It would add to the value of this chapter and would help the users to interpret model outputs if more details could be provided on any evidence or reasoning behind the definition of revised criteria when these differ from TAG, and possible impacts on forecasting uncertainty.

2.14. Chapter 13: Demand Model Estimation and Validation

The validation results of the demand model parameter estimation process are summarised in this chapter.

The mode and destination choice model calibration results and estimated parameters are summarised in Sections 13.2, Table 13.1 and 13.2 in particular provide estimated parameters for each demand segment. This section would benefit from adding some commentary for the users on how these values should be interpreted, both in terms of signs and magnitude of the estimated parameters. This would provide a basis for users to understand the uncertainty in the estimated parameters and implications for the model responsiveness.

- ➢ It is recommended that commentary is added supporting Tables 13.1 and 13.2 to explain how the signs and coefficients of the estimated parameters can be interpreted, perhaps with a limited number of examples. Furthermore, standard errors should also be reported, and commentary added to explain how these should be used by the user to understand uncertainty in the estimated parameters.

The estimated values of times are reported in Section 13.3 and compared with average TAG values. Some of these are different from TAG values e.g. VOT values are lower for rail. Explanation is given when these are different, setting out possible reasons for the discrepancies. There is however no discussion of the possible impacts of these on specific uses of the models.

- ➢ It is recommended that this section is expanded to discuss possible impacts of differences in VOT with TAG values on various model use cases and advise to users on how to mitigate any risk associated with this.

Validation results for mode shares and average trip lengths are given in Tables 13.4 13.5, 13.6 and 13.7. There is a general statement saying there is a good fit generally for Home Based (HB) purposes, but the fit is worse for Non Home Based (NHB) purposes. The results in these tables show larger differences for some modes / segments compared with others. There is uncertainty associated with observed values from NTS as well as that is different across segments, but no information is provided to give an indication of the relative confidence in the NTS observed values. A table of sample size comparison or similar would help interpreting the validation results provided.

- ➢ It is recommended that some information is provided in Section 13.4 on the relative confidence in the NTS observed values in Tables 13.4 and 13.5; for example, a table comparing sample sizes across modes and segment, or the 95% confidence intervals of the observed values. This will help users interpret and judge the importance of discrepancies with observed values.

Comparison of observed and modelled trip length distributions is given in Figure 13.1 for commuting, with results for other purposes provided in Appendix A. There is commentary below the table summarising the observed differences, but no explanation is given for possible reasons that would explain the observed differences.

- ➢ It is recommended that the text under Table 13.1 is expanded to discuss possible reasons that would explain the observed differences and the expected consequences with regards to the use cases.

The results for realism tests undertaken are reported in Section 13.5, including references to the guidance. As stated, there are large differences in elasticities between VDM and highway assignment model matrices. Whilst the differences in matrices are described as the reason explaining these, no discussion is included on the impact of this on various model uses.

- ➢ This section should be expanded to discuss possible consequences of differences in elasticities when calculated using VDM and highway assignment matrices when model is used to test different policies.

Whilst in general, the contents and level of information provided in this section is considered appropriate, the user would benefit from some minor improvements, as set out below.

- ➢ It would be helpful to add in the introduction a short sentence defining each of the elasticities, as defined in TAG e.g. “fuel cost elasticity is the percentage change in car vehicle-kms with respect to the percentage change in fuel cost.”
- ➢ Where elasticities are outside the range recommended by TAG (e.g. PT fare elasticity for Home Based Shopping in Table 13.11), it would be helpful to add a short commentary setting out possible reasons.
- ➢ TAG realism test elasticities cover a very limited set of tests. Advice should be provided to model users to understand responsiveness for the full set of use cases.

2.15. Chapter 14: Highway Model Validation

This chapter sets out the main principles and the overall approach followed for the highway calibration and validation. In principle, the adopted approach is in line with TAG Units M3.1. It also reports the data used in the process and the results of model validation.

For the calibration of the highway model, it was agreed with DfT to use all the available screenlines for calibration and a separate set of individual link counts for validation. Whilst this approach makes best use of all available data, it provides no information on the quality of matrices for movements not crossing the screenlines and therefore not adjusted.

- It is recommended that the screenline flow comparison results are also reported before the application of matrix estimation to inform users of the expected quality of prior matrices in representing movements where counts are not used for matrix adjustments.

According to Section 14.3.2, the extent of the routes was chosen so that journey durations were around one hour. However, we consider the journey time routes of one hour quite long and along with the selection of mainly motorways and A-roads, the journey time validation assessment could be weak in terms of routeing, and this should be caveated in the report.

Section 14.5.1 presents the refinements applied to matrices as part of the matrix calibration process. The summary is considered adequate, reporting the applied matrix adjustments in a concise way, without many details which could make the Quality Report unnecessarily long.

Section 14.6 reports the impact of matrix estimation in the prior demand matrices. The metrics used for this purpose are in line with TAG Unit M3.1. According to the results shown in the Appendix D, the matrix distortions are limited and within the thresholds of the TAG, apart from some changes in trip length profiles, but these are not considered significant. However, the matrix distortion would be expected to be small from a matrix-wide perspective as there are a few screenlines and only a small proportion of trips affected.

- It is recommended to investigate and present the changes local to the screenlines, analogous to the internal area of a standard model with a reasonably comprehensive set of screenlines.

The results of matrix calibration presented in Section 14.7, show that the calibration criteria agreed with DfT have been achieved in all time periods and user classes. However, there is no reference made to Table 14.3 in the text.

- It is recommended to add a reference to Table 14.3 in the main text.

The acceptance criteria for journey time validation, as documented in Section 14.9, is 10% below the thresholds that TAG recommends (TAG recommends 85% of the modelled journey times along routes). The relaxed criteria used for the matrix journey time validation could result in less accurate representation of journey times for assigned flows and uncertainty in economic appraisals.

- It is recommended to clarify the limitations of this approach by including a summary discussion of the routes which fail the criteria significantly and giving advice on possible consequences for specific model uses and set out he caveats.

The matrices marginally pass the relaxed journey time validation criteria agreed with DfT for all the time periods. However, as shown in Figure 14.5, there appears to be a bias with the journey times being overstated on average.

Section 14.10 presents the convergence of the NTMv5 model. As mentioned in the report, the standard measure of stability is not applied in PTV Visum but instead the link stability is monitored manually. This means that additional effort is needed to check the convergence of the model runs, as the models have to rerun for one less assignment to allow the user to manually assess the difference in link flow and cost between the penultimate and final assignment iteration. The Audit considers this as a limitation in the Visum model runs, having said that, it is adequately mentioned in the report.

Finally, as mentioned in Section 14.11, the validation statistics do not meet the TAG criteria for flow validation. We agree with the statement in the report that this issue is related to the fact that isolated counts are used for the model validation.

Bespoke validation criteria were defined to help ensure efficient use of the resource available to ensure a consistent quality of model performance was achieved across the country and in particular to place emphasis on the need to ensure that matrix estimation processes did not distort the prior demand matrices. The auditor concurs with the importance of this focus. The documentation provided does not however provide the user with an understanding of how to interpret the accuracy of the model outputs. The 'relaxed' standards define a greater error tolerance. The user will need to consider the implication of these.

- It would be beneficial if the Department could set out the implications for different use cases; it is likely that the errors are random rather than bias and if so it is likely to be feasible to provide guidance on the level of aggregation at which model outputs should be used for different purposes.

2.16. Chapter 15: Sensitivity Tests

Chapter 15 is a detailed (possibly slightly excessively) description of the five sensitivity tests carried out, how the inputs were prepared, and the outputs obtained. It is generally well laid out and covers the important information, although it does not offer much detailed commentary on appropriateness and robustness of results.

The chapter is very long and probably more detailed than most readers of the Quality Report will need. It could probably have been summarised further (reducing reported output to the one or two most illuminating issues for each test) with the detail left in Developer Guide Volume 6).

There are no prior hypotheses set out regarding the expected outcome of each test (e.g. from historic monitoring, literature review, mathematical plausibility). This makes it hard to judge whether the test outcomes are sound.

- Thought should be given to expected outcomes of each test independently of the model results.

Specific comments on two of the tests follow.

Test 1

Test 1 (Demand Growth) is slightly oddly specified. It is neither an exploration of the effect of changing **one** input (for example, forecast population/employment levels), nor is it a complete forecast of a future year.

The test includes population and employment changes, along with freight growth assumptions, as the name would suggest; but it also includes urban area speed changes, and values of time adjustments. However, it is not a complete future forecast, as public transport fares and major highway schemes are **not** considered. This makes it a little hard to assess plausibility of results.

For instance, bus mode share increases more than any other mode in this test. This appears an unlikely result, but probably results from the lack of fare increases in the assumptions, combined with the inclusion of value of time increases.

- A complete future year forecast should be undertaken and reported on, perhaps as a “demonstration” test if this has not already been done.

Test 3

No explanation is given for the overall increase in rail travel as a result of decreases in rail service quality. Although there are decreases in the areas affected, it is not plausible that an overall increase in rail demand would result. It appears that convergence "noise" may be overwhelming some real impacts; we suspect the test is not sufficiently well converged for many of the output metrics to be truly meaningful (although obviously some are; e.g. the effect on rail trips in Yorkshire & Humber).

Bus fare elasticities are higher than rail; this is perhaps unexpected, but not necessarily unrealistic.

- Convergence and stability of sensitivity test results should probably be explored further.

2.17. Chapter 16: Quality Assurance in NTMv5

This chapter explains the quality assurance process implemented during the model development. Table 16.1 provides a description of the model aspects that were checked, the tasks undertaken, and the nature of the checks.

Whilst this table sets out what tests have been undertaken, this does not provide sufficient information on the ways in which data, assumptions, and methods have been verified and the associated findings.

- A stand-alone technical note setting out details of the ways in which data, assumptions, and methods have been verified and the associated findings would give confidence to the users and confirm compliance with DfT’s “strengths in numbers”.

2.18. Summary and Conclusions

In general, the Quality Report has the appropriate structure and proportionate contents in each chapter considering the purpose of this report. There are some minor revisions identified that could further improve the usefulness of this report for model users with regards to better informed use of the model and correct interpretation of model outputs; these are discussed in the previous sections. There are two main points that are considered more important to ensure the Quality Report sufficiently serves it intended purpose; these are discussed below.

One specific area of concern is lack of sufficient discussion in the report around the impact of model limitations in terms of both structure and performance on specific applications of the models. The value can be added by a separate concluding section discussing these and recommending where the model outputs should be interpreted with caution and where additional verification and sensitivity testing is required.

In general, we would expect the report to set out in detail the ways in which data, assumptions and methods have been verified. Whilst Chapter 16 summarises the checks undertaken, it does not provide clarity around the checking and verification processes undertaken, and how the work has been reviewed. Documentation to provide this evidence would provide further confidence to the users and would confirm compliance with DfT's "strengths in numbers".

3. Documentation Review - User Guide

3.1. Overview: User Guide

This chapter sets out findings from a detailed review of the NTMv5 user guide and describes the areas of higher importance where the report can be improved.

The text in the user guide, although correct grammatically, is in places rather long-winded. It does not appear excessively jargon-laden (although as transport modellers themselves the auditors are perhaps not best-placed to assess this), but sentences are frequently very long, and often difficult to follow. A lot of the text, especially in the earlier higher-level chapters could be simplified, and this would make the document shorter and easier to read.

3.2. Chapter 1-Introduction and High-Level Structure

This is a very short chapter, which summarises the rest of the report. The high-level structure of the document into overview-installation-use is sensible and generally adhered to. The document really covers only *use* of the model; it is not sufficient for model maintenance, which would require access to the developer guides.

3.3. Chapter 2-Overview of NTMv5

This section provides a very short summary of the Quality Report, which is both a sensible idea and well executed. It also provides flow diagrams and tables showing the components of the model and how they fit together.

While these flow diagrams are sound in themselves, there are three of them, and it is not very obvious how each relates to the other two. Figures 2.2 and 2.3 in particular cover essentially the same area of the model in very similar detail but have slight differences; they are probably not both required.

Figure 2.1 is a higher-level plot including the systems surrounding the core model and may reasonably be justified as additional to the other two, but it could map more clearly to the terminology and structure in 2.2 and 2.3.

- We would suggest merging figures 2.2 and 2.3 and making 2.1 more consistent with these.

3.4. Chapter 3-Policy Tests, Roles and Processes

The inputs to a model run that may be varied by the user and the tasks that a user may carry out are summarised here and a framework for classifying users by experience and role is set out.

The user classification is not referred to anywhere else in any of the documentation. The tasks are helpful, but it would be useful if they, especially table 3.3, referred forward to the section of documentation in which they are explained in detail.

- Forward references in table 3.3 would be helpful.

3.5. Chapter 4-Implementation and key concepts

This is the first technical chapter and it sets out the way the model has been set up in VISUM. It is clearly targeted at a VISUM user, but is not too jargon-heavy. It outlines how VISUM concepts (e.g. Activity Pairs, Demand Strata, Main Zones) are used in NTMv5. Although the approach is described fairly completely, more tables and less text would probably make parts of it clearer to a user.

This is particularly true given that it has been necessary to use some of the VISUM concepts in a way not really intended by the VISUM developers. For instance, VISUM only allows one sector ("main zone") system to be defined at a time and NTMv5 thus combines several sectors systems into one in a neat, but unintuitive, way. This is explained in the user guide, but the explanation could be clearer

The chapter continues with tables that set out the matrices used in the model and the flow of processes run by the procedure sequence. These are well laid out and very useful.

The chapter overall feels a little technical for this position in the document. It contains information that is essential for an in-depth user to understand as is thus clearly needed somewhere in the documentation, but it might be better placed later in document, as an appendix, or even as an introductory developer guide. At this point the user has no idea how to run a model, what the model file structure is, or how to prepare inputs; so a list of matrices used within the VISUM version file seems over-detailed. These are, however, minor points.

3.6. Chapter 5-Hardware and Software Requirements

Hardware and software requirements for the model are set out here. The text probably needs more detail than it currently contains. For instance, the operating system is not mentioned. We have had difficulties in setting up python correctly with all installed libraries, and the version information here is insufficient to resolve this. Although Microsoft Office is mentioned, this is only in the context of Excel and parts of NTMv5 (the trip-end model) require Access as well. There is some reference to drive letters used by Atkins, but no reference to installation paths for the model or how important the drive letter and path are.

We would also suggest that this chapter be completely definitive about the correct versions of software to use, to minimise problems getting NTMv5 working and reproducing results. When and if a need to upgrade software versions arises, a new version of NTMv5 with updated user guide should be produced. Currently, the wording suggests that software versions are only guidelines/advice, and this could result in version control problems, particular since the VISUM version is not recorded as part of any logging of model or model run version control.

- A complete (rather than partial) set of software versions should be explicitly required by the document text,

3.7. Chapter 6-File Structure and Filing

This chapter sets out the model file structure, which seems logical, and is well explained, both in a table and a flow diagram.

There has been a general lack of sufficient attention to portability of the model across file systems and documentation of this, with large parts of the model using hard-coded absolute pathnames, some of them outside the model file structure itself, and no reference in the user guide to what path the model should be installed to. This could be significantly improved, both in the user guide and in the model setup.

As noted above, there is no discussion of where the model file structure should sit within the general filesystem of the computer upon which NTMv5 is installed.

- The user guide should explicitly set out file paths and drive letters and outline what the user would need to do to change these if they want to install the model somewhere different.

3.8. Chapter 7-Scenario Inputs

The version control scheme for the modelling leads chapter 7. The chapter then follows by describing how to edit or create inputs for NTMv5, covering highway networks and trip-ends (probably the most commonly-edited forecast inputs, and the most complex) in most detail.

- **Version Control**

The overall model is assigned a 3-element version number. It is slightly confusing that the "v5" in the title of the model “NTMv5” is missing (or implicit). This is not a serious problem.

There is a separate version numbering scheme for each type of input, as well as for the model itself. This is sensible. The user guide attempts to set out what constitutes a model version. Changes to the template .ver file are assumed to represent changes to the model version, while changes to inputs of any kind are not. This sounds clear, but it is undermined both by lack of clear definition of what a template version file should contain and inconsistent application later in this chapter. For instance:

> *There are three primary methods for making changes to the PT and active attributes, two of which involve editing the input matrices directly. The first is to create a new set of matrices prior to the run and import these in place of the base matrices, and the second is to apply changes to the base matrices within the procedure sequence. Both types of edits should be recorded in the NTM Model Version Log in the appropriate sheet, as well as creating a new model version where appropriate.*

This implies that a new set of public transport cost matrices would constitute a new model version. However, previous text suggests that inputs to the model (which include highway networks, and so should logically include public transport costs as well) would **not** constitute new model versions (although changes to the procedure sequence would).

- ➢ It is important that a clear convention is established regarding what changes would constitute a new version of NTMv5. Currently the text is not clear.

We consider that a clearer distinction between base and forecast model inputs and link between them might also be useful. NTMv5 is not a pivot-point model, and the base model does not in that sense have a special position in the process. However, NTMv5 does still have a calibrated and validated base year and parameters and incremental changes from the base year calibration are used forecasting. All forecasting is therefore based on a specific base year highway assignment, and the base model used should be tracked and documented.

All forecast networks and matrices should be based upon a particular base year version, and the version numbering does not directly link base and forecast networks, but simply treats all networks as having equivalent status.

It is also important to be clear whether a change to the base calibrated highway model (networks, or demand) does or does not constitute a model version change by itself. As currently specified, the impression given is that the answer to this is “no”, but it is not entirely clear and we think that changing the base highway model probably *should* imply a model version change.

- **Input Preparation**

  Many of the descriptions in the second part of chapter 7 on how to prepare inputs for the model assume fairly detailed knowledge of VISUM. They do contain links to section of VISUM documentation, which is helpful. However, there are cases where some VISUM experience would be required to change some model parameters; this is to be expected.

  It is clear that while the model developers have considered the possibility of "development zones" (additional zones not present in the base year added to test specific new developments), no robust and tested process to allow their use has been created.

  - Our view that the current model should be considered not to support development zones. While it is obvious that NTMv5 could be made to function with development zones, this would require some model development work.

  Generally, the information about editing model input parameters in the user guide appears sound. It does not constitute a complete guide in the case of some of the input processes (for example, the trip-end process); the user is directed via appropriate cross-references to developer guides in these cases for more detail, so it is important that these developer guides are available to users.

  We believe that a user with modelling experience, reading this chapter, will understand how to represent a policy within NTMv5.

3.9. Chapter 8-Model Running

This chapter outlines initiating, logging and monitoring a model run.

- **Version Control**

  Version control for model runs is outlined here. The scheme calls for "run numbers", "run series" and "run volumes" in increasing order of scope. Models are named using their volume and number only. We consider that the insistence on using strictly incremental run numbers and changing the run volume only when major changes are made to the system may be impractical.

  There may be a number of teams working on different applications of the NTM, using the same version. Under the convention, these would be different "run series", but run series don't have a numbering convention, so the teams would have to coordinate carefully with run numbers. They probably **should** use different run volumes in practice, but this isn't what the convention specifies. Also run volumes use single letters, meaning only 26 volumes are available. Possibly double letters may be needed eventually- runs could be named "AA" "AB" etc.

  - The DfT should consider the extent, nature and location of model uses and review the version numbering system if necessary.

  Logging of model results is then described. This is comprehensive and generally appears sensible. It is relatively onerous, to the point where it probably is not necessary to log a run to this level of detail at the testing stage of a modelling scenario. Aborted, obviously erroneous, and some immediately superseded runs possibly do not need documenting to quite this level of detail in practice. However, the full level of recording would be required for any model taken forward and used.

  It is reassuring to note that the base model on which the run is based **is** clearly described in the model log, noting the discussion in chapter 7 on a lack of clarity here.

It seems likely that much of the version control and logging specification has not been very heavily used in a practical context so far (all the existing logged runs in the log we have been given are for the base year). It may therefore be that some refinement is necessary as the process is used in practice.

- **Running a Model**

The text documents taking an initial "template" version file, applying .att files to make any required changes, pointing the procedure sequence imports at appropriate matrix input locations and making the version file ready to run, including a list of things to check prior to running.

Unfortunately, it is not entirely clear what is expected to be in a template version file. The text says

> *"As a rule, the template .ver file that is to be used for a run should contain a small number of matrices as standard"*

This is vague. The procedure sequence and some highway network must clearly be present, but which, if any, matrices are expected to be included is not outlined. It would help ensure consistent maintenance of the model across teams if this were set out.

Slightly surprisingly, nowhere does the text describe to a user how to initiate a model run. The text moves from a checklist of things to review prior to initiating a model run to a description of how to terminate a run early. A VISUM user would expect that a model run will be initiated by starting the VISUM procedure sequence from the beginning, and this is presumably what is intended, but this is not stated anywhere.

- ➢ The user guide should explicitly state how a model is run.

More discussion of resuming a crashed model from the point where it failed would be helpful. NTMv5 takes a long time to run, so this is of particular importance. There is reference to resuming from previous iterations, but not to resuming failed models in general. Model failures due to incorrect file paths appear to us to be particularly common in setting the model up on a new system.

A line

> *"Please ensure that all project directories are set to the Run folder on the E drive"*

is particularly unhelpful; this is vague and doesn't reference a particular file path. It is probably not reasonable to assume that the model will always be run on a drive mapped to "E" (and if this *is* assumed, it should have been stated earlier and more prominently in the user guide).

3.10. Chapter 9-Model Outputs

Chapter 9 sets out all the output analyses available from NTMv5, which come in two forms: analysis spreadsheets and VISUM .gpa files for producing graphical plots.

The text appears to contain all necessary information for the user to operate the model outputs. It begins by summarising what outputs are available, their functions, and advising on which are most critical to checking a model run. This is clearly essential.

However, the rest of the chapter is very long (nearly as long as the rest of the document combined). This is because it works carefully through how to operate each of the individual output processes and intersperses the text with many screenshots.

We consider that the screenshots rarely add materially to understanding and much of the detailed operational instructions might be better placed in “readme” tabs in the analysis spreadsheets, keeping this section of the user guide to a shorter summary and a pointer to the readme tabs. The analysis spreadsheets do have readmes; some of them are not sufficiently detailed to operate the spreadsheet without the user guide. This is a fairly minor point; however.

The chapter lacks any guidance on understanding whether model results are sensible and as expected, nor does it provide any advice for troubleshooting to deal with likely oddities in results (e.g. which inputs to check). It is strictly a mechanical explanation of how to use each output process.

- Supplementary guidance on interpreting outputs, investigating and diagnosing problems would be extremely helpful, if this is not included in the user guide

3.11. Summary and Conclusions

The user guide generally achieves its required goal of enabling a transport modeller with VISUM understanding to operate the model (given access to some of developer guides for coding some kinds of policy), produce and interpret outputs, and correct errors if found. It is not sufficient alone for many model maintenance tasks, for example, updating the base year model.

Its most significant weakness here is lack of clarity in drive letters, file paths, and edits required to the procedure sequence to operate the model in a new location. These are not insurmountable problems; a user is likely to eventually resolve them.

From the point of view of model maintenance and version control, more clarity and definitiveness on software versions would be the most helpful change.

There are other more minor issues that are documented above.

4. Documentation Review - Developer Guides

4.1. Overview: Developer Guides

This chapter sets out findings from a review of the NTMv5 developer guides and describes the areas of higher importance where the report can be improved. The following documents were part of the review:

- Volume 1: Model Zones and Highway Network;
- Volume 2: Base Year Demand;
- Volume 3: Highway Assignment Model;
- Volume 4: Non-Car Modes;
- Volume 5: Forecasting; and
- Volume 6: Testing.

The review process has considered both model use and implementation aspects. Recommendations are provided to improve robustness, suitability and usability of the report for model users. Recommended changes and additions to the documentation are suggested that we feel are necessary to enable a model user to:

- understand and operate the model;
- be able to prepare inputs; and
- interpret outputs whilst understanding the limitations of the model.

This review does not consider the documentation from the point of view in which a user would be required to make substantial changes to the model, such as preparing a base year model update or adding new development zones.

4.2. Volume 1: Model Zones and Highway Network

4.2.1. Overview

Volume 1 of the Developer Guides is intended to provide a detailed level of reporting on the construction of the NTMv5 model zoning and highway network.

4.2.2. Chapter 1 – Introduction to the Developer Guides

This chapter provides a more detailed description of the content of Developer Guides. It begins by setting the purpose of this set of documentation and its relationship to the other documents (Quality Report and User Guide). It also includes a simple overview of the model development process and contains information on the structure of each volume of the Developer Guides.

Section 1.1 provides a very brief description of the model and wider developer team. It then details the purpose of the documentation, it's hierarchy in relation to other model documentation and targeted audience. The Developer Guides are intended to present technical detail in the documentation and complement the Quality Report and the User Guide. This section reads well and provides a clear introduction to this set of reports.

Section 1.2 along with Figure 1.1 outlines key stages of the model development from the model specification all the way through to model completion. The list of stages seems to be complete and in a logical order. However, content of Section 1.2 is not linked in any way with the content of the developer guides to help navigate through them. Additionally, the descriptions of each stage of the process are very brief and do not cover the level of detail expected for this set of documents.

- ➢ Section 1.2 does not complement the content of the Developer Guides and does not help the reader to find relevant parts of the documentation. It is recommended that this section is removed or placed in an appropriate chapter of the Quality Report

Section 1.2.3 presents the dimensions and units used within the model. This section does not seem to fit the general structure of Section 1.2. This is important information from a perspective of a user of the mode and seems to be currently presented in a single volume of the developer guides.

- It is recommended that Section 1.2.3 is moved to a more appropriate chapter of the User Guide documentation and references are made to that section where required.

Section 1.3 describes the contents of each Developer Guide. This section is precise and provides references to relevant chapters and sections in the Quality Report and User Guide.

4.2.3. Chapter 2 – Model Coverage and Zoning

This is the first technical chapter (Chapter 2) of Volume 1 of the developer guides. The writer details both the intended methodology and requirements for the set-up of the NTMv5 model zoning system, as well as details of considerations made throughout the development, and the final methodology applied. The level of detail retained and appended to the zoning system implies that any user/analyser could receive the zoning system and trace back the methodology applied for each zone.

Section 2.1 sets out the requirements for the NTMv5 zoning. This section is incomplete as throughout this chapter references to other requirements are made. For instance, reference is made to requirements of the relationship between level of detail for the highway network and the zoning. Such requirements of which are not listed in this section.

- It is recommended that Section 2.1 is updated to account for all requirements considered during the development of the zone system.

At the end of the section, a statement is made that all requirements cannot be achieved, and trade-offs were required during the design of the zone system. This is a reasonable comment, however there is insufficient information on the decision process, such as which objectives were of a higher importance when the trade-off was made. Additionally, later in the chapter it is not clear what the trade-offs were and the associated limitations of the resulting zone system.

- It is recommended that Section 2.1 includes information on the levels of priority assigned to each objective which would help the reader to understand the decision process where all objectives could not be satisfied. It is recommended that a summary section is added to this chapter clearly stating which objectives were/were not met. Further detail should be provided to describe the limitations of the designed zone system in relation to the trade-offs undertaken during the zone system design process.

Section 2.2 intends to set out the approach for the development of the zone system. This section is very difficult to follow as there is very limited information on the content of this section. The list of stages of the zoning system development listed in the sub-section 2.2.1 does not align with the content of section 2.2 and introduces stages that are described in a different section (e.g. section 2.3).

- It is recommended that an introduction section is added at the top of the chapter that will be aligned with the content of the chapter/individual sections.

Section 2.2.2 describes the process to review the most relevant existing zone systems for the NTMv5 zoning, where most of the attention was on the RTM models. An appropriate summary is provided outlining the results of the RTM zone system review and identified challenges.

Other zone systems considered were from "PLANET, LoHAM and NTEMv6" but were quickly rejected due to significant inconsistences with MSOA and RTM. These models were not introduced in the document and abbreviations were used, making it hard for the user to understand the reference to these models. Section 2.2.3 describes the next stage of the process, to develop an initial zone system for NTMv5. As previously mentioned in the review of Section 2.1, some requirements defined in Section 2.2.3 are not aligned with the content of Section 2.1. The considerations made in this section and the methodology to develop an initial zoning system are clear and easy to follow.

Section 2.2.4 describes the process undertaken to split the zones into internal/external areas. This section reads well and appropriate amount of detail is provided to understand the methodology.

Section 2.2.5 describes the considerations that were made in relation to zone aggregation in the urban areas within the initial zoning system to meet the requirements for the final zoning system. This section provides enough detail explaining the requirements and associated issues. The final conclusions, explaining the decision process, are clear and justified. However, as previously mentioned in this report, the requirements in this section are not in line with those described in Section 2.1.

Section 2.3 sets out the methodology for setting the locations of zone centroids, as well as the approach taken with respect to ports, airports, and freight hubs. In some instances, these bespoke zones were created as point zones or by splitting existing MSOA zones. The approach seems reasonable and further sections add more detail to this methodology.

The methodology for creating Major Attraction zones in Section 2.3.3 is described through the application of a series of rules, based on workplace ONS data which contains total employment in each MSOA. The text reads:

To help identify such locations a series of rules were created as listed below:

1. Total the workplace employment data to MSOA level. Select MSOAs of more than 10,000 employment places and with a population / employment ratio of less than one.

2. Review total employment by workplace zone across MSOAs selected in step 1. If the difference in total employment across workplace zones is no more than 2,000 total employment then ignore as a potential bespoke zone candidate.

3. If there are workplace zones with more than 2,000 total employment compared to neighbouring workplace zones within an MSOA then include as a candidate.

The second and third rules in the list are difficult to understand.

- It is recommended that the second and third rule in the list of 2.3.3 is rewritten to allow the reader to more readily understand the process followed.

Section 2.4 provides detail on the process used to rezone demand and cost matrices following further splitting/aggregation of model zones. The three checks referenced seem suitable and it is noted that the process undertaken was reliable. This chapter is intended for the development of the zoning system. Although impacts of the methodology used for developing the zoning system, such as matrix adjustments due to zone aggregation/disaggregation, should be (and are) considered in this section, the actual methodology for adjusting the matrices does not fit in well with the content of this chapter. This could easily be missed by the reader if not referenced/documented in the relevant sections of the matrix development or matrix data inputs.

- It is recommended that the actual methodology for adjusting matrices due to zone aggregation/disaggregation in section 2.4 is removed and documented in the relevant sections of the matrix data inputs/matrix development sections.

Section 2.5 provides details of the attributes included in the zoning system of which all seem reasonable.

Section 2.6 sets out the sector systems available defined in the model which seems suitable.

Section 2.7 sets out the additional attributes available. Zone attributes are already covered in section 2.5 therefore combining these two sections would make it easier for the reader to follow the chapter.

- It is recommended that Sections 2.5 and 2.7 are combined as both report on zone attributes.

Section 2.8 is the chapter summary. The detailed zone system summary in table 2.3 and a plot of the zone system in figure 2.4 provide an appropriate level of detail for the zone system developed.

4.2.4. Chapter 3 – Highway network development

This chapter describes the process of developing the HAM network and the corresponding quality assurance undertaken.

Section 3.2 introduces the five RTMs and its corresponding versions used to develop the NTMv5 model. The section lists out the initial checks carried out on the received RTM models in SATURN and highlights some of the issues identified as part of the checks. Although it is mentioned that the issues have been addressed, no further information on the number of issues identified, the severity of the issues and its effect on the existing RTM models have been detailed. This is important as it would help users understand better the network quality while undertaking any tests and may also help DfT to resolve these issues in the future version of the NTM Highway Network. The absence of this information also precludes the use of RTMs as a source for forecasting assumptions.

- It is recommended that further details are provided on the issues identified on the RTM network and impacts associated with the changes. This will aid a better understanding of the network quality whilst undertaking tests and also help DfT to resolve the identified issues in any future NTM development

Section 3.2.2 explains the process adopted to combine the five RTM networks into one network. The explanation is concise and easy to follow.

Section 3.2.3 describes the process involved in exporting the SATURN RTM network into VISUM. Whilst the process described is brief and easy to understand, no additional information is provided on the level of complexity involved and challenges faced, if any, in obtaining the curved links using SATVIEW tool. The process seems to be straightforward which in practice usually is not the case. For instance, for a small roundabout depicted by a single node in SATURN, multiple links and nodes in SATVIEW are produced to map out the circulatory lanes. This can cause inconsistency between the two networks.

- ➢ It is recommended that further details are provided on the issues identified on the RTM network and its associated effect.

Section 3.3 sets out the process adopted to produce centroid connectors for the 7,000 zones in the model. An inherent automatic process in VISUM was adopted to produce the initial centroid connectors which is then expected to be refined later during the model calibration and validation stage. This section explains in detail the principles adopted to produce connectors in line with TAG Unit M3.1 and the assumptions in the VISUM process. Additionally, to determine the maximum number of connectors for each zone, zone loadings were approximated using the NTEM data and certain statistical analyses were carried out. However, the information is vague and there is no detailed explanation on the type of statistical analyses carried out. A summary table indicating the scale of multiple connectors (per zone) applied in the model would also be a useful piece of information for this section as it can have a significant impact on the model performance if applied extensively.

- ➢ It is recommended that additional information is provided on the types of statistical analysis carried out to determine zone loadings along with a summary to quantify the number of centroid connectors generated and the scale of zones with multiple connectors.

Section 3.4 explains the two types of link attributes required on highway network. The first set of link attributes which includes distance, cost and time are briefly mentioned and references to more detailed sections are provided. The second set of link attributes are mentioned to be those which are helpful for analysis and scenario testing. However, further information or references to other sections for those attributes are not provided.

- ➢ It is recommended to include references to other sections and/or additional information in section 3.4 for attributes related to the scenario testing.

Section 3.5 details the link types and Volume Delay Function (VDFs) adopted in the HAM. The link types defined in RTMs are applied in the NTMv5 highway network with scope for further refinement and expansion during the calibration process. These link types are defined with specific free flow speed and capacity.

Additional link types were also applied to the different slip roads based on road intersect type. The free flow speed for these link types are depicted in Table 3.1. However, there is no discussion about the associated capacity.

- ➢ It is recommended to include information on the capacity applied for the new link types for different slip roads.

Section 3.5.2 provides a detailed explanation on the adoption of the appropriate VDF. A clear and detailed comparison is made between the Speed Flow Curve (SFC) in SATURN and different VDFs available in VISUM. The limitations in adopting the BPR function is clearly explained using numerical analysis. BPR type 3 VDF function along with a factor is deemed more appropriate to replicate the SATURN SFC. This is based on detailed analysis and is explained very well in the report.

It is worth to note that while comparing the speed flow relationship between SATURN SFC and VISUM BPR, in an instance where the arriving flow exceeds capacity, it is mentioned that delay derived from SATURN SFC reflects the magnitude of delay that drivers experience. However, no further explanation is provided to indicate if this statement is based on any previous research or purely an assumption.

- ➢ It is recommended to provide additional information on the evidence/research that led to the decision to conclude if the delay derived from SATURN SFC when arriving flow exceeds capacity reflects the reality.

Section 3.6 explains the fixed speed approach adopted in the central area of major cities and towns along with its limitations. It clearly highlights the areas where fixed speed approach was adopted and contains sufficient level of detail.

References in section 3.6 are out of date, should refer to 11.4 of Quality document and Section 7 of the Develop Guide Volume 5

- ➢ It is recommended that references to other documents in section 3.6 are corrected

Section 3.7 explains the approach adopted to junction modelling in VISUM. It clearly mentions that the Intersection Capacity Analysis (ICA) was not used, instead a simplified and proportionate junction model is proposed to capture delays occurring at junctions.

This section does not provide enough detail for the reader to assess the impact and extent of the methodology deployed. Types of junctions considered in the methodology are not explicitly provided in this section. Similarly, the description of the extent (model areas) and relationship of junction coding to different representation of link delay (e.g. areas with fixed speed network and areas with VDF functions) is incomplete.

- ➢ It is recommended that section 3.7 provide clear explanations on where the simplified junction modelling approach was deployed and how it complements the representation of link delays in those areas where applied.

Additionally, no consideration has been given throughout the report to merge nodes, an important aspect of strategic networks.

- ➢ It is recommended that some text is provided in this section or as a separate section within this chapter, on what consideration has been given to the merge nodes and, either a methodology used to model those, or an explanation why these have not been accounted for in the model.

Whilst some of the parameters used in the approach referred to as “standard turn delay table” are defined in the text, this information is not presented in this section. For consistency purposes, this information is critical when a user needs to code a new scheme. Without this information the consistency of coding between the existing and new network would be compromised.

- ➢ It is recommended to include the standard values adopted in the turning movement delay calculations based on junction type along with the source of information. This is critical for consistency purpose when a user needs to code a new scheme.

Section 3.8 discusses the Generalised Cost for route choice by each user class in the HAM. The source of VOT and VOC values and assumptions are clearly explained in the section. The final values of VOT and VOC for each user class are clearly depicted in table 3.4 and table 3.5 including all units.

Section 3.9 discusses the Road User Charging (RUC) for London and tolls coded in the HAM network. It clearly tables out each toll road along with the toll price in pence for each user class. A brief explanation on the approach adopted in VISUM to incorporate the RUC/tolls is also discussed along with some implications which seem reasonable and clear.

Section 3.10 focuses on the HGV restrictions applied to certain links within the NTMv5 network. It clearly explains where the restrictions have been applied. The Ordnance Survey Highways Geodatabase was used to extract the location of the restrictions. A list of HGV restrictions on A Roads applied is provided. However, detailed information on the start and end points of the restriction along a section of the road is not clearly mentioned.

- It is recommended that additional information is provided on the exact start and end points of HGV restrictions for each road mentioned in the list.

Section 3.11 discusses the inclusion of PSV as pre-loads into the network. It explains the source of the information used and the approach adopted to load the preload data into the NTMv5 network. Within this section it is stated that bus flows calculated are lower than DfT PSV counts in almost all cases for a small sample used for comparison. This statement cannot be fully commented on, as the scale of issue is not quantified but the explanation provided by the model developer seems reasonable.

- It is recommended that further detail is provided to inform the user of the scale of disproportion between bus preload flows and DfT PSV counts.

Additionally, no further information is available on the implemented PCU factor for pre-loads adopted in the model.

- It is recommended to provide information on the PCU factor adopted for the Public Service Vehicles in the model

Section 3.12 discusses the Quality Assurance approach adopted in line with the DfT's *Quality Assurance for Analytical Modelling guidelines14*. The document sets out five different tests. Each test inspects in detail the quality of the network and associated evidence. Network statistics are also discussed in detail by comparing the road length by road type and region against the DfT 2015 Road Statistics. Link lengths are also checked against crow-fly distance followed by detailed explanation on the differences. Additionally, tests to check whether the route choice between OD pairs are logical were also carried out for an agreed series of OD pairs. It is observed that sufficient tests on routing and quality was undertaken to advise users of the accuracy of network coding.

Appendix A contains information on the 50 HAM link types imported from SATURN. Each link type contains appropriate level of detail in terms of number of lanes, type, SATURN SFC and VISUM BPR3 VDF parameters. The information seems sufficient to help a user code the specified links for future projects.

Appendix B reviews 45 sample OD routes against Google Maps routing. It includes sufficient information on the origin, destination and the performance of the route against Google Maps. A user is able to clearly understand the overall performance of the specified routes.

4.3. Volume 2: Base Year Demand

4.3.1. Overview

Volume 2 of the Developer Guides describes the base year demand and the associated matrix development process.

4.3.2. Chapter 1 – Introduction

This is a very short chapter, which summarises the rest of the report. The high-level structure of the document is sensible, with helpful references to the Quality Report and other supporting documents when needed.

4.3.3. Chapter 2 – Overview of methodology

This chapter presents the overall approach followed to build prior base year personal trip matrix. The purpose of the chapter is not to provide any particular detail of any individual procedure, but to familiarise the reader with the main procedures of the car matrix development process followed in NTM.

4.3.4. Chapter 3 – Data for base year matrix building

Chapter 3 introduces the data used for the base year matrix development. Details about these datasets are presented only for the NTEM trip rates, National Population Database, Schools Census and Highways England's Trip Information System. It would be more helpful to report some information about all the datasets which have been used in the process.

- It is recommended to have a summary table of which datasets from list presented in Section 3.1 were used in the matrix development process, together with a concise explanation of strengths and limitations, and how the data were used.

4.3.5. Chapter 4 – Base year trip ends

This chapter presents the process followed to generate the base year trip ends. It is a well-structured section, reporting with adequate details the stepwise approach to build trip ends, separately for home-based and non-home-based trips.

However, for completeness and according to the since published TAG M2.2, a trip rate comparison should be included between the underlying trip ends and the National Travel Survey (NTS) dataset. However, we understand that there was no such guidance when NTM base year demand was built.

Whilst the structure of this section overall seems appropriate, a more detailed review of the technical details included in this section will be undertaken at a later stage alongside the model implementation review process.

4.3.6. Chapter 5 – Base year personal highway matrices

In this chapter, the process used to build base year matrices is being presented. It shows with enough details the matrix development process for commuting and education trip purposes in separate sub-chapters as it is different than the process followed for all the other personal travel purposes, which is being illustrated in a single chapter.

Also, the matrix development process is being reported for the external trips, personal LGV trips, airports and ports surface access trips.

In reporting on the synthetic matrices for personal travel purposes, the parameters of the gravity model were reported and also provided in the logfiles. The estimated parameters in those logfiles are consistent with the reported table (Table 5.14 of the 'NTM Dev Guide Vol2-BY Demand v2.0').

In the sub-chapter explaining the development of airport trips, a number of parameters do not appear to be reported in section 5.6.2 of the 'NTM Dev Guide Vol2-BY Demand v2.0' but are used in the airport matrices development process. It is thus recommended to include the following in the documentation:

- the number by which monthly data is divided to get a 'normal' weekday demand;
- number of weekdays in March;
- percentage of demand for March 2015 figures; and
- percentage of 'no mode' demand which was assigned to either car or taxis was mentioned in the report but not tabulated.

In all the sub-chapters a detailed validation section is missing. The validation presented in the Chapter 5, is related only to trip length profiles.

- It is recommended to provide a summary of matrix verification for the base year matrices. The verification results should not only include comparison of trip length profiles, but also, trip rates analysis, trip purpose and time period splits and confirmation of their consistency with NTS, along with sector-to-sector comparison plots to test matrix symmetry. For commuting and education matrices, some independent verification with NTS should be possible and would add value. This would provide the user a clearer picture of the base year matrices used in NTM.

4.3.7. Chapter 6 – Weekend demand

This chapter presents the weekend demand which was originally suggested to be introduced to the model but eventually it was agreed not to be included. Hence, this short chapter is just for reference without having a role in the matrix development process.

4.3.8. Chapter 7 – Base year freight vehicle matrices

This chapter presents a light summary of the base year freight matrix development developed by MDS Transmodal. More information about the data and methodology used to build freight matrices is being presented in the "HGV & Van Origin-Destination Matrix Documentation for National Transport Model" report which was not reviewed in this draft document.

4.4. Volume 3: Highway Assignment Model

4.4.1. Overview

Volume 3 of the Developer Guides describes the implementation of the NTMv5 highway assignment model (HAM) and the calibration/validation process.

4.4.2. Chapter 1 - Introduction

This short chapter introduces this volume of the developer guide, setting the context of the volume with respect to the other volumes in the Developer Guide. References are made to other elements of the suite of documents to aid understanding.

4.4.3. Chapter 2 - Initial Testing of HAM

This chapter describes the initial process undertaken to check the feasibility of building and operating the NTMv5 in PTV Visum.

Section 2.1 introduces the chapter, outlining the tests to check if PTV Visum could accommodate the model, and if so whether it could feasibly assign it within desired run times. It surmises that the tests successfully showed that they could be. As an overview, this is sufficient summary of the chapter. However, this effectively acts as an executive summary rather than an introduction.

Section 2.2 details the tests undertaken to assess the feasibility of using the PTV Visum software. It describes how a first-cut network of the proposed NTMv5 model was used to undertake the tests, along with existing "PTV Validate UK" model as a comparator. No explanation is provided of what the PTV Validate UK model is, or its relevance for a comparison with respect to the purpose of the tests. Whilst it is described that using the PTV Validate UK is to provide "slightly more certainty on the range of possible outcomes", the lack of context undermines this statement.

Table 2.1 outlines some high-level information about the two models being used in the tests (PTV Validate UK and NTMv5). The volume of information is suitable and provides enough information for an experienced modeller to benchmark subsequent test results. The description of the table in the body of the text is misleading however and should be modified to explain the table outlined the models, not the tests that are to be undertaken.

Table 2.2 and Table 2.3 outline the results of the feasibility tests undertaken, the former for the PTV Validate UK model and the later for the NTMv5 model. Tests have been undertaken using three assignments methods available in Visum, namely LUCE, Lohse and Standard Equilibrium. The tables provide sufficient information to understand how quickly each of the models converged for each method, along with a measure of convergence (GAP). The subsequent discussion of the information in the tables appears reasonable, weighing up the various merits of the run times versus convergence in the tests. A number of caveats are also provided which could affect run times at a subsequent stage. These caveats appear reasonable.

Whilst it is described that the tests are being undertaken to assess the feasibility of the model against the desired run times, the actual criteria that is being aimed for is not defined. Whilst a reference to the target run time is made at the end of the discussion (4 supply-demand iterations in 48 hours), it is not made clear if this is the specific target being aimed for or if it is only a target. No information is provided on the machine used to achieve the run-times either. Providing information on machine specification would put these times into context for the reader.

- Clearly stating the specified run times / performance criteria that tests are checking for initial conformity, would assist the reader in judging the reported test outcomes against this.

Whilst it was not a stated purpose of the tests, the tests appear to have also been used to inform a preference on the type of assignment (LUCE) to be used for the NTMv5 model "going forward".

Section 2.3, titled "Final implementation", briefly states that the assumptions described in the previous section were carried forward and that *"a number of indicators, such as run time, convergence and link stability, were monitored to ensure the working assumption of LUCE was still the best option."* This appears to confirm that LUCE is adopted as the assignment method, but it is not stated. The method of assignment is not mentioned at any point in the following chapters of the volume.

- ➢ It is recommended that the decision around the assignment method in the model be more clearly documented, along with all factors and checks that informed this decision.

4.4.4. Chapter 3 – Generalised Costs

Chapter 3 provides information on the Generalised Costs used within the model and the nature of their application.

The chapter provides sufficient information for an experienced model user to understand how the values of time and values of costs have been derived and details the source of the assumptions made. The only surprising result is that the average network speed for HGVs (65 km/hr) is as high as that of car business trips (also 65 km/hr).

- ➢ It is recommended that some evidence or justification for the average speed by purpose is provided, as it is somewhat surprising that average business car trips and HGV trips are reported to be the same.

The chapter describes the calibration of, and the justification for, the factor used to increase the value of time for HGVs in line with TAG.

4.4.5. Chapter 4 – Data for Calibration and Validation

Chapter 4 provides information on the traffic count data and journey time data used in the model, and how it has been used to develop the model screenlines and journey time routes. **Section 4.1** of the chapter summarises as much but fails to mention that the chapter covers journey time data and journey time routes (i.e. Section 4.3 of the chapter).

- ➢ It is recommended the introduction be updated to reflect the full contents of the chapter.

Section 4.2 focuses on the traffic counts and the logic used to form them into screenlines. The section details how data has been taken from Highways England's Regional Traffic Models (RTM) for use in developing the model. The use of this data is sensible due to the described alignment between the RTMs base year and time periods with that of the NTMv5. However, it is worth noting that HE's focus is the Strategic Road Network, and the RTMs (along with the data collection for them) reflects this. There is no reference to any data collection that may have occurred in urban areas / on local authority roads to compensate for this. Additionally, the informal reference of the data being "carried through the RTMs" jarring as the context of what the RTM's are has not been set.

- ➢ It is recommended that documentation be provided for the consideration of urban areas / local authority roads when deciding upon count sites / screenlines. The reference to the RTMs should also be formalised for readers that may be unfamiliar to the RTMs.

The section focuses on the "quality" of the counts being used, as defined by the RTMs development teams. Whilst the overview of the quality scoring system is suitable to the body of the text, the subsequent scores provided in Table 4.1 do not have the required supporting information to explain what each of the specified quality scores represent. Without providing the scoring criteria, the scores do not have any meaning.

- ➢ It is recommended that the scoring criteria used to score the counts be provided with the report.

Subsequent to Table 4.2 is a small paragraph describing the use of counts from the DfT counts database to “supplement” the counts retrieved from the RTMs. The description of these counts is largely accurate, though it may be beneficial to mention that for many years these counts are also estimated and not based on observed counts. Whilst it is stated these counts are only used for infilling where RTM TRADS counts are unavailable, it would be useful to supply a final proportional mix of counts from the RTMs and counts from the DfT Count Database.

- ➢ It is recommended that the final proportion of counts from the RTMs and the DfT Count Database be outlined as part of the report.

Finally, the section relies on the use of the term “TRADS” for Highways England’s count database. TRADS is now a defunct system and the use of the term is a dated reference, with the system being replaced by “WebTRIS”.

- ➢ Whilst it is acknowledged the counts may have been originally extracted from the TRADS system, it is recommended that WebTRIS in its current form be referenced (in addition to TRADS) to aid reader comprehension.

Section 4.2.2 describes the process of forming the screenlines to be used within the model. It provides a description of what screenlines are, how the screenlines (and mini-screenlines) have been based on those of the RTMs and the approach to infill gaps that exist in the selected screenlines. Whilst the section provides information on the approach to infilling gaps on screenlines and introducing new screenline cordons around urban areas, it does not outline the approach taken to produce the redrawn screenlines.

- ➢ It is recommended that a paragraph be added outlining the approach to selecting screenlines in the model.

It is specified that with the agreement of the DfT, all screenlines have been used in calibration and individual link counts used in validation. No information is provided on the split of counts between calibration and validation however. Whilst this provides a random overview of performance, it prevents any validation checks on the underlying shape of the prior matrix / level of distortion being undertaken as part of matrix estimation.

- ➢ It would be useful to provide the resulting proportional split of counts in calibration and those in validation. It should also be noted the lack of use of validation screenlines prevents the ability to undertaken validation checks on the matrix shape.

Following the report text, four figures are provided namely Figure 4.1 to Figure 4.4. Figure 4.1 displays the gaps in the screenlines, coloured according to the whether the gap is on a major or minor road. The formatting and resolution of the figure means that interpreting the location of the gaps is difficult.

- ➢ It is recommended that Figure 4.1 be updated to more clearly allow identification of the screenline gaps.

Figure 4.2 shows the extent of the screenlines, with Figure 4.2 showing the extent of the mini-screenlines. These provide a suitable overview of the extent of the screenlines and the general spatial coverage of them. It is not possible to make out specific screenlines and their exact coverage though. Figure 4.4 finally shows the location of the screenline counts and ad-hoc counts. Whilst it is specified that all counts on screenlines are in calibration it is explicitly stated that all ad-hoc sites are in validation. On the assumption that they are, Figure 4.4 therefore provides the spread of calibration and validation. The scale of count sites being used nationwide means that the suitability of the calibration and validation sites and their coverage can not be confirmed from the image. If the purpose of the image, and indeed the previous three images, is to provide a general overview of the coverage, the images are satisfactory. However, if they are there to give a detailed presentation of the screenlines / counts and their suitability of use, more detailed (i.e. zoomed in) imagery is required.

- If the purpose of Figures 4.1 – 4.4 is to provide detailed information on coverage and extent, more detailed imagery is required to allow this information to be ascertained.

Reviewing the coverage of the counts as a whole, both individually and in respect of the positioning on screenlines, it appears their coverage is designed to capture movements at an intra/inter regional level. Shorter-trips between neighbouring local-authorities would likely be missed unless they intersected the SRN. Whilst this is understandable given the national nature of the model, it reduces the capability of the model to assess trips under approximately 50km (based on the rough distance between screenlines displayed in Figure 4.2.

Section 4.3 sets out the approach to developing the journey time validation routes.

Section 4.3.1 details four principles that were used to select the journey time routes, along with some high-level information on the resulting number of routes selected. The first two principles pertaining to the type of road used and the avoidance of fixed-speed areas are sensible.

The third principle looks at the length of the route. It makes the case that the usual TAG criteria that routes should be between 3km and 15km isn't relevant because the NTMv5 is focused on long distance strategic movements. It specifically goes on to state:

> *"Analysis from Google Map API data shows that typically the average travel speed for longer distance traffic is around 85-90 km/hour. The journey time routes would have a length up to 110 km, to keep journey duration to around 1 hour;"*

The logic for using the longer journey time routes seemingly ignores the principle that using limited-length routes prevents routes becoming so long that the aggregate statistics of the route inadvertently (or otherwise) validate, whilst performance along the route at a disaggregate level may be poor. A journey time of an hour has a validation range of 18 minutes (+/- 9 mins from 15% criteria). This therefore undermines confidence in the journey time validation achieved if the statistics are not suitably reported at a later stage.

The fourth principle details cutting the routes into segments, up to a maximum of 20 per route. No information is provided on the logic used to decide how many segments to create per route, other than "appropriate timing points". Cutting the large routes into segments however does allow for more confidence in the journey time validation to be gained if these are used for the purposes of validation.

- It is recommended that information be provided on how segments were selected (e.g. length) and a breakdown provided (perhaps in an Appendix) detailing the segments per route. These segments should then be used as the bases for validation.

The discussion following the principles states that that there are 45 journey time routes in England, with some additional statistics provided of what this represents with respect to the network. It is then stated that routes crossing regions (presumably RTM regions) need to be split further, but the following example of the route on the M1 seems to suggest the logic for splitting is based on distance regardless of where the resulting sections are. The paragraph concludes that there are actually 101 journey time routes after this process is undertaken. The phrasing of this paragraph is confusing, and it took multiple attempts at reading the paragraph to interpret it in the described way. The additional splitting per region appears to be a key part of the final route selection and it is not clear why this has not been described and presented as a fifth principle, rather than added in a concluding paragraph.

- It is recommended this paragraph be rephrased to more clearly stated the outcomes of creating the journey time routes and journey time segments, and integrate the information pertaining to route splitting into the previous principle listing section.

Section 4.3.2 briefly details the process employed to generate the journey time routes from the NTMv5 model links. It provides a plot in Figure 4.5 to evidence that the length of the journey time routes in one direction correlates with that of the opposite direction. Whilst this provides confidence that the lengths are the same, it does not prove that the routes themselves are correct, or that both directions follow the same route. More concerningly, the plot shows a large number of routes which are seemingly in excess of 110km, with the largest around 190km. This undermines the information provided in the previous section and calls into question what routes have been created and how.

- It is recommended that the Section 4.3.1 be updated to reflect the actual process employed to develop the journey time routes, considering the fact routes do not seem to abide by the principles defined.

Section 4.3.3 details the TrafficMaster data used to derive the observed journey times and the process used to create the journey time routes within the associated TrafficMaster ITN layer. It details how "in-house" python scripts were used to generate the routes and explains that there were two issues. The first is that a number of TrafficMaster links on the routes identified had no associated journey time data. The number of ITN links with missing data per time period is detailed in Table 4.2. Presenting the data in such a way is unhelpful, as it does not provide any context to allow the reader to understand the scale of the issue.

- It is recommended that context be provided to data in Table 4.2 (such as percentage coverage) to allow understanding of the issue.

The second issue is that the in-house process was unable to fully match the ITN layer to the NTMv5 network links. As manually fixing was deemed "onerous", it was decided to infill the gaps using "*average speed of the available ITN links in the journey time section".* No statistics to the scale of this issue are provided in the body of the text, with the reader referred to Appendix A for more information. When Appendix A is observed, it becomes apparent that a large number of journey time routes have a reasonably high proportion of estimated data applied to them (up to 53% infilled and 7.6% of total journey time route distance).

- ➢ It is recommended that the scale of journey time data infilling be displayed more prominently in the main report.

In addition, it is foreseen that the scale of the infilling may be problematic in ensuring validation has been truly achieved and this may wish to be reviewed.

- ➢ It is recommended that the level of TrafficMaster journey time route infilling be reviewed to ensure the integrity of journey time validation is not being compromised.

Finally, there appears to be 164 journey time routes listed in Appendix A. It is not apparent how this number correlates to the 45 routes in England or 101 “total” routes described in previous sections.

- ➢ It is recommended that an explanation is provided in the report as to how the 164 routes listed in Appendix A correlate with the information provided in the body of the main report.

Section 4.3.4 provides a summary of the journey time sections and provides a figure showing the 101 described journey time routes. The figure is suitable for providing a brief overview of where the routes are and their coverage.

4.4.6. Chapter 5 – Network Calibration and Validation

Chapter 5 provides information on the aspects of the model network that were reviewed as part of the iterative process of model calibration and validation.

Section 5.1 provides, for each of the four iterations that were undertaken, a bullet pointed list detailing the aspects of the network that were updated. The introduction to the iterations, along with the overview of what occurred in each iteration, is proportionate and assists in the understanding of the type of network changes undertaken. The aspects addressed in each iteration also appear proportionate and sensible. The section finishes by stating that the following report sections will detail the *“more significant strands of work*” undertaken in the four iterations.

Section 5.2 considers the placement of zone connectors, with sections 5.2.1, 5.2.2 and 5.2.3 looking at connectors crossing screenlines, connectors crossing/joining motorways and connectors crossing/joining other one-way links respectively. The information provided on the issue, the approach taken to address it and the scale of the issue are all covered proportionally and reasonably.

Section 5.3 covers the review of link types, describing how some *“very short links on major roads”* links appear to have invalid link types associated with them and how these were modified. Again, the issue is described well and the resolution process also understandable. The scale of the issue is not quantified however, and there is no information provided to confirm if all problematic links were rectified.

- ➢ Information should be provided on the scale of the issue documented and the success achieved at rectifying the issue.

Section 5.4 covers network updates made in the Midlands RTM area. It describes that the area was found to have a high number of anomalies, and that an updated version of the Midlands RTM network was provided at too late a stage to be integrated into the NTMv5 network. Whilst these anomalies were presumably rectified, it isn’t stated in the report. The report instead focuses on specific changes made to the area which seem to be to incorporate some of the changes from the second version of the Midlands RTM into the NTMv5 network.

- It would assist the reader if this paragraph was amended to clarify if the anomalies were rectified and how that interfaces with the apparent subsequent changes due to the second cut of the Midlands RTM area.

Section 5.5 displays a figure of the final form of the HAM network after the discussed iterations were completed. The resolution and colouring should be enhanced to improve the legibility and quality of the image (specifically the presence of B roads).

- The figure in Section 5.5 should be improved to enhance quality and legibility.

Section 5.6 describes the validation of route choice undertaken in the model. The approach taken to check route choice appears sensible, with details of each route checked detailed in Appendix B, along with information on any deviation from the expected route. Figure 5.2 and Figure 5.3 also display an example of the route choice between Doncaster and Newcastle. Whilst the figures are illustrative of what a route choice check looks like and the table provided in the appendix provides a breakdown of each route, there is no summary information provided in the main body of the report to allow the reader to gain a feel for the overall success of the tests detailed in the Appendix.

- It is recommended that summary statistics be provided in the main report to allow an overarching understanding of the results of the route choice tests.

Section 5.7 described a validation check that was undertaken to assess the volume of flows on centroid connectors across the model, respective of the TAG requirement that flows on connectors should not exceed 400 vehs/hr. The reasoning for connectors exceeding this limit in this type of model is reasonable, and the summary information provided in Table 5.1 and Figure 5.4 provide confidence at a high-level that loadings in the model are reasonable.

4.4.7. Chapter 6 – Matrix Improvements

Chapter 6 provides information on the changes made to the prior matrix to enhance performance in Matrix Estimation (ME).

Section 6.1 introduces the chapter, stating in general terms what the following sections cover. It also states briefly what the ME results were used for, namely shaping the 24 PA matrix and producing the Post-ME assignment matrices.

Section 6.2 describes the approach taken to ME. **Section 6.2.1** details the two matrix estimation methods available in Visum (T-Flow Fuzzy and Method of Least Squares [MoLS]) and the approach taken to select which option was best. This section could be arguably shortened to remove the theory behind the two ME approaches as it is not relevant to understand why the specific method used was chosen (i.e. MoLS because the test of T-Flow Fuzzy failed).

- It is recommended this section is be distilled to focus simply on what ME approach was used and why.

Section 6.2.2 describes the way the approach to undertaking ME was developed. The first paragraph explains that the Visum defaults were generally adopted for the MoLS parameters described in the previous section. It would arguably make more sense to include this paragraph in the previous section as it relates specifically to the information being described within.

- It is recommended that the first paragraph of Section 6.2.2 be moved to the end of Section 6.2.1.

The following element of the section describes the approach to grouping counts in ME (screenlines, mini-screenlines or individual links). The report states *"the use of screenline constraints alone during matrix estimation did not improve individual link calibration to the same degree".* It is hypothesised that the reason for this is due (in brief) to the synthetic nature of the prior matrices. This explanation appears somewhat convoluted, as only constraining ME to link counts allows ME more degrees of freedom as compared to constraining to screenline groups. This therefore will always lead to a higher level of link flow calibration. The reason for TAG recommending that ME be undertaken at a screenline level is two-fold – to avoid overly distorting the strategic movements in the prior matrix and to avoid ME undertaking matrix changes to account for network assignment issues. In this respect, the adopted approach of estimating using mini-screenlines and individual link-counts appears reasonable if there is reduced confidence in the strategic movements and the use of mini-screenlines is applied sensitively and responsibly. However, this is not what the paragraph currently describes and no evidence is provided of how this has been approached.

- It is recommended that section be rephrased to address the reasoning behind the use of mini-screenlines and links flows in ME as opposed to screenlines.

The final element of the section details the approach to grouping Assignment User Classes in ME. The logic and decision to use three groups (Car, LGV and HGV) described in the report appears reasonable.

Section 6.3 describes the way the matrix has been shaped prior to it undergoing ME.

Section 6.3.1 is titled "Refinements to data and parameters", however it focuses on the principle of adjusting the method of creating OD matrices from the PA matrices by adding a distance band factor into the process. Using information from the NTS, these distance bands have the purpose of splitting personal van trips from car trips and assisting in splitting the 24 hour PA trips into the relevant model time periods. Whilst the general principle is described and some generic information on the bands provided in Tables 6.1 and 6.2, there is not enough information to understand how these factors interact with the overall approach of converting the PA matrices into the assignment OD matrices. Furthermore, the scale of impact of using distance as an additional method of disaggregation is not quantified (as opposed to not using distance bands). As such, the section provides little information other than simply stating the matrix has been split into car/LGV vehicles classes using some distance bands. Finally, acronyms are used for the trip purposes, with no definition provided of what these acronyms are.

- It is recommended that the section be expanded to explain how the distance factors interact with the overall process of converting from PA to OD matrices, providing more detail on the banding used per trip purpose, and provide a definition of each trip purpose acronym.

Section 6.3.2 describes factors that have been derived and applied to further shape the 24 hour P/A matrix based on trip length distributions of the post-estimated matrices compared to observed data (NTS, Census Journey to Work etc). These factors have been derived and applied on a trip purpose level per distance band. As post-estimation OD matrices will be grouped by AUC (not at trip purpose level), it is unclear how individual factors per trip purpose have been derived from the post-estimated AUC matrices. If the prior matrices are based on other sources (e.g. the RTM prior matrices), it is understandable why the adjustments described have been undertaken. However, if the synthetic prior matrices have been developed specifically for the NTMv5, a better approach to improving the matrices if deficiencies were detected would have been to refine the parameters used to generate the PA matrices. In addition, insufficient information is provided in the report to allow a reader to determine if the factors actually applied are reasonable.

- It is recommended the reasoning for applying shaping factors and not adjusting the PA matrix production parameters be justified, and some sample graphs are provided to show the effects of applying the factors described.

Section 6.3.3 describes an adjustment to occupancy factors to control traffic levels in the model. Whilst no data is provided as to the before and after occupancies, it is stated that these are within range of the standard occupancy statistics available (NTS, Census JTW and those in the TAG databook).

- It is recommended that the occupancy statistics and the occupancies adopted in the model be provided for comparison by the reader.

Section 6.3.4 describes an adjustment to productions and attractions on the Isle of Wight "*to ensure that a reasonable number of trips cross to and from the mainland in a 24-hour period"*. The principle of this adjustment is reasonable. However, no explanation is provided as to why/how this was identified to be an issue and is the issue is isolated to this specific ferry crossing. The table provided in the section (Table 6.4) is not introduced in the body of the text and it is not completely clear if these are Productions and Attractions before the adjustments or after. The table also has no context (such as the mentioned ferry counts), so it is not clear if the figures are reasonable.

- It is recommended that method of issue identification be detailed and clarity on the potential extent of issue (isolated or potential for issues at other crossings) be documented. Table 6.4 should also be introduced and its relevance clarified.

Section 6.3.5 describes adjustments made per trip purpose at a sector level. These adjustments have been informed the performance of assignments of the matrices. A list of sample adjustments is provided showing that adjustments have been made per trip purpose – not Assignment User Classes. Whilst the principle of applying sectorial adjustments based on assignment performance is reasonable, it is not clear how it has been possible to apply changes to specific trip purposes without basing this on underlying demographic / population data.

- Providing more information as to how sectorial adjustments have been developed would provide confidence to their suitability.

The sectors used as part of this process are detailed in Table 6.5, but the fundamentally spatial nature of this information would have benefitted from an accompanying figure(s) to show where the sectors are and their extent.

- It is recommended that a figure(s) be provided of the sectors used as part of the sectorial matrix adjustment.

The overall effect of applying the sectorial changes are provided for the 24-hour PA trip purpose totals in Table 6.6. This shows that at a matrix total level, the changes to the overall size of the matrix have been minimal. However, it is not possible to gain an understanding of the level of distortion to the matrix, either at a sectorial level or a more detailed level. This information is important to provide confidence in the changes that have been made to the prior matrix.

- Providing the distortion factors in a sectorial matrix (as an Appendix) and other methods would better inform the reader as to the effects of the changes described in Section 6.3.5, and the changes described in Section 6.3 overall (i.e. the level of distortion which has occurred to the prior matrix).

Section 6.3.6 describes adjustments applied to the HGV matrices. It states that similar sectorial adjustments to those described in the previous section have been applied to the HGV matrices, though no information has been provided as to what these changes were.

- It is recommended that sectorial changes to the HGV matrices are documented.

The section goes on to describe how global scaling factors have been applied based on *“both the published national vehicle km statistics both regionally and by road type, in addition to specific classified counts.”* The nature of these adjustments are reasonable, though no information is provided on the make-up of the HGV prior matrix and why these adjustments are retrospectively required.

- It is recommended that the nature of the HGV prior matrix be documented to allow the requirement and suitability of the scaling factors applied to be understood.

The section finally goes on to describe how additional sectorial adjustments have been made to compensate for an HGV PCU issue, whereby PCU factors for HGVS in urban areas are likely to be on average lower due to a higher mix of rigid body vehicles. Whilst the principle of adjustments to the matrix to compensate for this are understandable, the logic of how the varying factors per sector / city have been derived is missing. Furthermore, if the reported issue is as significant as that stated (to warrant modification) it raises the question of whether separate HGV matrices should have been developed or a method of applying different PCU factors explored.

- Providing clarification on how sectorial PCU adjustment factors have been calculated would aid in providing confidence to this approach, in addition to providing evidence of why this adjustment was required.

Table 6.7 shows the overall effect of the adjustments to HGVS on a matrix total level per time period. Again, providing a sectorial matrix showing the adjustment would aid in appreciating the effect of the changes described.

Section 6.3.7 details the adjustments made to LGV matrices. This section is very brief, simply mentioning in general terms the LGV matrices have been adjusted and provides a single statistic that sectors in “the North” have been factored down by an average 3%.

- It is recommended that more information is provided on the level of adjustments applied, similar to that in sections for cars and HGVs.

The section goes on to detail an adjustment to personal and freight proportions to better align with the TAG databook proportions. The principle of the adjustments being described is reasonable, though there is no information provided to confirm the veracity of the factors applied – both with respect to the source of the factors and the age of the TAG assumptions. Table 6.8 shows the final split of freight LGVs (to personal LGVs) in the model as compared to that of the TAG databook. The splits per time period are reasonable.

4.4.8. Appendix A and Appendix B

The information in Appendix A and Appendix B are reviewed as part of the review into their relevant main report sections. The review of Appendix A information is included as part of the review into Section 4.3.2 and that of Appendix B in Section 5.6.

4.5. Volume 4: Non-Car Modes

4.5.1. Chapter 1: Introduction

This short chapter provides a summary of the contents of Volume 4 of the Development Guide, containing three chapters. These chapters are Chapter 2 “Public Transport times”, Chapter 3 “Rail and Bus fares”, and Chapter 4 “Walk and Cycling distance and time inputs”. The contents of this section are considered proportionate and appropriate.

4.5.2. Chapter 2: Public Transport Times

Introduction

This chapter explains how public transport journey time data were created using TRACC software, developed by Basemap. The version of the software is not mentioned.

- ➢ It is recommended that the version of the TRACC software used is reported.

TRACC modes

The list of public transport modes that are processed by TRACC is provided.

TRACC PT algorithm

Maximum walking distances and average walking speeds, used in PT walk legs, are presented. For bus access/egress, walking speed of 4.8 kph is used, while for rail access/egress, 15 kph is used to account for longer trip legs that are typically done by car. No explanation is provided about this simplification, and how this influences the model results.

- ➢ It is recommended that either more detail is added to Section 2.3.2 to explain how rail access/egress walk speed were determined, with special regard to the mix of walk and car access/egress trips at stations.

The maximum transfer distance of 500m is presented. A way around this limitation for the rail mode is also presented, but the explanation is not entirely clear.

An interchange penalty of 10 min was selected based on initial model test and complying with best practice from TAG. The section provides sufficient explanation on the selection of the parameter value.

TRACC runs and outputs

The PT journey time generation process is explained in this section. TRACC journey time runs were generated for morning peak (07:00-10:00), interpeak (10:00-16:00) and daily (24 hour) periods (total of 7 path data sets). Several versions of the morning and interpeak period TRACC runs were generated by varying access speeds and connection distances, and by differentiating between bus and rail networks. The excessive number of required TRACC path sets is given as an explanation as to why there was no TRACC run generated for the evening peak (16:00-19:00) period.

- The consistency of journey time data collected in TRACC and applying them in the modelled time periods need to be clarified. We suggest a table that sets out the relationship between relevant time periods in TRACC and the model.
- It is recommended that more explanation is provided about the omission of generating PT journey times for the evening peak, e.g. by demonstrating that morning and evening peak PT services and routes are essentially the same. If this is not the case, then the generation and application of evening peak PT path sets are recommended. In case the evening peak period does not allow for generating rail connectivity between enough zone pairs, we recommend to extending this time period out toward the evening, mirroring to extension of the morning peak period.

Table 2.1 provides the TRACC journey time summary. The table introduced the use of morning peak time period 05:30-10:00, but there is no explanation as to why this differs from the default morning time period (07:00-10:00). Normally the extension of a peak time creates more zone pairs with rail connectivity by allowing for longer journeys to complete, and it includes more services in general, resulting in more robust PT journey times.

- It is recommended that explanation is provided about the time periods used for the TRACC journey time runs for the morning peak.

Table 2.2 provides a summary of the PT access/egress, interchange, walk distance and speed settings. “Connection distance to nearest stop” (max 2 km) appears in this table, but there is no explanation about this value in preceding section 2.3. In chapter 2.3, the access distance of 0.8 km for bus stops, and 20 km for rail is set out, which seems to be inconsistent with Table 2.2.

- It is recommended that connection distance values descriptions in section 2.3 and values in Table 2.2 are reconciled.

Table 2.4 explains the data fields of PT files from TRACC. The description is vague for a series of fields, i.e. “plus potentially and unknown amount of wait time”.

- It is recommended that the descriptions in Table 2.4 are clarified.

Table 2.5 summarises the results of the PT journey time generation in terms of the percentage of OD pairs with a valid path. The explanation includes a statement “the coverage was considered reasonable and good that almost all zone pairs are covered by the all day run”. The document later on addresses the problem that 29 model zones were not connected to the network. The solution offered for this problem is to put trips from the unconnected zones to a nearby substitute zones with proper connectivity. While this is a pragmatic methodology, which eliminates the need to recode the ITN network and to rerun TRACC, it distorts costs for the relevant zones and adds an element of error to the model.

- It is recommended that the 29 zones without PT connectivity are fully rectified and TRACC is rerun to obtain comprehensive PT journey time set for all zones.

Conversion of TRACC runs to bus and rail attributes

The section explains how the main mode of each journey is assigned by identifying the mode with the longest trip distance. Table 2.8 presents the average speed by mode, which is used to calculate PT journey distances by multiplying speed with journey time. Applying average speeds across the entire transport segments (especially rail or coach) across England seems crude.

- It is recommended that the possibility of distance-based average speed is investigated, especially for rail and coach, where average speeds are highly correlated with distance.

Overall, the description of the TRACC-based journey attribute generation is not detailed enough to be reproducible. It is not clear how TRACC could be used to produce systematic, robust and consistent attributes for forecast years. The rest of the section addresses the calculation of bus and rail attributes sufficiently

- It is recommended that the TRACC journey attribute generation is explained in more detail allowing for the reproduction of the processes.

There is no mention of TRACC-based journey data verification by third party sources in the section.

- It is recommended that the TRACC journey attributes are verified against third party data on a sample of routes and locations.

Processing TRACC outputs for NTMv5

The section discusses the checks made on the value of the PT attributes, and the various interventions applied to fix perceived errors. The problem of excessively high number of interchanges was solved by capping the number of interchanges at 8, reducing any interchange in excess of this, and reducing associated penalty time from the journey times. This is a pragmatic solution, reflecting that the corrections of errors in TRACC network is out of scope.

The treatment of interchange, in-vehicle, walk, access and egress times are addressed in the subsequent section.

In the next section, intrazonal attribute calculations are explained in sufficient detail.

Finally, the content and format of the PT attributes that are input into Visum are explained.

4.5.3. Chapter 3: Public Transport Fares

Introduction

This section explains public transport fare data sources and processing into Visum.

Data Sources

The section discusses the source of fare data. Rail station to station fares are available from the LENNON database, which, in turn, have been processed to obtain fares for different ticket types, in the MOIRA and PLANET models. MOIRA2 was used to estimate rail fares for NTMv5.

Bus fares were derived by using a distance-based approach and applying the NTMv2R methodology.

Rail Fares

The section discusses input types from MOIRA2 database, and how these were assigned to NTMv5. It is reported that 1,319,207 OD pairs have associated travel demand and revenue data from 2015/16. It is also mentioned that a large number of OD pairs need to be infilled to provide fares for possible future travel. The methodology of this infilling was not provided.

- ➢ It is recommended that a reference is provided about the infilling of fares for possible future travel.

The terminology used can be improved, e.g. “producer-attractor” format correctly: “production-attraction” format.

In the next section, the process of assigning rail stations to the model zones is explained. Stations in a given model zone were grouped together into a zone station group and were associated to the model zone. Zones without a station group were associated with the nearest station group. Figure 3.1 provides a good visual to explain this process.

The calculation of station group to station group fares from MOIRA2 database is explained in great detail in the next section. Derived average fare per kilometre values are used to infill missing fare data.

This is followed by the methodology of calculating intrazonal fares in sufficient detail.

There was no mentioning of TRACC-based fare data verification by third party sources in the section.

- ➢ It is recommended that the TRACC fare attributes are verified against third party data on a sample of routes and locations.

Bus Fares

The section summarises the calculation of bus/coach fare for each OD pair. The methodology followed the process used by NTMv2R. The explanation is clear and sufficiently detailed.

Post processing PT fares

The section summarises the formatting of fare data for input to Visum, and the rezoning of the fare matrices from 7,183 model zone to the final version with 7,131 zones. Further information is provided on rezoning in Section 2.4 of Volume 1 of the Developer Guide in sufficient detail

4.5.4. Chapter 4: Walk and Cycling Attribute

Introduction

This section explains walking and cycling input data types, their processing and their input into Visum.

Inputs

The section summarised the waking and cycling input data types, defines average walk and cycle speeds used, and explains the process of setting the maximum walking and cycling distance.

In the section that describes speeds and distances, the units are used inconsistently. Values are shown sometimes in kilometres, sometimes in miles, sometimes both.

- ➢ It is recommended that the units of speed and distance are used consistently.

TRACC outputs

The section describes the type of walking and cycling data that is input into Visum in matrix format, particularly distance and journey time. The section also describes the sense checking process of distance and journey times. The data input and the checking process and the resulting decisions are described in sufficient detail.

Processing of TRACC outputs for NTMv5

The first section explains the implementation of maximum trip distance in terms of actual distance, instead of crow-fly distance.

The next section describes the processing of speeds for “missing zones”. It can be assumed that these zones were unconnected to the network because their walk and cycling distance to their nearest neighbour was higher than the distance cut-off. However, this is not clear from the description. It is also unclear, whether the 29 zones mentioned are the same as the 29 zones mentioned in the discussion of zones without PT connectivity (Section 2.4.3 and. Section 4.3.2).

- It is recommended that the description in Section 4.4.2 is clarified.

The next section describes the calculation of intrazonal times and distances. The formulas and the explanation are sufficiently clear.

The final two sections summarise the formatting of walk and cycling data for input to Visum, and the rezoning of the fare matrices from 7,183 model zone to the final version with 7,131 zones. These processes are identical to those implemented for the PT matrices.

4.6. Volume 5: Forecasting

4.6.1. Overview

This report gives a more technical description of data sources used for demand model estimation, choice model estimation process, implementation of the VDM in VISUM, linking of the VDM and HAM, and the process to derive future year trip end.

In general, this report includes a number of spelling mistakes and consistency issues and can benefit from a process of detailed review and revision to address these. The following provides a summary of our high-level review for each section of this report.

4.6.2. Data for Demand Model

Section 2 of volume 5 introduces the data used for the demand model estimation, including calculation of costs, derivation of level of service data by mode, the NTS trip data used for parameter estimation process, and the zonal attraction data. In general, this section gives a good coverage of data sources used, but could be strengthened by adding some clarity and more details, such as those recommended below:

- Definition of area types in Tables 2.3 to 2.5 should be added.
- Section 2.4.2 summarises LOS data for non-highway modes. It is reasonable to presume that these are network skims, but this is not documented. This should be expanded to explain the source of data used to derive time, distance, and cost matrices used for each mode.
- Section 2.8 describes the attraction data used but does not provide the source of data. The source for each variable listed in Table 2.9 should be added.

4.6.3. Choice Model Estimation

The objective of this section is to describe the estimation process and to set out the issues associated with various stages of this process. The section is structured reasonably and summarises the approach used and the key findings. The expectation is that the readers have general technical knowledge of mode and destination choice estimation process. Below are some recommendations believed to result an improved documentation of the estimation process.

- Section 3.1 refers to an external document which can provide more details on the estimation process (National Transport Model for England: Estimation of mode-destination models, RAND Europe, August 2019). As this is a supplementary document and required to understand the estimation process fully, more information on how this can be accessed, such as a web link if this exists, should be added.
- No reference is made to Table 3.3 within the text in Section 3.4.3. This should be added together with more details on how these Gamma parameters have been determined.
- Estimated parameters are reported in various tables in this section. No information is provided on statistical significance and error of these estimates (e.g. t-values, standard errors, or confidence intervals). These should be added or supplementary evidence appended to enable a more informed interpretation of the results.
- The issue of lack of data at detailed spatial level within NTS is clearly set out, but the section does not provide sufficient information to describe the two-stage approach followed to address this issue (e.g. Section 3.4.7). More clarity on the composite approach used should be provided or reference is given to supplementary documentation when this is described.

The care taken to consider limitations to segmentation are imposed by practical run time constraints on operational sensitivity of the model; this seems an appropriate balance which is applied by model developers.

4.6.4. Variable Demand Model Implementation

Section 4 of volume 5 generally describes the implementation process of the variable demand model in VISUM. Section 4.2 gives a helpful description of the tests undertaken to investigate the run time implementation of various demand structures. Section 4.3 and 4.4 describe the process of defining the final demand segments and intrazonal costs, respectively. The utility functions specified by mode are set out in Section 4.5. The formulation and parameters of the choice models are described in Sections 4.6 and 4.7, respectively. Section 4.8 and 4.9 discuss the implementation of trip ends and the demand model in VISUM. These are considered to be adequate for the purpose of model documentation.

4.6.5. Incremental Modelling and VDM-HAM Linkage

This section covers implementation of the incremental approach, transfer of data between VDM and HAM, and the pivot process.

A technical background to incremental modelling is given in Section 5.2. Table 5.1 in particular, comparing merits of AMAI and IPP methods, is informative and gives a helpful context to the chosen AMAI approach.

Section 5.2.2 sets out the pivoting method used and table 5.2 defines the 5 different cases applied within the model in the pivoting process. The number of cases seems inconsistent with the 8-case approach defined by RAND Europe introduced in Table 5.1. Our understanding is that the same cases are being used but for simplicity 8 cases have been aggregated into 5. Additionally, the inequality sign used in Table 5.2 for case 2, synthetic forecast is incorrect (">" should be used instead "≥").

- It is recommended that a conversion from the 8-case to the 5-case pivoting approach is explained for the readers clarity.
- It is recommended that the inequality signs in Table 5.2 are corrected for Case 2, synthetic forecast (">" should be used instead "≥").

Section 5.2.3 sets out the normalisation method used and explains why this was needed. No discussion is included on the potential risks in using the aggregate sectoring system for this purpose.

- It is recommended that a discussion is included in Section 5.2.3 around any potential risk of using the aggregate sectoring system for the normalisation process in representation of detailed / local behavioural responses in model forecasts.

The conversion of matrices between VDM and HAM is explained in Section 5.3 and checks undertaken on the pivot process are summarised in Section 5.4. The example discussed here is for 'Car Other' AUC. A summary of findings for similar checks for other user classes is missing.

- It is recommended that Section 5.4 is expanded to briefly summarise findings of similar checks undertaken for other AUCs and provide confidence that the effective growth ratios remain consistent.

4.6.6. Future Year Trip End Growth

The process of forecasting trip ends is described in Section 6. It is noted that while the process is based on NTEM, the overall growth may differ from NTEM due to differences in segmentation.

A background to NTEM is given in Section 6.2. The correspondence between NTEM and NTMv5 trip purposes is given in Section 6.3, mapping of segmentation and zoning is discussed in Sections 6.4 and 6.5, respectively. These are considered to provide sufficient technical details for model users.

The methodology to calculate NHB, production and attraction growth from NTEM forecasts and apply these is described in Sections 6.6 to 6.10. Section 6.10 (and Section 6.12) makes reference to the Juypter tool developed, allowing users to define additive growth factors. Calculation of gender proportions is sufficiently described in Section 6.11.

The documentation of the consideration given to select the appropriate software for trip end processing in Section 6.14 is informative and transparent and provide sufficient details.

4.6.7. Implementation of Urban Area Speeds

The approach to derive and implement urban area speeds is covered in Section 7. The chosen method is based on overall growth in trip ends only. The calculations to derive speed reduction factors for base and forecast years are provided in Section 7.2. Further details on the basis for these factors, including the implementation of the method, is provided in Section 7.3. The implementation on VISUM is discussed in Section 7.4.

Whilst the structure of this section overall seems appropriate, a more detailed review of the technical details included in this section will be undertaken at a later stage alongside the model implementation review process.

4.7. Volume 6: Testing

4.7.1. Overview

The testing developer guide is a generally well-arranged document. It contains most of the required information about the tests undertaken and results and is at an appropriate level of detail for the target audience. What it lacks is prior hypotheses regarding expected model outcomes and sufficiently full interpretation of validity/robustness of outputs.

The text does suffer from some similar problems to the rest of the documentation, in that it is often excessively wordy and difficult to read. Paragraphs remain too long in general; some strategic use of bullets and numbered lists would in places improve readability.

We spotted slightly more typos and similar mistakes than in the Quality Report or user guide; it appears not to have undergone quite as much or as thorough checking. It is not by any means full of mistakes, though.

There is generally somewhat excessive use of abbreviations in tables, even where there is ample space for a full description (e.g. regions in table 3-12). For another example, Table 2-7 uses "Sb", "Sf" and "Fn" abbreviations without definition; this is not very helpful.

4.7.2. Realism Testing

There is probably slightly excessive detail for most purposes in the elasticities presented in this chapter, but this is intended as the most detailed level of reporting.

The text should define an "elasticity" or at least direct the reader to the definition in TAG; it does neither. There could also usefully be more discussion of the distinction between car driver/vehicle elasticities and car occupant elasticities. The NTMv5 is relatively unusual in having a true vehicle occupancy response, so these can differ. TAG guideline elasticities are quoted for drivers/vehicles.

- Table 2-6 and 2-13 (network fuel cost elasticities) should include annualised averages for comparison against the TAG criteria.

Although the VDM itself responds at the required sensitivity, the overall model elasticities (at the level of the actual traffic in the assignment matrices) are too high probably by around a third. **This is worrying for forecasting.** The text clearly and coherently explains why there is a discrepancy, but no adjustment has been made to address it.

- This discrepancy between VDM and calibrated assignment demand sensitivities needs to be carefully considered, and either appropriate advice given to users, or adjustments made to the model.

Depending on the scenarios being tested, this could easily result in over-sensitive responses being reported.

4.7.3. Sensitivity Testing

In contrast to chapter 15 in the Quality Report, the testing section as a whole has no conclusions.

See remarks under chapter 15 regarding results of specific tests; the same comments apply here.

- Prior hypotheses should be set out regarding the expected outcome of each test (e.g. from historic monitoring, literature review, mathematical plausibility), and more in-depth commentary on plausibility of results.

4.8. Summary and Conclusions

In terms of the model build volumes of the developer guide, the documents generally provide a transport modeller with an understanding sufficient to operate the model. In general terms there is sufficient information available to allow a user to allow a user to prepare inputs, although in some instances key information is missing that would necessitate the user to make assumptions, an example here being the missing parameters used for defining standard turn delays necessary for coding new highway schemes.

The guide is detailed in terms of its technical discussion of the key model development processes. It is difficult from a review of the documentation to fully understand the limitations of the model as there are instances where it is difficult for a user to be clear on the level of confidence a user may have in the base data processing due to the lack of detailed documentation. Key examples of this are:

- the quality of the base matrix validation;
- the effect that the process to convert PA to OD matrices has had on matrix quality;
- the quantity and distribution of traffic counts and the quality of the journey time data; and
- the quality of TRACC data processing.

There are also some instances where sufficient information has not been provided to allow the model to be easily updated in a consistent manner in the event of new or updated base information being available such as updated RTM highway network data, or updated TRACC data.

With reference to the model testing volume, although this guide is very detailed in technical aspects of inputs and outputs for the sensitivity tests, it fails to fully assure the reader that the developers have genuinely demonstrated the model's plausibility and suitability.

Fewer tables and plots and more detailed and more complete commentary on test results would reassure. Many (by no means all) commentary sections baldly state the results found in the following table with essentially no comment.

There is no consideration given to stability or convergence of the results, except for the fuel cost realism test. This is a significant weakness.

5. Model Review- Model Implementation

5.1. Overview of Implementation

This section documents the audit of the model implementation in Visum undertaken as part of NTMv5 development. This process includes reviewing the following components:

- the development of the model zoning system;
- the development and implementation of the highway network;
- the implementation of generalised cost functions and attributes;
- the implementation of the VDM functionality and parameters;
- the incremental modelling and VDM-HAM linkage implementation; and
- the procedure sequence.

The structure of this chapter is based on the above model components. Each section provides a detailed description of the approach undertaken as part of the model audit and a summary of the outcomes from this process.

5.2. Model Coverage and Zoning

This chapter describes the process and findings of the audit undertaken on the development of the NTMv5 zoning system against the model documentation and the principles underpinning the guidance set out in in TAG. The chapter details:

- a review of how the zone system was constructed;
- identification and classification of bespoke zones;
- classification of the internal/external zones; and
- compatibility between the NTMv5 zone system against RTMs and NTEM/ONS zone systems.

The following spatial datasets along with attributes assigned have been exported from the NTMv5 model for assessment:

- zone centroids (7131 locations/points); and
- polygon zones (7029 zones/polygons).

There are 6936 zones in England, 66 in Wales and 27 in Scotland.

5.2.1. Zone Classification/Correspondence Attributes

The NTMv5 Developer Guide Volume 5: Forecasting Model v2.0 states that there are 7131 NTMv5 zones broken down as follows in Figure 5.1 and Figure 5.2.

Table 6.6 – Number of zones by category

Zone category	Number of Zones
0 – MSOA	6,587
1 – Modified MSOA	280
2 – Enterprise	49
3 – Airport	37
4 – Seaport	107
5-8 – Major attractors	53
9 – Inter-modal rail freight hub	18
All zone types	7,131

Figure 5.1: Documented Zone Classification

Table 6.7 – Number of NTMv5 zones by match type

Type of Zone (NTMv5:NTEM)	Number of NTMv5 Zones
MSOA or Modified MSOA – 1:1 match	6,806
Aggregated MSOA – 1:many match	61
Bespoke Zone – 1:1 match	261
Bespoke Zone – 1:many match	3
Total	7,131

Figure 5.2: Documented Zone Correspondence

5.2.2. NTMv5 Zone Comparison with MSOA/NTEM zones

A review of the linkage between model zones and MSOA / NTEM zones has been undertaken. It is noted from the documentation the key objective for the NTMv5 zoning system was to maintain the correspondence to the MSOA zoning system which was used to link the model to the NTEM datasets which forms a key part of the model.

The correspondence between the NTMv5 zones and NTEM/MSOA zones was found to be stored in multiple locations within the model files. Correspondence appeared in the following locations.

- The zone attribute table in the NTMv5 Visum model file (.ver).
- The 'NTM_NTEM Correspondence v1.0.csv' file in the model structure.

At the beginning of the audit process, it was unclear from the documentation if these correspondences are interlinked somehow or independently stored in different parts of the model structure. Early assessment revealed that the correspondences are not consistent and contain errors. Whilst developing the knowledge of the model structure, it was concluded that the zone shapefile attribute table contained in the VISUM .ver file was not used anywhere in the model application and the "NTM_NTEM Correspondence v1.0" text file was used in the evaluation of forecast trip ends. For completeness both correspondences have been reviewed independently and reported in this chapter. It is appreciated that due to formatting and model set up, combining these files and having a single reference/input to the MSOA/NTEM zoning systems may not have been possible. However, to aid the model users in model application and updates, it would be useful to clearly state in the documentation all references to the correspondences related to the MSOA/NTEM zoning system and where they are used.

➢ To aid model users it is recommended that the documentation is updated to include all references to the correspondences related to the MSOA/NTEM zoning system and where within the model they are used.

Subsequent to the audit team undertaking a number of checks, the team was made aware of the “NTMZoneSystem Spreadsheet”. This spreadsheet is a main database for zonal attributes. This data was therefore used to validate findings of the independent checks undertaken by the audit team.

One of the biggest advantages of Visum over other modelling packages is that it can act as a centralised database for all model related attributes/data. It is recommended to store all the zonal attributes from the “NTMZoneSystem Spreadsheet” in the NTMv5 Visum model file as this is the main source a model user is going to check for model related data.

> ➢ It is recommended that all zonal attributes included within the “NTMZoneSystem Spreadsheet” are also stored in the Visum model file to ensure crucial attributes are not missed by a model user.

NTM-NTEM Correspondence

A csv text file was extracted from the model file structure which details the correspondence between NTMv5 zones and NTEM zones (“NTM_NTEM Correspondence v1.0.csv”).

The NTMv5 centroid points have been mapped against the NTEM polygon zones to identify any correspondences which may have been listed incorrectly. There are 7977 correspondences in the file, as the correspondence between NTMv5 points and NTEM zones is not one to one.

7082 of the correspondences (88.8%) have a centroid which falls within the corresponding NTEM zone, i.e. these are categorised as having a correct correspondence. The remaining 895 (11.2%) have been checked and categorised as follows.

- 848 (10.6%) are NTMv5 centroids which relate to aggregated NTEM zones (and therefore the centroid falls within an alternative NTEM zone to the correspondence listed). These are categorised as a correct correspondence. Validation against the ‘NTMZoneSystem Spreadsheet’ has shown that all zones in this group have a zone category of 0 (MOSA) or 1 (Modified MSOA) which was expected given that NTEM/MSOA zones are aligned.
- 25 (0.3%) correspondences where the NTMv5 centroid falls in an adjacent NTEM zone to the correspondence provided. In these cases, it is not clear why the adjacent NTEM correspondence has been chosen. All of these zones are classified as bespoke zones in the ‘NTMZoneSystem Spreadsheet’
- 14 (0.2%) correspondences where either the NTMv5 centroid falls marginally outside of the corresponding NTEM zone or the NTM centroid is in an adjacent NTEM zone but given the land use the correspondence is justified. These have been categorised as correct correspondences.
- 8 NTMv5 zones which have an incorrect correspondence with NTEM zones (e.g. NTMv5 zone 6957 incorrectly corresponded with NTEM zone 3249, and NTMv5 zone 6973 incorrectly corresponded with NTEM zone 5594). All of these zones are classified as bespoke zones in the ‘NTMZoneSystem Spreadsheet’

> ➢ To aid accurate model usage it is recommended that the NTEM correspondence is reviewed for the 33 zones identified (25 from the second group and 8 from the last group). If these zone correspondences were intended given that they are classified as bespoke zones, it is recommended to update the documentation with the methodology/explanations for these exceptions.

NTM-MSOA spatial mapping using the model zone polygons

MSOA zones (Middle_Layer_Super_Output_Areas_December_2011_Boundaries) have been downloaded from the ONS government website for England and Wales. This dataset has been mapped against the NTMv5 zoning system for comparison. It should be noted that it is unclear which version of the MSOA zone system was used to formulate the NTMv5 zones, and this could be one reason for some of the discrepancies shown below.

- For clarity, and to aid further model updates, it is recommended that the MSOA version is reported with the model documentation.

Figure 5.3 and **Figure 5.4**: NTMv5 zones (black) overlaid on MSOA zones (pink) show that the NTMv5 zones (shown in black) appear to follow the MSOA boundaries (shown in pink) in most cases. A review of these layers in GIS at a zoomed in level shows that the exceptions are where bespoke zones have most likely been created or adjustments made to MSOA boundaries. It can also be seen that MSOA zones have been aggregated in the Isle of Wight. This has also been applied for zones in Wales.

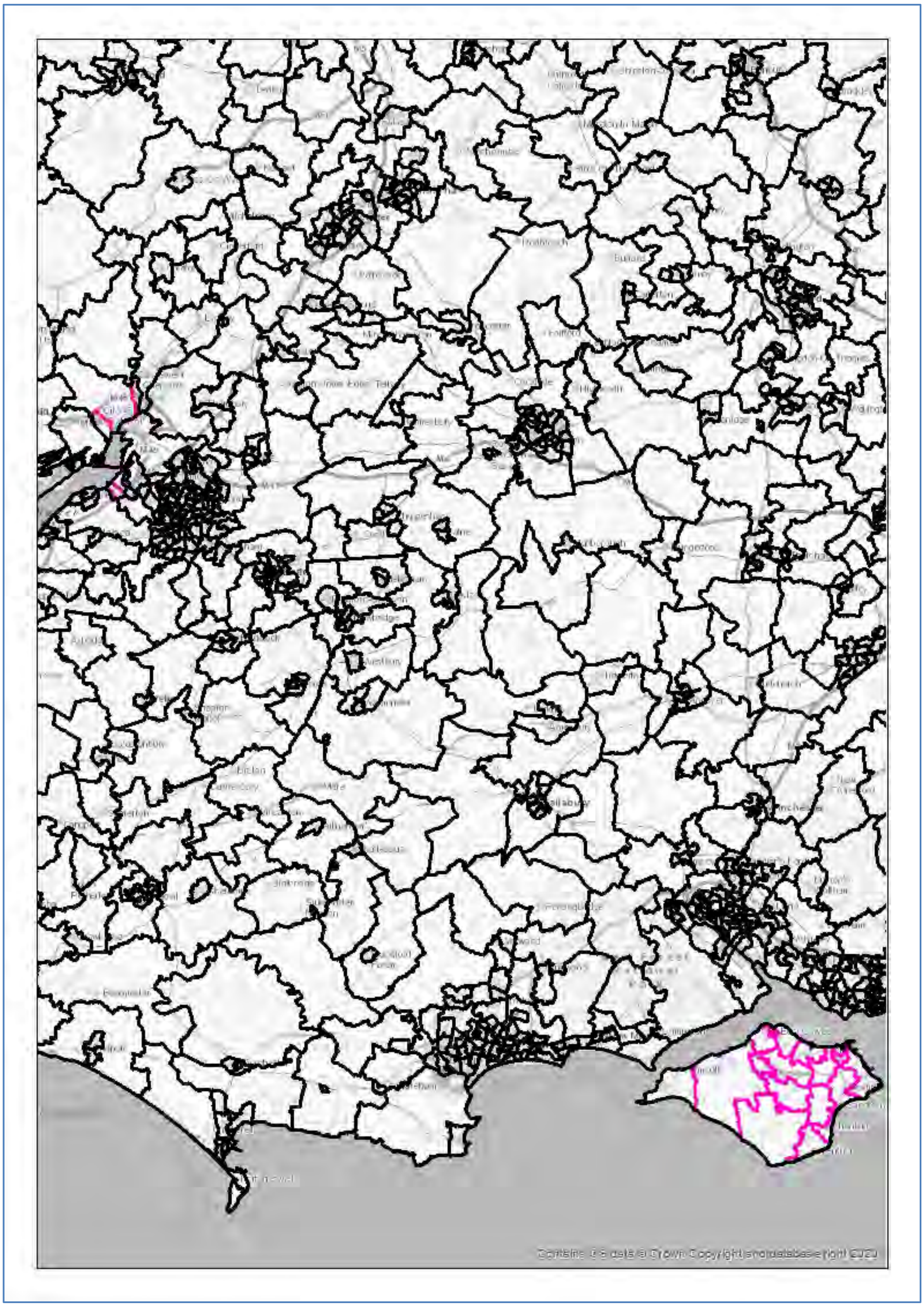

Figure 5.3: NTMv5 zones (black) overlaid on MSOA zones (pink)

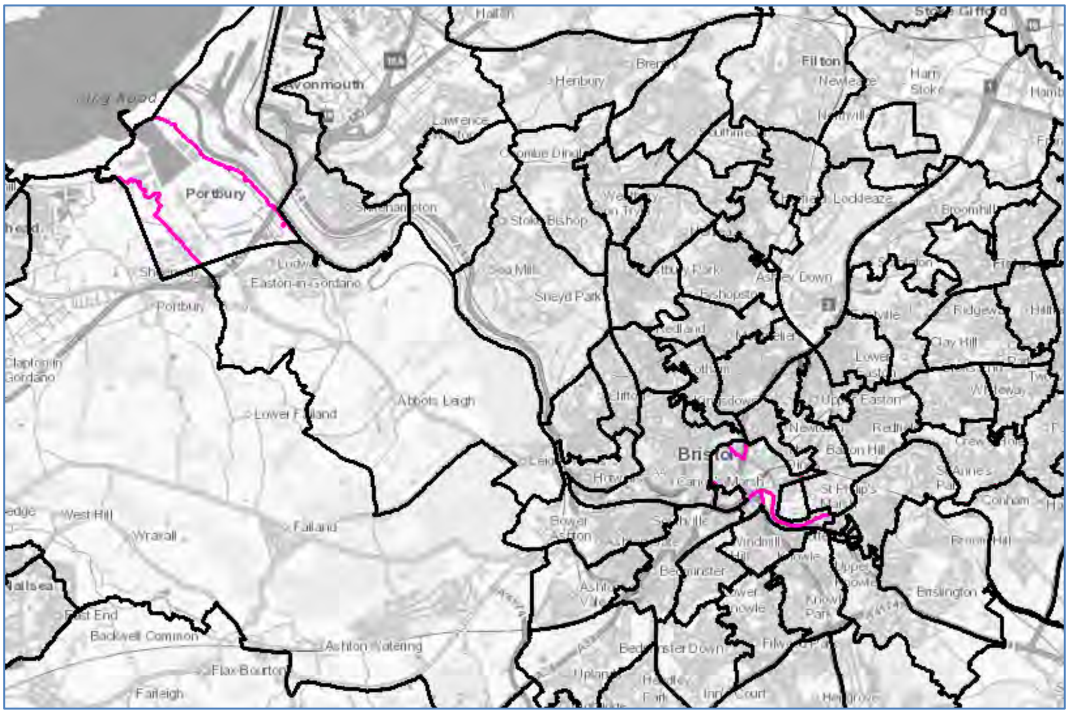

Figure 5.4: NTMv5 zones (black) overlaid on MSOA zones (pink)

Figure 5.5 and **Figure 5.6** are similar plans but with the layer order reversed. This plan also shows that MSOAs have clearly been used to form NTMv5 zones. It highlights in specific sections where bespoke NTMv5 zones most likely have been cut within some MSOAs.

Figure 5.5: MSOA zones (pink) overlaid on NTMv5 zones (black)

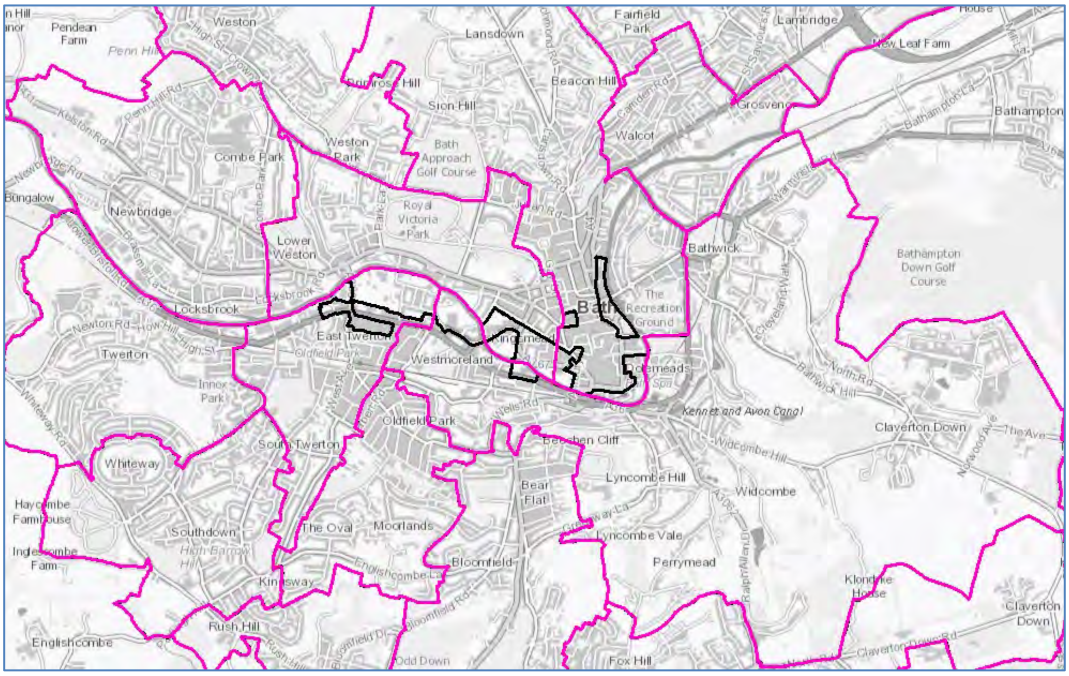

Figure 5.6: MSOA zones (pink) overlaid on NTMv5 zones (black)

A tabulated intersection has also been calculated in GIS, where the area of each overlapping section (between NTMv5 zones and MSOA zones) is calculated and measured against the total NTMv5 or MSOA area.

Table 5.1 shows the quantity of NTMv5 zones which fall within each band of percentage of NTMv5 covered and percentage of MSOA covered.

The first two columns define the area overlap calculated i.e. in the left hand overlap below, all of the NTMv5 zone is covered by the MSOA zone. A zone which has 100% covered by MSOA and NTMv5 is an NTMv5 zone which is an exact match with MSOA zone.

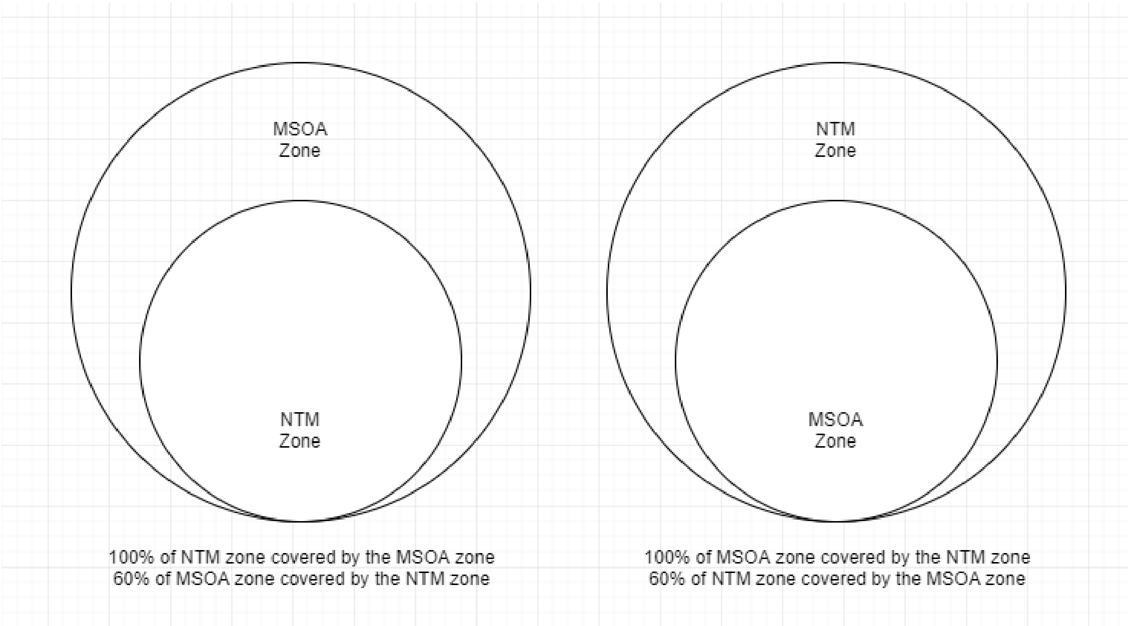

Table 5.1: NTMv5 to MSOA tabulated intersection overlaps

Percentage of NTMv5 Covered	Percentage of MSOA Covered	No.	Comments
> 99.5%*	> 99.525%	6278	Assumed all MSOA Zones
	99.5% - 99.525%	54	Majority MSOA Zones – checked
	99.25% - 99.5%	73	Majority MSOA zones containing a bespoke zone – checked
	< 97%	282	Assumed bespoke zones – spot checked
99.25% - 99.5%	>99.5%	2	MSOA Zones – checked
	99.25% - 99.5%	184	MSOA Zones – spot checks
	< 99.25%	7	Majority bespoke zones – checked
99% - 99.25%	> 99%	7	MSOA Zones – checked
	< 99%	2	Bespoke zones - checked
98.5% - 99%	> 98.5%	1	MSOA Zone - checked
	< 98.5%	1	Bespoke zone - checked
98% - 98.5%	> 98.5%	1	MSOA Zones
97% - 98%	< 97%	2	Bespoke zones
< 97%	> 99.5%	41	Aggregated MSOAs
	<99.5%	94	Bespoke zones
* Note: A tolerance of 0.5% overlap mismatch has been allowed. i.e. if the error is less than 0.5% then an exact match has been assumed.			

Following specific checks on each band with a low number of zones, and spot checks on the other bands, our interpretation of a categorisation was formed. This is shown in Table 5.2 which is a summary of Table 5.1. Classification of zone types for each category was also included in the table, taken from the 'NTMZoneSystem Spreadsheet'.

Table 5.2: NTMv5 to MSOA Mapping Review

Checking	Zone Type	Number of NTMv5 zones (mapping check)	MSOA Zones[1]	Modified MSOAs[1]	Bespoke Zones[1]
A	The MSOA and NTMv5 boundaries match	6527	6514	12	1
B	An MSOA has been split to form the NTMv5 zone	2	0	2	0
C	An MSOA has been slightly modified	1	1	0	0
D	NTMv5 zone has an MSOA boundary, but has a section removed (bespoke zone)	72	0	72	0
E	The NTMv5 zone does not follow the MSOA boundary	360	7	193	160
F	The NTMv5 zone is an aggregation of MSOA zones	40	38	1	1
G	NTMv5 zone in Scotland[2] (where MSOA does not exist)	27	27	0	0

The table above shows that:

- 13 NTM zones which appeared to map correctly with MSOA zones are categorised as modified MSOAs or bespoke zones. These have been noted as potential errors;
- 8 NTM zones map correctly against the MSOA zones but the zone category is 0 (MSOA zone). This has also been noted as a potential error;

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[1] Based on the zone classification from the 'NTMZoneSystem Spreadsheet'

[2] In Scotland, MSOA zones are not available. However, NTEM Zones are based on MSOAs, and are available in Scotland. The assessment in this section for Scotland is based on NTEM zones.

- 193 NTM zones which were assumed to be bespoke from the overlap mapping are classified as Modified MSOAs. These zones have been noted as potentially unclear; and,
- All other NTM zones appear to have been assigned the correct zone category, being validated by the overlap mapping.
    - ➢ To aid model usage, it is recommended that the MSOA correspondence is checked and corrected.

In summary the values in Table 5.2 are not dissimilar to those shown in **Figure 5.2**: Documented Zone Correspondence. Specifically, in relation to a direct match between model zones and MSOA zones, our analysis concluded 6527 model zones that match a MSOA zone directly, compared to 6587 zones stated in the documentation. Thus, whilst the exact numbers have not been replicated, it is clear that in the majority of cases and where bespoke zones are not involved, NTMv5 zones are formed from MSOA zones. This is important as a key principle of TAG Unit M3.1 is that the primary building block of the zone system should be Census and administrative boundaries.

5.2.3. NTMv5 Zone Comparison with RTM zones

One of the objectives for NTMv5 zone development was to retain consistency between NTMv5 zoning and the RTMs. The model developers reported that, it was not possible to achieve consistency across England, Wales and Scotland without editing of RTM zones (see Section 2.2.3 of the NTMv5 Developer Guide Volume 1-Model Zones and Highway Network v2.0). Nevertheless, they stated that it was desired to use RTM disaggregation of MSOA's in rural areas.

The TPS RTM was chosen at random for a comparison of RTM zones and NTMv5 zones. **Figure 5.7** shows that NTMv5 zones (shown in black) do not entirely map against TPS-RTM zones (shown in pink). This suggests that in some locations NTMv5 zones consist of RTM zone aggregations (this may be accepted as NTMv5 zones are expected to be larger than RTM zones in some locations). Therefore, it can be concluded that RTM zones can be further dis-aggregated than NTM/MSOA zones.

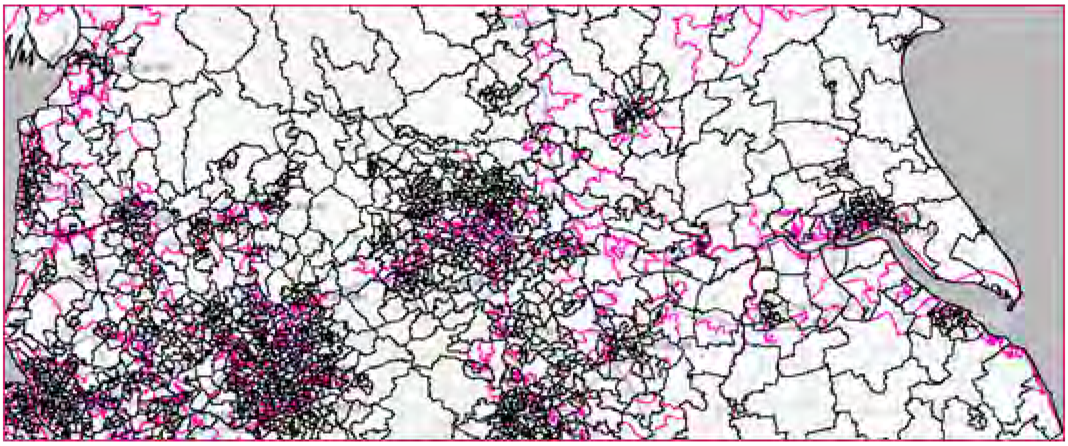


Figure 5.7: TPS-RTM zones (pink) overlaid with NTMv5 zones (black)

Figure 5.8 is a similar map, but with the order of layers reversed. It shows that in some locations NTMv5 zones are smaller than RTM zones. It is not anticipated that NTMv5 zones be smaller than RTM zones (or more detailed). It is noted that some of the boundary discrepancies shown in this figure may be a result of bespoke zones.

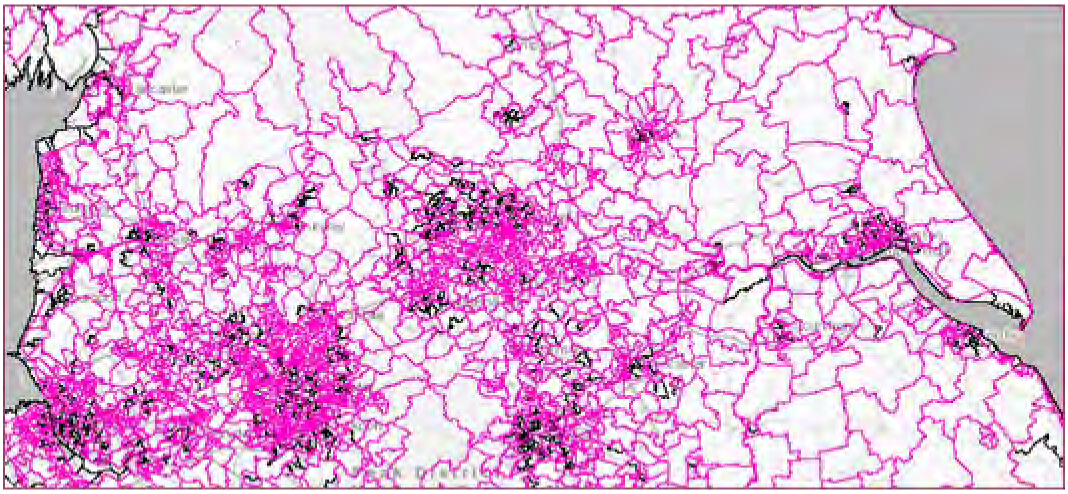


Figure 5.8: NTMv5 zones (black) overlaid with TPS-RTM zones (pink)

However, on review it can be seen that some RTM zones are combined MSOA zones. This results in NTMv5 zones smaller than RTM zones e.g. shown in map below.

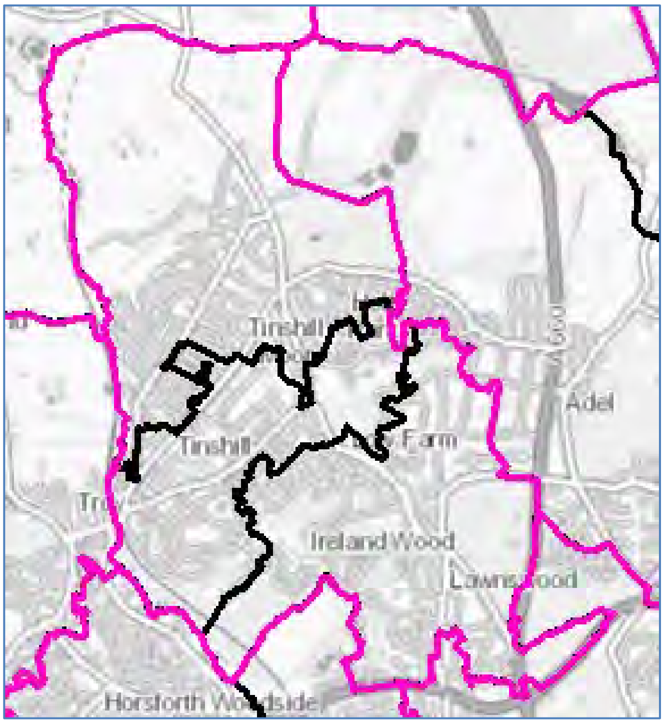


Figure 5.9: NTMv5 zones (black) overlaid with TPS-RTM Zones (pink)

Further examples show the area overlapping both NTMv5 zone and RTM zone in **Figure 5.10** covers over 99% of the RTM zone. However, it can be seen that some boundary discrepancies occur where the NTMv5 zone is extended at one section and removed in another (**Figure 5.11**).

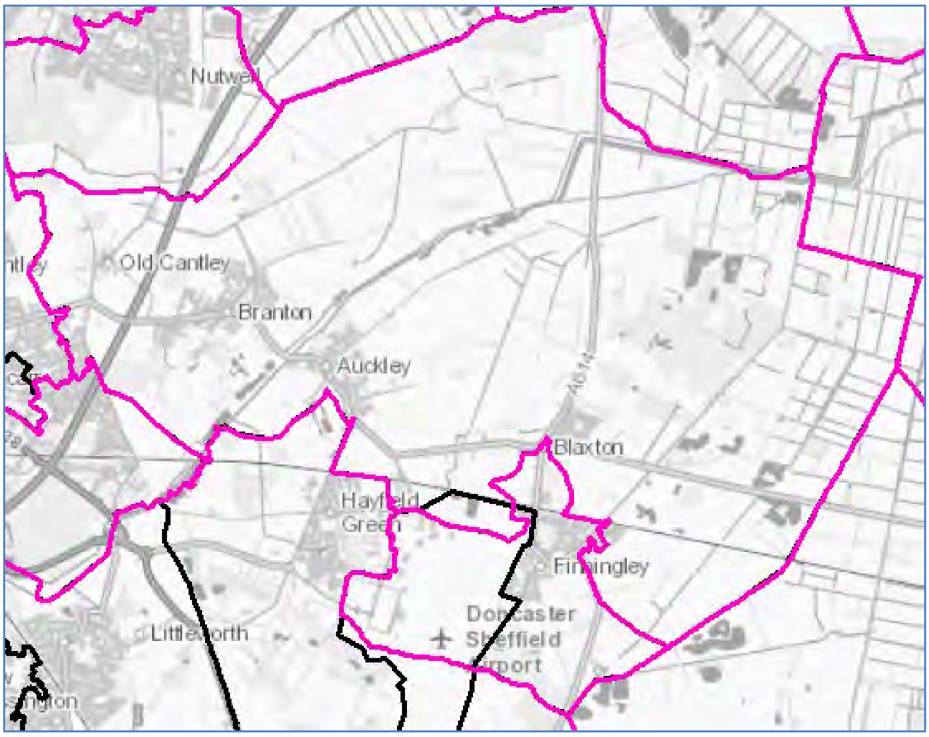


Figure 5.10: NTMv5 and RTM zone comparison

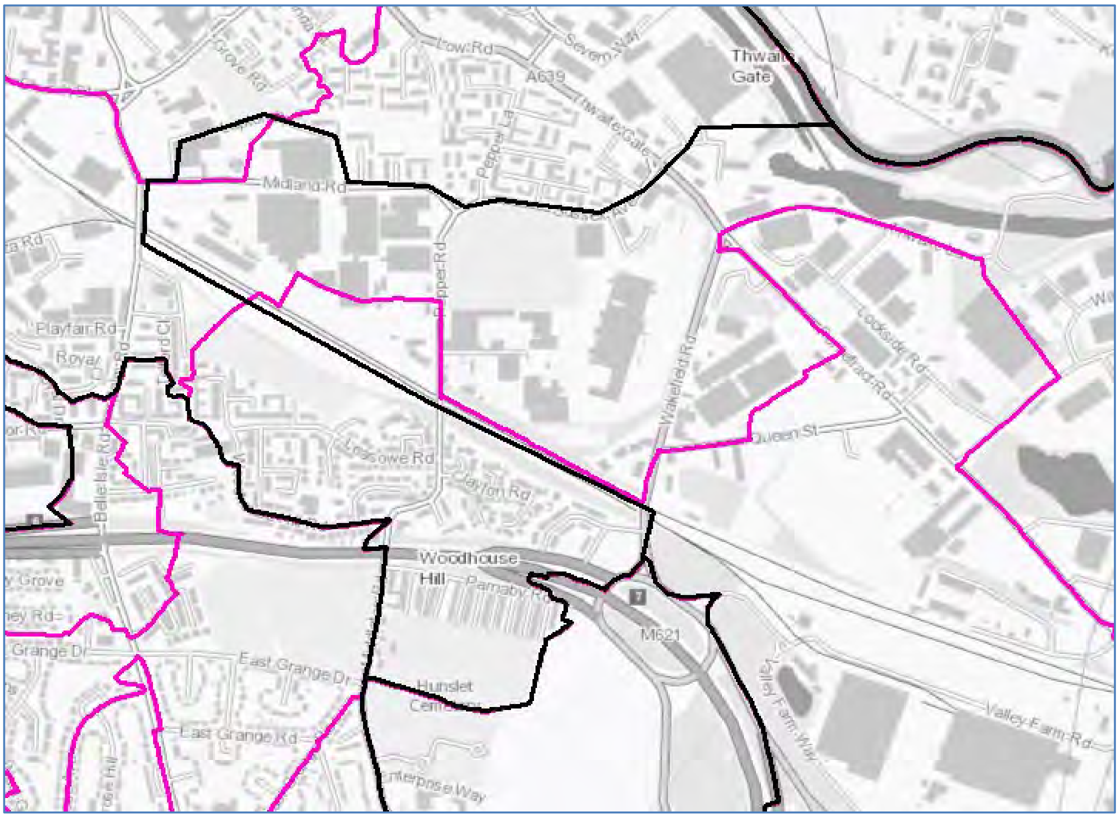


Figure 5.11 : NTMv5 and RTM zone comparison

Given that Section 2.2.2 of the NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0 suggests that RTM to NTMv5 compatibility is important, it appears that this is not always followed. It is therefore recommended that further explanations as to why specific NTMv5 zones are combined RTM or disaggregation's of RTM zones have been formed.

- For completeness, it is recommended that further information be provided relating to the correspondence between the RTMs and NTMv5 to provide evidence that the model is meeting (or otherwise) its stated objectives. If the lack of match to the RTM does not affect model use, then it is suggested that refences to matching the RTM zone system be removed from the model documentation.

5.2.4. A Review of the NTMv5 Zone Sizes

TAG Unit M3.1 describes the interdependency between the definition of the zone system and the network. Thus, the size of a model zone and the level of highway network detail should be considered when coding strategic transport models to ensure that trips can load onto the network in a realistic manner such that zone loading does not distort traffic patterns in the network.

To gain an understanding of the network provision with reference to zone size, the number of nodes within each zone has been counted.

Table 5.3- Number of nodes within a zone

Number of nodes within zone	Number of Zones
0 (zero) nodes	1296
1-5 nodes	3182
6-20 nodes	2061
20+ nodes	490
Total Zones	**7029**

There are a significant number of zones with zero nodes within them. This may lead to issues with loading as trips from a zone have limited options to access the network.

Figure 5.12 shows the zones which contain zero nodes. Areas with zero nodes (shown in red) can be classified into 2 groups.

- The first group refers to more built-up areas, where smaller zones are expected in areas with high numbers of trip productions/attractions. It should be noted that there is often a crude representation of the highway network in urban areas. This is discussed further in Sections 5.3.3 and 5.3.5. It is still expected that each zone has reasonable access to the network, and for zones with zero nodes, this presents a possible unrealistic loading of trips into/from the model zones.
- The second group of zones appears in rural and coastal parts of the model where strategic roads are expected to be less dense and roads within those zones in most cases may be too insignificant for a model of this scale.

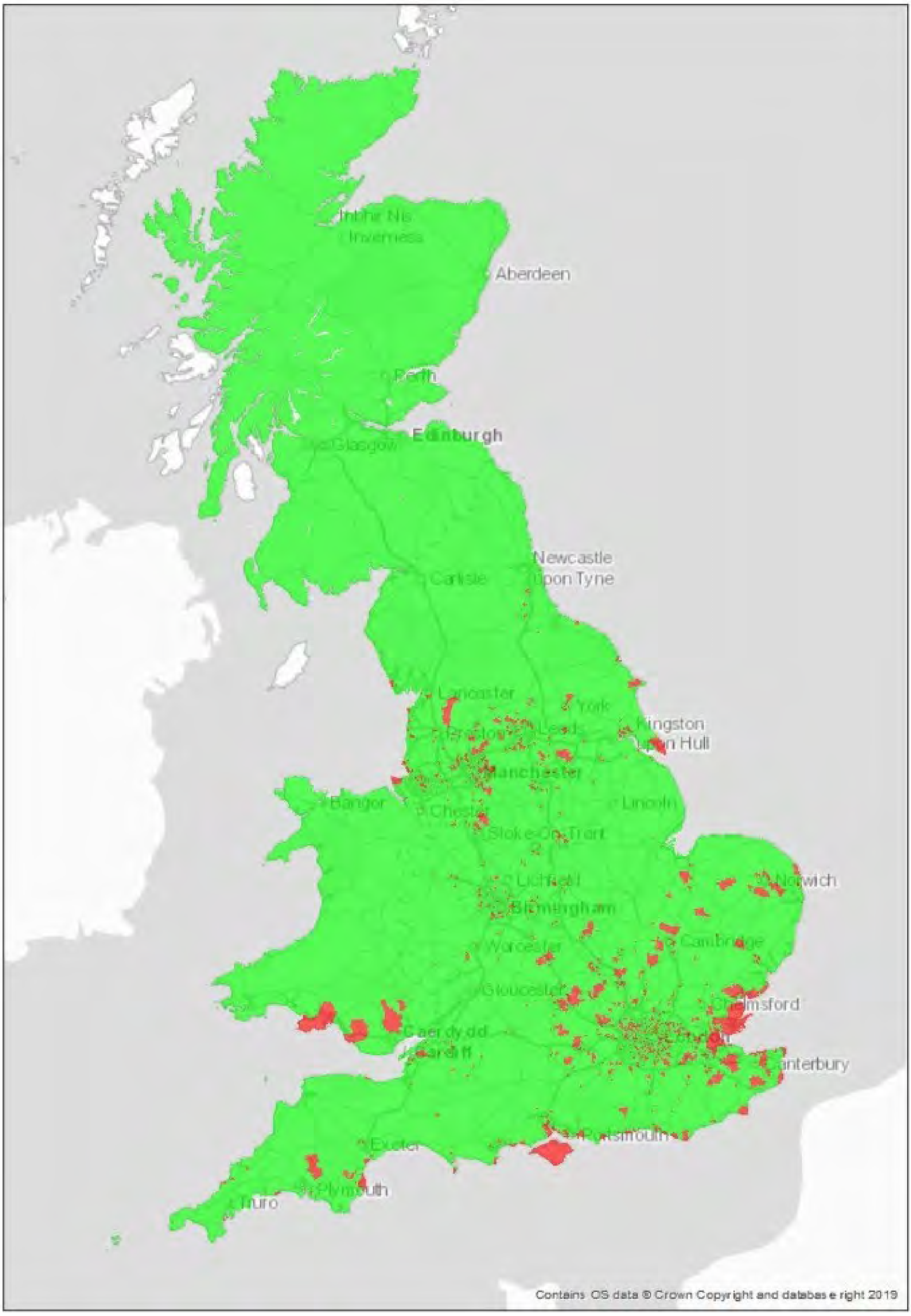


Figure 5.12: Zones with zero nodes

Assessment of individual zones in the more built up areas was undertaken to investigate zones with zero nodes inside the boundaries. The following 3 examples have been identified to highlight the various issues. The three examples have been chosen and are considered to be representative of the majority of the group of zones with zero nodes found in urban areas.

Example 1 is shown in **Figure 5.13**. In this example, in Newton Heath Manchester, there are no links passing through the zone. The highway network is less detailed when compared to the level of detail of the zone system. A connection is made to a node on the A62 outside of the zone boundary. Given that; there is no access to the M60, there is no access to the south over the railway line, and the nature of the lower order road network within the zone area, this is considered to be a reasonable representation of the access to the highway network within a strategic model.

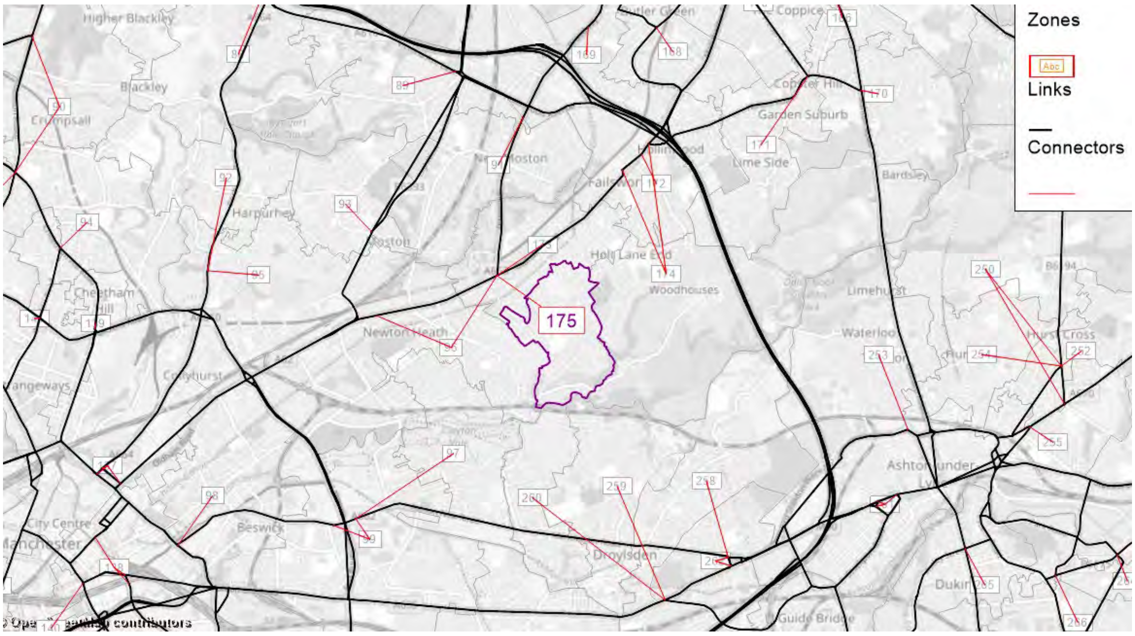


Figure 5.13: Zones with Zero Nodes: Example 1- Newton Heath Manchester

Example 2 is shown in (**Figure 5.14**). In this example, in Hatfield Hyde Welwyn Garden City there are links on the edge of the zone, but no node within the zone. However, in this instance there are four different points at which the zone accesses the network. For stability of the networks it would be preferable to load using a single connector, but if this means that the routing from the zone is poorly represented then there is a case for adding additional road network from which to attach the zone.

In this example:

- It is very unlikely that the flows on the A1000 (running parallel to the railway line) would be accurately represented within the area shown below.
- The flows from the zone could possibly be incorrectly loaded on to the A414 running to the south of the urban area shown, as it is possible that traffic from the zone would use the junction at Cole Green in the model in preference to the A1000/A414 junction in the south west corner of the figure.
- The A414 links to the A1(M) running to the west of Garden City and is connected to the local road network at 3 junctions (Junction 4 to 6). It is possible that the relative lack of local road network could influence loading of the A1(M) at this location.

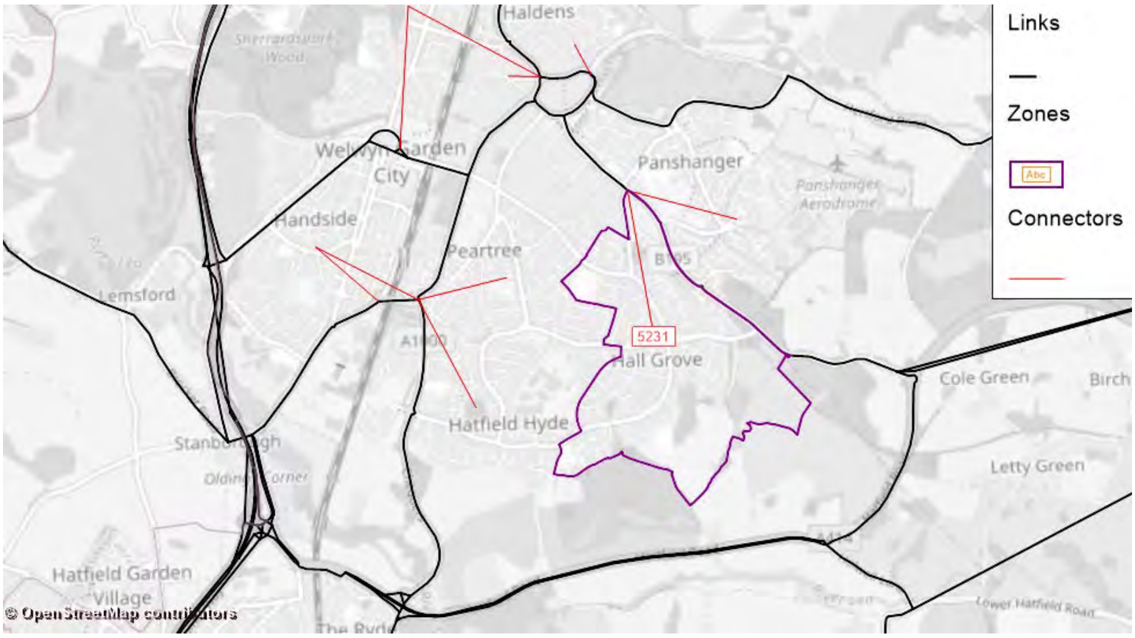


Figure 5.14: Zones with Zero Nodes: Example 2 Hatfield Hyde

Example 3 is shown in **Figure 5.15**. In this example, in Bury, there is a link representing the B6123 passing through a zone, but no nodes along the link within that zone. The zone is connected to a different road, the B6124. To load the zone correctly one would need to split the link representing the B6123 to enable a connection to be made at an appropriate point within the zone. This highlights an erroneous zone loading which would lead to poor representation of flow on the B6213 and the B6214, together with the A676, the road which connects these links to the north.

Section 3.3 of Volume 1 of the NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0 states that the starting point for coding zone centroid connectors was undertaken by automatic process in Visum, which was then refined during model calibration and validation stage.

The result of this methodology (i.e. that automatic zone loading process was only checked during the calibration / validation stage) is that any zone not located in the vicinity of a calibration or validation screenline, or on a journey time route could potentially be loaded inappropriately.

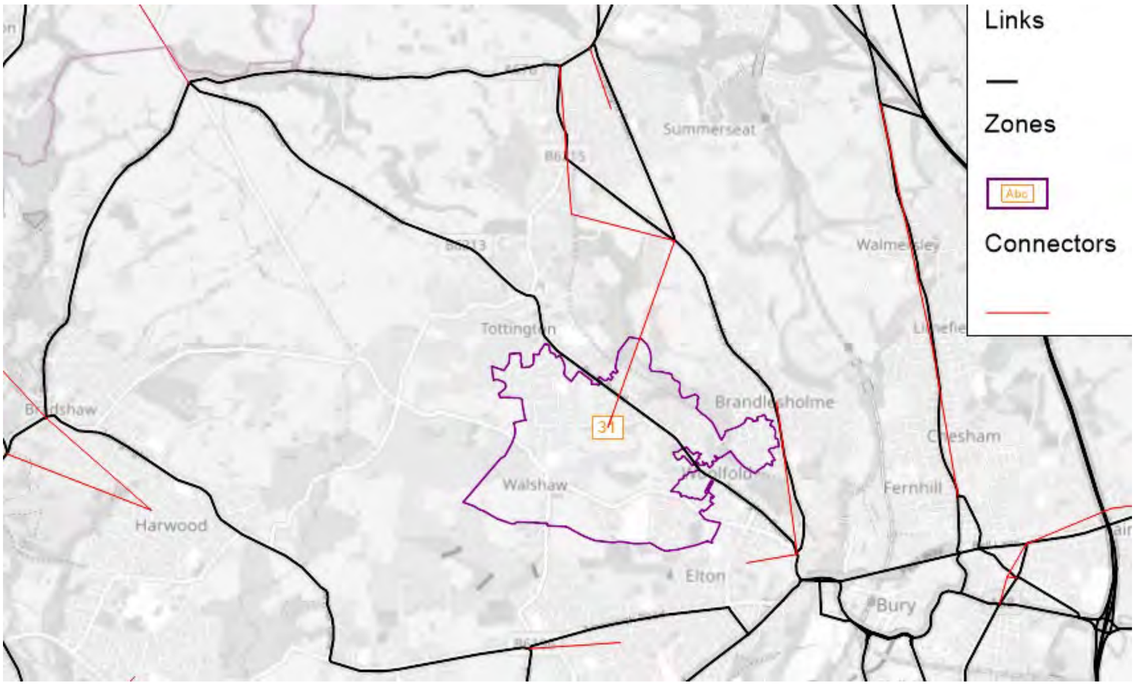


Figure 5.15: Zones with Zero Nodes: Example 3 Bury

Considering the examples above, in only one example did the loading look to be completely reasonable, whilst in the remaining two, the loading in one was questionable, and in the remaining example, it was clearly erroneous. Given that almost 20% of the zones have zero nodes it is difficult to be confident that the representation of flows in built up areas away from calibration or validation screenlines will be consistently well represented within the model. This would suggest that this model should not be used to consider local investment (UC3) without the need for bespoke review by the model user. For use cases concentrating on the SRN (UC1), or those considering aggregate outputs (e.g. UC5) then the effect of this issue would be less significant, although it would be recommended that results are considered at a suitably aggregate scale.

- To improve the representation of flows it is recommended that a review of the zone loading be undertaken, in the first instance focusing on the zones with 0 nodes. Additional road links should be provided in locations where reasonable zone loading cannot be achieved from the existing network.

5.2.5. Identification of bespoke zones

TAG Unit M2.1 describes the principles of demand modelling. An important part of this is trip and person segmentation, so that travellers in the same category can be treated in the same way. It is therefore important that bespoke zones for certain large distinct trip generators are defined carefully. A review of the bespoke zones has therefore been undertaken.

There is some detail provided around approach to bespoke zones in the NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0 Section 2.3.2. It states that both major and minor seaports have been considered for inclusion, with the majority to be included. The figure below shows how Falmouth (a minor seaport) has been included as a bespoke zone.

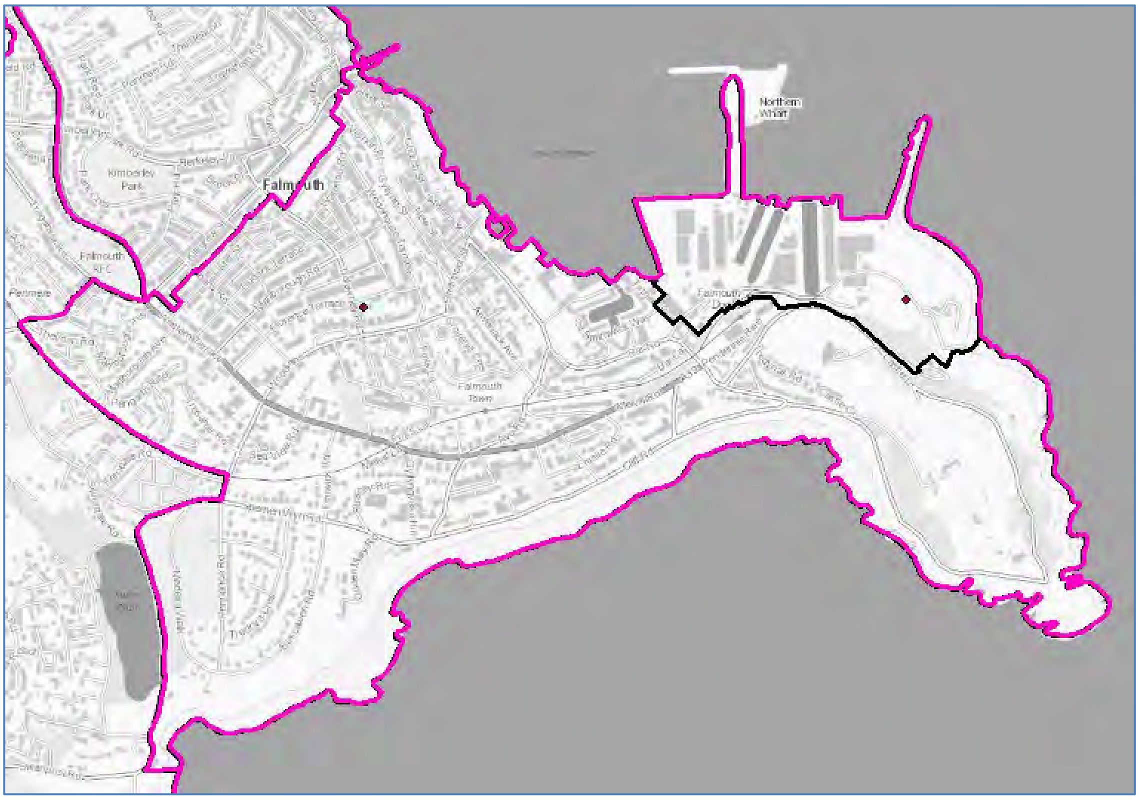


Figure 5.16: Seaport of Falmouth included as bespoke

Spot checks have been completed to identify a handful of other major and minor seaports created in the model, including a check at Teignmouth where the guidance confirms that the seaport was not included as a bespoke zone.

Heathrow Airport is also shown as an example of airports included as bespoke zones. Spot checks have been completed to identify that other airports have indeed been created in the model.

Although the guidance states that Heathrow has been given 3 zones for the various terminals, it is unclear how the zone boundaries have been formed.

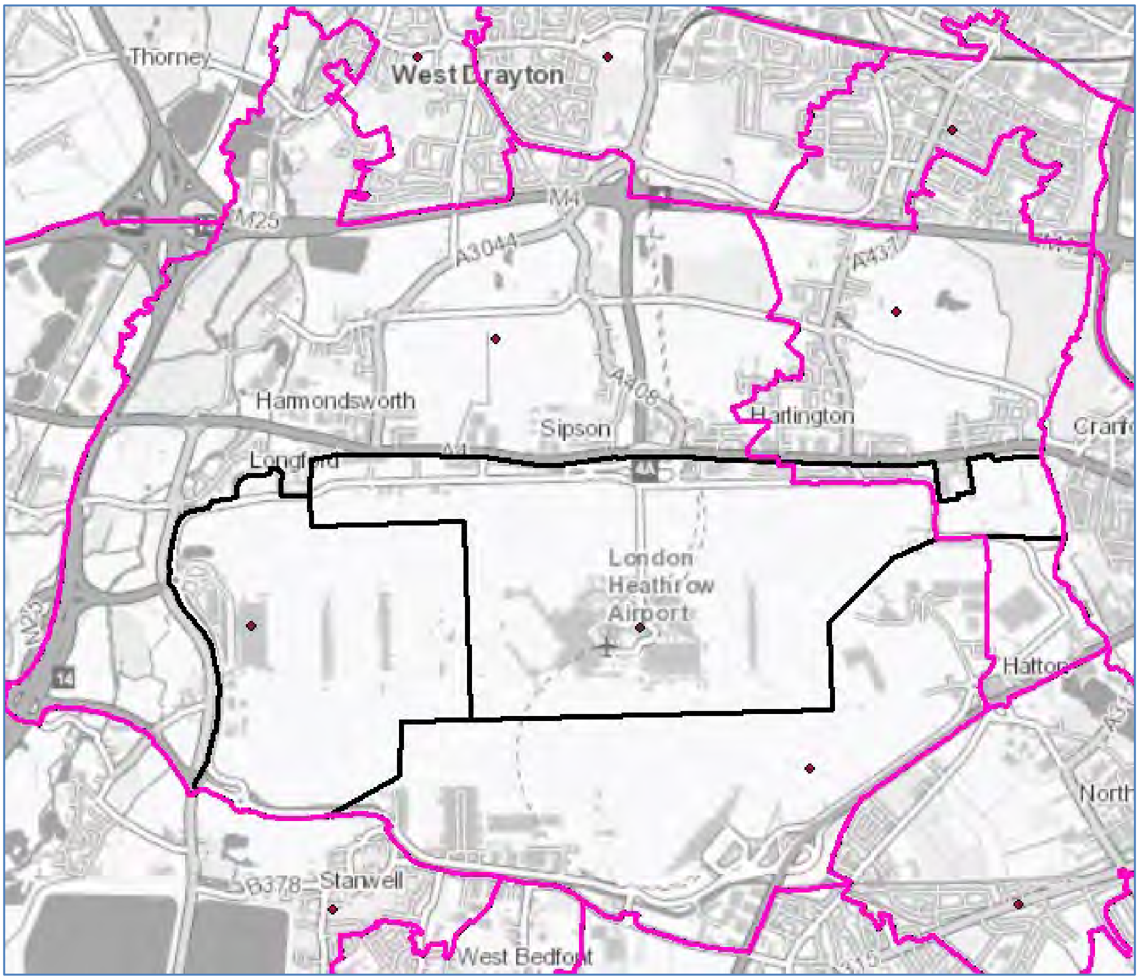


Figure 5.17: Heathrow Airport bespoke zones

Seaports and airports have been given bespoke zones. Rail freight interchanges have been assigned point zones as described in NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0. The figure below shows the point zone added for Doncaster International Railport, where a polygon zone is not created.

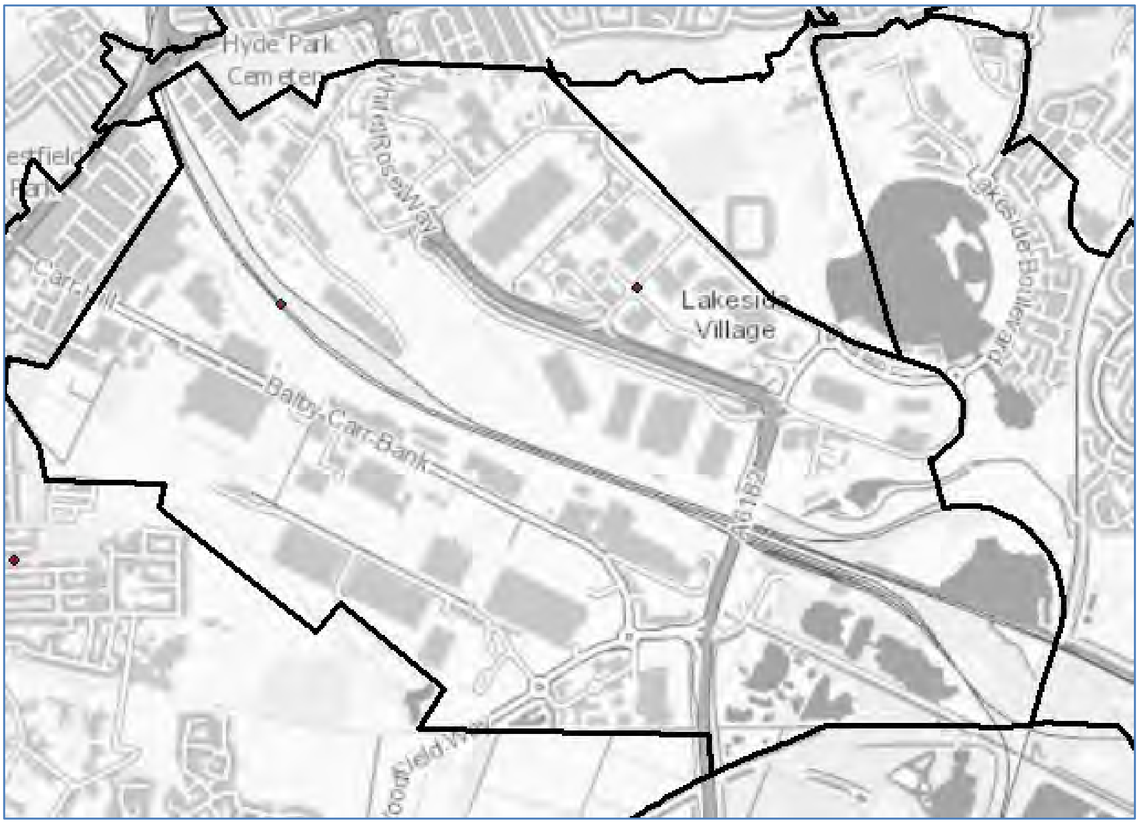


Figure 5.18: Doncaster International Railport

5.2.6. Zone attributes vs Documentation attributes

Table 5.4 below provides a comparison of the model zone data fields and the attributes described in the documentation.

Table 5.4: Zone Attributes

Zone Attribute Listed in Documentation	Within NTMv5 Zone List	If missing, auditors view on significance
Zone Type	All returned as 0	High
Region	Yes	
NTEM7 Area Type	No	High
Screenline	Yes	
Region_NTEM_AreaType	Yes (although none relate back to the areas described in the guide, or the NTEM zones)	
MSOA_District	Yes	
NUTS2	Yes	
NUTS3	Yes	
UAS	No	

Zone Attribute Listed in Documentation	Within NTMv5 Zone List	If missing, auditors view on significance
NUTS1_5	Yes	
Zone name	Yes	
ActiveInactive	No	
PointPolygon	No	
Internal/External	Yes	
RTM Focus Area	No	
CMLAD11cd	No	
Local Authority District codes	No	High
MSOA codes and names	Yes, although not reliable (see above)	
LSOA codes and names	No	
X and Y for zone centroid	No	
Enterprise Zones	No	High
NTMv2R zone numbers	No	
Area in square km	No	
2015 population		
Centroid type	No	
TIS zone number / MSOA code	No	

A significant number of the attributes defined in the documentation are missing in the model data. There are key attributes that are missing such as ‘Zone Type’ which are essential for a complete audit of the model and important from perspective of a model user. Some other missing attributes are considered less important.

- It is recommended that a full list of zone attributes be provided to assist model users undertaking and reporting model tests.

5.2.7. Zone Centroids approach

Zone centroids for England/Wales non-bespoke zones are based on MSOA population weighted centroids. To check the approach MSOA 2011 population weighted centroids have been downloaded and plotted against the NTMv5 centroids. The distance between each NTMv5 zone centroid and MSOA Population Weighted Centroids (PWC) is measured. This is done by taking each NTMv5 zone centroid and measuring the distance to the closest MSOA PWC.
For 7131 MSOA’s in England/Wales, **Table 5.5** breaks down the distances from NTMv5 centroids to the PWCs.

Table 5.5: Distance from MSOA PWC to NTMv5 Centroid Check

Category	Checking/Assumptions	Number of NTM Zones
Scotland	Not checked	50
Wales	Not checked	75
Isle of Wight	Not checked	1
NTM Centroid to MSOA PWC Distance 0	Assumed direct match NTM-MSOA	0
NTM Centroid to MSOA PWC Distance 0-1m	Assumed direct match NTM-MSOA	436
NTM Centroid to MSOA PWC Distance 1-2m	Assumed direct match NTM-MSOA	4609
NTM Centroid to MSOA PWC Distance 2-3m	Assumed direct match NTM-MSOA	1563
NTM Centroid to MSOA PWC Distance 3-4m	Assumed direct match between NTM centroid and MSOA PWC	150
NTM Centroid to MSOA PWC Distance 4-100m	Checked - all appear to be minor differences between NTM centroid and MSOA	7
NTM Centroid to MSOA PWC Distance 100-1000m	Checked - NTM Centroid is a modified PWC	3
NTM Centroid to MSOA PWC Distance 100-1000m	Checked - NTM Centroid is a bespoke zone	103
NTM Centroid to MSOA PWC Distance >1000m	Checked - NTM Centroid is a modified PWC	2
NTM Centroid to MSOA PWC Distance >1000m	Checked - NTM Centroid is a bespoke zone	132
TOTAL		7131

Each of the categories have been checked and compared against the zone classification listed in the 'NTMZoneSystem Spreadsheet'. A summary of the findings is provided below.

- Where the distance between MSOA PWC and NTM centroid is below 4m, all zone categories are 0 or 1 (MSOA zones), and therefore the good match is expected.
- Where the distance between MSOA PWC and NTM centroid is between 4-100m, all zone categories are 0 or 1 (MSOA zones). The discrepancy for these zones (7

zones) is thought to be either an issue with the version of MSOA PWC being used, or alternatively the PWC has been adjusted.

- Where the distance between MSOA PWC and NTM centroid is greater than 100m:
    - 6 zones with zone category 0 or 1 (MSOA zones). The discrepancy is thought to be either an issue with the version of MSOA PWC being used, or alternatively the PWC has been adjusted.
    - 234 zones which have a zone category not equal to 0 or 1 (bespoke zones). There is expected to be a difference between MSOA PWC and NTM centroid at these locations.

NTMv5 centroids in Wales, Scotland and Isle of Wight have not been assessed against the MSOA PWCs as these zones consist of aggregated MSOAs.

The documentation states that PWCs have been used throughout the model despite noting that non-residential zones should have a centroid based on non-residential land use. On review, it appears the PWCs have been used in the majority of cases and where not, these are the result of bespoke zones where alternative locations for centroids have been used. It is unclear from the documentation how the location of the centroids in bespoke zones has been selected.

Figure 5.19 below shows 2 bespoke zones within an MSOA, where the PWC has been used in the zone to the north, and 2 additional centroids have been created for the created bespoke zones. It is these centroids where the methodology is unclear for selecting the location.

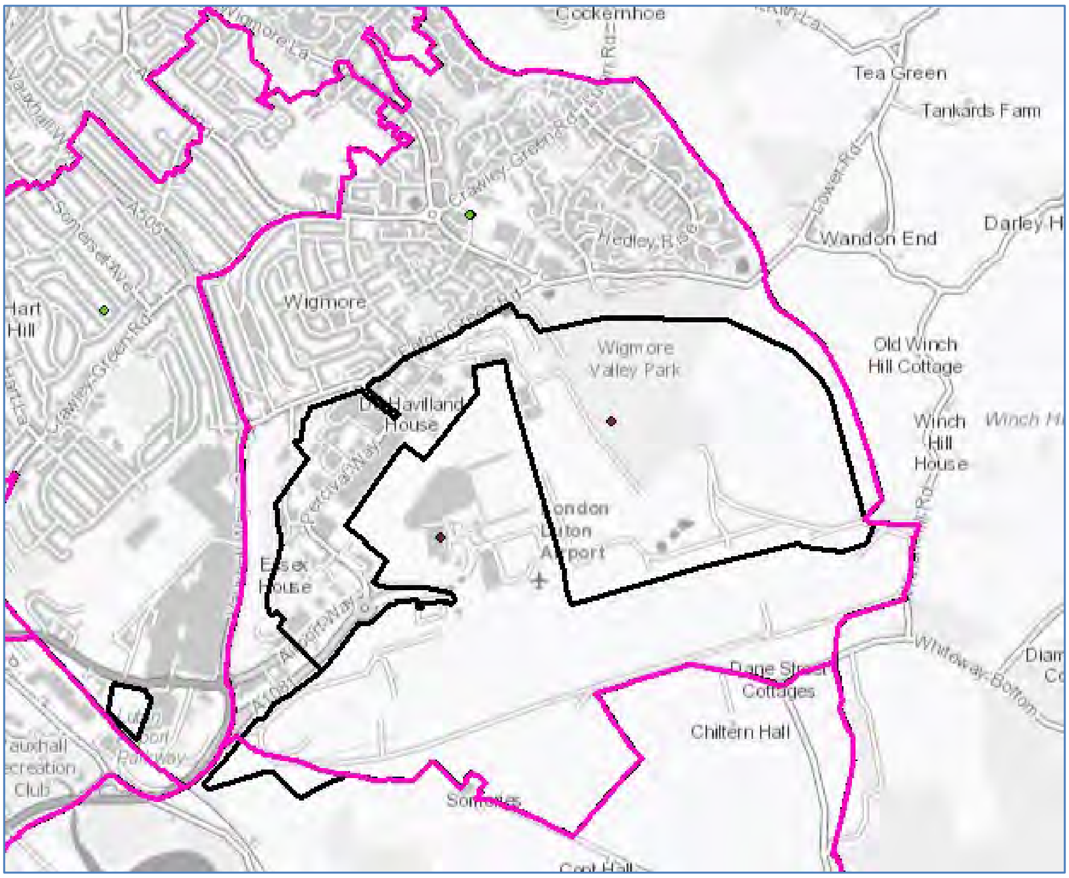


Figure 5.19: Bespoke centroids

It is concluded that the majority of NTMv5 centroids are based on MSOA PWCs.

5.2.8. Zone sector definitions and implementation

There are many sector systems defined in the model to aid model analysis. It was concluded from the documentation and the model review that the NUTS sector systems are key in the model development and use (NUTS 3 in particular is used in the pivoting process) and so have been were checked in within this audit. A spatial comparison has been performed to verify NUTS zone sector systems used in the model.

NUTS3 Boundaries

There are 179 NUTS 3 zones downloaded and 138 unique NUTS zones in the model. The discrepancy relates to NUTS zones in Northern Ireland and therefore this is not an issue relating to the model i.e. NUTS covers a wider area.

Figure 5.20 and **Figure 5.21** below show the NTMv5 NUTS by colour, with the downloaded NUTS zone boundaries overlaid. It can be seen that in England, NUTS3 zone sectors are closely followed. However, the boundaries in external area of the model, i.e. Wales and Scotland are not always followed.

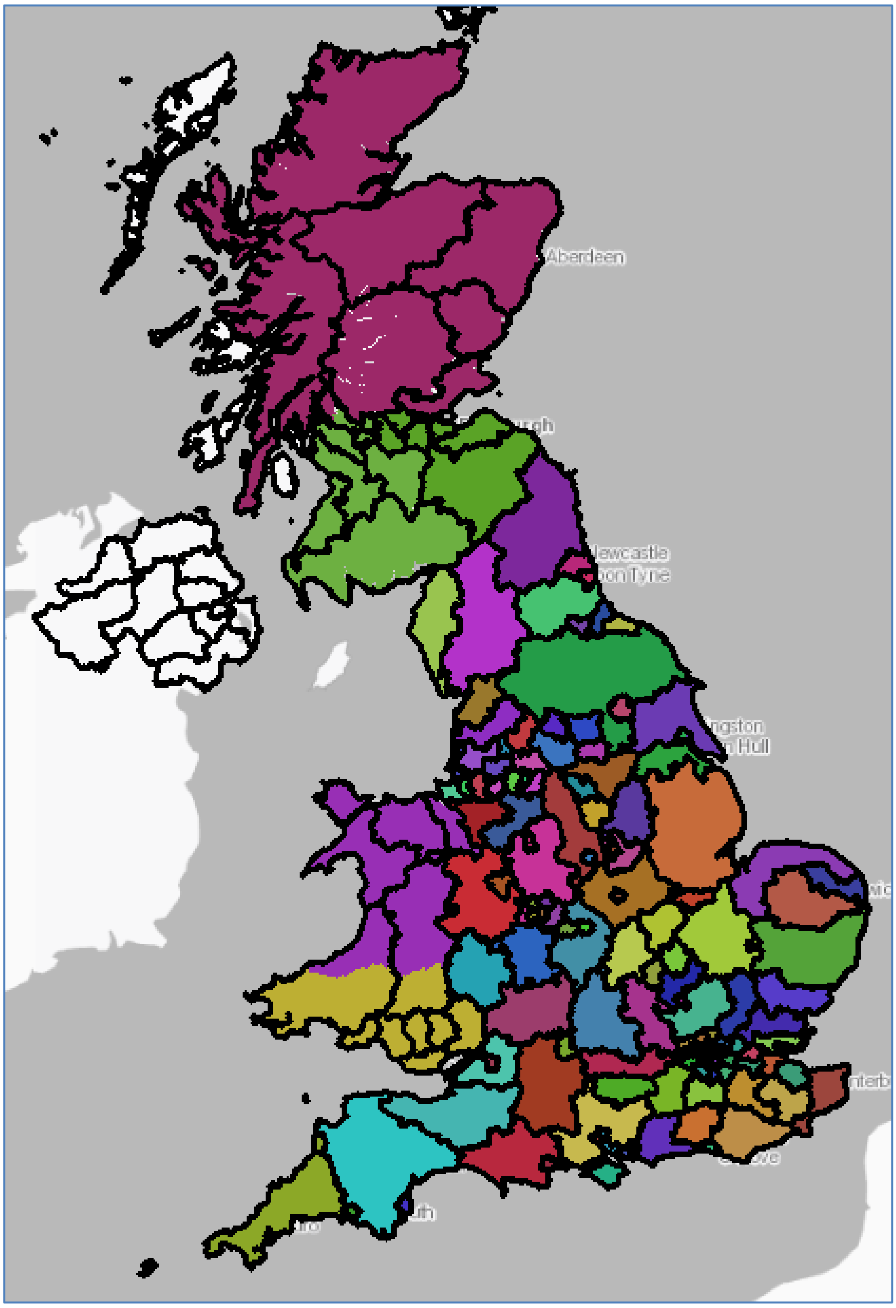


Figure 5.20: NUTS 3 boundaries to NTMv5 NUTS3 sector attributes

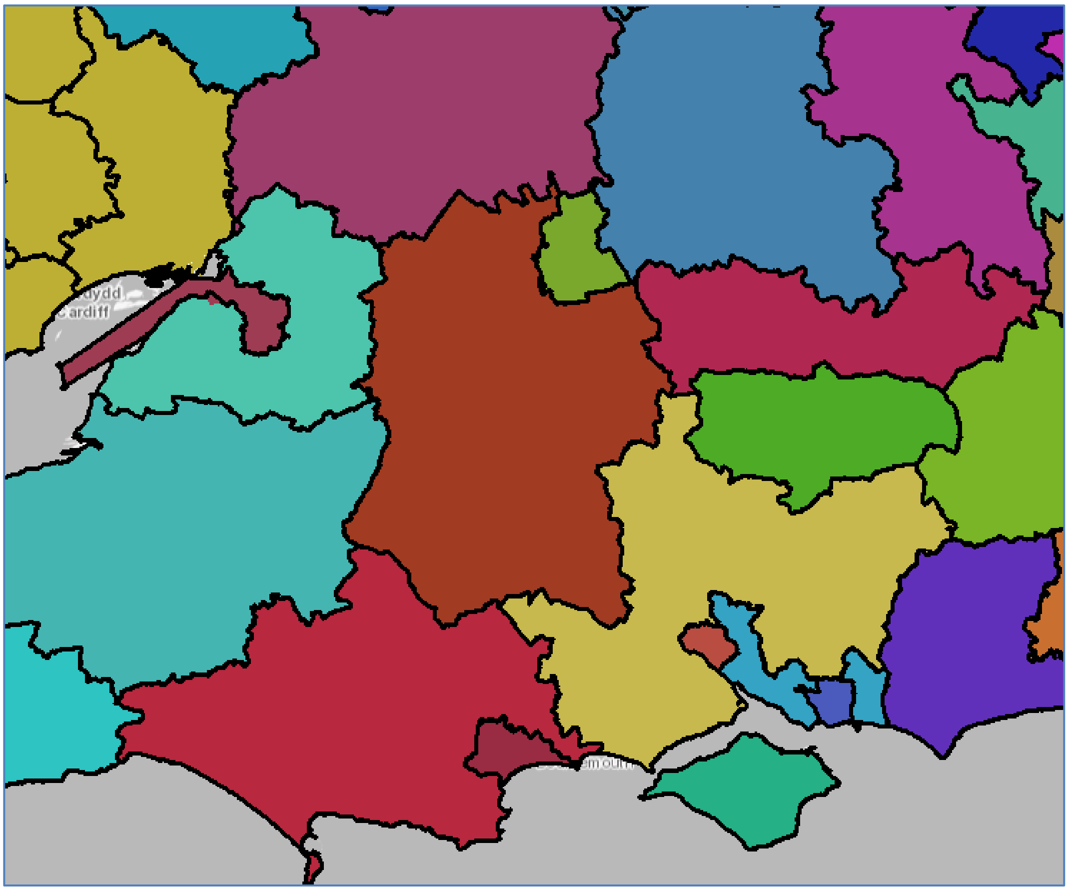


Figure 5.21: NUTS 3 boundaries to NTMv5 NUTS3 zone sector attributes - detail around Hampshire, Wiltshire and Berkshire.

NUTS2 Boundaries

There are 41 NUTS2 zones downloaded and 38 unique NUTS2 zone sectors in the NTMv5 model. The discrepancy is a result of zones in Northern Ireland.

NUTS2 boundaries are closely followed in England. There are obvious discrepancies in boundaries in the external model area covering and Wales/Scotland, as shown in **Figure 5.22** and **Figure 5.23**.

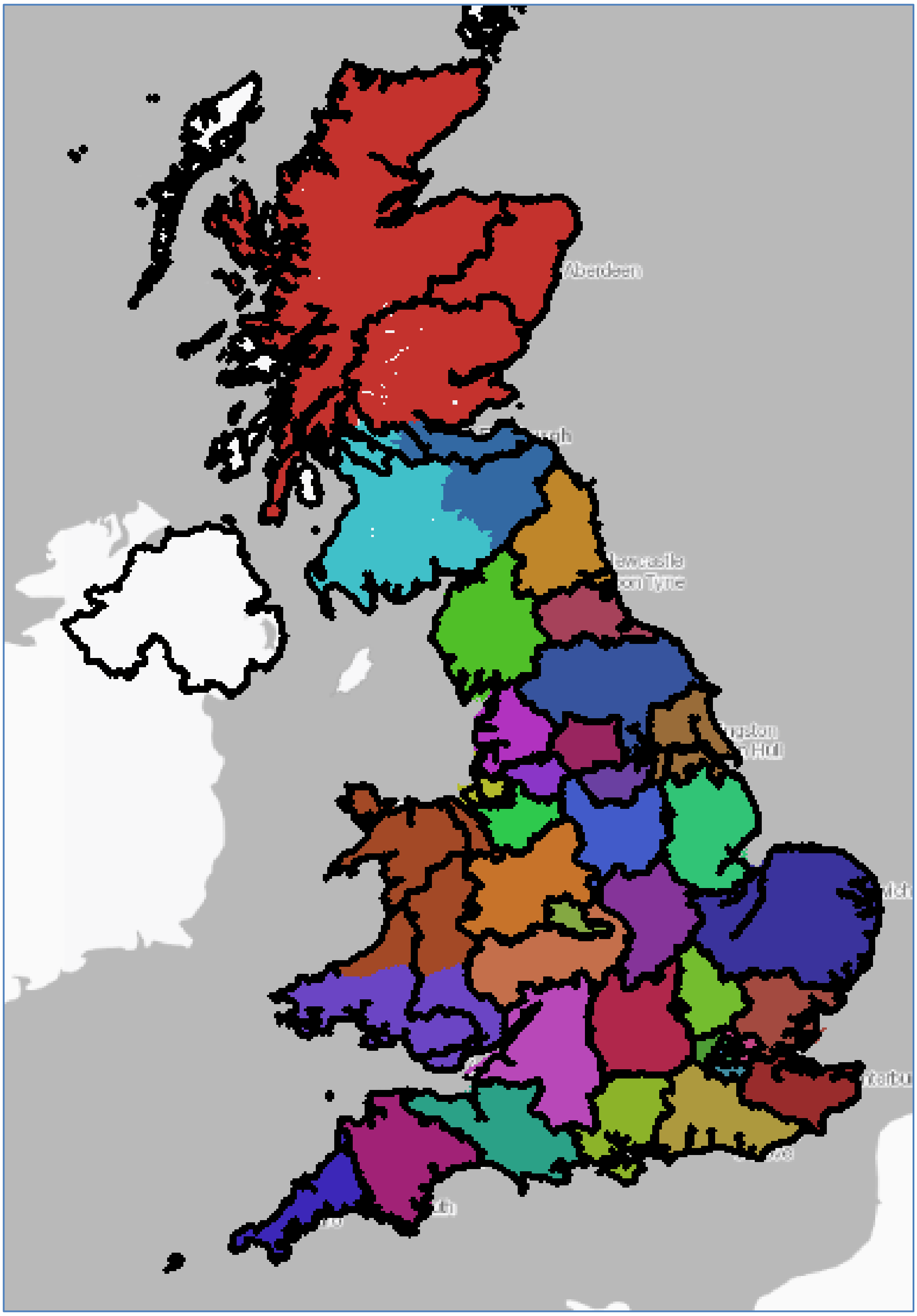


Figure 5.22: NUTS 2 boundaries to NTMv5 NUTS2 zone sector attributes

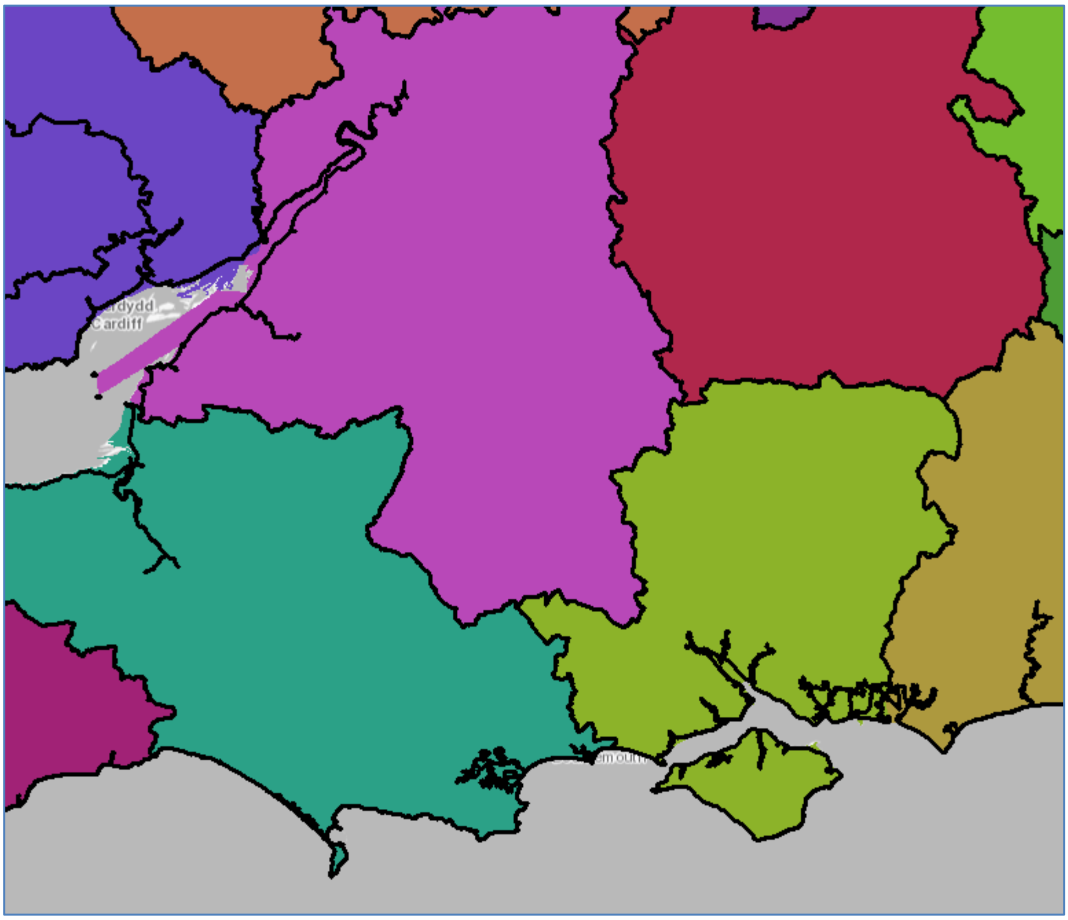


Figure 5.23: NUTS 2 boundaries to NTMv5 NUTS2 zone sector attributes

NUTS1 Boundaries

There are 12 NUTS1 zones in the downloaded dataset and 31 unique NUTS1 zone sectors in the NTMv5 model. The NUTS 1 attribute in the NTMv5 model is labelled 'NUTS1_5'. The documentation explains that it's an aggregated version of the NUTS 2 boundaries. This couldn't be checked with the information available.

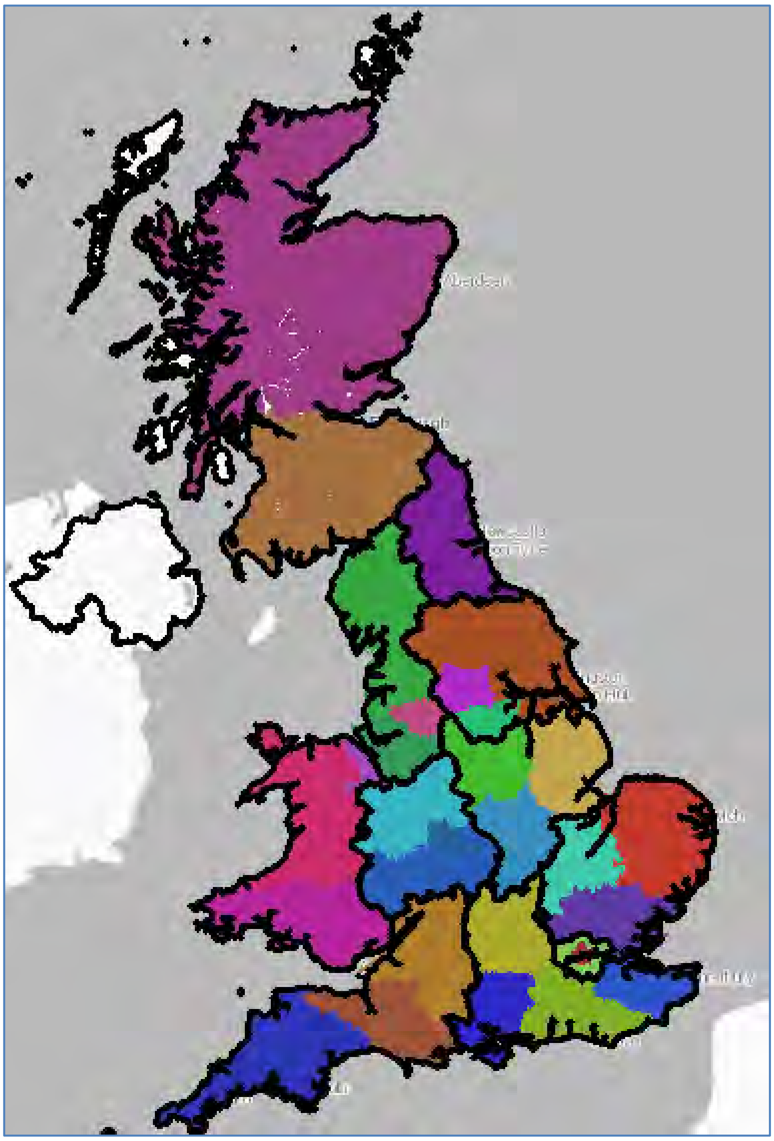


Figure 5.24: NUTS 1 boundaries to NTMv5 NUTS1_5 zone sector attributes

- ➢ In order to avoid confusion amongst model users, it is recommended that further details be provided regarding NUTS1_5, such that users do not believe that outputs are being produced at NUTS1 level.

5.3. Highway Network Development

This section sets out findings from a detailed review of the highway network development assessed against the principles underpinning the guidance set out in TAG M3.1 and against the NTMv5 model documentation. The audit process was undertaken and reported on by high level highway network components listed below:

- links
- connectors
- congestion delay representation in the following:
    - junction modelling
    - volume delay functions, and
    - fixed Urban Area Speed (UAS).

Additionally, the following aspects of the model were also considered as part of this section:

- HGV restrictions;
- tolls;
- roadworks; and
- bus preloads.

5.3.1. Links

Highway links coding has been reviewed considering the spatial representation of the network. The network was developed by combining 5 RTMs together with further refinements during the model development stages such as model calibration. Additional independent checks were undertaken using ITN network (OSMM ITN, 19th March 2015) to identify if there are any strategic routes not accounted for in NTMv5.

Key descriptive data appended to the links using link attributes was also checked. Link type is the key attribute in the model that defines the delay functions applied to each link as well as attributes describing characteristics of the link, for instance; capacity, speed, and number of lanes. The link type number attribute was inherited from the RTM models. The following attributes were independently checked against the ITN network to ensure links are accurately represented in the model:

- number of lanes;
- road class (Motorway, A Road, etc.); and
- road type (Single/Dual Carriageway).

5.3.2. Network Coverage

The initial NTMv5 network is a result of the stitching together of the five SATURN RTM networks. The network coverage of NTMv5 was checked against the network coverage of RTM models. The Midlands Regional Transport Model (MRTM) was chosen at random to check against the NTMv5. The MRTM has an extensive network within its region of focus, but only includes strategic links for the remainder of the country which is represented in a greater detail in each of the other RTMs. **Figure 5.25Error! Reference source not found.** (with the NTM network displayed as the top layer) and **Figure 5.26:** (with MRTM network displayed as the top layer) below shows the network coverage comparison between the NTMv5 and MRTM modelled network. A detailed visual inspection of the networks was undertaken around the Midlands region of focus by identifying areas where the colour of the bottom layer is visible. Through this review no issues or clear differences were identified.

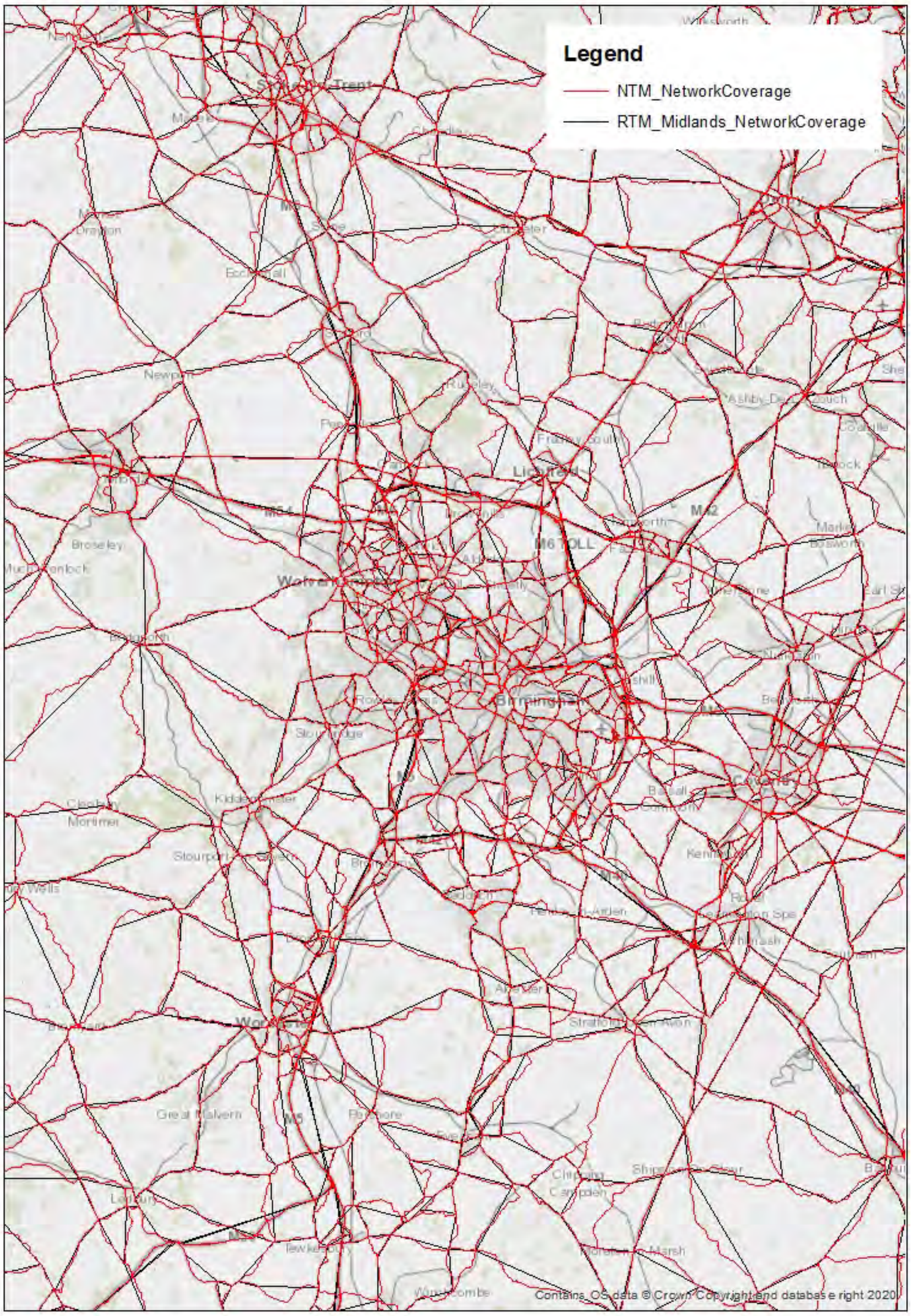


Figure 5.25: Comparison of network coverage: NTMv5 (top layer) vs MRTM (bottom layer)

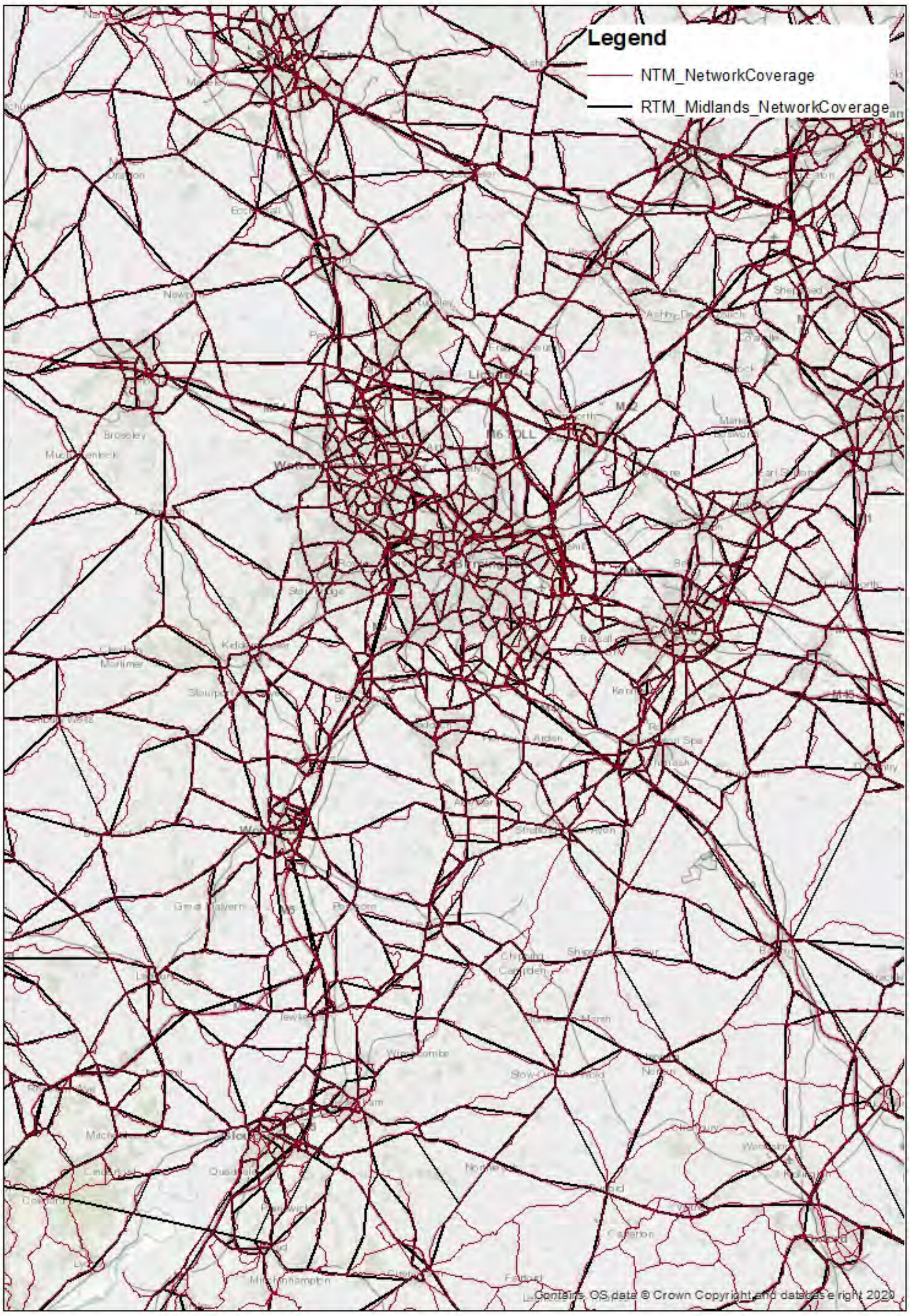


Figure 5.26: Comparison of network coverage: NTMv5 vs MRTM

The boundary between the MRTM and SWRTM models have also been compared against the NTM model to assess the outcome of the stitching process. A visual inspection was carried out at the boundaries of the region of focus of both RTM models to check if the details are captured correctly. **Figure 5.27** below depicts the overall link structure in the MRTM and SWRTM.

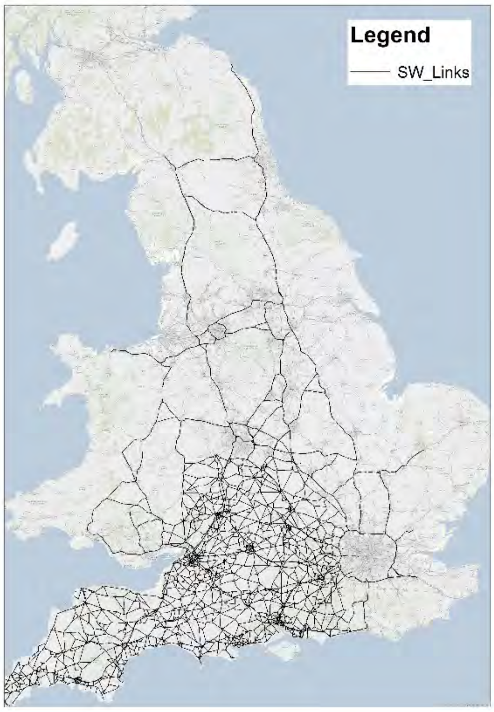


Figure 5.27: MRTM (left) and SWRTM (right) highway model networks

Spot checks in the area near the boundaries were undertaken as shown in **Figure 5.28:** There was found to be a good match between the NTMv5 links and the links of each RTM within its own region of focus. It was concluded that no boundary issues were identified.

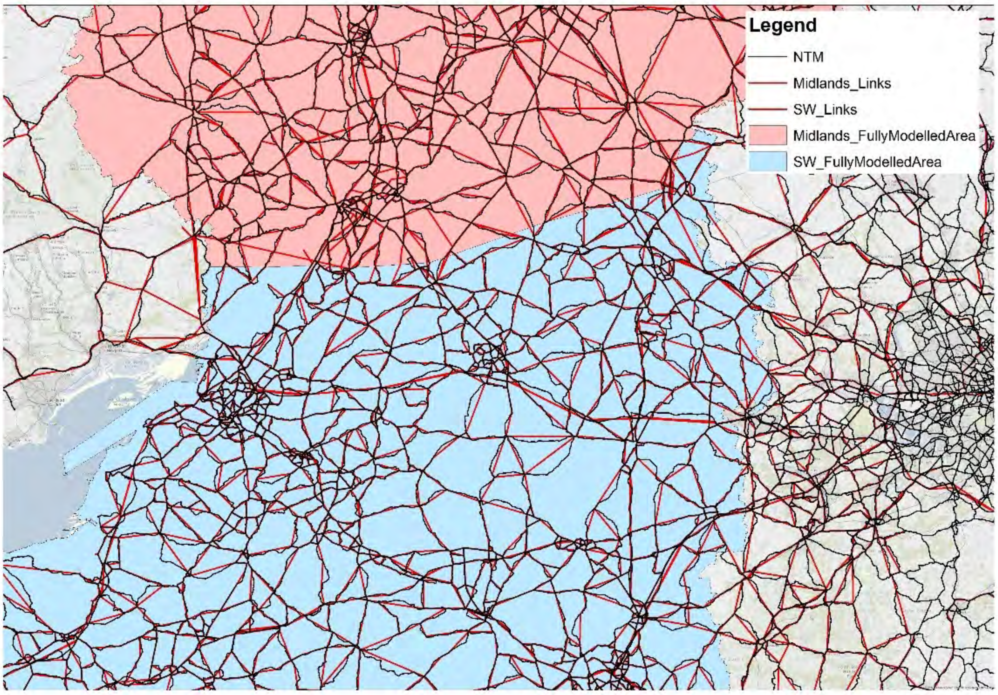


Figure 5.28: Comparison of network coverage: NTMv5 vs MRTM and SWRTM

In the absence of any attribute in NTMv5 to indicate which links are part of the Strategic Road Network (SRN) or Major Road Network (MRN), the Motorways and A roads in NTMv5 and ITN networks were compared to check the completeness of the representation of higher rank roads in NTMv5.

The review of the Motorway network has shown that all Motorway links were represented in the NTMv5 study area. Using road class classification revealed that the motorway links in Scotland (included as part of the external network) are classified as fixed speed that have a lot of descriptive information missing (e.g. road class).

It is worth noting that the network in Northern Scotland is not represented in the model and very long connectors with crow-fly distance are used instead. The issue of the use of crow fly distances for connectors is discussed in Section 5.3.3.1.

In relation to the A roads, it was observed that there are additional A Road links in the NTMv5 network which are not present in the ITN network (**Figure 5.29**). Further investigation revealed that these links in the ITN network are classified as lower rank roads instead. These links were checked against the Google Maps to check the type of the link and a few spot checks indicated that the road class matches the ITN road class. The below figure shows a part of the network of A Roads in the NTMv5 and ITN model highlighting the scale of these differences. As the link type classification in NTMv5 does not use the A Road classification, it is assumed that this will not impact performance of the model.

- For completeness it is recommended that erroneous labelling of A roads within NTMv5 is rectified.

In summary, it was concluded that the coverage of strategic links in the model is appropriately represented.

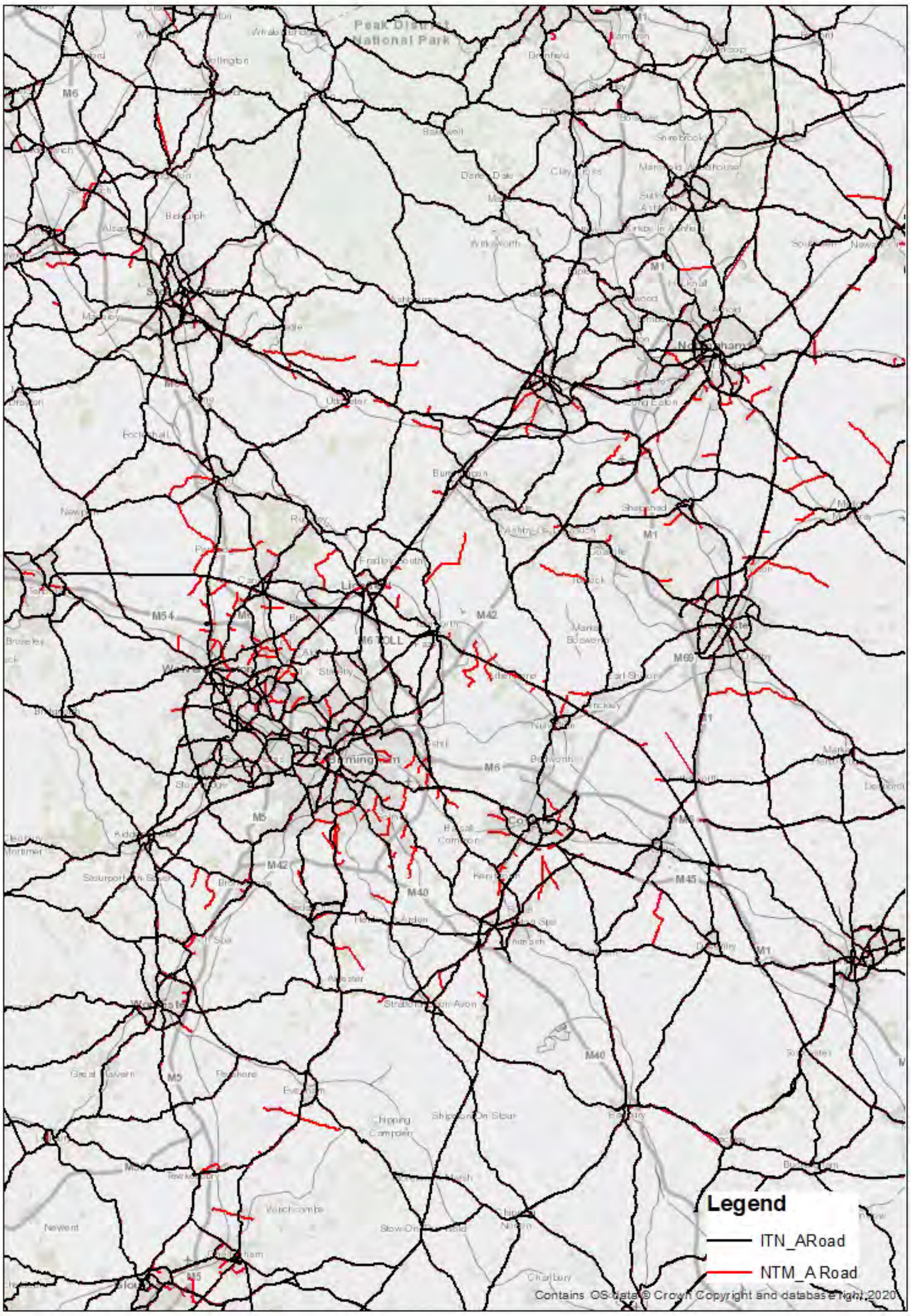


Figure 5.29: Comparison of A road: NTMv5 (bottom layer) vs ITN (top layer)

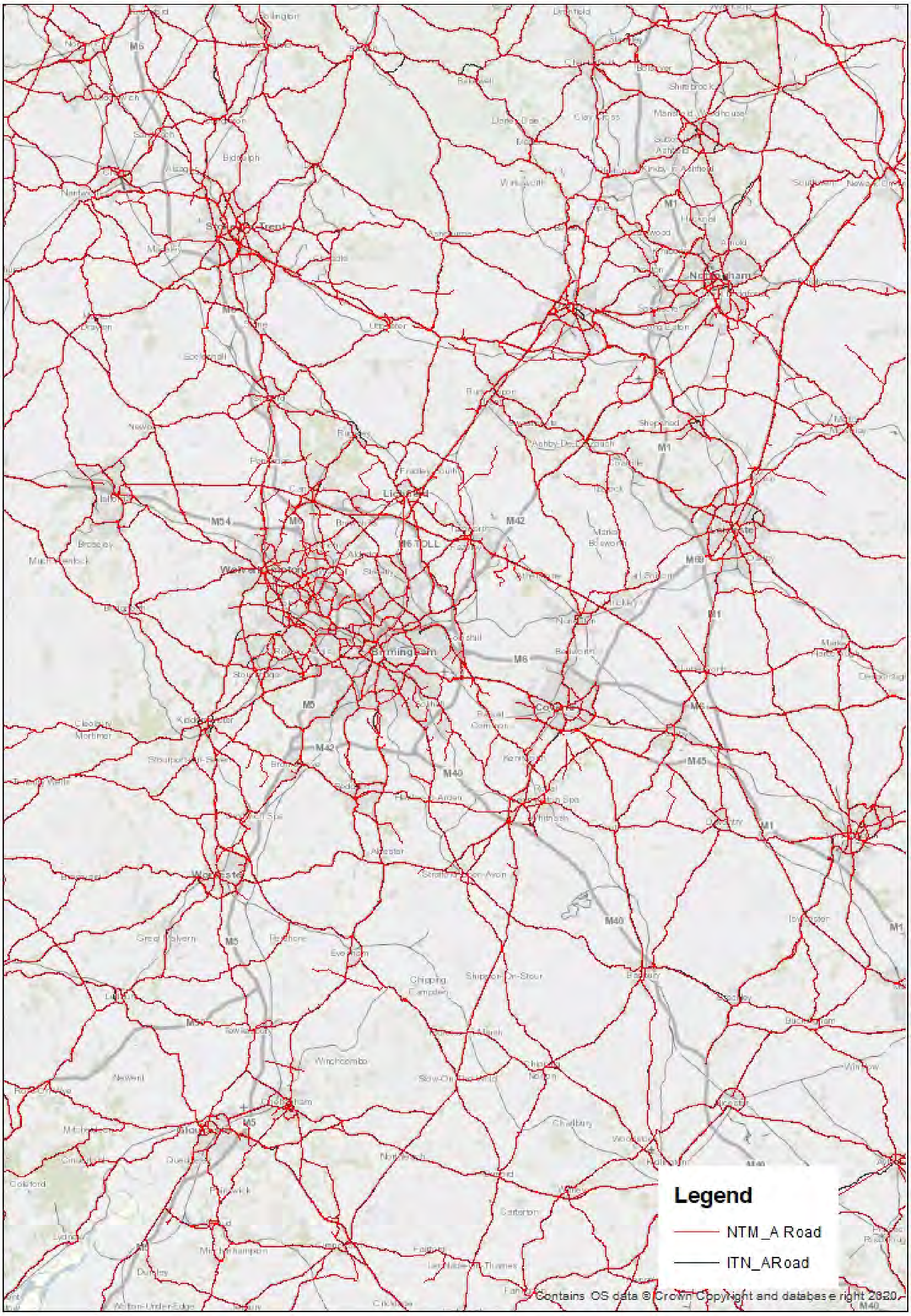


Figure 5.30: Comparison of A Roads: NTMv5 (top layer) vs ITN (bottom layer)

5.3.2.1.Link Type Definitions and Attributes

Link Types

In NTMv5 the link type definition assigned to the links enforces the values of other descriptive attributes such as number of lanes, capacity and speed of the links. A common issue during model development is that intentional/unintentional edits are made that overwrite default values; a check of link attributes was therefore made as part of this review. It was observed that no manual edits have been made and therefore, it is concluded that the attributes inherit the default values based on the link type.

Number of lanes

A visual check was carried out in GIS between the MRTM network (chosen at random) and the NTMv5 network to spot if there are any differences in the number of lanes that could impact on incorrect link classification in NTMv5. Significant differences in the number of lanes were spotted at various locations. **Figure 5.31** depicts the NTMv5 and the MRTM network in and around Birmingham. It is noted that the two networks do not directly overlap spatially as the RTM network is represented as a ‘stick’ network, such that nodes are connected via straight links. The RTM stick network is represented in red and the curved network in blue represents the NTMv5 network.

To further investigate these errors, the links in each direction were graphically represented by the number of lanes for both RTM and NTMv5 in **Figure 5.32**. Significant discrepancies in the number of lanes can be observed between the two networks. Links that are closely aligned, that are displayed with different colour indicate areas where the number of lanes attributes do not match. Further spot checks were carried out by checking the NTMv5 network against the satellite images. It was observed that the number of lanes in the satellite image matched the NTMv5 network. As the NTMv5 network was taken from an early version of the RTM networks, which themselves have been refined since, it is perhaps unsurprising that errors have been found in the RTM network. Nevertheless, it is reassuring that the correction of these errors within NTMv5 shows evidence of manual checking of data inputs having been undertaken.

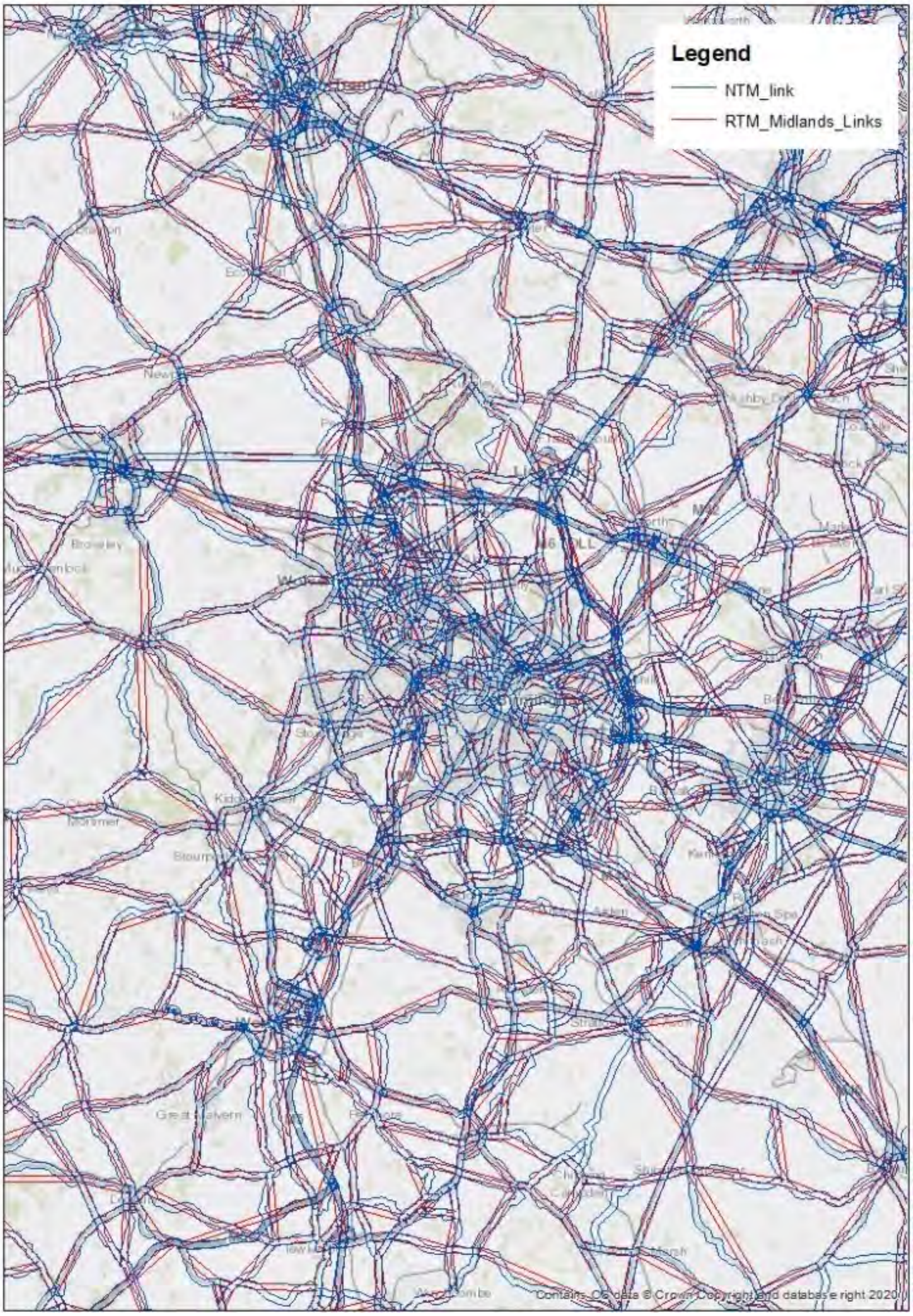


Figure 5.31: NTMv5 and RTM networks overlapped

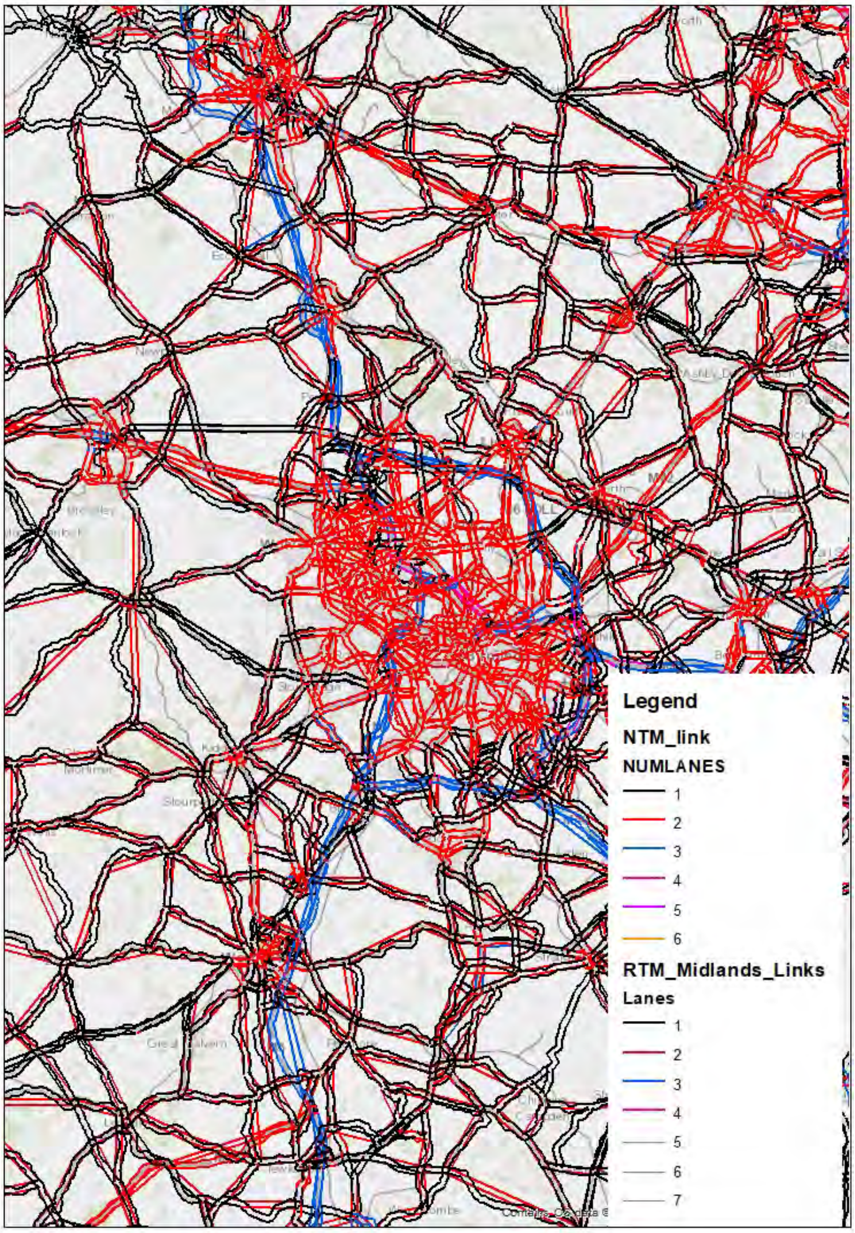


Figure 5.32: Number of lanes comparison: NTMv5 vs RTM

An additional observation was made regarding the number of lanes. 116 links were found to be coded with zero number of lanes. Although this is an issue of a cosmetic nature and does not influence the model performance, it is recommended that this is updated to avoid any implications caused by future use of these attributes.

- For completeness it is recommended that erroneous number of lanes values within NTMv5 are rectified.

Road Type (Single/Dual Carriageway)

The attribute, 'Road Type' in ITN was compared against the road type in NTMv5 derived from the description in link type definitions. A visual comparison was carried out by checking if the dual carriageways and single carriageways definitions match across the two datasets. The checks were based on the Motorway and A road networks. It was observed that there is an appropriate consistency between NTMv5 and ITN network for representation of single and dual carriageways.

5.3.3. Connectors

This section summarises the review of connectors in the model and checks in relation to the requirements stated in the model documentation and recommendations published in the TAG guidance. The following aspects of connectors coding in the model have been checked:

- connector attributes;
- zones with multiple connectors;
- connectors connected to modelled junctions;
- centroid connectors from adjacent zones connected to same point;
- connectors connected to motorways and major A roads; and
- connectors crossing screenlines.

5.3.3.1. Connector Attributes

Travel time and distance along connectors is represented in the model with hard-coded attributes. It is important to code these characteristics accurately as they influence route choice in the assignments and contribute to the skimmed costs subsequently used as an input in the VDM. It is also difficult to represent new schemes if you have no confidence in base / comparator.

The NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0 describes that the length of the centroid connectors is taken as the crow-fly distance from centroid to the designated node and a fixed speed of 50kph is adopted. This methodology differs from typical practice which would assume the length to be the crow fly distance multiplied by a factor (usually 1.3. to 1.5) to account for the bendiness in the road network.

An extreme example of the connector coding is shown on **Figure 5.33**. The majority of the network in Northern Scotland is not represented in the model. Instead very long connectors are coded with distance set to crow-fly distance to connect zones in that region to the highway network. This significantly underestimates the true distance for these movements in the model. Evaluation of the generalised cost for these trips where the vehicle operating costs (based on distance) and journey time will be significantly smaller can introduce a bias making highway trips more attractive in comparison to public transport.

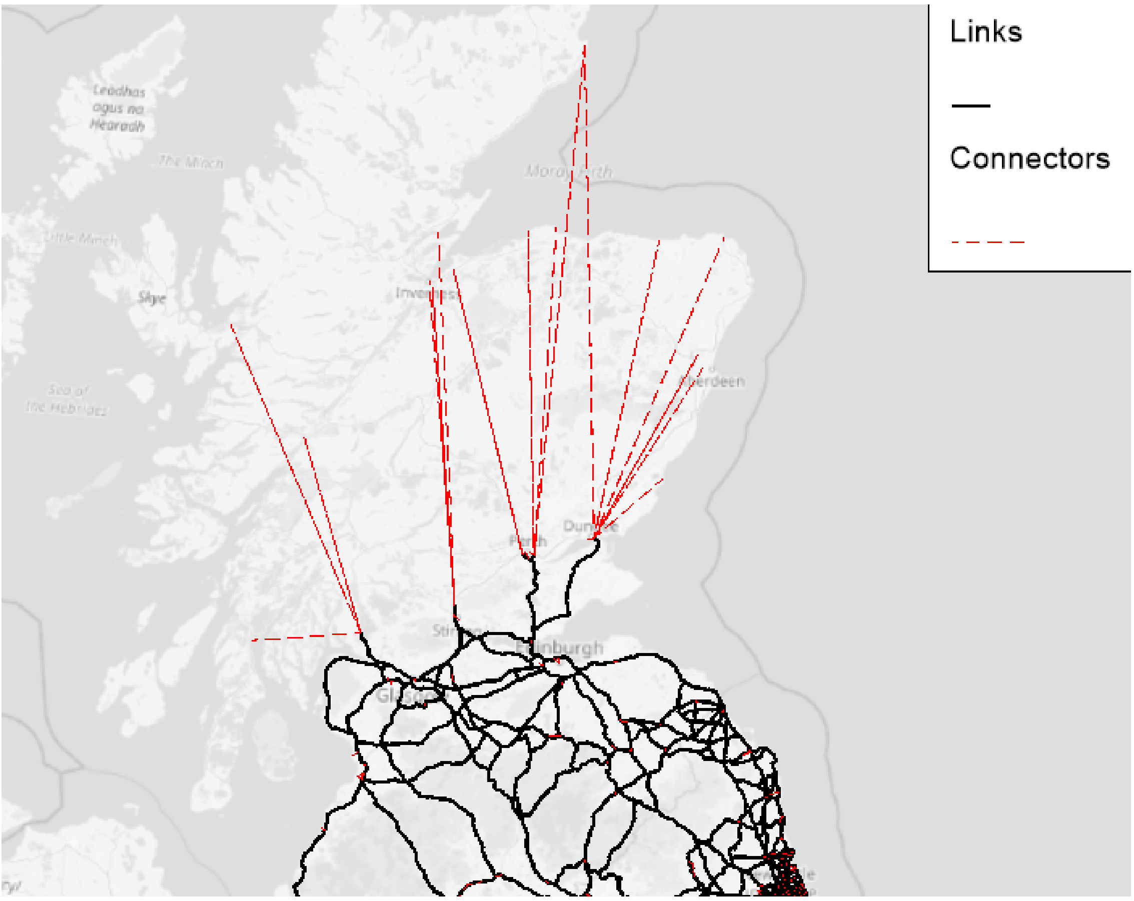


Figure 5.33: Example of connectors coded with long crow-fly distances

To check if this accurately describes the implementation the length of connectors was extracted from the model using the connector attributes 'length' and 'direct length', which represents crow fly distance between the zone centroid and the connection point. The differences between the two attributes were checked and it was found that in only 58 out of 22,272 connectors (Origin & Destination) did the length not match the crow-fly distance. Only 10 out 58 connectors have a difference in length of 1 km or more. Given that the centroid length is underestimated it is therefore concluded that in the majority of cases the overall trip length is slightly underestimated.

- It is recommended that an adjustment is applied to centroid connector lengths to reflect the bendiness of the roads they are representing.

A similar check was carried out to verify speed assumptions in the model to calculate connector travel times. It was found that most of the connectors have a speed of around 30kph, and all less than 40kph. This is different to that reported in the developer guide above.

In relation to both length and speed of connectors, there is no information in the report if manual edits were carried out during model calibration on these connectors resulting in the difference. Although the impact of this is assumed to be minor, it is not aligned with the documentation. If new connectors are coded by a model user following the assumptions in the documentation, this may lead to a bias making new connector more attractive with faster travel times.

- It is recommended that the developer guide is updated to report on the methodology used to calculate the travel time on the centroid connectors, to include a description of the reasons why some of these speeds may have changed during model calibration. This would allow the user to understand how to code any new connectors.

In addition to the above attributes, it was observed that the connectors are differentiated by type number in the model. There is no mention about this attribute in the report and it's unclear if it is used anywhere in the model.

The zone type definitions were not present in the model as described in section 5.2.1. The connector type attribute might be related but the audit team were unable to confidently make an assumption with the available data

- It is recommended that a list containing zone classification be included within the model to improve transparency for auditors and usability for the model user.

5.3.3.2. Zones with multiple connectors

TAG Unit M3.1 recommends that the use of multiple connectors for each zone should be minimised as this leads to loadings at the periphery of zones, underestimating travel and therefore, traffic within the zone itself. Typically, any zone that requires more than one connector are typically larger zones. Therefore, there it is a greater weight applied within Vissum to ensure there is appropriate routeing on the modelled network at each connection point. Due to insufficient information regarding the use of multiple connectors in the NTMv5 Developer Guide Vol1-Model Zones and Highway Network v2.0, the connectors coded in the model were checked to quantify the number of zones with multiple connectors. Table 5.6 below shows the number of zones segmented by the number of connectors.

Table 5.6: Number of Connectors per Zone

Number of connectors	Number of Zones	Percentage Distribution
Zones with 1 connector	3391	47.55%
Zones with 2 connectors	3476	48.74%
Zones with 3 connectors	263	3.68%
Zones with 4 connectors	1	0.01%
Total	7131	100%

More than 50% of the zones have more than 2 connectors.

Spot checks have been carried out on the remaining zones with 2 or more connectors to determine the reasoning behind coding of multiple connectors. For instance, the zone with 4 connectors represents entry/exit points to London Heathrow Terminal 2 & 3. Google earth observation indicates that this is the only entry/exit in the surrounding area with two separate in-links and two separate out-links which means that use of 4 connectors for this zone is appropriate.

The documentation states that the coding of connectors was undertaken using automated procedures in Visum with manual adjustments in the later parts of the model development. It is unclear what the criteria were that determined the number of connectors per zone and choice of the connection points on the network. Without knowing these assumptions, it is difficult to apply consistent coding of connectors during model updates and implementation of new zones.

- It is recommended that the developer guide is updated to detail the approach undertaken for coding the connectors so that users can understand the possible issues that may arise with regard to the possibility of zone loadings distorting traffic flows on links.

One particular issue that has been noted within this audit is the case where multiple connectors from the same zone are connected to either end of a single link. An example of this is shown in **Figure 5.34**.

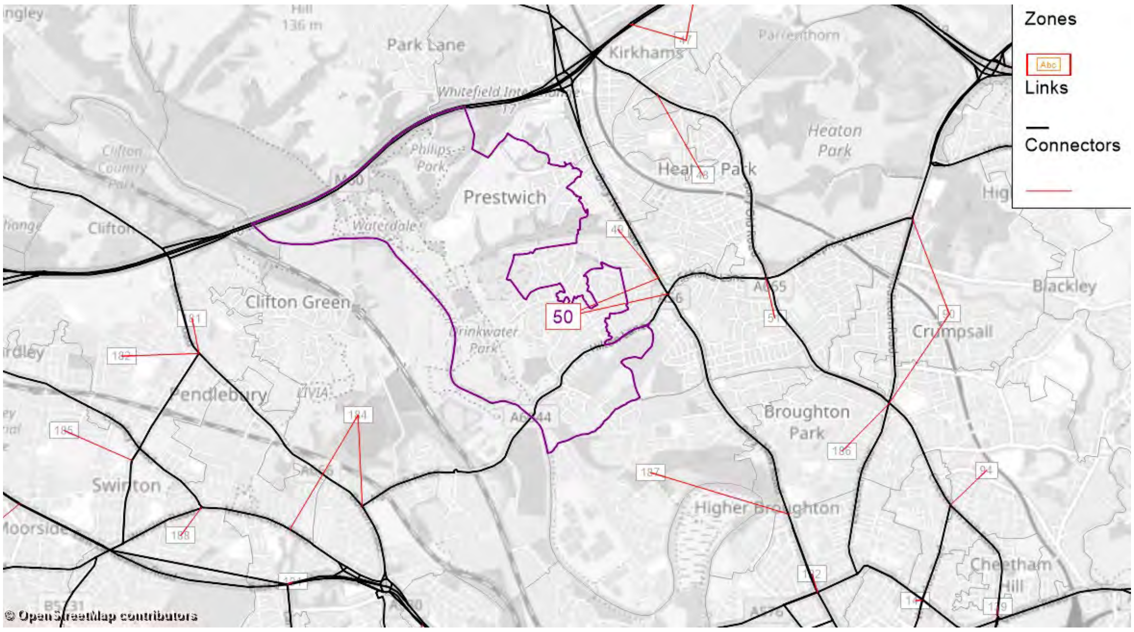


Figure 5.34: Example of coding of multiple connectors connected to the same point on the network

In these instances, it is clear that use of multiple connectors increases complexity of the model and does not provide any improvement to the level of detail represented.

TAG Unit M3.1 suggests that trips per zone should be reasonably uniform and should be limited in size to avoid unrealistically high loads appearing at some points of the network. Zone trip frequency was therefore evaluated and is show in **Figure 5.35** below (evaluated for the AM base year model). A similar assessment was undertaken by the model developer and show in Table 5.1 of the NTMv5 Developer Guide Vol3-HAM v2.0. Our assessment was undertaken by zone whereas the summary of zone loadings in the Developer Guide was evaluated by connector. There are significant differences in the shape of the distribution between the audit assessment and the values reported in the Developer Guide noting that over 50% of zones in the audit assessment are associated with more than 1100 trips, compared to 3% of connectors reported in the Developer Guide. It can therefore be concluded that the multiple connectors have been used as a method of distributing trips from the largest zones such that they minimise the impact on the highway network.

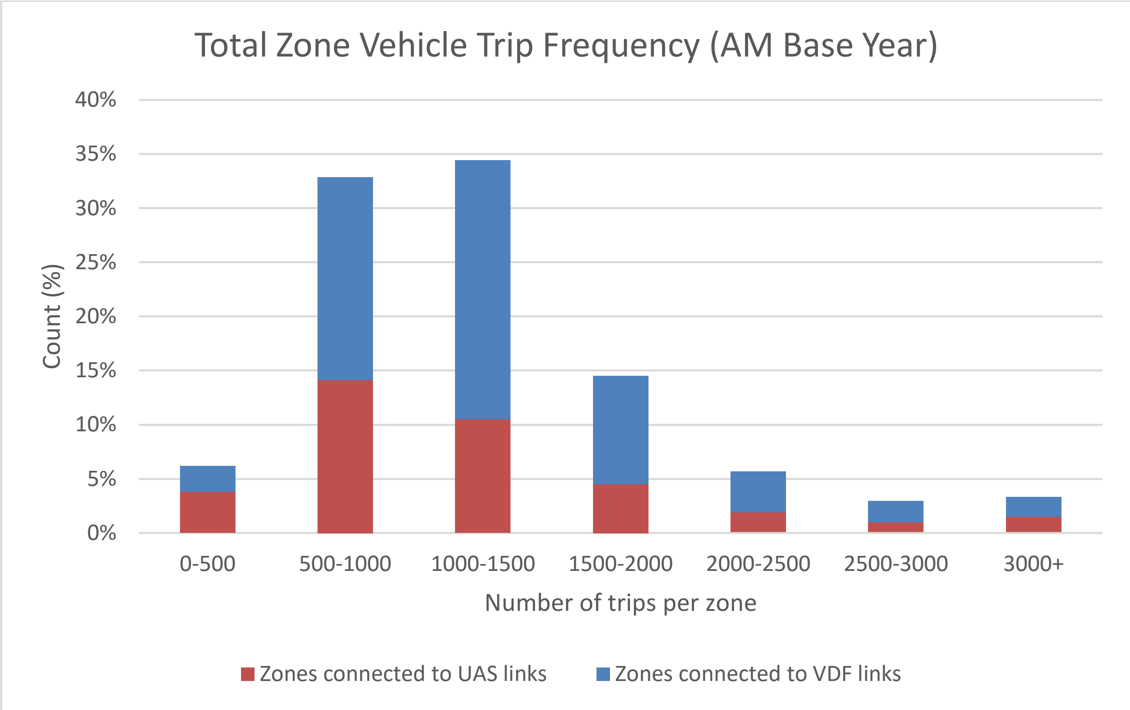


Figure 5.35: Zone Trip Frequency Distribution

Figure 5.35 also distinguishes between zones connected to network with volume delay functions, and those that area connected to fixed speed or UAS links, as large volumes of trips loading on UAS links would be less of a concern. It is noted that significant number of zones with high trip frequencies are connected directly onto network with volume-delay functions implemented.

To consider this issue further **Figure 5.36** and **Figure 5.37** below, confirm that a large proportion of zones with high trip frequency (1000+) are outside of areas where UAS were implemented.

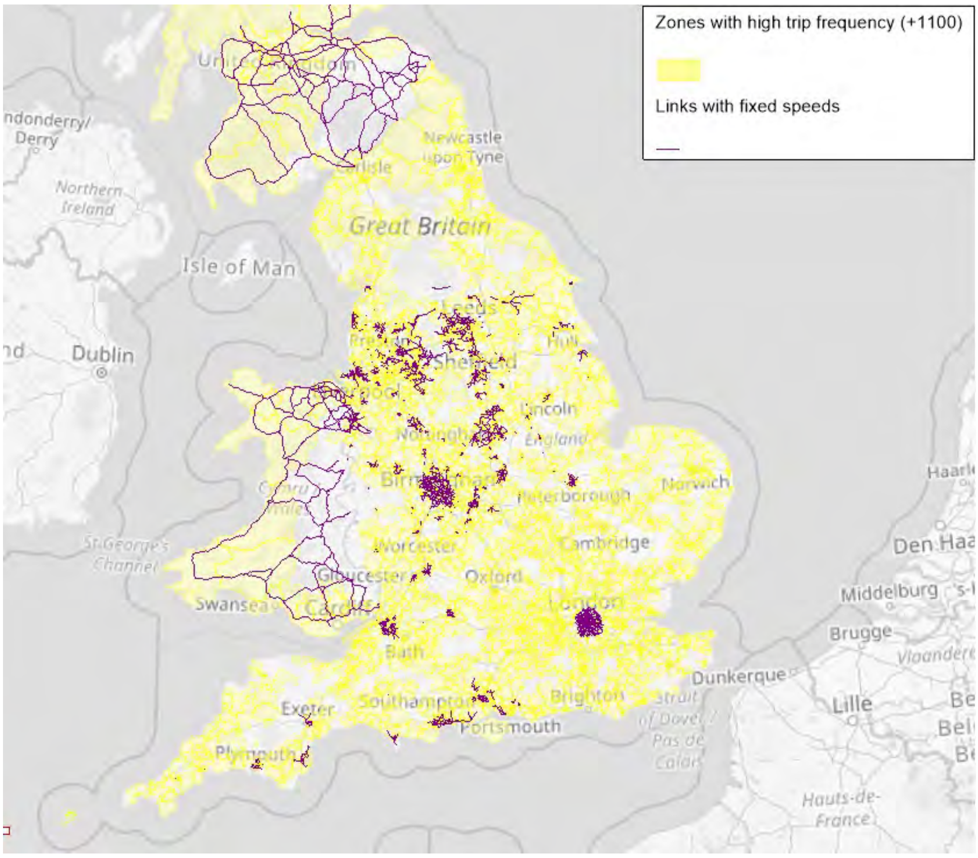


Figure 5.36: Zones with high trip frequency

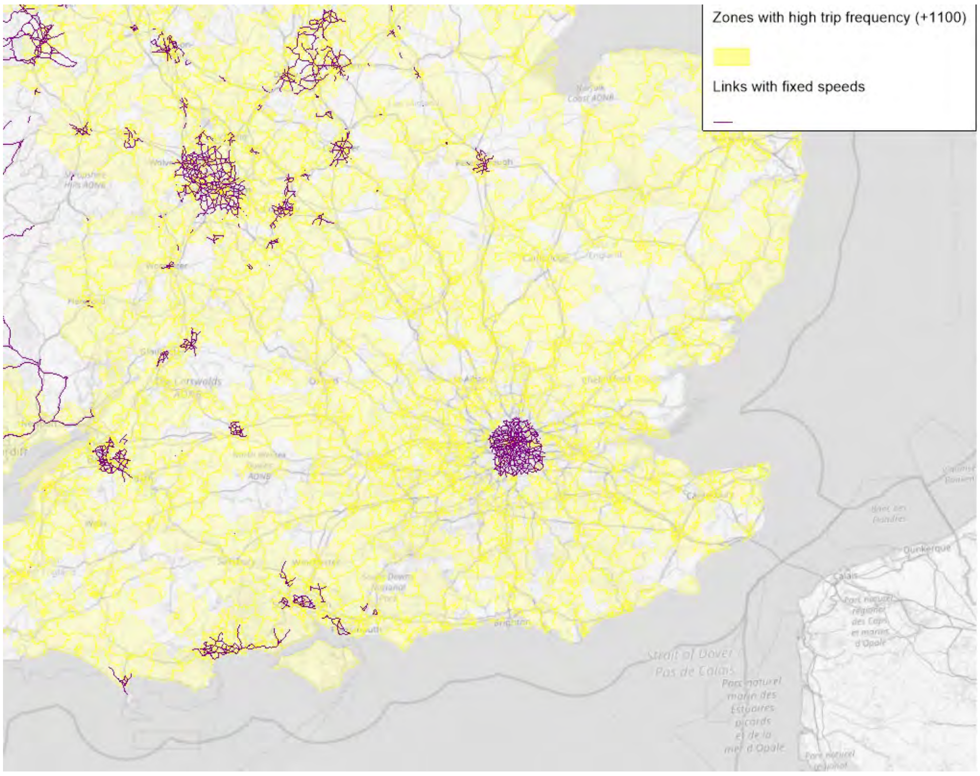


Figure 5.37: Zones with high trip frequency (South East Region)

In areas where volume delay functions are used, together with high connector flows, there is a high risk that the model would be unable to represent local conditions realistically. Links that are along sections connected to connectors with high vehicle flows will have very unstable volume/capacity ratio. **Figure 5.38** shows a V/C plot for an example area with high demand connectors. Labels on the connectors show a total (two-way) vehicle flow along those connectors. It can be observed in the center of the image that a combined flow of over 6000 trips is loaded/unloaded to a signle road resulting in a large degree of variation in volume capacity ratio on a single link.

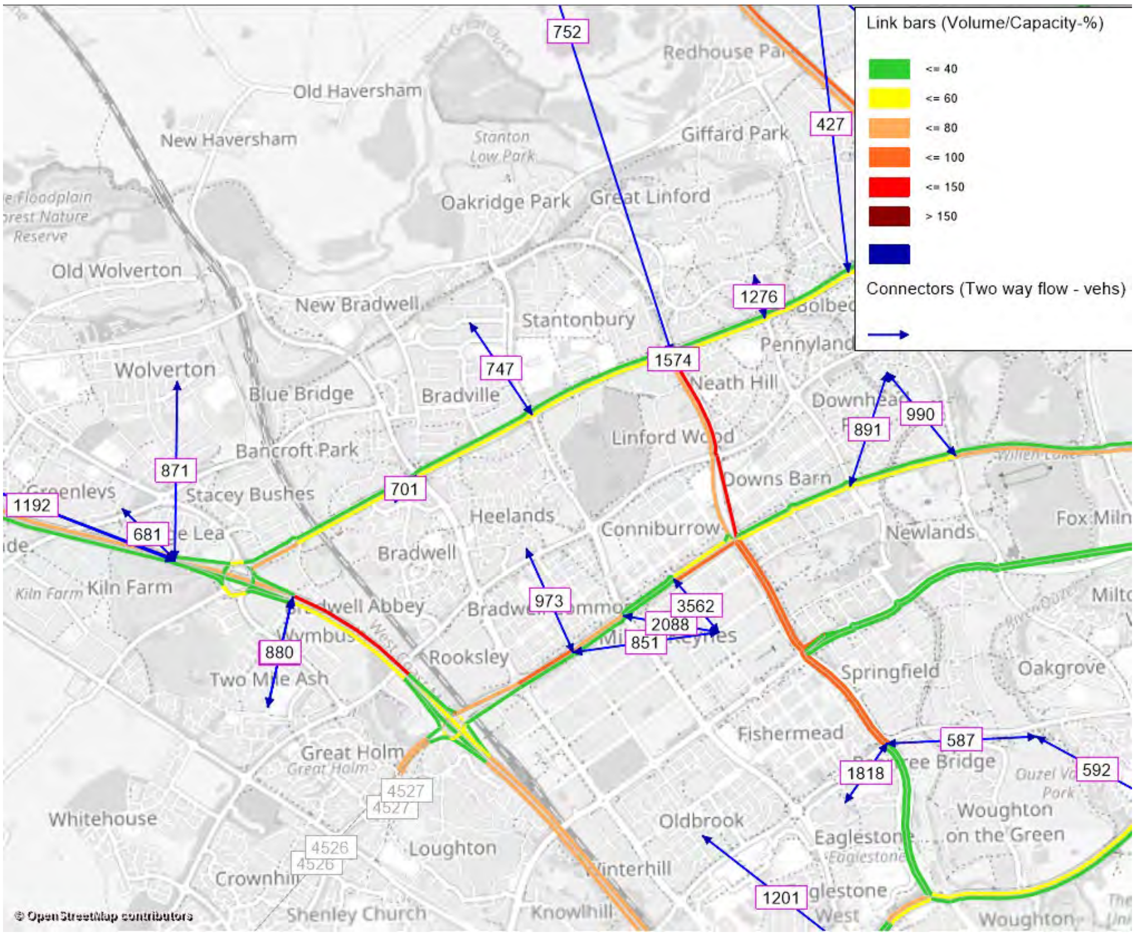


Figure 5.38:Example area (Milton Keynes Centre) with high connector demands (V/C plot)

Observation of volume delay ratios on other links within the model suggests that the above example in Milton Keynes is an extreme example of the problem described. It is therefore suggested that model users ought to be aware that care should be exercised when considering model outputs at a local level. This would suggest that this model should not be used to consider local investment (UC3) without the need for bespoke review within the local area by the model user.

- It is recommneded that users should be aware that the relative size of the zone centroids reults in variable local area volume delay representation, and therefore this model should not be used to consider local investment (UC3) without the need for bespoke review within the local area by the model user.

A further issue (also discussed in TAG Unit M3.1) that arises with large zones is that a considerable number of (short) trips will be represented as intra-zonal trips and therefore may not be loaded onto the network. Examination of the model suggests that the intra-zonal vehicle kilometers from a typical model run make up approximately 4 to 6% of total vehicle kilometers. This value of intra-zonal vehicle kilometers are reported as part of the standard model outputs, and is important to be included as part of the aggregate model statistics.

5.3.3.3. Connectors connected to modelled junctions

Analysis was carried out to quantify number of connectors that are connected to nodes with junction delay. 6709 out of 46341 nodes (~15%) were identified which are connected to a modelled junction. Whilst TAG Unit M3.1 recommends that the centroid connectors should not be connected directly to modelled junctions unless a specific arm exists to accommodate that movement, it is accepted that in a model of this scale the challenge of finding alternative loading points may be considerable. Taken together with the issues raised in the previous section, (5.3.3.2) i.e. that local flows may be distorted by large connector flows, then the recommendation above is reinforced:

- It is recommneded that users should be aware that delays are not accurately represented when connectors are loaded directly onto a modelled junction, this model should not be used to consider local investment (UC3) without the need for bespoke review within the local area by the model user.

5.3.3.4. Centroid connectors from adjacent zones connected to the same point

TAG recommends that centroid connectors from adjacent zones should not be loaded onto the same point as this will lead, at worst, to movements between the zones not appearing on the network. Indeed, this can be a common source of errors and warnings from TUBA.

An automated test was carried out to find out the number of nodes with connectors from multiple zones. The test reveals that there are 1450 such nodes. This suggests that there is insufficient network to accommodate the zone structure.

- It is recommended that any review of zone loadings should consider the case of zones connected to zero nodes. Additional road links should be provided in locations where reasonable zone loading cannot be achieved from the existing network.

5.3.3.5. Connectors connected to motorways and major A roads

The Developer Guide points out that centroid connectors should not be connected to nodes which are located on motorways and major A roads. This principle of identifying a secondary road network onto which connectors should be loaded is a good modelling principle; the secondary network will be modelled with lower tolerances, and therefore it is of less consequence if issues linked to ‘lumpy’ connector loading distort the flow representation. For the purposes of improving road hierarchy definition within the model, it would be useful to split the A road network into categories with an attribute to indicate which links are part of the SRN and which are part of the MRN. Such an attribute would also be useful for reporting purposes.

- For the purpose of recording aggregate outputs from model tests it is recommended that a link field is added to identify the SRN and MRN network, or it be made clear within the documentation / model where this attribute is.

In the absence of this categorisation, and for the purpose of audit only, links with the user defined attribute “Road name” and a link type number associated to motorways and A roads were considered with further filter applied to A Roads, identifying those with speed over 90kph (it is accepted that this approach is far from perfect, i.e. some

SRN and MRN roads will have lower speed limits, whilst a large number of non SRN /MRN roads may have speed limits above 90kph). Analysis was carried out to quantify how many of those identified links have a connector connected to them.

Table 5.7: Number of connectors connected to Motorways and A roads

Connectors connected to nodes by road type	Count
Motorway	24
High Speed A Road (with speeds greater than 90kph)	722
Other A Roads	2703
Total	**3449**

Spot checks have been carried out on these 746 nodes (i.e. on Motorways and High Speed A Roads) to determine if it is sensible to connect the connectors directly to these nodes and it was found that in most instances there was no minor road to which the connector could alternately be loaded. It is considered however in these situations the lumpy allocation of demand from a zone at a single point will make interpretation of flows on these roads difficult.

Although the report specifies that connectors should not be connected to motorways and A roads, no further information is available whether steps were taken to address this issue. The document only gives a very high-level explanation and does not specifically include details about the model.

- ➢ There is a need for the model user to be confident in the flow representation on major links, particularly motorways. It is therefore important that the documentation includes detailed explanation as to why such a large number of zones are connected to A roads and motorways, to allow users to form an opinion as to if the flow representation will have been compromised.

In the longer term it is suggested that principle of attempting to load connectors on a secondary network is worth pursuing. This would provide the model user with the assurance that there is a higher order road network on which the flow and delay representation is likely to be of a higher standard.

A possible solution that would tie in with general theme of providing additional network detail (mentioned in audit sections 5.2.4, and 5.3.3.4) would be as follows.

- Identify the SRN and MRN as the higher order road network.
- In areas were zones are currently loaded on this network, additional supporting network should be added.
- Additional supporting network could also then be added in locations where; zones are loaded at the same point, or in zones with zero nodes where the current zone loading is questionable.

While it is unlikely that the calibration and validation of the model at a local level could match the standards of a local highway model, any improvement in the representation of speeds and delay would be beneficial to the accuracy of responses within strategic / national tests.

- ➢ In order to improve the standard of flow and delay representation across the model it is recommended that within any model update a review of the network is undertaken with a view to improving the consistency of the modelled road network on the higher order roads.

5.3.3.6. Connectors crossing screenlines

The NTM Developer Guide Vol3-HAM v2.0 states in section 5.2.1 that connectors crossing screenlines were identified as an issue in the development of the network and further refinements were made to adjust connectors that were incorrectly crossing screenlines. It can be concluded then that only in instances where the coding was deemed inappropriate, manual changes were applied.

Review of the NTMv5 coding has revealed that there are still instances where the connectors are found to cross strategic screen lines. 127 out of 11,136 connectors cross a screenline in the final version of the network. Spot checks were undertaken, and no significant issues were identified. Considering the limited number of instances, the audit is satisfied that there is not a significant residual issue.

5.3.4. Congestion Delay Representation

Volume Delay Functions

Link Volume Delay Functions (VDF) in NTMv5 are a core mechanism in the model to represent travel delays caused by congestion. The VDF constant parameters in the model were compared against those in the report. All parameters were correctly transferred into the model.

Spot checks were additionally carried out to ensure that the Visum VDF constant parameters, have been correctly translated from the SATURN RTM SFC. These values are derived by using the SATURN SFC parameters S0, S2, capacity and n values from the report. The spot checks indicate that the conversion from SATURN SFC to Visum VDFs has been correctly implemented. However, it is worth noting that it is assumed that the inputs into the parameter's calculation (i.e S0, S2, capacity and n values) are correct.

Each link type in the model needs a Link VDF function assigned to it. Checks were undertaken to ensure that correct VDF functions are applied to each link type defined in the model. This was found to have been undertaken successfully.

It was noted that VDF functions were assigned to link type numbers which represent links with UAS implemented (fixed speed). It seemed confusing why a VDF function was used to represent links with fixed speed instead of a built in 'constant' function. However, further investigation revealed that the choice of constant parameter applied for the VDF function is equivalent to using a 'constant' function. It was further noticed that the same function was applied to links classified as slip roads. This seems appropriate although confusing to the model user at first.

- ➢ The developer guide should be updated to reflect and clarify the reasons for applying VDF functions to fixed speed areas and slip roads to assist the understanding of the model user and to provide assurance that it has been applied consistently.

Junction Coding

Junction delays within the NTMv5 model are represented using two different approaches:

1. Node Volume Delay Function (Node VDF) using the TModel function in Visum

2. Turn Volume Delay Function (Turn VDF)

Considering Visum mechanics, in cases where the Node VDF is applied, the final delay for each turn is a combined delay from a Node VDF function and a Turn VDF function. This seems an appropriate approach to represent junction delay in a model of this size where main node VDFs are used to evaluate general delay at the node level and turn VDF is used to introduce a differentiation between different turn types at a junction. It should be noted that it is important when implementing these functions that there is confidence in the flows on the links at which junction coding is used.

Although all turns are assigned with a Turn VDF, the choice of constant parameters in the functions implies that turn delay in NTMv5 is effectively coded as fixed delay and is not responsive to demand levels. It is further noted that Turn VDF approach was predominantly used in the areas where fixed UAS coding was implemented. As the extent of the junction coding was not defined in the documentation, it is important to firstly understand the scale and detail at which junctions are represented in the model. **Figure 5.39** indicate locations and quantity of modelled junctions.

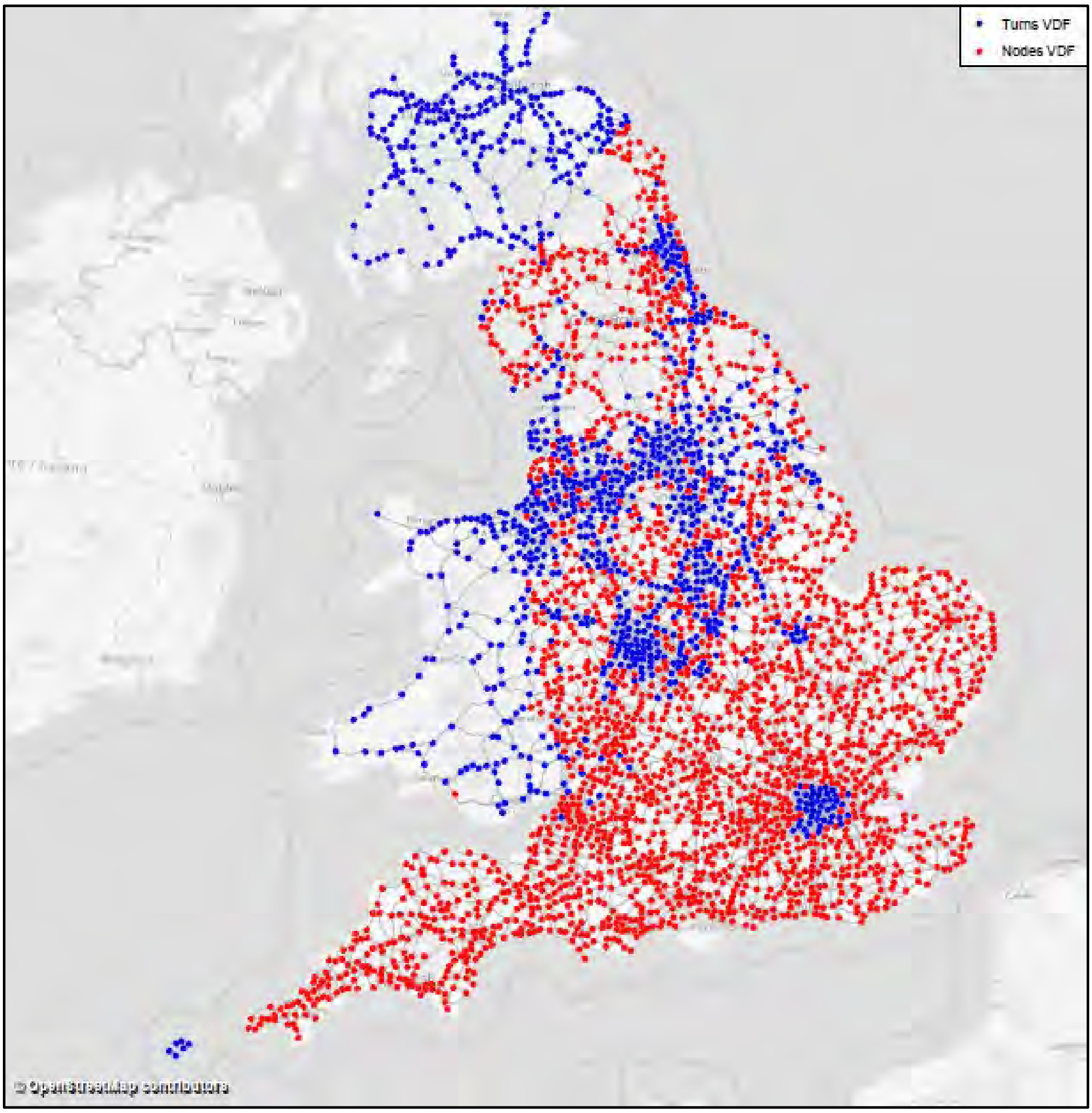


Figure 5.39: Junction type coded in the model

Nodes VDF (TModel)

In relation to junction coding using the TModel, the documentation seems to be incomplete and split across multiple documents without clear references between related parts, i.e. the Quality Report, User Guide and NTMv5 Developer Guide Vol1: Model Zones and Highway Network. The level of detail in the Developer Guide is not appropriate and does not include key assumptions such as how the TModel functions were derived or node definitions for coded junctions (e.g. junction type, capacity). These assumptions and definitions were later found in the User Guide.

- ➢ To improve model usability, it is recommended that the model documentation be updated to include the necessary parameters to allow users to understand the methodology and implement junction coding within the model. Alternatively, other documents should be referenced appropriately to aid the reader in navigating across multiple locations.

The NTMv5 node type definitions were extracted from Table 7.3 of the User Guide and shown in the **Figure 5.40** below. Spot checks were undertaken in the model to check consistency of implementation of these parameters. The following issues were noted:

- "Name" and "Control Type" are essentially representing the same characteristics with the only difference being that "Name" is a cosmetic attribute and "Control Type" defines which TModel VDF function is used at that node. It was found that 182 nodes with "Name" attribute set to "Priority" were coded with control type "Roundabout". Further spot checks against satellite images revealed that the "Name" attribute was in most cases correct which means that an incorrect TModel function is used at those nodes.
- It's unclear from the documentation and model coding what node type 10 represents and what are the assumptions behind it. There are 6579 such nodes coded in NTMv5
- **Figure 5.41** below show the allocation of TModel VDF functions to each node type. It appears function #2 is applied by default to all node types apart from node type groups 30-35, 40-45 and 50-53 which have a unique function assigned. It is unexpected to see a dedicated function to be assigned to node types not used in the model (50-53). Three groups of nodes are expected (priority, roundabout and signalised junctions) and can be identified in **Figure 5.40** and **Figure 5.41**. However, the node type numbers associated with these groups across the two figures are not aligned. This may indicate a potential miscoding in the model which cannot currently be verified with the information available in the model documentation.

- ➢ It is recommended that the documentation provides additional detail in relation to junction coding using the TModel functions and is verified against issues identified in the model. Where required, the coding should be updated to ensure consistency with the documentation.

Node Type Number	Name	Number of total Incoming Lanes	Junction Capacity (PCUs per hour) (CapPrT)	Control Type	UseMethodOfImp	MethodOfImp
10	Uncontrolled	Any	99999	Unknown	Ticked	NodesVDF
20	Priority	<=2	3200	Two-way Stop	Ticked	NodesVDF
21	Priority	3	4100	Two-way Stop	Ticked	NodesVDF
22	Priority	4	4800	Two-way Stop	Ticked	NodesVDF
23	Priority	5	6000	Two-way Stop	Ticked	NodesVDF
24	Priority	>=6	7200	Two-way Stop	Ticked	NodesVDF
30	Signal	<=3	2700	Signalized	Ticked	NodesVDF
31	Signal	4	3500	Signalized	Ticked	NodesVDF
32	Signal	5	4600	Signalized	Ticked	NodesVDF
33	Signal	6	5250	Signalized	Ticked	NodesVDF
34	Signal	7	5800	Signalized	Ticked	NodesVDF
35	Signal	>=8	6500	Signalized	Ticked	NodesVDF
40	Roundabout	<=3	2700	Roundabout	Ticked	NodesVDF
41	Roundabout	4	3500	Roundabout	Ticked	NodesVDF
42	Roundabout	5	4200	Roundabout	Ticked	NodesVDF
43	Roundabout	6	4800	Roundabout	Ticked	NodesVDF
44	Roundabout	>=7	5500	Roundabout	Ticked	NodesVDF
99		any	99999	Unknown	UnTicked	N/A

Figure 5.40: NTMv5 Node Type Definitions

Node types

	*0	*1	*2	*3	*4	*5	*6	*7	*8	*9
0*	2	2	2	2	2	2	2	2	2	2
1*	2	2	2	2	2	2	2	2	2	2
2*	2	2	2	2	2	2	2	2	2	2
3*	4	4	4	4	4	4	2	2	2	2
4*	5	5	5	5	5	5	2	2	2	2
5*	4	4	4	4	2	2	2	2	2	2
6*	2	2	2	2	2	2	2	2	2	2
7*	2	2	2	2	2	2	2	2	2	2
8*	2	2	2	2	2	2	2	2	2	2
9*	2	2	2	2	2	2	2	2	2	2

Volume-delay functions

No	Function
1	TMODEL_Nodes (0.00 2.00
2	TMODEL_Nodes (0.00 3.00
4	TMODEL_Nodes (0.00 7.00
5	TMODEL_Nodes (0.00 5.00

Figure 5.41: Node Type to TModel VDF function correspondence

As discussed in the model documentation, non-opposed movements at the junctions (e.g. Major-Major movements at priority junctions or movements on a gyratory of a non-signalised roundabout) should not experience delay except a fixed delay related to ‘geometry delay’. Approach links for these turns must be marked with the attribute TModelSpecial set to 1 to disregard any congestion delays. However, it is found that the priority junctions (represented in Visum by node types ‘Two way stop’, ‘All way stop’ and ‘Two way yield’) do not make use of the ‘TModelSpecial’ attribute. This results in those movements being penalised with delay from congestion. Further investigation revealed that ‘TModelSpecial’ attribute is not used at all which contradicts the documentation. It is difficult to make a general statement quantifying how much delay is being added incorrectly at each junction without running a test, given the delay at each location would vary depending on the flow level. The journey time calibration that has been achieved is based on very long routes (see section 4.4.5 of this audit), therefore it is possible that the additional delay found at unopposed turning movements is being compensated for by a lack of delay within a different volume delay function.

- ➢ It is recommended that junction coding using TmodelSpecial be correctly implemented to ensure unopposed movements at priority junctions and roundabouts are not incorrectly penalised. If this feature has not been implemented for a reason, then this needs to be clarified within the documentation.

A repeating pattern has been noticed in the model that there are nodes which have junction coding implemented which are not actual junctions, such as at splitter islands on the approach to major interchanges. An example is shown in **Figure 5.42** below with incorrectly coded junctions highlighted with red circles. This will have an impact on the overall delay being overestimated and ‘misplaced’ (present in unrealistic locations).

- ➢ It is recommended that junction coding is removed from locations where no junction exists.

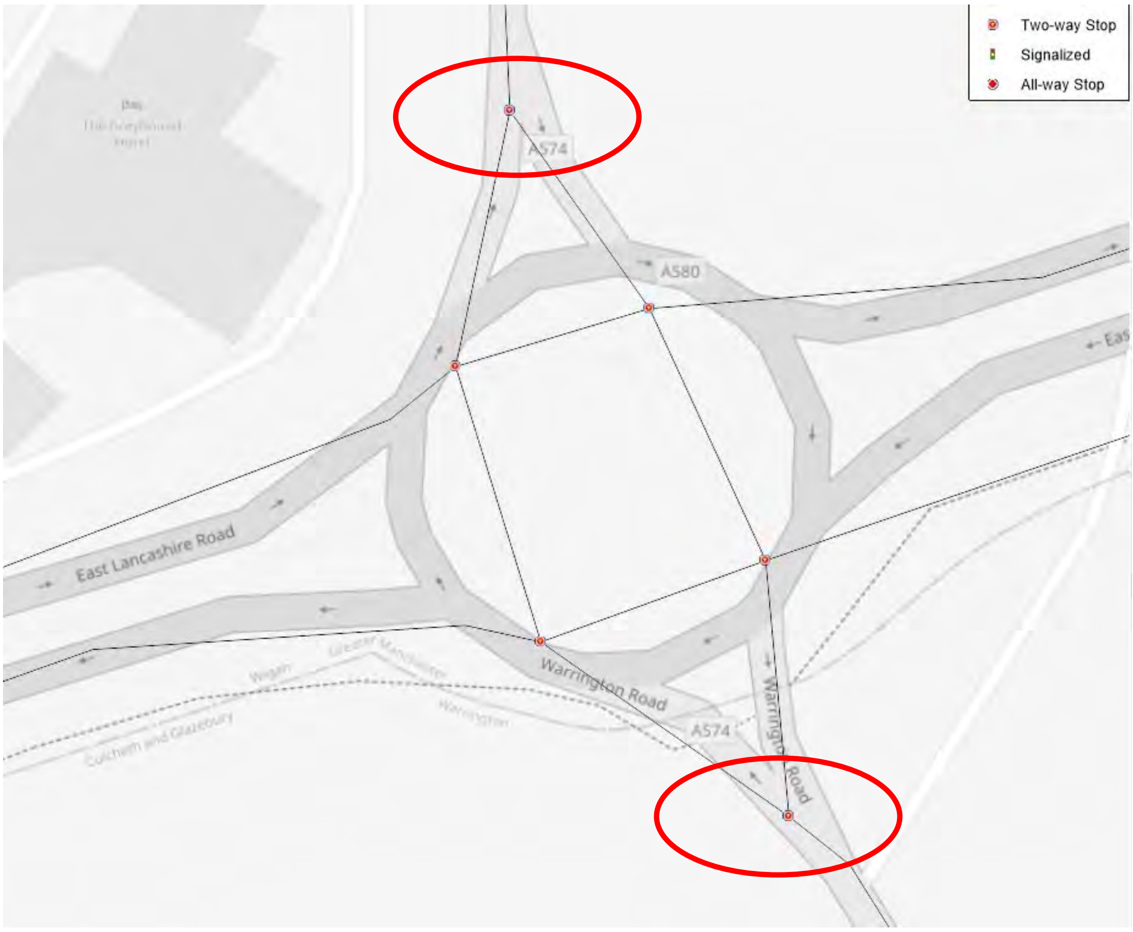


Figure 5.42: Example junction coding at locations where junctions do not exist

Turns VDF

Turn delays are represented by fixed delays using a Turn VDF which is specified through constant parameters. It should be noted that the Turn VDF do not generate additional delay with increasing demand. Although this approach does not impact the model performance, simply using a 'constant' function as opposed to 'Turn VDF' in the settings would make this approach a lot more transparent for the model user. Turn fixed delays are not defined in the report and therefore could not be reviewed.

Merge Nodes

It is observed that no consideration has been given throughout the report to merge nodes, an important aspect of strategic networks. The model was inspected to ascertain if the merge nodes have been represented in the model. Investigation has revealed that merge nodes are in most cases coded with the same control type as priority junctions, with free-flow delay equivalent to 5 seconds and default capacity of 99999. This will result in delay at merge nodes to be set to free-flow delay in most cases. Based on the sample checks, the majority of merge nodes had the same parameters, it may not apply to all merge nodes. It is recommended to provide some text in the report, on what consideration has been given to the merge nodes and the methodology adopted to model those.

Significant amount of work has been undertaken by the developer to precisely replicate link VDFs used in the RTMs and ensure that delay is represented in a consistent manner across the models. It is important to note that RTMs have additionally implemented a very robust approach to merge node coding that was used in conjunction with the link VDFs replicated by the NTMv5. There is a very high risk that although link delay is consistently replicated, the overall journey time along grade-separated roads is significantly different due to a different approach to merge node coding that often become a significant source of delay. This could potentially have significant implications for use cases concentrating on the SRN (e.g. UC1), or schemes that are focused around detailed local investment (UC3).

- It is recommended that the parameters at merge nodes are reviewed to ensure that observed delays can be represented.

5.3.5. Urban Area Speeds (UAS)

Journey times in some areas of the model are represented using fixed speeds which were inherited from the RTMs. The approach outlined in the Quality Report seems reasonable from an implementation point of view but there are some unavoidable differences in the methodology applied across the models as the RTM fixed speed area forecasting uses the forecast speed changes by road type and region from the Road Traffic Forecasts (RTF). The RTF are based on NTM, and as such cannot be used as an input into the current NTMv5 forecast models.

Base Year Coding

The NTMv5 reporting states that the speeds from the urban areas of the RTMs have been used in the development of the NTMv5. These are from an early version of the RTMs during the model build phase. It should be noted that the RTMs have developed significantly since this stage through a high level of usage. For instance, a key difference in the urban area assumptions in the current versions of the RTM is that the SERTM now contains fixed speed coding in areas outside of Inner London, unlike the early version of SERTM which only contained fixed speed coding within Inner London. This raises the question as to whether this change should be applied to NTMv5

The model documentation does not discuss if updates from the RTM should be considered for NTMv5. It is anticipated that applying updates automatically from the RTM to NTMv5 would not be a straightforward task. It would require rebuilding the correspondence between NTMv5 and RTM links spatially, as the correspondence to the RTM links in NTMv5 is not present in the model attributes.

The NRTM model does not contain any fixed speed areas and urban areas in the North of England in the NTMv5 are modelled using volume delay functions. This is consistent with the RTMs.

For the external areas of Scotland and Wales, the NTMv5 reporting states that the base year link speeds have been adopted from the NRTM for Scotland and the MRTM for Wales.

The RTMs which were used in the development on the NTM, have been matched to the NTM, using common link IDs and a spatial join to match the simulation areas of the RTMs to the NTM, a separate match was created for the external links. The speeds from the RTMs have then been compared to link types 97 and 98 in the NTMv5. Only the AM period RTM models were made available for the TPSRTM and SERTM, as such there is no comparison for them in the IP and PM.

Table 5.8 below summarises the speed difference comparison between NTMv5 link type 98 fixed speed links for and those in the RTM models for all three time periods. Overall in the AM period 86% of NTMv5 link type 98 links have a link speed which are within 5km/hr of the RTMs, with close matching between the TPSRTM and SERTM in particular. There are 200 links matched to the SWRTM model where the speed is significantly lower in the SWRTM than NTM. In the NTMv5 these links are coded with a speed of 37, 48, 58 or 93 km/hr, with much lower and more variable speeds in the RTM. It is unclear as to why this difference exists. For those NTMv5 links matched to the MRTM, there is a tendency for the NTMv5 links to be coded with a lower speed than the RTM, again it is not clear what drives this difference. The IP and PM show similar patterns to the AM for the MRTM and SWRTM matched links. A small handful of NTMv5 links remain unmatched to the RTMs.

It is not clear what the order of hierarchy is in terms of selecting which links / speeds are selected from which RTMs for the use of the NTM, as such these are our best estimates of the match between the models. **Figure 5.43** and **Figure 5.44** show which RTM the NTMv5 links have been matched to in this comparison.

- It is recommended that the differences identified between the fixed speeds within the MRTM and NTMv5 within the base model are investigated further.

For the external areas, although the reporting states that the MRTM model was used to provide the link speeds within Wales, we have found the match between the TPSRTM and the NTMv5 is much closer, both in terms of the level of modelled detail and the speeds used within the model.

Table 5.9 presents a comparison between the NTMv5 and RTM link speeds for NTMv5 link type 97, in Scotland and Wales. The majority of links match to the NRTM and TPSRTM. Overall, 91% of NTMv5 links have the same speed as coded in the RTMs. However, there are around 300 links in the NTMv5 matched to NRTM where the speeds in the RTM are significantly higher. It is not clear why this difference exists.

- It is recommended that the documentation is updated to reference the TPSRTM as being the source for the speed of NTMv5 links in Wales. The difference in speed between the NRTM and NTMv5 on a small number of links should be investigated further.

Table 5.8: RTM link speeds vs NTMv5 link speeds in urban areas (Link Type 98)

	AM					IP		PM	
Speed Difference Band (km/hr)	SERTM	TPS	SWRTM	MRTM	Total	SWRTM	MRTM	SWRTM	MRTM
>15	4	13	18	1580	**1615**	26	1712	30	2065
10 - 15	0	6	18	142	**166**	27	172	18	135
5 - 10	1	6	16	298	**321**	33	525	42	342
0 - 5	5	15	23	850	**893**	145	852	128	989
0	2908	5744	2920	2971	**14543**	2744	2568	2766	2292
0 - -5	10	10	11	110	**141**	31	128	16	127
-5 - -10	6	1	22	21	**50**	20	17	23	18
-10 - -15	3	1	19	7	**30**	24	9	27	8
<-15	1	14	213	11	**239**	210	7	210	14
-	4	23	4	0	**31**	4	0	4	0
Total	**2942**	**5833**	**3264**	**5990**	**18029**	**3264**	**5990**	**3264**	**5990**

	AM					IP		PM	
Speed Difference Band (km/hr)	SERTM	TPS	SWRTM	MRTM	Total	SWRTM	MRTM	SWRTM	MRTM
>15	0%	0%	1%	26%	**9%**	1%	29%	1%	34%
10 - 15	0%	0%	1%	2%	**1%**	1%	3%	1%	2%
5 - 10	0%	0%	0%	5%	**2%**	1%	9%	1%	6%
0 - 5	0%	0%	1%	14%	**5%**	4%	14%	4%	17%
0	99%	98%	89%	50%	**81%**	84%	43%	85%	38%
0 - -5	0%	0%	0%	2%	**1%**	1%	2%	0%	2%
-5 - -10	0%	0%	1%	0%	**0%**	1%	0%	1%	0%
-10 - -15	0%	0%	1%	0%	**0%**	1%	0%	1%	0%
<-15	0%	0%	7%	0%	**1%**	6%	0%	6%	0%
-	0%	0%	0%	0%	**0%**	0%	0%	0%	0%
Total	100%	100%	100%	100%	**100%**	100%	100%	100%	100%

Table 5.9: RTM link speeds vs NTMv5 link speeds in external areas (Link Type 97)

	AM					IP			PM		
Speed Difference Band (km/hr)	TPS	SW	NRTM	MRTM	Total	SWRTM	NRTM	MRTM	SWRTM	NRTM	MRTM
>15	2	0	280	0	**282**	0	324	1	0	275	1
10 - 15	0	0	22	2	**24**	0	33	1	0	17	1
5 - 10	0	0	21	0	**21**	0	39	0	0	28	0
0 - 5	0	1	24	0	**25**	3	17	0	3	16	0
0	1523	13	2186	0	**3722**	11	2121	0	11	2197	0
0 - -5	0	1	1	0	**2**	0	0	1	0	1	1
-5 - -10	0	0	0	1	**1**	1	0	0	1	0	0
-10 - -15	0	0	0	0	**0**	0	0	0	0	0	0
<-15	0	0	0	0	**0**	0	0	0	0	0	0
-	2	0	0	0	**2**	0	0	0	0	0	0
Total	**1527**	**15**	**2534**	**3**	**4079**	**15**	**2534**	**3**	**15**	**2534**	**3**

	AM					IP			PM		
Speed Difference Band (km/hr)	TPS	SW	NRTM	MRTM	Total	SWRTM	NRTM	MRTM	SWRTM	NRTM	MRTM
>15	0%	0%	11%	0%	**9%**	0%	13%	33%	0%	11%	33%
10 - 15	0%	0%	1%	67%	**1%**	0%	1%	33%	0%	1%	33%
5 - 10	0%	0%	1%	0%	**2%**	0%	2%	0%	0%	1%	0%
0 - 5	0%	7%	1%	0%	**5%**	20%	1%	0%	20%	1%	0%
0	100%	87%	86%	0%	**81%**	73%	84%	0%	73%	87%	0%
0 - -5	0%	7%	0%	0%	**1%**	0%	0%	33%	0%	0%	33%
-5 - -10	0%	0%	0%	33%	**0%**	7%	0%	0%	7%	0%	0%
-10 - -15	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	0%	0%
<-15	0%	0%	0%	0%	**1%**	0%	0%	0%	0%	0%	0%
-	0%	0%	0%	0%	**0%**	0%	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

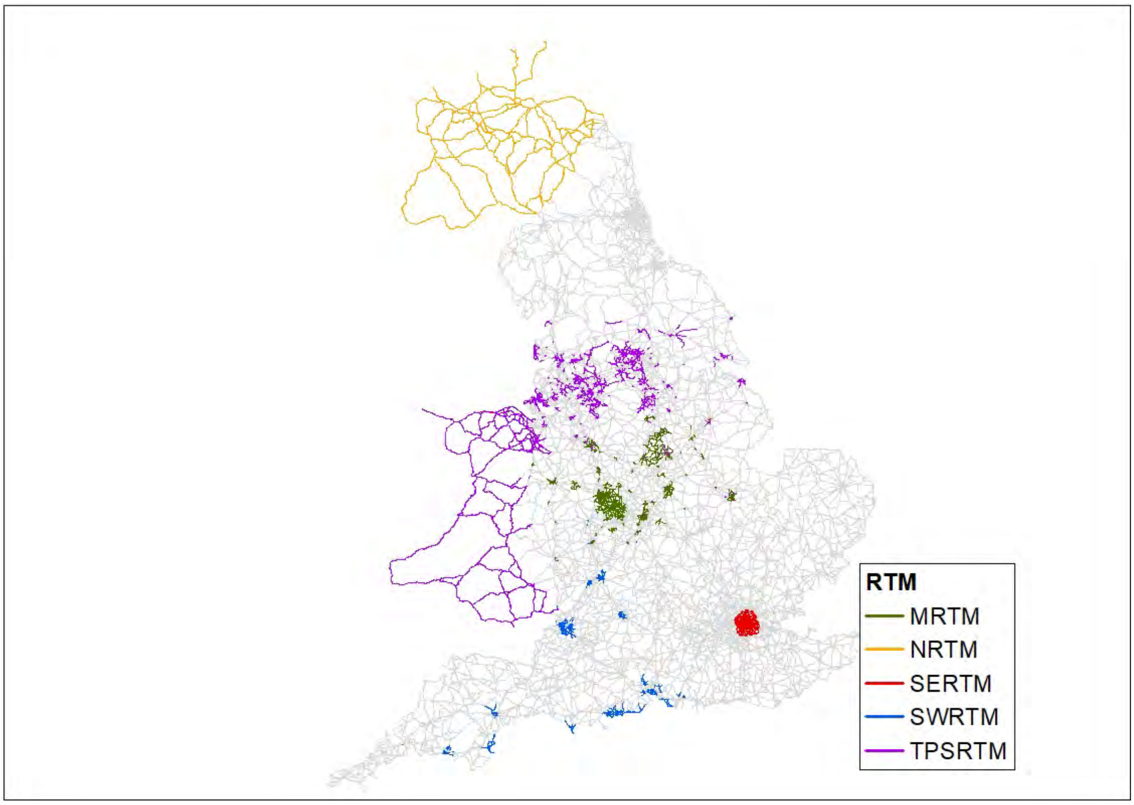


Figure 5.43: RTM link speed used in NTM

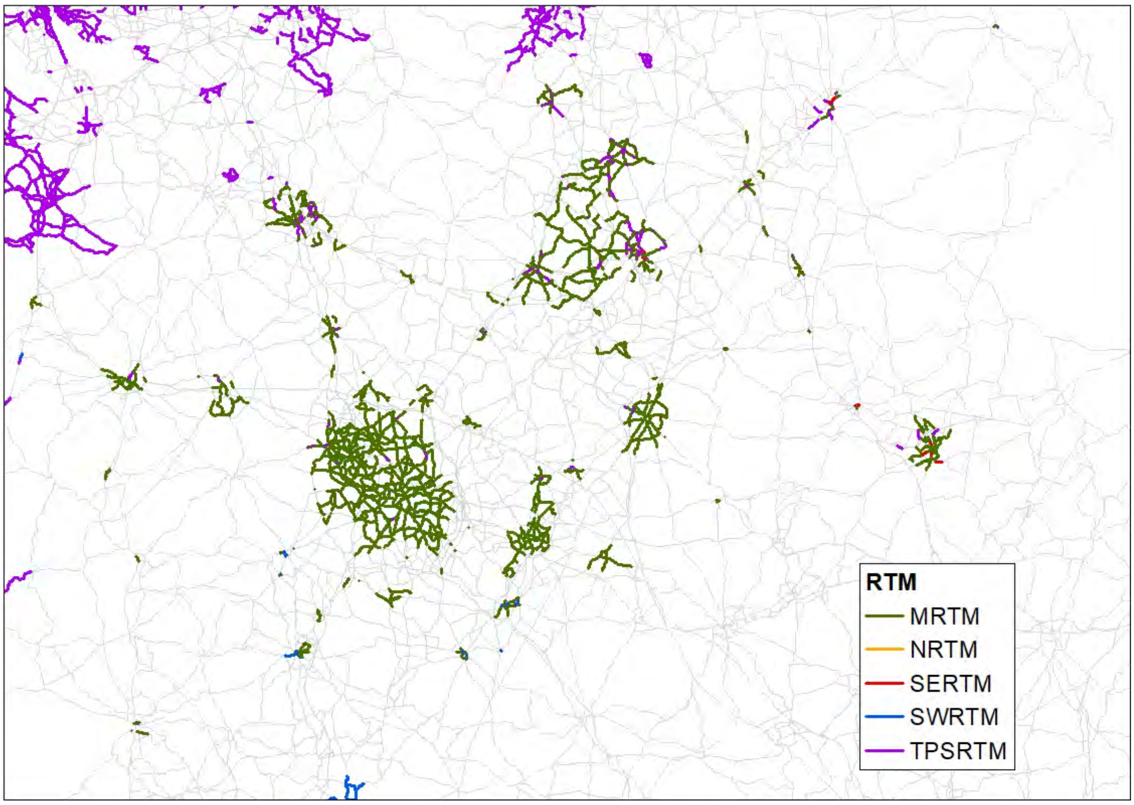


Figure 5.44: RTM link speed used in NTM, Midlands

Forecasting Approach

The RTM approach is to adjust the base year fixed speeds in line with RTF by region and road type. However, this is not appropriate for NTMv5 given that RTF is based on NTM. The options for application in NTMv5 are set out in in the Developer Guide. The option chosen was method 2 following discussion with DfT. This comprises a response to overall growth in trip ends but no capacity change response.

This approach is based on considering the ratio between free flow speed and the congested speed in the base to calculate a speed reduction factor for the base. This is then used in the forecast along with the trip end growth to adjust the base year speeds. This approach does not account for any capacity changes between the base and forecast years. This generally appears a pragmatic approach to calculate the forecast speeds, however sensitivity testing in areas where there are likely to be significant capacity changes which may impact strategic re-routing should be considered to assess the robustness of this approach.

Base speed reduction factor

Base year reduction factors have been calculated by dividing the speed coded in the base by an estimate of freeflow speed – itself taken from observed off-peak speeds in TrafficMaster. The RTM fixed speeds are based on the median speed from the May/June 2015 TrafficMaster for each time period, which was also used for the NTM. As such the data sources are consistent. These factors have been calculated by LAD and road type.

Table 7.2 of the NTMv5 Developer Guide Volume 5: Forecasting Model v2.0, presents the base year reduction factors by road type and region. It is noted that Urban motorways do not exist / are not modelled in fixed speed in some regions (for example, the South West, London), hence no factors are presented in this table.

Review of the base speed reduction factors coded in the model against those reported in Table 7.2 and it was noted that the factors in the report and in the model are not aligned. The documentation states that the factors should be consistent for links the same link type/Local Authority District classification which is not the case in the model. This suggest that the values in the model are most likely incorrect.

- It is recommended that speed base year reduction factors are updated in the model to match those reported in Table 7.2 of the Developer Guide.

Forecasting Speeds

The process to calculate forecasting speeds are calculated by defining total trip productions plus trip attraction in the ‘area’ at the start of each run to create the trip end growth. Areas have been assumed to be either the LA or Borough for London within the model area, and external to this Wales and Scotland define the remaining areas. These do not vary between iterations of the model, so are not VDM responsive. The use of HB trip ends is intended to pick up changes responsiveness to land use activity. This assumption appears sensible and the trip end growth is a reasonable proxy for providing the likely growth in flows on the links. It should be noted that this therefore does not account for induced demand due to GDP and other cost related factors. We expect that this influence would be moderate as it should be limited mostly to through traffic on the fixed speed links.

In some cases, the documentation defines formulas and constant parameters used in the process. It is however unclear in the documentation where these functions/parameters originated from. Taking equation 7.13 in the forecasting report as an example, only after further analysis was it concluded that the equation is derived from the BPR VDF function, adopted to take trip end growth factors as an input and substituting the speed reduction factors in for free flow time. It is not clear from the reporting how the constant $.n = 1.5$ was derived.

- It is recommended that clarity is added to Chapter 7 of the Developer Guide Volume 5, to ensure the reader can understand how functions and constant parameters were derived and if there are any implications to be noted.

Implementation in Visum uses the factors in table 7.2, equation 7.13 along with the base link speed and the relevant area growth factors (HB). The coding in the model seems appropriate.

Sensitivity testing to compare the vehicle km changes to the base with zero demand growth (Table 7.3 of the forecasting report) generally appears sensible, however the change in veh-kms on non-fixed speed motorway links differs by 28% which suggests some potential issues in the model response to this approach. However, the reporting indicated that this is due to the inclusion of a new motorway in the highway supply.

Junction Coding in locations with UAS

It was noted during the model review that junction coding was implemented in areas with fixed urban area speed. Junction coding was not expected in these areas as junction delay is expected to be captured within the fixed speeds. One reason for not providing junction coding within these areas within the RTMs was that it is unlikely that the flow representation within these areas will be accurate enough to generate realistic junction delays. The addition of junction coding in these areas within NTMv5 will means that (a) junction delays are inaccurately modelled, but also (b) the delay is captured twice, once within the fixed speed coding, and secondly within the junction coding.

Figure 5.45 to **Figure 5.47** show examples of model areas coded using UAS to some extent.

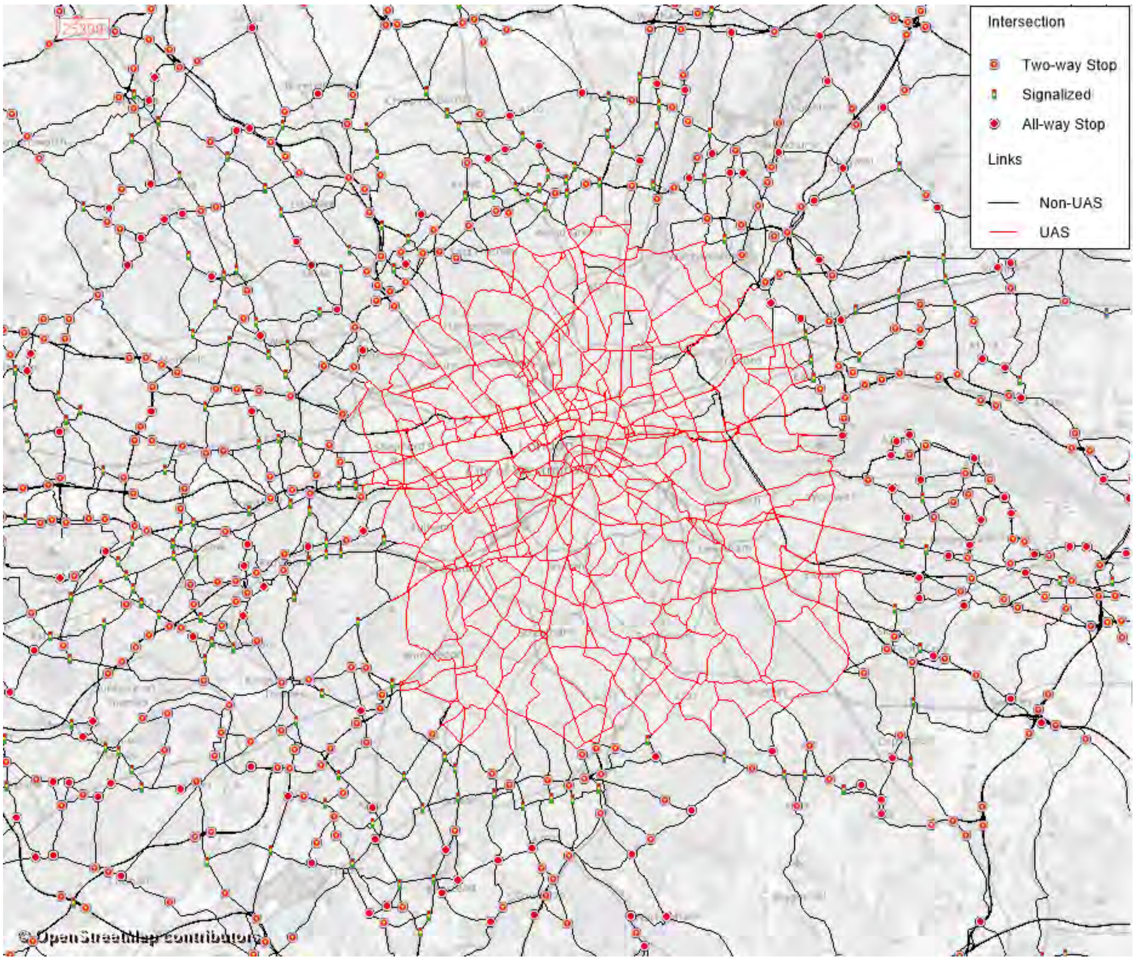


Figure 5.45: London Urban Speed Area

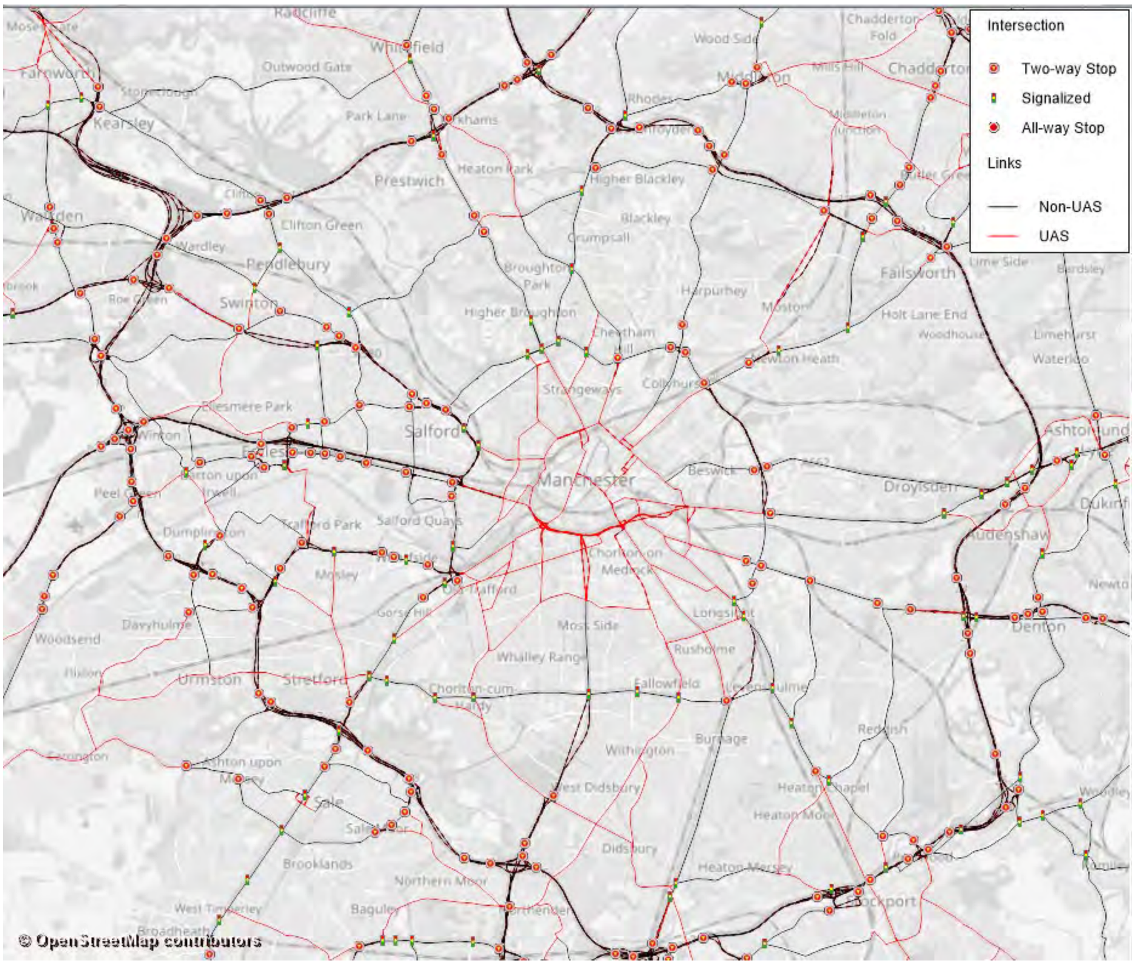


Figure 5.46: Manchester Urban Speed Area

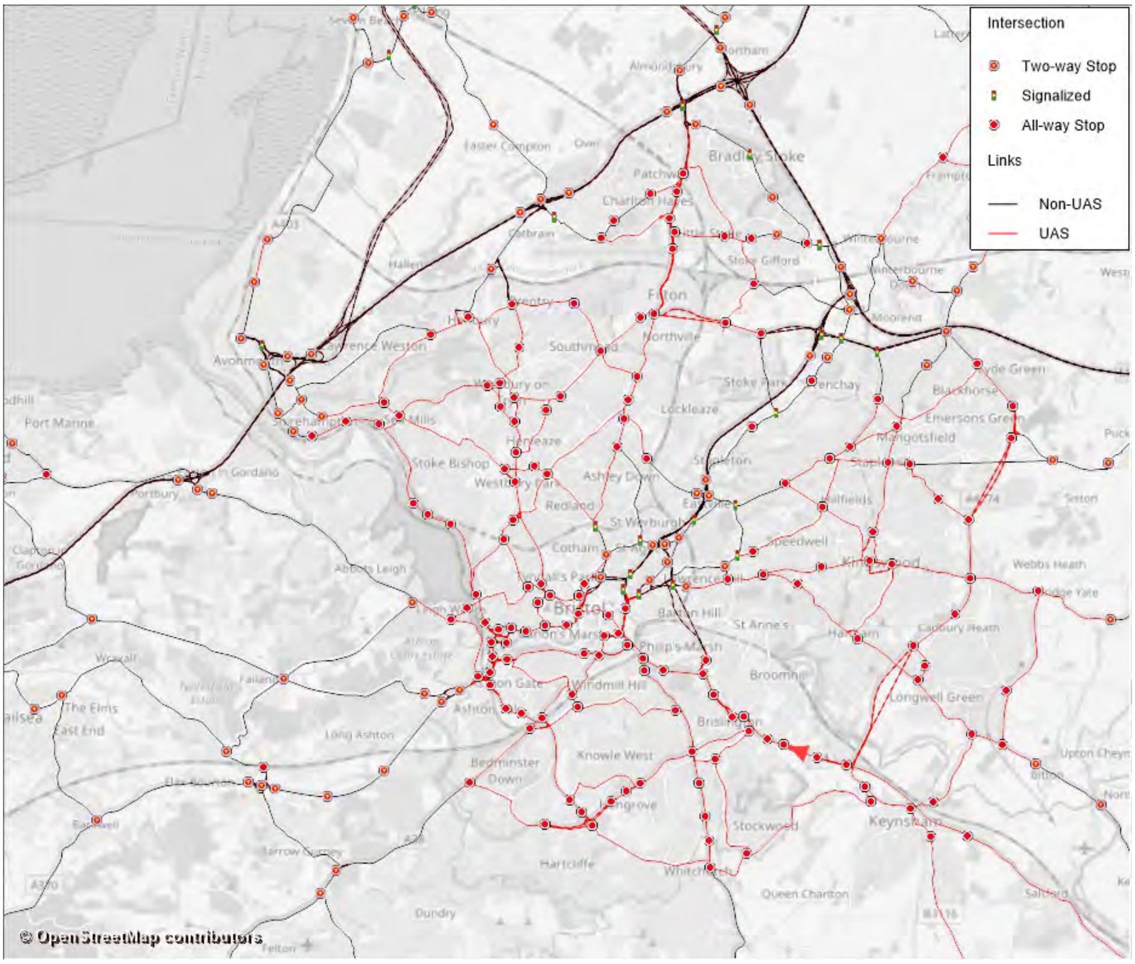


Figure 5.47: Bristol Urban Speed Area

Each figure represents a slightly different approach implemented for coding these areas which can be categorised into the following methodologies.

- Area coded using UAS (no junction coding). This method has been applied in London(**Figure 5.45**).
- Areas coded mainly using UAS with selected key strategic routes coded using VDFs. Junction coding implemented along the routes with VDFs. This method has been applied in Manchester (**Figure 5.46**).
- Areas coded mainly using UAS with selected key strategic routes coded using VDFs. All junctions in the area represented with junction delay. This method has been applied in Bristol. (**Figure 5.47**).

Considering the three methods, the implementation is highly inconsistent, resulting in model responses to be different by area dependant on the methodology implemented.

The first two coding methods are a result of the different methods employed by different RTMs. However, it is argued that while this is an inconsistency inherent within the five different RTMs, the coding within each individual RTM is internally consistent. Applying these different methodologies within one model, such as NTMv5, is inconsistent.

The third method adds junction delay within NTMv5 that is not present within the RTM to the fixed speed area. This is incorrect as the delays will be double counted. Users should therefore be aware that in their current state, it is unlikely that the models could be used to test schemes that effect central urban areas (e.g. within UC3 or UC5).

- It is recommended that junction delay coding is removed from all fixed speed urban areas (such as that found in the coding of Bristol). Further, improved consistency could be achieved within urban areas of the NTMv5 if a consistent approach was chosen for applying fixed speeds, either applying UAS exclusively within a cordon (as that found in the London coding), or by UAS within a cordon but maintaining VDFs on strategic links (as that found in the Manchester coding). A bespoke method could be developed for the NTMv5, as opposed to one used within the RTMs, should that be deemed more appropriate so long as it is applied consistently.

5.3.6. Roadworks

During the audit of the NTMv5 forecast model, it has been noticed that reduced highway capacity, representing roadworks were represented in some areas of the model. The documentation does not provide the model user with any information on how roadworks has been approached in the model development. It is suspected that coding of roadworks was inherited from the base year RTM development. There was significant thought put into the methodology for forecasting within the RTMs around how to forecast and the extent to which base demand was affected. This involved creating a ‘base minus’ developed to generate base year costs used as the basis from which to forecast. This was achieved by removing the roadworks present in the calibrated and validated base year networks. If this ‘base minus’ step is missing from NTMv5 there is a material risk within NTMv5 application with regard to how cost changes are generated, as it appears, they include delays from base year roadworks. This would have implications for forecasts undertaken for all use cases.

- It is recommended that the model documentation is updated to reflect the methodology for including roadworks within the model. A list of locations at which roadworks have been assumed should be included as part of this. If the ‘base minus’ (or equivalent step) is missing from the forecasting methodology then this should be developed and implemented in NTMv5.

5.3.7. Tolls

Section 3.9 of Volume 1 of the Developer Guide report is comprehensive to include the list of tolls coded in the model. The toll list in the report was checked against the list coded in the model. All tolls except one listed in the report is found to be coded in the model. The model network is not sufficiently detailed within the local area for Warburton Bridge Toll Road to need to be modelled.

The report also specifies that tolls are referenced by the government’s website (https://www.gov.uk/uk-toll-roads). Therefore, a check is carried out to compare the toll list on Motorways and A roads in the Government Website to the list in the report. The list in the website matches against the report for all sites except two. Two tolls, A4-Batheaston Bridge and Mersey Gateway(A533) are not represented by a link in the model and therefore, no toll is included in the model.

- A minor recommendation is that the user guide should be updated to reflect the fact that tolls are not represented within the model at the three noted locations.

5.3.8. Public Service Vehicle pre-loads

Public Service Vehicle (PSV) pre-loads are link attributes within the NTMv5 road network which indicate the number of PSVs that are expected to be using the road network. PSV include scheduled local buses but exclude private buses and coaches. The NTMv5 has separate preload data for different times periods, because frequencies and availability of local bus services tend to vary across the day and over the week. It is unclear whether the preload data are summarised as the total, maximum or average of all hourly counts within the defined time period.

- It is recommended that the user documentation clarifies whether the preload data are summarised as the total, maximum or average of all hourly counts within the defined time period.

According to the NTMv5 Developer Guide Volume 1 Zones and Network, Section 3.11 the data have been calculated using a 2015 output from TRACC, which lists the set of ITN links traversed by each bus route and the frequency of the services on those links in the defined time periods. It is not clear how the output was created in TRACC and which TRACC calculation module was used. The Audit team has contacted Basemap to clarify, but they did not identify an automatic process under the current version of TRACC.

As it is not possible to follow the same calculation process as the one that has been specified in the Developer Guide, the audit has instead used TRACC to calculate hourly 'Combined Stop Frequency' of bus service arriving at/departing from each stop, to compare them against bus frequencies on adjoining NTMv5 link sections. It is acknowledged that in some cases, bus stop frequencies can be lower than link frequencies because some buses may only call at major stops and pass minor stops, but their difference should be insignificant.

Out of the 135,962 NTMv5 road links, 100,654 links have bus preload data attached. Each link represents one traversing direction. Some road sections have buses operating on both directions and others only have buses on one direction. To simplify the process, this audit has examined the combined frequencies of the two directions.

Our analysis has identified 20,490 NTMv5 bi-directional links which have bus stops in its proximity (less than 15 metres distance from the link).

Figure 5.48 shows two scatter plots comparing the NTMv5 preload values with the results from the TRACC combined bus frequencies calculation. The first one compares the NTMv5 values with peak hour averages, and the second one compares them with time period totals.

This audit focuses on the AM Peak, between 07:00 and 10:00. Based on the initial inspection it is not clear whether the preload data represent the average number of buses per hour or the total number of buses over a time period. Although it is noted that the PSV pre-loads are expected to be representative of an average hour for the modelled periods. The units are expected in PCU values as the conversion to vehicle units takes places using the conversion factors defined in the general procedure settings.

The second plot with time period totals shows a better correspondence overall as it has more data points positioned along the 45° Reference line. This suggests that the NTMv5 preload data most likely represents the total number of vehicles over the time period instead of a peak hour average.

Although the second plot shows better correspondence, a significant proportion of its datapoints are showing substantial discrepancy. There is also a general tendency that NTMv5 preload values are higher than the TRACC data. The higher the NTMv5 preload values also shows much higher discrepancy. In some cases, NTMv5 preload values are 3-4 times higher than the TRACC data.

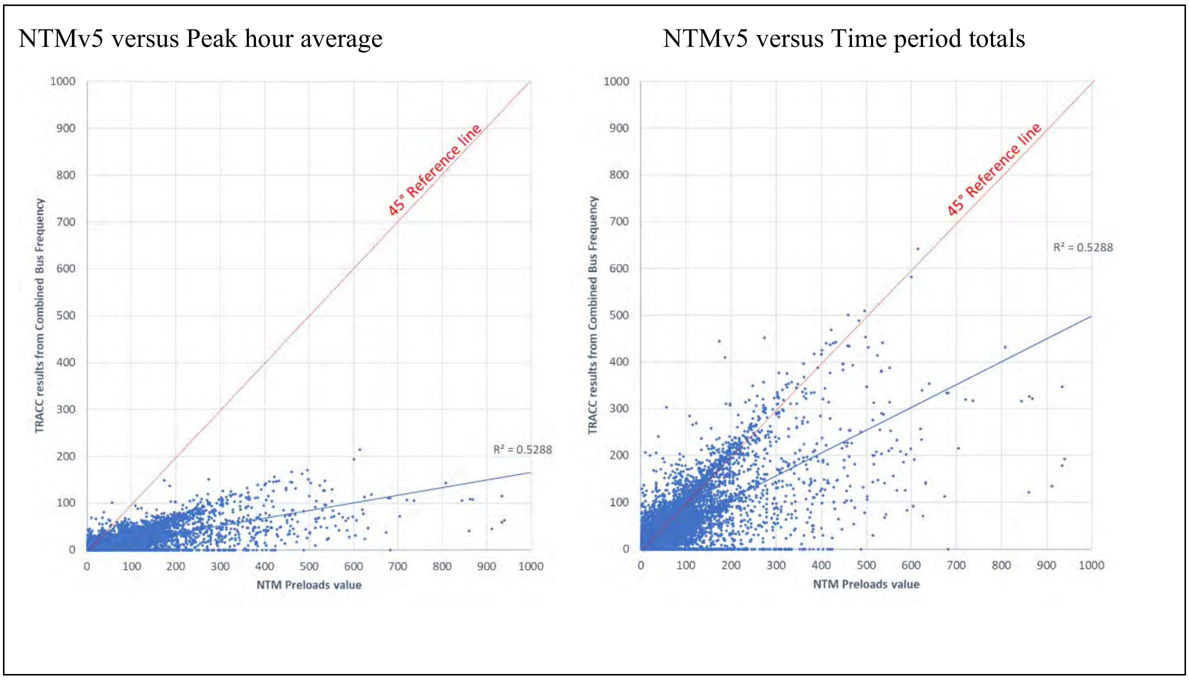


Figure 5.48: NTMv5 and TRACC data scatter plot

Figure 5.49 to **Figure 5.51** show some examples of area where large discrepancies have been observed.

Figure 5.49 shows an example along the A3 by the Elephant and Castle station where an NTMv5 model link have assumed the same number of buses for the two directions (i.e. 652 buses) but according to the TRACC analysis bus flows on one direction has only got 103 buses which is substantially less than the other. Both sections are substantially less than the NTMv5 modelled flows.

Figure 5.50 shows an example in Bristol city centre where an NTMv5 model link represent a long stretch of road that serves two bus groups. The northern half of the link is used by 177 buses, and the southern half of the link (downstream) is used by another 64 buses. In total, there are would be 177 buses on the northern section and 241 buses on the southern section. Both sections are substantially less than the NTMv5 modelled flows.

Figure 5.51 shows an example in a suburban part of north Oxford where an NTMv5 model link has substantially over-estimated bus flows. Woodstock Road currently serves 4 bus routes on each direction. The 4 routes are a mix of low to medium frequency services from hourly up to quarter hourly. However, the NTMv5 model link have assumed a total of 69 buses on each direction, which would imply 4 routes of highly frequent 6-hourly services.

A3 by Elephant and Castle Station

Link 7843 in the NTMv5 model

	BUSFLOWS 1
Direction A	652
Direction B	652
TOTAL	**1,304**

4 corresponding bus stops

	3 hours total
490000073T (NB)	69
490000073S (NB)	159
490000073V (NB)	161
490000073P (SB)	103
TOTAL	**492**

Figure 5.49: Case study 1 – London city centre area

A38 (southbound) by Bristol Haymarket

Link 19247 in the NTMv5 model

	BUSFLOWS 1
Direction A	456
Direction B	N/A
TOTAL	**456**

2 corresponding bus stops on the northern section

	3 hours total
0100BRP90347	43
0100BRP90349	134
TOTAL	**177**

1 corresponding bus stop on the southern section

	3 hours total
0100BRP90396	64
TOTAL	**64**

Figure 5.50: Case study 2 – Bristol city centre area

Woodstock Road in North Oxford

Link 24109 in the NTMv5 model

	BUSFLOWS 1
Direction A	69
Direction B	69
TOTAL	**138**

2 corresponding bus stops

	3 hours total
340000995CNR	28
340000995OPP	43
TOTAL	**71**

Figure 5.51: Case study 3 – Woodstock Road, North Oxford area

To further understand the discrepancy, the 20,490 links data have been broken down by NTMv5 road types, and the relative difference between the NTMv5 preload and the TRACC data. The results can be seen in **Table 5.10** and **Figure 5.52** below.

The results show the majority of large discrepancies relate to trunk road, rural and suburban links, while those in small towns appear to correspond more accurately.

Table 5.10: Relative difference (RD) between NTMv5 preload data and TRACC analysis data by NTMv5 road type

Relative Difference	<10%	10-20%	20-30%	30-40%	40-50%	>50%
Trunk road	6%	2%	4%	3%	26%	59%
Rural	24%	11%	10%	7%	7%	40%
Suburban	22%	13%	10%	6%	11%	38%
Small Town	29%	16%	12%	8%	7%	28%
Urban	27%	14%	9%	6%	8%	35%
Other	25%	13%	8%	6%	12%	36%

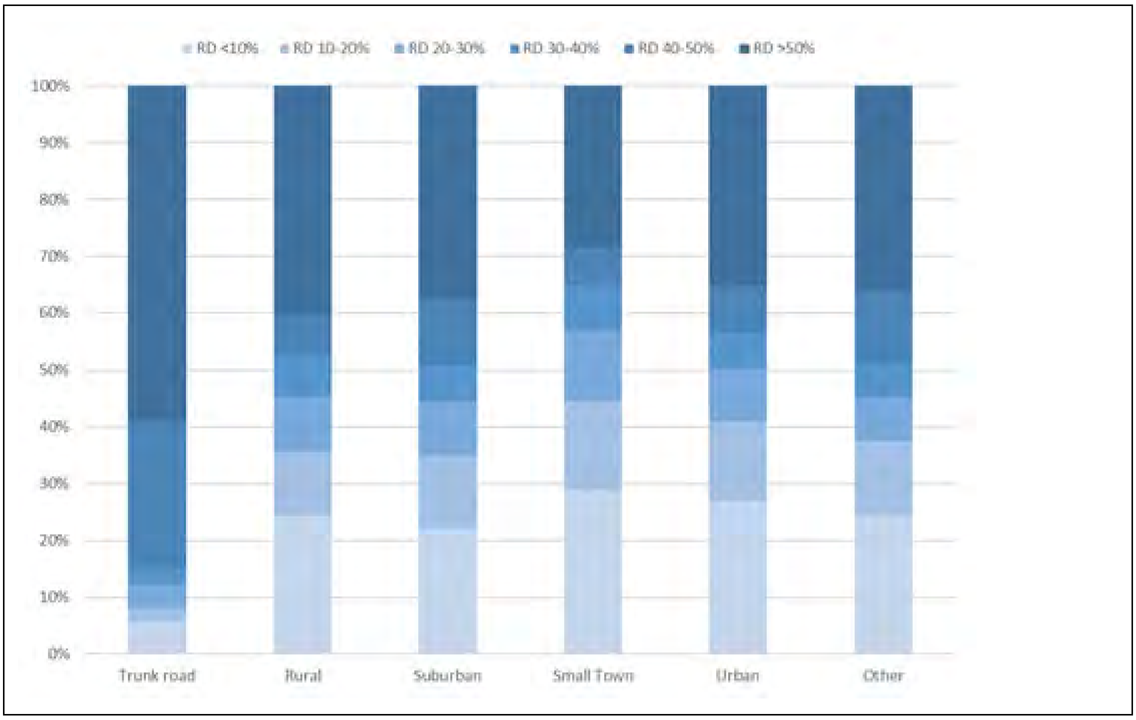


Figure 5.52: Relative difference (RD) between NTMv5 preload data and TRACC analysis data by NTMv5 road type

It is not clear from the Developer Guide how the preload data was summarised. Our scatter plots suggest that the data could represent the total bus frequency over the specified time period (i.e. 7:00 to 10:00 for AM peak) as it shows a better correspondence. It is found that there is a tendency for the NTMv5 preloads data to be higher. The discrepancy tends to be higher for links with high NTMv5 preload values (300 buses over the 3 hours period) and for links along trunk road, rural and suburban areas. It is noted that it is most likely that any link with more than 300 buses per 3 hours is likely to be within an UAS location.

The discrepancy could relate to the following:

- Preloads on bi-directional links – all bi-directional links appear to have the same preload data on the two directions of traverse, and the data is likely to be the higher frequency of the two. Case Study 1 demonstrated an example where this could lead to over-estimation of flows. There could also be overestimation in suburban and rural areas where buses often operate in one-way loops, or morning-inbound and evening-outbound services.
- Long NTMv5 links including different groups of bus corridor – NTMv5 links are often formed by multiple road links, and in some cases, they could be serving different bus corridors. Case Study 2 in Bristol demonstrated an example where a link serves two major groups of buses, with some using the whole length of the link and others using part of the length. It is unclear in the model Developer Guide how bus flow in this instance would be calculated.

The potential errors found are not of a large enough order to greatly affect the capacity of the road network, and therefore by extension the cost of highway journeys. They are not therefore considered to significantly impinge upon the ability of the model to be used for any of the potential use cases.

- It is suggested that the Developer Guide be updated to clarify the method of identifying ITN links traversed by each bus routes in TRACC, and clarify the method of summarising bus frequencies over the peak periods i.e. actual total frequencies across the time period, or multiplication of the peak hour frequencies and number of hours.
- If having provided this clarity it is considered that the current preloads are considered to be unsuitable, then consideration should be given to improving the preloading methodology in any future update. For instance, one could examine the accuracy of bi-directional links in suburban and rural areas where one-way loops and morning-inbound-evening-outbound services take place; and, cross examine actual bus routeing information as detailed in DfT/Traveline's TransXChange dataset.

5.3.9. HGV Restrictions

The HGV restrictions imposed in the model were checked against the reporting. A complete list of expected HGV bans is provided in Table 3.7 in the Developer Guide Volume 1. It was found that all the restrictions listed in the report are stored in the User-Defined attribute 'HGV_BAN'. It was also checked that transport systems enabled for these links with HGV bans do permit HGVs to use them and the coding seems appropriate.

5.4. Generalised Costs

This section focuses on the audit of implementation of generalised cost function within VISUM which is used in the assignment and influences the route choice.

The generalised cost is derived based on time and monetary costs associated to making a trip which along with VOT and VOC coefficients can be converted to the same units. The generalised cost calculations implemented in the model procedure sequence have been checked and are considered to be appropriate. The treatment of VOT and VOC parameters is discussed further in following sections.

5.4.1.1. Vehicle Operating Costs

The calculation of VOC cost coefficients which are part of the generalised cost function used in NTMv5 is based on the TAG databook (v1.9.1 December 2017) values and assumed average speeds derived from preliminary model runs, which were later verified by the developer against the final base year models. Independent calculations were undertaken to derive VOC coefficients and the analysis concluded on the same values as reported in the documentation (using the same average speed assumptions).

The speed assumptions presented in NTMv5 Dev Guide Vol3-HAM v2.0, Table 3.2 are used in NTMv5 for calculation of VOC coefficients. The audit notes that the approach to use an average speed instead of assessing it on a link by link basis is consistent with TAG.

The final base year demand, journey time and distance matrices were used to verify the average speed assumptions. The calculation was undertaken for car modes, split by purpose. **Table 5.11** summarises the calculated and assumed average speeds, noting that the NTMv5 speeds are not segmented by time period.

Table 5.11: Speed assumptions for VOC calculations

Mode & Purpose	Time Period	Average speed calculated within the audit (km/hr)	NTMv5 Assumed Speed (km/hr)	% Difference
Car Commute	AM	50	54	-7%
Car Commute	IP	50	54	-7%
Car Commute	PM	49	54	-9%
Car Business	AM	60	65	-8%
Car Business	IP	60	65	-8%
Car Business	PM	58	65	-11%
Car Other	AM	49	54	-9%
Car Other	IP	52	54	-4%
Car Other	PM	50	54	-7%

It can be concluded from **Table 5.10** that the calculated speeds are lower across all purposes by around 8%. There is insufficient information provided on how exactly these speed assumptions were derived.

- It is recommended that further information is provided on the assumptions and methodology to derive speed assumptions for VOC calculations. Although likely to have a minor impact, it is suggested that the speed assumptions are verified and updated if necessary.

5.4.2. Values of Time

VOTs are taken directly from the TAG Databook (v1.9.1 December 2017) and imported into the model in a form of User-Defined attributes. The implementation is considered to be appropriate.

5.4.3. VoT and VOC Forecast Changes

VoT and VOC parameters are expected to change over time and it's important to capture these changes in the model to be applied within the demand and assignment models.

In relation to forecast changes to the VoT parameters, a factor can be calculated and applied to the base year values which is a reasonable approach. Some essential files to undertake that process were not provided as part of the model files transfer.

It is however surprising to find that the VOC values are only calculated for the base year and forecast changes captured in the TAG Databook do not seem to be accounted for explicitly in the NTMv5 documentation nor implemented in the future baseline model (Run256) provided by DfT in the handover package.

- Whilst it is possible for a user to update the VOC values within NTMv5 in line with those forecast within the TAG Databook, it is suggested that further explanation is provided in the documentation in relation as to how to do so.

5.5. Variable Demand Model Implementation

The VDM is implemented using VISUM's standard absolute nested logit model and contains both a distribution and mode choice component. It makes use of complex utility functions, including time, distance, monetary cost, log of monetary cost and constant terms. The utility is calculated dimensionless, with an implicit "lambda" of 1; this is perfectly sound theoretically (and identical in function), but not as a logit model is described in TAG. The latter suggests the calculation of a "generalised cost" in minutes, and the use of non-unity lambdas.

This makes comparison of sensitivities and values of time with TAG standard values a little harder (although by no means impossible, and indeed the developers have done such comparisons for values of time). It is not a significant problem, merely an observation; and indeed, is acknowledged by the documentation.

A somewhat different utility has been used for non-home-based employers' business trips. This model adheres much more closely to TAG advice, and indeed reflects the business value of time function of distance now advised by TAG. It is slightly strange that the home- and non-home-based business purposes use very different models of utility (the demand models themselves are similar), but not of great concern provided both models have been demonstrated to behave robustly, as the realism testing in most respects does (subject to caveats as discussed below).

There is no cost-damping applied to time or distance components of cost, except for non-home-based business trips. This was slightly concerning to us in a model covering the whole country and full range of trip-lengths; long distance trips in the model could be oversensitive to (for example) changes in travel speed affecting the whole network. However, we have undertaken a sensitivity test in which speed changes are made to the whole network to explore this. The resulting changes in vehicle distance (traffic) and trip-lengths do not appear unreasonable, so we are content that this is not a critical problem.

Monetary components are damped through the "cost plus logcost" method.

Gap calculation for the purpose of understanding model convergence is present in the procedure sequence but disabled (we understand the size of the model prevented it from working). This is very unfortunate.

- A manual (i.e. using matrix calculations rather than the bespoke "GAP calculation" tool) implementation of the calculation should be attempted; this may work better than the bespoke tool.
- We would advise that care is taken to explicitly inspect the convergence and stability of any conclusions from model applications.

Based on the sensitivity testing we have undertaken, we believe the model is reasonably converged for the purposes of drawing high-level conclusions from large-scale policy/scenario highway changes. Smaller changes (e.g. public transport fares) and more detailed results may not necessarily produce stable or robust conclusions.

Slightly concerningly, the implemented coefficient for logcost term for home-based work in the VISUM model has the opposite sign to that reported in the documentation (both the Quality Report and the NTMv5 Developer Guide Volume 5: Forecasting Model v2.0) The model has a negative value; the documentation has a positive one.

Although negative is more intuitively logical; given the existence of both linear and log terms it is not necessarily obvious which is correct. This may be a typo in the documentation or an implementation error.

There are a few specifics of implementation in VISUM that are slightly unexpected, and not explained in the documentation. None of these is concerning, but they are outlined below for completeness.

- VISUM's nested logit model allows the calculation of utilities and specification of sensitivities and ASCs within the bespoke procedure. This functionality has not been used; utilities are calculated in full using matrix calculation procedures prior to the nested logit model and the explicitly specified ASCs and sensitivities are zero and one respectively. This is probably because the explicit inputs are insufficiently flexible to implement the models fitted by RAND.
- It is not entirely obvious why utilities are initialised immediately following the demand model, making it impossible to inspect these after the model has completed, but this is probably to keep file sizes down.
- It is also not obvious why 100 is subtracted from all utilities. This shouldn't affect any results so long as it is done for all modes and cells; possibly it is implemented to prevent overflows in calculations.

➢ It is recommended that the Developer Guide Vol5 is updated to explain why cost damping has not been applied to all journey purposes, why utilities are initialised immediately following the demand model, and why 100 has been subtracted from all utilities.

5.6. Incremental Modelling and VDM-HAM Linkage

The linkage between the variable demand model and the highway assignment model is implemented using the AMAI approach (absolute model applied incrementally). The synthetic VDM model response between the synthetic base and synthetic future is used to apply these changes onto the observed base year matrices through the pivoting and normalisation process.

As part of this process some matrix manipulation is implemented prior to pivoting to convert variable demand model matrices to the same units as the HAM matrices. The steps are undertaken using VISUM's standard matrix manipulation procedures, are considered appropriate and follow the process described in the documentation.

During this process, matrices are converted from 24hr person PA by demand strata and mode into average hour OD matrices by assignment user class. This is undertaken by applying the following steps.

- Splitting personal travel from VDM into car and LGV personal trips.
- Converting 24hr PA matrices into OD matrices by period using time period (Rho) and return time period (Phi) factors.
- Converting matrices by period into average hour.
- Aggregating demand strata into assignment user classes.

All of the steps above are fully automated within the model run and are based on hard coded attributes for relevant factors. The car/LGV split, Rho and Phi factors have been correctly transferred into the model and match those in the documentation.

It has been noted that an incorrect conversion factor is applied when LGV synthetic future matrices for the IP period (6 hours) are converted to an IP average hour using a factor of 1/3 rather than 1/6. This has a direct impact on the overestimated demand levels for OD trips in the final assignment matrices where pivoting cases that use values from the synthetic future matrices will be deployed (case 2, 4 and 5).

- It is critical that the script converting LGV synthetic future matrices for the IP period to IP average hour is corrected from 1/3 to 1/6.

The implementation of pivoting, normalisation and smoothing seems appropriate and aligned with the documentation.

The nomenclature of the matrix manipulation code used within the Visum procedures is generally not user friendly. As part of the normalisation process matrices are set up with almost identical names, where the only difference is through use of an apostrophe at the end of the name. Although this does not impact model performance, it makes checking and understanding of the process difficult, particularly so as the matrix names in the code are bounded by quotation marks therefore apostrophises in the matrix names can easily go unnoticed.

- Consideration should be given to reviewing the nomenclature used to refer to matrices within the normalisation process with a view to providing greater differentiation between matrix names.

5.7. Procedure Sequence

The procedure sequence is an essential part of NTMv5 which connects all components on the model and is how a user controls the model runs in NTMv5. The procedure sequence in NTMv5 is segmented into different steps undertaken during the model run which are summarised in Table 4.1 of the Quality Report.

Each group has been reviewed (line by line) to ensure it is consistent with the documentation and does not contain any errors. For most groups, this audit has concluded that the implementation is appropriate, however the following issues were identified. Some of the issues are described in detail in the corresponding model component chapters, the remaining issues are detailed in this chapter.

1) Group "GV/PSV Growth"

   Implementation of this group along with limited documentation imposes a risk of incorrect model runs. This is explained in detail in Section 5.7.1 below.

2) Group 11: Period TH/FH to Avg Peak Hour OD

   The conversion factor for LGV matrices from period to average period hour is incorrect. This is discussed in detail in Chapter 5.6 of this report.

3) Assignment convergence criteria

   Assignment result with relaxed criteria are used to generate standard model outputs This is explained in detail in Section 5.7.2 below.

5.7.1. Group "GV/PSV Growth Growth"

This group is implemented in the model but is not accounted for in Table 4.1 of the Quality Report. It appears that this group handles manipulation of PSV pre-loads and freight demands in relation to forecast growth. This is achieved by factoring relevant attributes/matrices by a constant factor that is an embedded user input. No references have been found in the documentation to the source of these factors. It also appears that there is insufficient information in the documentation to inform the user about making changes/updates to these constant parameters in the model set up.

- ➢ It is recommended that the User Guide be updated to explain / reference the source of the assumed PSV growth, and how different growth could be applied should the user need to.

The above constant factors are applied in a way that overwrites the original values. Although freight matrices are part of the initial data imports and original values will be restored in each model run it is important to note that the PSV pre-loads are not defined so in the documentation.

The following implications are a result of the above:

- If the model procedure sequence is run multiple times, the effects of PSV factors will be combined and not reversed to the original values; and
- If a model user runs the model multiple times but assumes that the importing of data was undertaken at the previous model run and does not need to be undertaken again, values of the freight matrices will not be restored, and the same factors will be applied multiple times.

These implications should be communicated to any model user to prevent any unintended errors arising in users model runs.

- ➢ It is recommended that the User Guide warn users not to run the model multiple times without checking that the model produces exactly the same results after re-running it using the previous run as a starting point.

5.7.2. Assignment Convergence

The implementation of assignment convergence criteria is aligned with the documentation. In summary, a relaxed convergence condition is applied inside the VDM loop. A set of final assignment with the convergence criteria set to values aligned with the TAG guidance is undertaken after the VDM loop converges or reaches maximum number of iterations.

The reasoning for this implementation is to keep the model run times to minimum, however in this instance it may be deemed to be a significant trade off, compensating model stability. It is important to note that although the documentation does state that for any model outputs the last set of assignments should be used, some standard model outputs are generated using the assignments with relaxed convergence criteria (e.g. vehicle kilometre statistics). The documentation does not seem to explicitly warn the model user that these outputs are based on models that did not converge to the required standard.

A flow difference plot was generated between the assignment from the last VDM loop iteration (relaxed criteria) and the final assignment using the 2030 Baseline PM models. This is show in **Figure 5.53** and **Figure 5.54**.

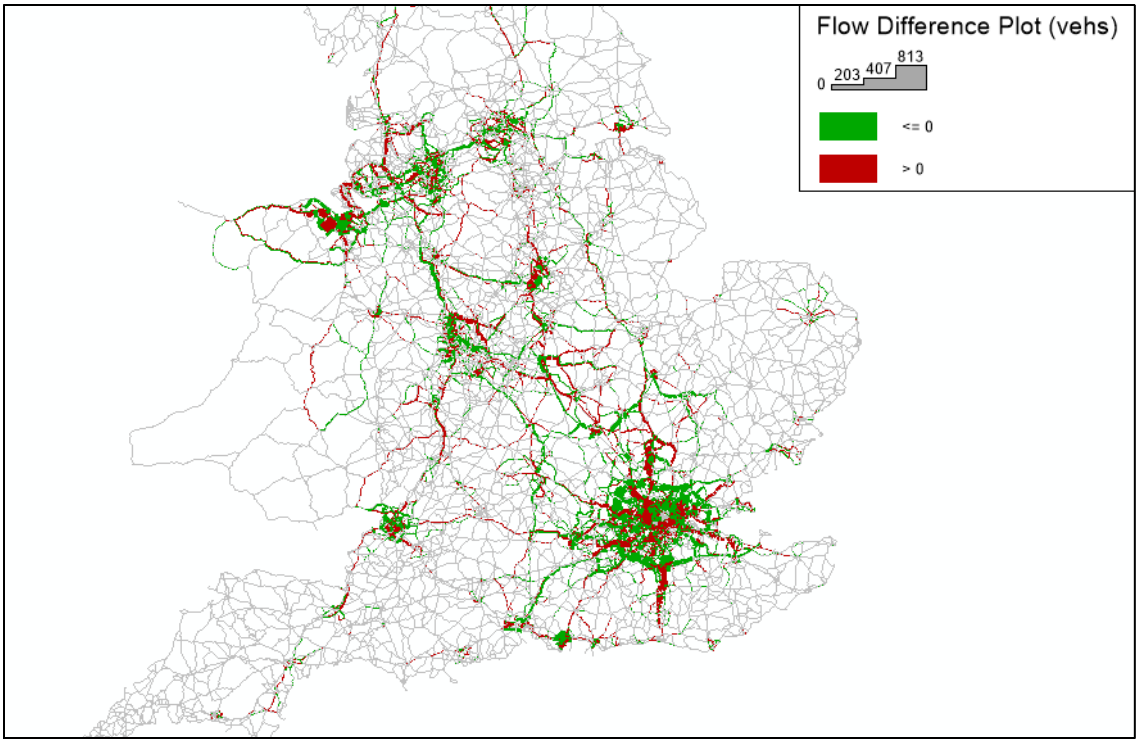


Figure 5.53: Convergence noise between different convergence criteria used in NTMv5

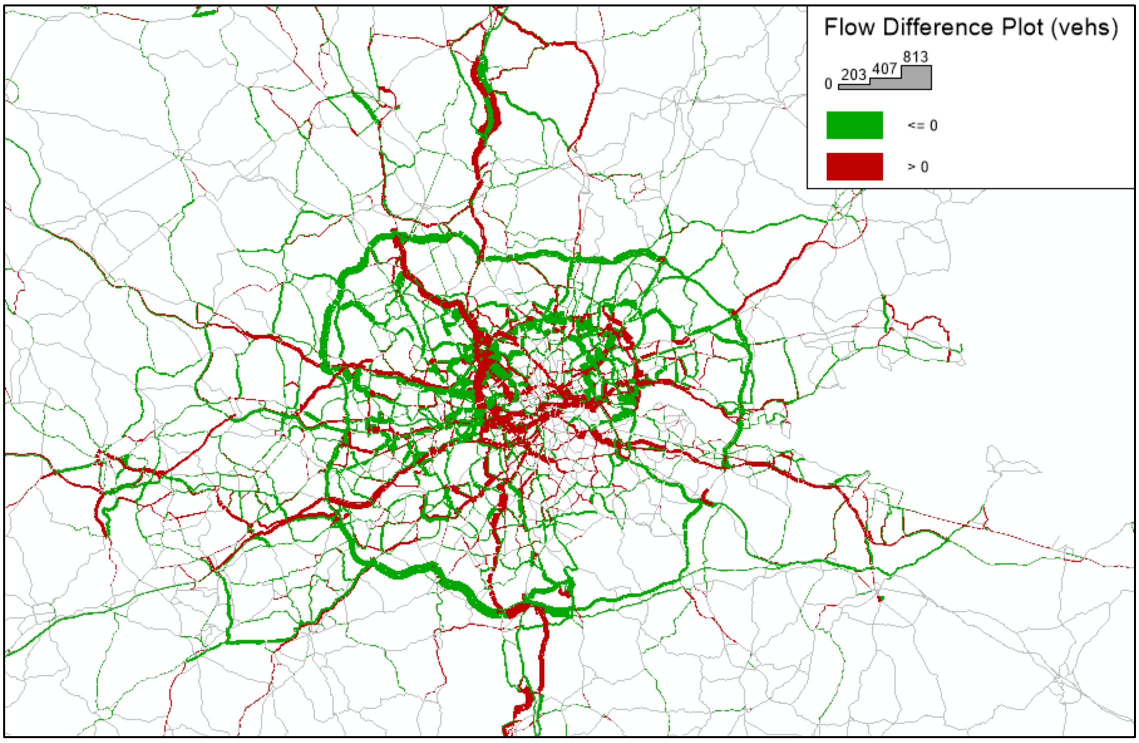


Figure 5.54: Convergence noise between different convergence criteria used in NTMv5 (South East Region)

The implementation of relaxed convergence criteria in the VDM loop resulted in an additional set of assignments being required. These are the same assignment as within the last VDM iteration loop but run for more iterations (due to a tighter convergence criteria). This approach saves run time in the VDM loop but adds an extra set of assignments at the end of the model run that could potentially be avoided. The following potential solutions were identified that could be investigated to improve model convergence and/or reduce model run times.

- Implementation of warm start for the final assignments (applicable if the VDM loop is capped to a constant number of iterations).
- Tightening of assignment convergence criteria incrementally within the VDM loop with the last iterations set to converge to the required standard. The final set of assignments would not be required in this instance.
- The latest Visum software upgrades developed by the software vendor implemented improvements to the assignment algorithms that significantly reduce model run times. Reduced assignment times in general, may allow for running the assignments within the VDM loop with appropriate convergence. This would result in the need to no longer require the final set of assignments.

  - It is recommended that to improve consistency of outputs, and to improve model accuracy consideration be given to removing the final assignment from the procedure sequence.

5.8. Model Implementation Conclusions

This chapter has reviewed the following components:

- the development of the model zoning system;
- the development and implementation of the highway network;
- the implementation of generalised cost functions and attributes;
- the implementation of the VDM functionality and parameters;
- the incremental modelling and VDM-HAM linkage implementation; and
- the procedure sequence.

5.8.1. Model Coverage and Zoning

In terms of model zone development and structure the audit considered a number of aspects including the following key topics; how the zone system was constructed, the identification and classification of bespoke zones, and the compatibility between the NTMv5 zone system against NTEM and RTM zone systems.

In the majority of cases, and where bespoke zones are not involved, NTMv5 zones are formed from MSOA zones. It was found that the NTMv5 zones do follow RTM zones in many cases. Additionally, in the majority of NTMv5 centroids are based on MSOA PWCs.

Issues raised by the audit included:

- The documentation of zone information is incomplete. Information missing included; the zone category, and correspondence to RTM zone. In terms of model categories, there is no information regarding which zones are bespoke zones. A complete list is essential for those wishing to use or update the model.
- The audit found that almost 20% of the zones have zero highway nodes. This suggests that the correct balance between zone size and highway network may not yet be achieved. Coarse or incorrect loading can distort flow representation at a local level. The consequences of this would be most likely limit model use in considering local investment (UC3) without the need for bespoke review by the model user. This theme is considered further in the following review of the highway network.

5.8.2. Highway Network Development

A detailed review of the highway network development was assessed against best practice guidance. Elements including; links, connectors, screenlines and congestion delay representation were reviewed. Additionally, the following aspects of the model were also considered; HGV restrictions, tolls, roadworks and bus preloads.

The audit concluded that the coverage of strategic links in the model is appropriately represented, together with comprehensive link attribute recording. The audit raised a number of questions regarding how the zones were connected to the network, such as where connectors been connected to motorways and A roads (contrary to what was stated in the documentation), more than one zone being loaded to the same point on the highway network, and crow fly distances being used for connector lengths including for some very long connectors in northern Scotland. These issues would again result in distorted flow representation, and misrepresentation of true journey distance.

In order to remedy the issues, it is suggested a review of zone loading is undertaken. Within this it is suggested that principle of attempting to load connectors on a secondary network (i.e. away from the SRN and MRN) is worth pursuing. This would provide the model user with the assurance that there is a higher order road network on which the flow and delay representation is likely to be of a higher standard.

The review would tie in with general theme of providing some additional network detail (also discussed in relation to zone size and network balance) and could be undertaken as follows.

- Identify the SRN and MRN as the higher order road network.
- In areas were zones are currently loaded on this network, additional supporting network should be added.
- Additional supporting network could also then be added in locations where; zones are loaded at the same point, or in zones with zero nodes where the current zone loading is questionable.

In terms of junction coding a number of inconsistencies were found including the following.

- The coding of priority junctions was found to contain systematic errors which would be likely to affect the accuracy of the distribution of delay across the network.
- No specific consideration has been given to delays at dual carriageway merge nodes.
- Inconsistencies were found in the coding of Urban Area Speeds including where junction delay coding had been included in these fixed speed areas, potentially double counting delay.

It is difficult to make a general statement quantifying the possible distortion of network delays caused by these issues. This is because the journey time calibration that has been achieved is based on very long routes (see section 4.4.5 of this document) , therefore it is possible that different local errors cancel each other out in the strategic context.

Finally, the documentation does not provide the model user with any information on how roadworks has been approached in the model development; there are some areas within the base model where reduced capacity representing the location of active roadworks have been included. These areas of reduced capacity need to be removed before the model is used for forecasting.

Considering the highway network representation, it is suggested that this model should not be used to consider local investment (UC3) without the need for bespoke review by the model user. For use cases concentrating on the SRN (UC1), or those considering aggregate outputs (e.g. UC5) then the effect of the issues found would be less significant, although it would be recommended that results are considered at a suitably aggregate scale.

5.8.3. Generalised Costs

The application of generalised cost parameters within the base model was found to be appropriate. It is surprising to find that the VOC values are only calculated for the base year and forecast changes captured in the TAG Databook do not seem to be accounted for explicitly in the NTMv5 documentation nor implemented in the future baseline model (Run256) provided by DfT in the handover package. Whilst it is possible for a user to update the VOC values within NTMv5 in line with those within the TAG Databook, it is suggested that further explanation and instruction is provided in the documentation.

5.8.4. Variable Demand Model Implementation

The implementation of the VDM has been applied in an acceptable manner. There is no cost-damping applied to time or distance components of cost, except for non-home-based business trips. This was slightly concerning to us in a model covering the whole country and full range of trip-lengths; long distance trips in the model could be oversensitive to (for example) changes in travel speed affecting the whole network. However, we have undertaken a sensitivity test in which speed changes are made to the whole network to explore this. The resulting changes in vehicle distance (traffic) and trip-lengths do not appear unreasonable, so we are content that this is not a critical problem.

Gap calculation for the purpose of understanding model convergence is present in the procedure sequence but disabled (we understand the size of the model prevented it from working). This is very unfortunate. It is recommended that a manual (i.e. using matrix calculations rather than the bespoke "GAP calculation" tool) implementation of the calculation should be attempted; this may work better than the bespoke tool. We would advise that care is taken to explicitly inspect the convergence and stability of any conclusions from model applications.

Based on the sensitivity testing we have undertaken; we believe the model is reasonably converged for the purposes of drawing high-level conclusions from large-scale policy/scenario highway changes. Smaller changes (e.g. public transport fares) and more detailed results may not necessarily produce stable or robust conclusions.

5.8.5. Incremental Modelling and VDM-HAM Linkage

An error has been found in the implementation of the incremental modelling and VDM-HAM linkage: it is critical that the script converting LGV synthetic future matrices for the IP period to IP average hour is corrected from 1/3 to 1/6. Otherwise the implementation of pivoting, normalisation and smoothing seems appropriate and aligned with the documentation.

5.8.6. Procedure Sequence

The implementation of assignment convergence criteria is such that a relaxed convergence condition is applied inside the iterations of the VDM loop. A set of final assignment with the convergence criteria set to values aligned with the TAG guidance is then undertaken after the VDM loop converges or reaches maximum number of iterations. It is important to note that although the documentation does state that for any model outputs the last set of assignments should be used, some standard model outputs are generated using the assignments with relaxed convergence criteria (e.g. vehicle kilometre statistics).

This approach saves run time in the VDM loop but adds an extra set of assignments at the end of the model run that could potentially be avoided. In this regard, a number of potential solutions have been suggested that could be investigated to improve model convergence and/or reduce model run times, including the use of a warm start, tightening of convergence criteria incrementally within each run or implementing the latest Visum software upgrades.

6. Model Review - Data Processing

6.1. Overview of Data Processing

The audit of data processing undertaken as part of NTMv5 development includes reviewing the following tasks:

- assembling data for base year matrix development;
- base year matrix development process;
- processing of data for demand model development;
- process of estimating mode – destination choice model parameters;
- processing of count data for calibration and validation of highway model; and
- processing of journey time data for calibration and validation of highway model.

Following initial discussion with the Department, it became clear that as the contract with the model developers was expired, and some of data processing files have not been provided to the Department, it would not be possible to obtain access to all of the processes and the data relating to the above tasks.

Table 6.1 summarises the individual processes or data that were developed and used as part of the model development process, and hence should be available for audit. The latest status for each of these with regards to auditors' access to the files is also given in this table, highlighting a number of processes where access could not be obtained. The consequence of this is that we were not able to provide assurance through independent checks of the process undertaken.

In response to this and noting some limitations in respect of model verification through the documentation review, we mitigated this through discussions with the Department by undertaking verification checks on the outcome instead of a direct audit of the processes, where the latter was not possible. This was in principle based on comparing the final outputs from the source data processing that are used in the model either with the original data they are sourced from and the documentation describing the process in order, or with independent data, to form and document a view of the consistency and credibility of the output with source data, model documentation, and industry best practice.

Nevertheless, it is important to note the fact that, as many of these model components are not owned by the Department, the processing used to develop the NTMv5 base year model cannot be fully traced and repeated, and the base year model cannot be rebuilt or updated without significant effort and cost to the Department.

The approach undertaken for the audit of each model development component and the findings from it are described in the following sections.

Table 6.1: Summary of Data Processing Components and their Availability for Model Audit

Task	Model Component / Data	Status for Audit
Base Year Matrix Development	Population / school data supplied by HSL in NTMv5 zoning.	Available
Base Year Matrix Development	"Any Year Census" process	Atkins' tool. Access is not provided due to IPR
Base Year Matrix Development	NTMv5 data tables produced by "Any Year Census"	Access is not provided due to significant preparation effort needed
Base Year Matrix Development	The process of calculating trip ends and attraction weights	Access is not provided due to significant preparation effort needed
Base Year Matrix Development	NTEM7.2 data tables	Available
Base Year Matrix Development	Census data	Available
Base Year Matrix Development	The process of building commuting trip matrices from JTW data	Access is not provided due to significant preparation effort needed
Base Year Matrix Development	The process of building education trip matrices from school census	Access is not provided due to significant preparation effort needed
Base Year Matrix Development	Inputs to Kalibri i.e. trip ends, target generalised cost profiles, skims	Access provided to trip ends, NTS data, and skims.
Base Year Matrix Development	The Kalibri process used to build the base year matrices	Ver files are too large. Only matrix outputs and log files is provided.
Base Year Matrix Development	CAA data used for the airport surface Access trips and the process	CAA data and the process are provided.
Base Year Matrix Development	The logit model application used to derive distribution of port trips	Available as ver file
Base Year Matrix Development	Freight matrix development process	Owned by MDST. Access is not provided.
Base Year Matrix Development	Final highway prior matrices	Available in binary Mtx files
Highway Calibration and Validation	TRADS data via RTMs	Available
	GIS of screenlines and cordons	Available
	Observed screenline and link flows	Available
	Source Trafficmaster journey time data	Available
	Trafficmaster journey time data processing	Available
	Processed journey times by route	Available
Demand Model Development and Calibration	LOS data by mode used for parameter estimation	Available
	Process used to prepare the data for estimation	Owned by RAND. Access is not provided.
	Parameter estimation process	Owned by RAND. Access is not provided.
	National Travel Survey	Available

6.2. Base Year Matrix Development

6.2.1. Demand Data Assembly

This section focuses on the process of developing the base year trip ends. We did not have access to the "Any Year Census" process, the NTS data tables and the process of calculating trip ends. We therefore could not review the detailed codes and processes developed to build the base year trip ends. However, NTS, NTEM7.2 data tables and Census were available.

The following checks were undertaken to establish if the process used to assemble the data and generate trip ends is robust with a reasonable level of confidence:

- consistency of zonal trips ends by purpose and mode of NTMv5 with NTEM7.2;
- consistency of zonal distribution of trip ends with NTEM by purpose and mode;
- consistency of outturn trip rates with NTS trip rates at aggregate level; and
- comparison of mode shares with NTEM / NTS.

6.2.1.1. Trip Ends Analysis

Input preparation

NTEM trip ends were not provided by the model developers for the base year 2015. As such, 2011 and 2016 NTEM data were used to derive 2015 trip ends at different level of aggregation, in order to allow the comparison of trip ends with NTM. Base year NTEM7.2 trip ends were derived by interpolating the 2011 and 2016 NTEM7.2 employment, population, and car ownership data sets. A summary table was extracted and subsets produced by purpose and mode to reach the average weekday productions and attractions.

Base year trip ends for NTMv5 have been derived by the model developers using the DfT's Trip Rate Forecasting tool and the Any Year Census (AYC) population forecasts, as set out in the *'NTMv5 Dev Guide Vol2-BY Demand v2.0'* supporting documentation. These were derived for all modes to reproduce data provided by the model developers, with a focus on cars for detailed checks at different spatial aggregation levels against NTEM.

Base year trip ends were provided in the format of an input file to the synthetic matrix build process, *'tblAllDayPAs.csv'*. This provided production and attraction totals by NTMv5 zone, purpose, and mode. For the purpose of this audit, all of the subsequent analysis of the NTMv5 trip ends was based on the provided input trip ends file, as opposed to calculating trip ends from the final matrices, which were not provided for all purposes at all-day person level. Any mode or purpose dependent analysis was only available from the trip end inputs.

Trip ends overview

The total productions from the *'tblAllDayPAs.csv'* file, across all modes and purposes, was 54,348,003. The specific units of the trip estimates in this file were not known, but after comparing totals with Table 4.7 in the *'NTMv5 Dev Guide Vol2-BY Demand v2.0'* supporting documentation, it was deduced that the input file was showing home-based tours by mode and purpose.

The same units of data were extracted independently from NTEM7.2 and compared with the trip ends provided; the results are shown in **Table 6.2**.

Table 6.2: NTMv5 and NTEM 2015 totals by purpose, tours, all modes, NTMv5 internal zones

Trip purpose	NTEM v7.2	NTMv5	%Diff	*NTEM v7.2 (previously reported)*	*NTMv5 (previously reported)*	*%Diff (previously reported)*
Commuting	14,383,863	13,287,071	-8%	*14,754,117*	*13,254,180*	*-10%*
Education	10,453,300	10,866,879	4%	*10,686,037*	*10,908,253*	*2%*
Shopping	11,899,497	10,979,849	-8%	*12,083,283*	*11,024,901*	*-9%*
Personal Business	5,700,796	6,058,494	6%	*5,827,679*	*6,083,290*	*4%*
Recreation	6,081,437	5,556,668	-9%	*6,133,814*	*5,579,649*	*-9%*
Visiting	4,872,876	4,162,919	-15%	*5,019,087*	*4,180,096*	*-17%*
Holiday	1,882,602	1,503,613	-20%	*1,876,203*	*1,510,084*	*-20%*
Employers' Business	1,771,871	1,932,510	9%	*1,808,235*	*1,918,640*	*6%*
All HB (internal)	**57,046,242**	**54,348,003**	**-5%**	***58,188,455***	***54,459,094***	***-6%***

It should be noted the numbers calculated independently, shown in columns 2 and 3 in **Table 6.2**, do not directly match what was provided in Table 4.7 of the *'NTM Dev Guide Vol2-BY Demand v2.0'* document. There are a number of possible reasons which could explain the differences:

- NTEM7.2 data tables are available for the years 2011 and 2016 (among others) so the 2015 inputs for CTripEnd have been interpolated by the model auditors based on these years. Since the original input files and the process were not provided to us, it is not clear if the 2015 NTEM7.2 production data were derived by model developers in the same way.
- The zone correspondence file provided by the model developers lists 6,960 internal polygons, which is consistent with the GIS layer provided. The 'tblAllDayPAs.csv' file also contains 6,960 UniqueIDs, however there are 18 zones that do not exist in the zone correspondence file. As a result, their location cannot be identified or directly matched with an MSOA. There are also 17 internal polygons present in the zone correspondence which do not exist in the 'tblAllDayPAs.csv'. **Table 6.3** lists the two sets of missing zone correspondences, and **Figure 6.1** shows the 17 zones missing from the 'tblAllDayPAs.csv' input file. Based on the missing zone correspondences it is possible that the 'tblAllDayPAs.csv' file provided was from a previous version of the synthetic input or the zone correspondence is not up to date; this might explain the differences between the two NTMv5 totals.

Table 6.3: Missing zone correspondences

In PA input file, not in zone correspondence (18)	In zone correspondence, not in PA input file (17)
6277, 6278, 6279, 6280, 6281, 6282, 6283, 6284, 6285, 6286, 6287, 6288, 6289, 6290, 6291, 6292, 6293, 6294	6847, 6792, 6793, 6840, 6841, 6845, 6806, 6795, 6800, 6798, 7696, 6833, 7697, 6804, 6805, 6832, 7702

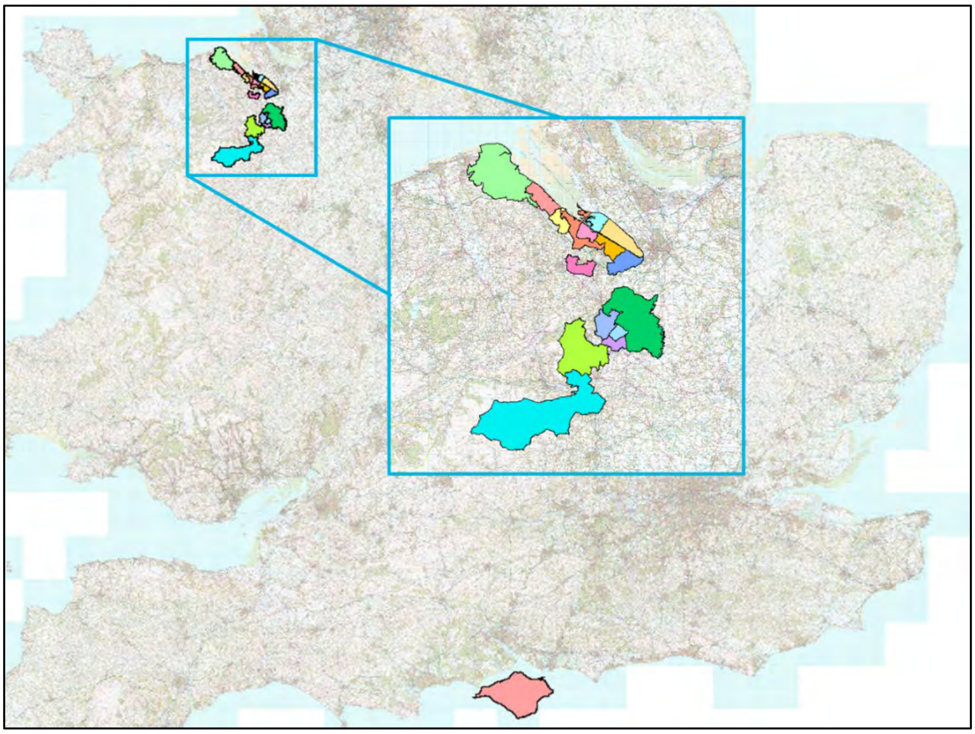


Figure 6.1: Location of 17 missing zones in trip end input file

Trip ends comparison by MSOA

The *'tblAllDayPAs.csv'* file was converted to MSOAs based on the zone correspondence file. The total car productions and attractions by MSOA were compared between NTMv5 and NTEM.

From the *'tblAllDayPAs.csv'* file, there were eight MSOAs which had low daily car productions, including one that had zero, across all home-based purposes. **Table 6.4** lists these zones, and the corresponding number of daily car productions, and **Figure 6.2** shows these zones, all located in the South West region. Based on the land use of these zones, the small number of trips seemed unlikely hence they were excluded from the MSOA comparison analysis.

Table 6.4: Low car productions by MSOA

MSOA	NTMv5	Daily car productions
E02004254	6,493	5
E02003198	6,190	5
E02003201	6,193	114
E02003204	6,196	12
E02003205	6,197	0
E02003208	7,516 & 7,514	68
E02003210	6,202	6
E02004268	6,507	26

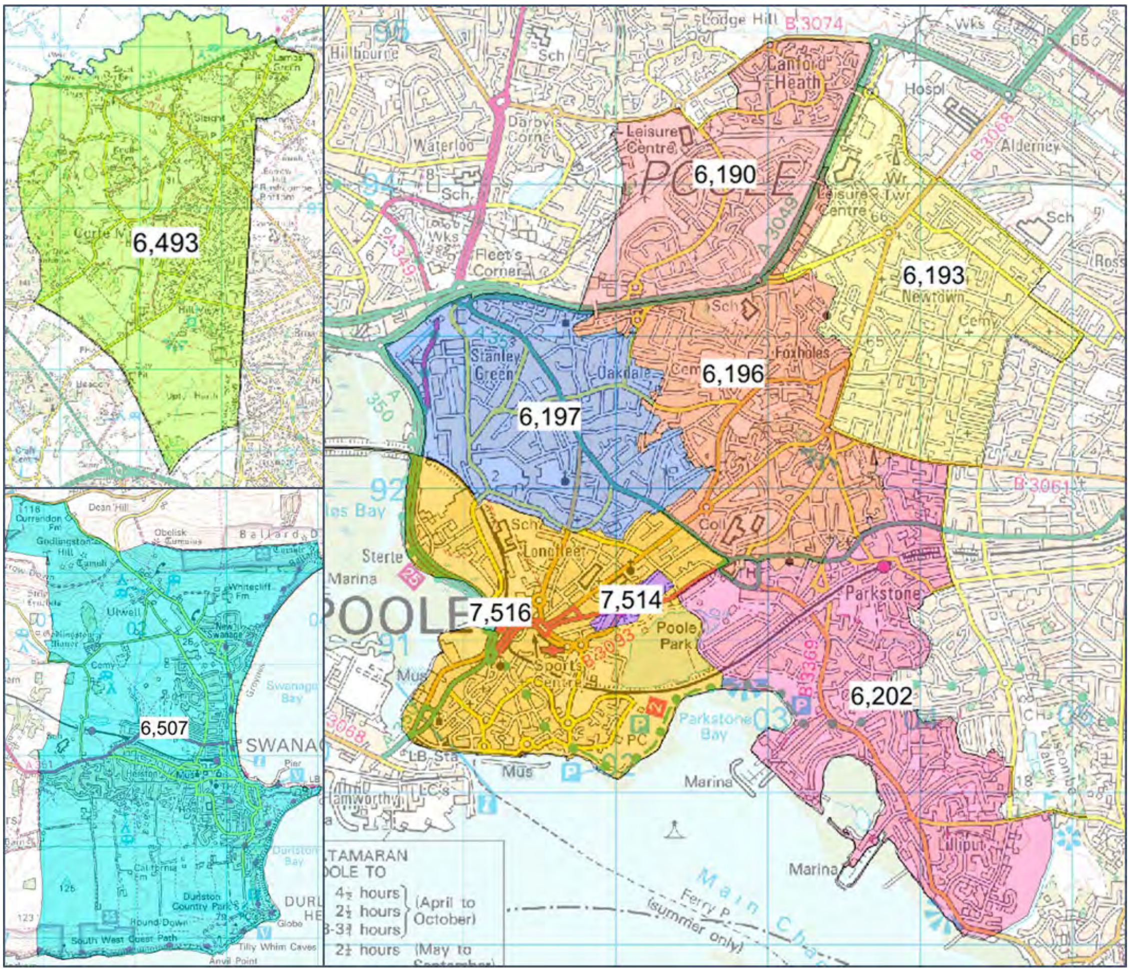


Figure 6.2: MSOAs with low/no daily car productions, all home-based purposes, with corresponding NTMv5 zone numbers

Table 6.5 shows the car trips entering and leaving the corresponding NTMv5 zones from the model developers' prior matrices. It can be seen the low trip numbers have been resolved throughout the matrix development process. However, as we do not have access to the full processes and all the intermediate adjustment steps, we cannot verify how these are produced or adjusted.

Table 6.5: Prior car trips in low/no production zones

	Trip origin			Trip destination		
NTMv5 Zone	AM	IP	PM	AM	IP	PM
6,190	96	211	278	341	187	129
6,193	210	452	724	803	486	348
6,196	147	317	603	703	304	214
6,197	164	356	537	643	338	231
6,202	137	291	402	451	299	214
6,493	126	294	361	375	296	215
6,507	106	180	226	210	146	103
7,516	429	915	1,744	1,997	951	662
7,514	111	241	262	268	272	182

Figure 6.3 shows the comparison of daily car productions and attractions across all home-based purposes at MSOA level. There were MSOAs which had significantly different numbers of car attractions; for example, the City of London (E02000001) had 428,683 total home-based car attractions in NTMv5, compared with 29,270 in NTEM7.2. Removing this outlier from the attraction scatter plot will increase the R^2 to 0.46.

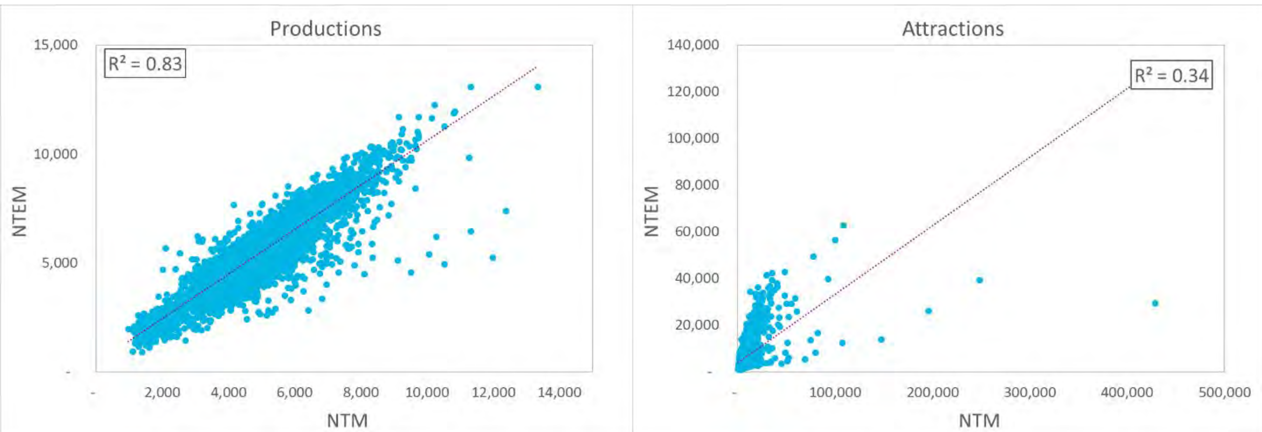


Figure 6.3: Comparison of NTMv5 and NTEM car productions and attractions at MSOA level, all home-based purposes

The equivalent analysis was done for a single purpose, home-based employers' business, again excluding any zero production zones. **Figure 6.4** shows the comparison of daily car productions and attractions for home-based employers' business. Similarly, removing City of London outlier from the attraction scatter plot will increase the R^2 to 0.46.

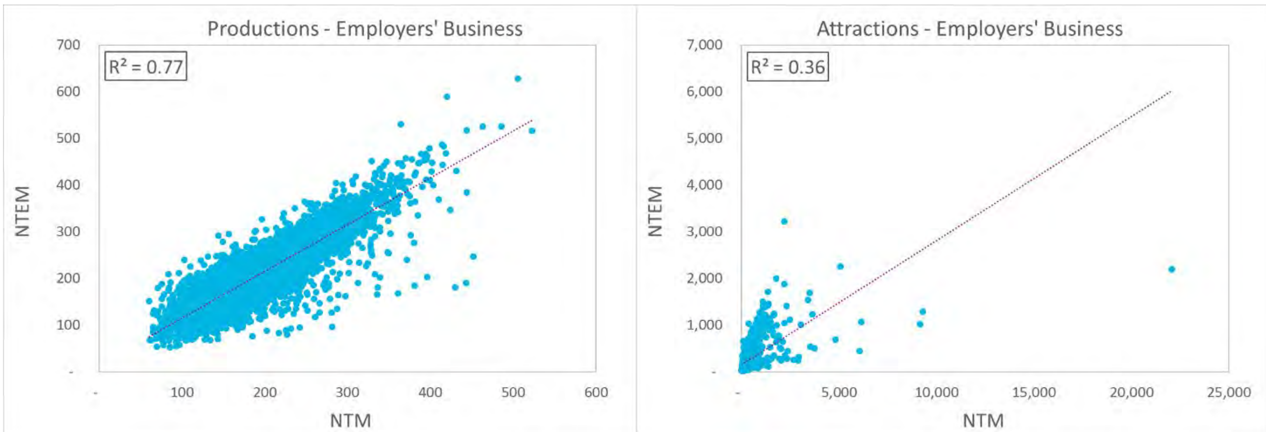


Figure 6.4: Comparison of NTMv5 and NTEM car productions and attractions at MSOA level, home-based employers' business

It can be seen that overall, the correlation between NTMv5 and NTEM productions are reasonably strong, and the differences that are seen are likely to be due to the differences in underlying population data. As laid out in the *'NTM Dev Guide Vol2-BY Demand v2.0'* document, the home-based trip productions for each internal NTMv5 zone were obtained by multiplying the 2015 population data from the AYC by the 2015 trip rates from the NTEM trip rate forecasting tool, as opposed to being sourced directly from NTEM7.2.

The correlation between NTMv5 and NTEM attractions is weak. The input trip attraction weights to the 'Kalibri' process initially were the HSL land use indicators combined for each trip purpose, as used in the VDM. However, using these weights resulted in far too many car trips being attracted to densely populated urban areas with extensive public transport provision, as pointed out by the model developers. It can be seen from the graphs that there are multiple points where the NTMv5 attraction is significantly larger than the NTEM value, which is likely to be caused by the land use indicators.

The same analysis was undertaken at a more aggregate level, comparing district level car productions and attractions across the UK. **Figure 6.5** shows that at a more aggregate level, the correlation between the two sources is much stronger. This supports the explanation provided above for differences at MSOA level; there are local variations that may mainly be due to differences in underlying zonal planning data. The analysis was also undertaken for a single purpose, home-based employers' business, and is shown in **Figure 6.6**. In both cases, the difference between the findings for production and attraction correlations are consistent with what is described above.

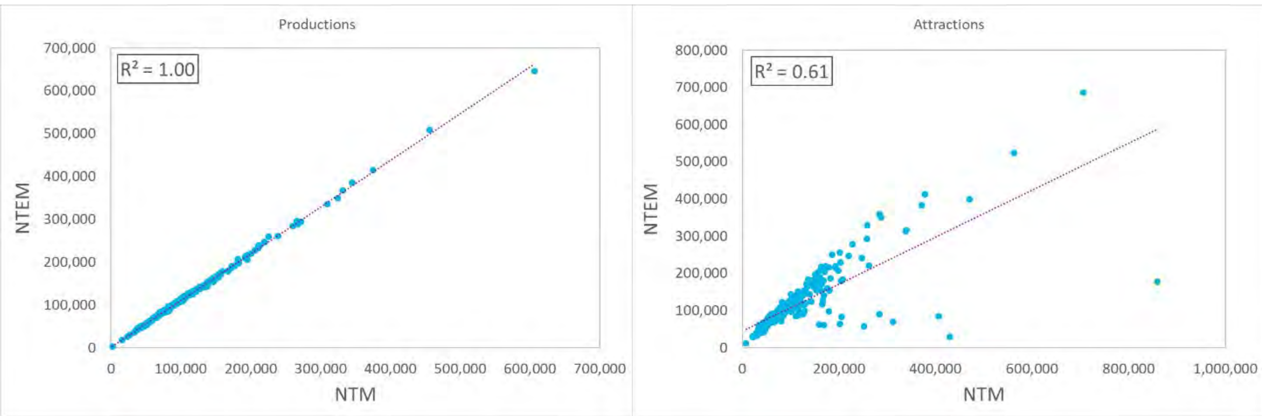


Figure 6.5: Comparison of NTMv5 and NTEM car productions and attractions at district level, all home-based purposes

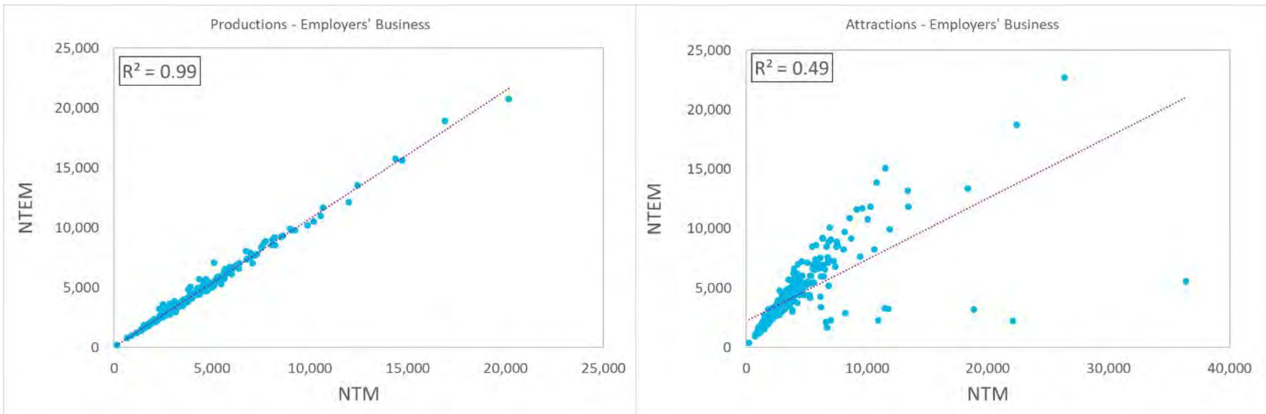


Figure 6.6: Comparison of NTMv5 and NTEM car productions and attractions at district level, home-based employers' business

Trip ends comparison by region

Figure 6.7 shows the comparison of daily regional level car productions and attractions across all home-based purposes. It is seen that total productions and attractions are broadly consistent between NTEM7.2 and NTMv5, and hence differences seen at a more spatially disaggregate level were likely to be due to the local variation in the underlying population data.

Figure 6.7also highlights the differences in car attractions for Greater London. This is a result of the differences observed at MSOA mainly for the City of London shown in **Figure 6.3** and **Figure 6.5**. It suggests that the differences in underlying planning data used for NTMv5 has a greater effect on dense urban area attractions, which is not seen in NTEM7.2. The processing set out in Section 5.3.2 of the *'NTM Dev Guide Vol2-BY Demand v2.0'* document state the Land Use indicators used to derive attractions were weighted using the Census JTW attraction car driver mode share. This resulted in reduced car trips being attracted to London and the Metropolitan areas, which were subsequently used as inputs to the synthetic build.

- It is recommended that the model documentation is updated to provide more clarity and information on the adjustments made to zonal trip ends.

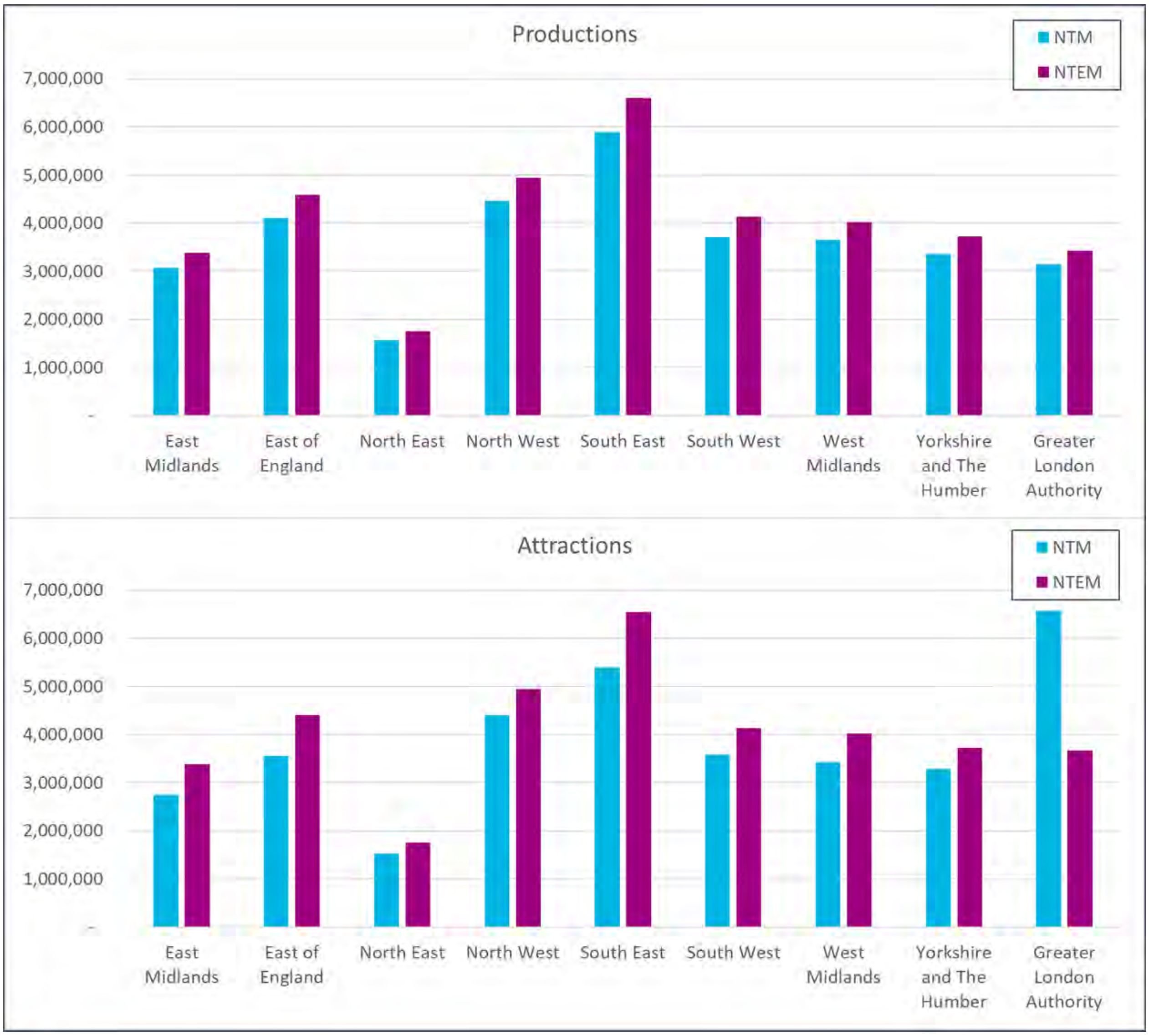


Figure 6.7: Comparison of NTMv5 and NTEM regional car productions and attractions, all home-based purposes

6.2.1.2. Trip Rate Analysis

Figure 6.8 shows the trip rate comparison between NTMv5 input trip end file, local NTS data, and NTEM7.2 for five urban districts in the West Midlands (a randomly selected region). The NTMv5 trip rates were initially extracted from the DfT's Trip Rate Forecasting tool, whereas for this analysis the trip productions have been divided by the NTEM7.2 population estimates to calculate outturn trip rates. Also, the NTEM7.2 and NTS trip rates have been extracted for 2016, as opposed to the 2015 base year. Both of these points will be a source of discrepancy in the trip rate comparison. The results show that for the five urban districts included in the analysis, the NTMv5 trip rates were consistent with the other data sources and were systematically within the NTS confidence intervals.

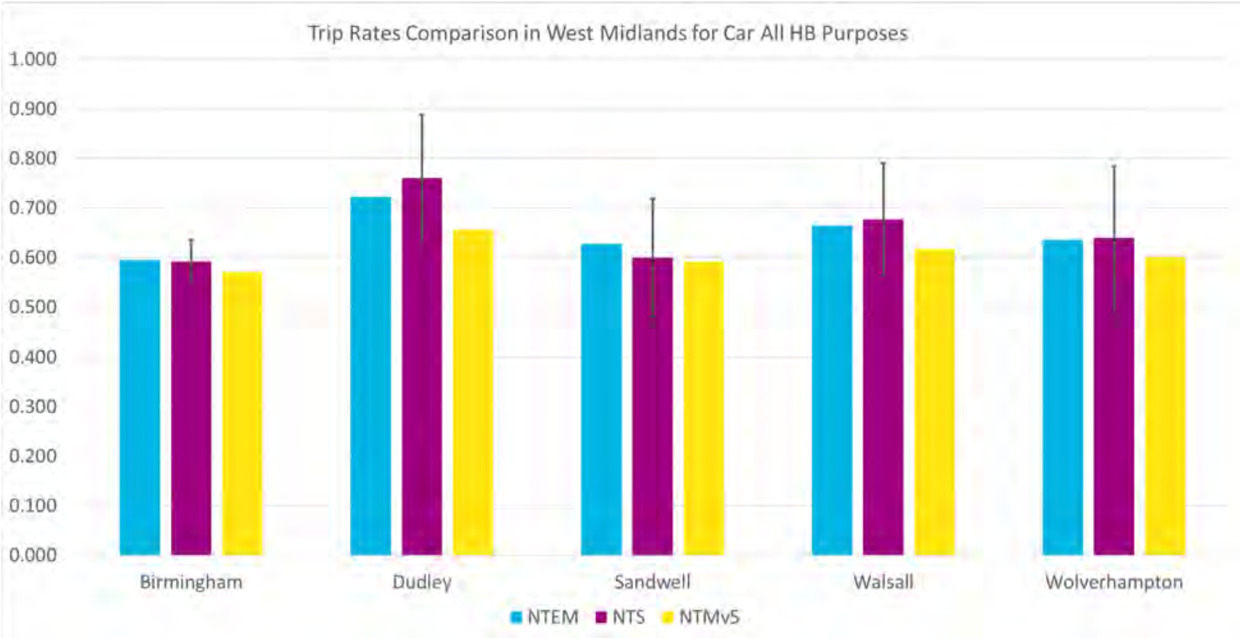


Figure 6.8: Car trip rate comparison by district, all home-based purposes

Equivalent analysis of trip rates was undertaken for a single selected purpose, home-based employers' business, the result of which is shown in **Figure 6.9**. Again, despite the differences in derivation methods, the NTMv5 2015 trip rates are consistent with the other data sources, and systematically within the 95% confidence interval of the NTS data. It can be seen in Wolverhampton how the sample size of the NTS data can cause the reliability of trip rates to vary.

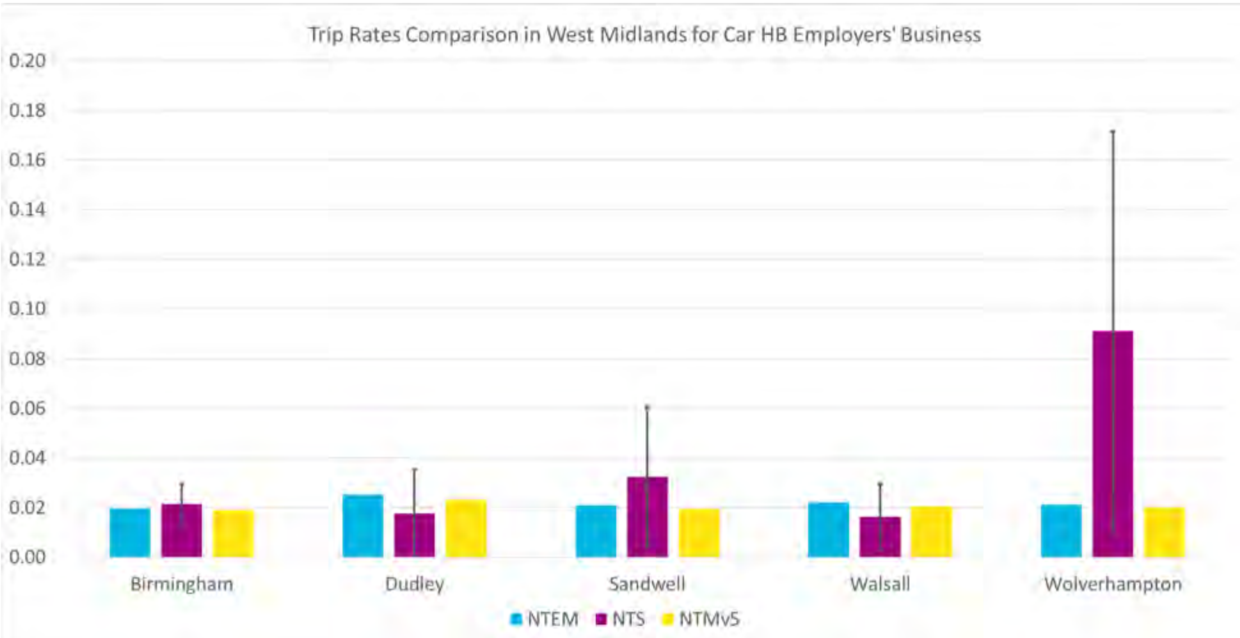


Figure 6.9: Car trip rate comparison by district, home-based employers' business

6.2.1.3. Mode Share Analysis

The only mode share information provided was the *'tblAllDayPAs.csv'* input file, not from the final matrices. **Figure 6.10** shows the comparison of NTEM and NTMv5 trip ends for five districts in the West Midlands. To allow a comparison with NTEM, the NTMv5 mode share was derived from the *'tblAllDayPAs.csv'* input file, as the resulting prior matrices are car, LGV, and HGV.

It can be seen that the mode split across each of the five districts is largely consistent between NTEM7.2 and the input to NTMv5. It should be noted that the mode share for commuting trips is updated in the base year matrix build process based on Census Journey to Work data, as described in the *'NTM Dev Guide Vol2-BY Demand v2.0'* document, which could contribute to the differences seen below.

Figure 6.10: Comparison of NTEM and NTMv5 trip end mode share, all home-based purposes

6.2.2. Matrix Development Process

We did not have access to the relevant Version files that include the 'Kalibri' process to develop synthetic matrices in the model, hence the code used for this process was not checked in detail. However, access to the inputs to this process was provided i.e. trip ends, NTS-sourced cost profiles, and skim files. these were used to verify the inputs and process of matrix development, segmented by mode and purpose, by reviewing the following:

- the log files;
- matrix totals by time period, purpose, segment, mode and government region;
- consistency of zonal trip productions / attraction with input trip ends;
- consistency of observed trip cost profiles used in the process with the NTS data; and
- goodness of fit of the modelled trip cost profiles with observed cost profiles used for gravity model calibration process.

Similarly, access to the processing of Census data was not provided to build commuting and education trip matrices, hence these were not checked in detail. Instead, the model auditors reviewed the consistency and integrity of the developed matrices with the source data i.e. Census Journey to Work and school Census data for commuting and education trips, respectively. Conclusions were drawn based on the documentation available explaining the processes undertaken to comment on any differences found.

Access to the CAA data and the processing of these were provided to generate the airport access demand matrices and have review these as intended.

Access to the logit model application used to derive distribution of port trips was also provided and therefore reviewed as intended.

Access to the source data and process used to develop freight matrices was not provided, but the documentation/technical notes describing this process was provided. The approach was reviewed and commented and checked against the statistics derived from the final freight matrices provided.

6.2.2.1. Synthetic Matrix Development

Synthetic matrices using the 'Kalibri' process have been developed and were provided by the model developers for eight purposes:

- home-based (HB) shopping
- HB personal business
- HB recreation
- HB visiting
- HB holiday
- HB employers' business
- non home-based (NHB) employers' business, and
- NHB other.

For each of these purposes, log files and the final synthetic matrices for the chosen scenario reported in the 'NTM Dev Guide Vol2-BY Demand v2.0' were provided. The log files include the estimated parameters and the empirical (observed) versus theoretical (modelled) distributions.

For the home-based scenarios, observed generalised time from the NTS were also given alongside the TAG-based formulas/parameters used to calculate generalised time using NTS travel time and travel distance data.

The synthetic matrices in '.mtx' format were also provided for each of the eight purposes. This allowed us to further investigate the consistency of the inputs and outputs of the synthetic process.

Table 5.14 of the 'NTM Dev Guide Vol2-BY Demand v2.0' presents the estimated parameters for each purpose. Using the log files, the estimated parameters are consistent with the reported table for all the eight purposes.

In comparing the input HB Employers' Business trip ends with the output synthetic trip ends, it was noticed that the trip ends input file does not have data for 17 zones which do exist in the output synthetic matrices yet have non-zero productions/attractions. These zones are shown in **Figure 6.1**. Potential reasons were explained in section 6.2.1.1 This inconsistency can slightly influence the analysis produced in this section.

The analysis undertaken included the following:

- comparing matrix totals for home-based purposes between input trip ends and output synthetic matrices;
- comparing matrix totals for two selected purposes (HB Employers' Business and HB Shopping) at regional level between input trip ends and output synthetic matrices;

- comparing matrix totals for two selected purposes (HB Employers' Business and HB Shopping) at zonal level between input trip ends and output synthetic matrices;
- comparing generalised times from NTS with those provided by Atkins as input to the 'kalibri' process for all purposes;
- comparing the observed and modelled generalised times obtained from the log files of the 'kalibri' process for all purposes; and
- comparing synthetic with NTS trip length distributions using distance skims (for NTMv5 synthetic matrices) and observed NTS distances, respectively, for two selected purposes (HB Employers' Business and HB Shopping).

Education and commuting matrices are treated differently and are not developed using the 'kalibri' process. These are discussed in Sections 6.2.2.2 and 6.2.2.3.

Table 6.6 shows the results of comparing car matrix totals. It is expected that input trip ends to have the same number of trips as the output synthetic matrix. The 'NTM Dev Guide Vol2-BY Demand v2.0' mentions that the synthetic matrices use adjusted zonal car driver trip ends. In Section 6.2.1.1, the input trip ends were compared with NTEM7.2 and it was concluded that the input file was for cars rather than car drivers. However, **Table 6.6** shows significant differences in the totals. The NTMv5 Synthetic totals were checked against log files and verified that they are consistent. **Table 6.6** shows that while synthetic values are lower than input values for most purposes, HBEB has higher synthetic productions. It is thus not clear if the inconsistency between the two is a result of inconsistent definitions.

> - It is possible that the NTMv5 synthetic matrices are car driver trips. If this is the case, a clear explanation of how the input trip ends are converted to car driver should be provided.

Another potential reason behind the discrepancy is that the 'kalibri' is conducted for internal to internal trips only, whereas the input trip ends is assumed to include internal to external trips as well. However, this does not explain the reason behind HBEB having higher productions than the input.

Table 6.6: comparison of matrix totals for car internal trip productions

Purpose	Input Trip Ends	NTMv5 Synthetic	% Diff	NTEM Car Driver	% Diff
Shopping	6,772,604	4,536,966	-33%	5,728,426	-15%
Recreation	3,856,593	2,254,686	-42%	2,685,372	-30%
Personal Business	3,933,495	2,513,393	-36%	2,609,512	-34%
Holiday	1,201,326	705,457	-41%	940,223	-22%
Visiting	2,937,880	1,772,760	-40%	2,394,979	-18%
Employers' Business	1,308,381	1,367,540	+5%	1,467,848	+12%

Similar analysis to the above was undertaken at a regional level for two randomly selected purposes, HB Employers' Business and HB Shopping. Generally, **Figure 6.11** and **Figure 6.12** show consistent production/attraction trip ends at regional level for the HB Employers' Business trips, consistent with **Table 6.6**. However, while the pattern is captured for the HB Shopping in **Figure 6.13** and **Figure 6.14**, there are differences across the regions reflecting the 33% difference in the totals shown in **Table 6.6** for shopping trips.

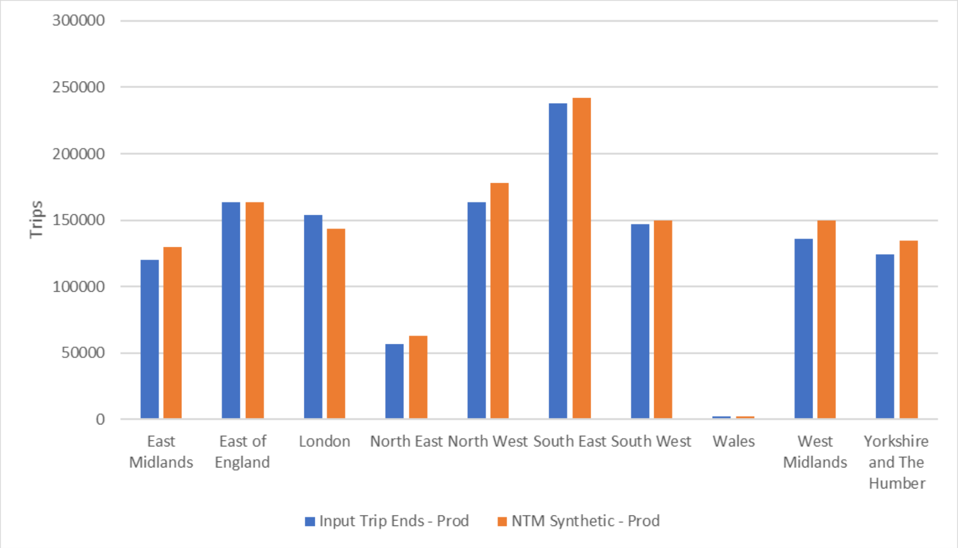


Figure 6.11: HB Employers' Business internal production regional trip ends, input vs synthetic output for cars

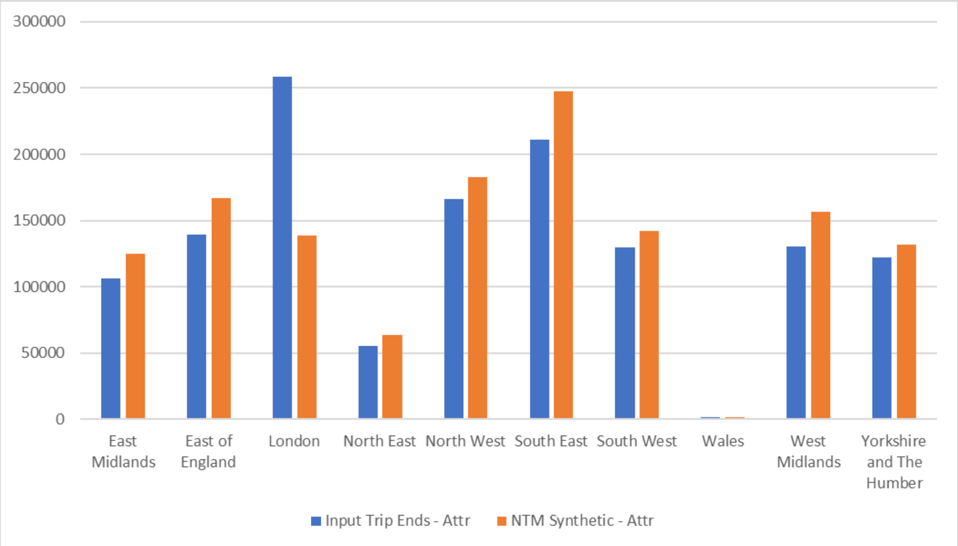


Figure 6.12: HB Employers' Business internal attractions regional trip ends, input vs synthetic output for cars

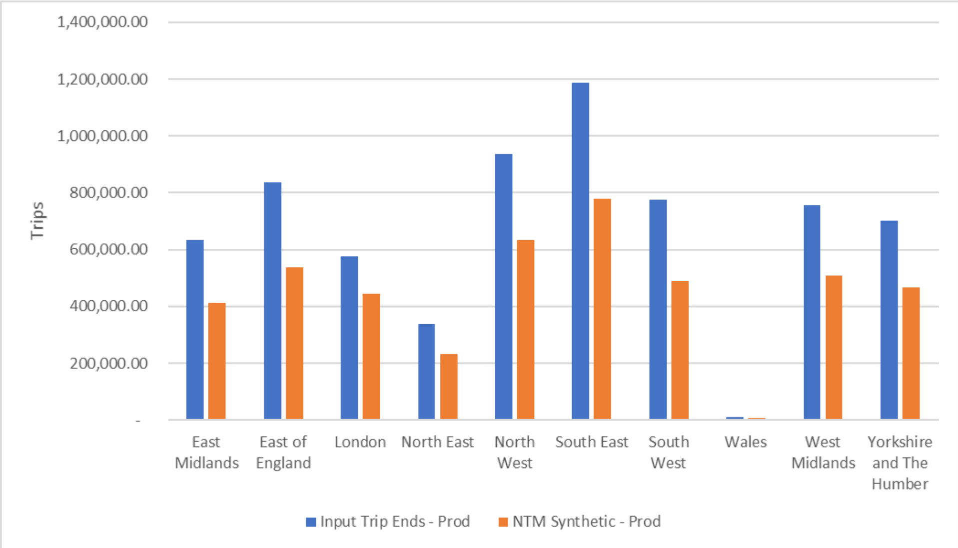


Figure 6.13: HB Shopping internal production regional trip ends, input vs synthetic output for cars

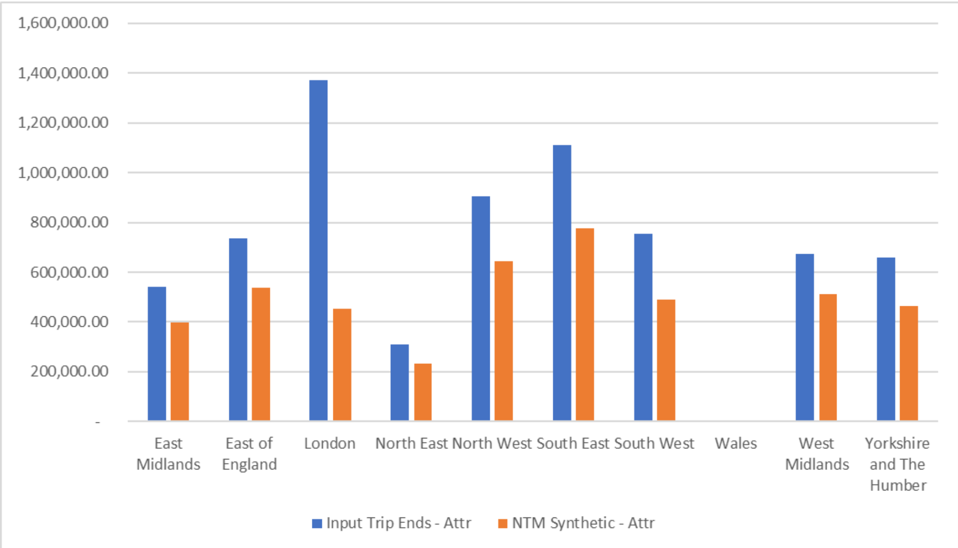


Figure 6.14: HB Shopping internal attraction regional trip ends, input vs synthetic output for cars

- There is clear discrepancy between provided trip ends and synthetic matrices produced by the Kalibri process, with no information available to explain the reasons behind this. Whilst we have discussed possible reasons, this should be clarified so that existence of significant errors in the process can be ruled out.

Figure 6.15 and **Figure 6.16** show the analysis at a more detailed NTMv5 zone level for HBEB production and attraction trips, respectively. If both the production trip ends and synthetic matrices are consistent, then it is expected to have a perfect correlation between the two. 'NTM Dev Guide Vol2-BY Demand v2.0' does not provide any analysis or verification for these. Although the results show a good correlation for the production trips, trip numbers are not the same. It is understood from the 'NTM Dev Guide Vol2-BY Demand v2.0' that the `Kalibri` process was singly constrained to productions, which explains the poor fit of the attractions in **Figure 6.16**. nonetheless, the poor fit is improved when removing few outliers with input trip ends higher than

5,000. This is shown in **Figure 6.17** for HB employers' business purpose. Similar patterns are found for HB Shopping production and attraction correlation shown in **Figure 6.18**, **Figure 6.19**, and **Figure 6.20** respectively.

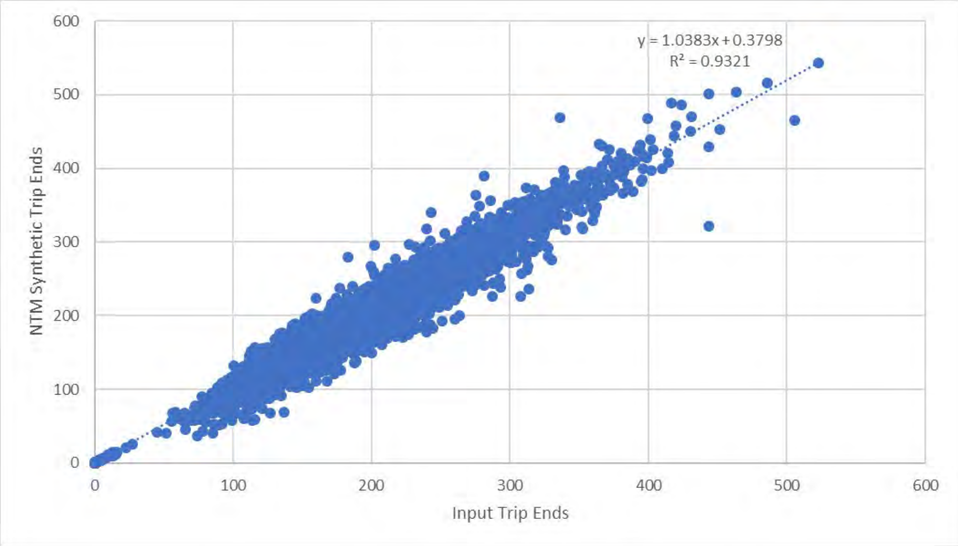


Figure 6.15: HB Employers' Business internal production zonal trip ends, input vs synthetic output for cars

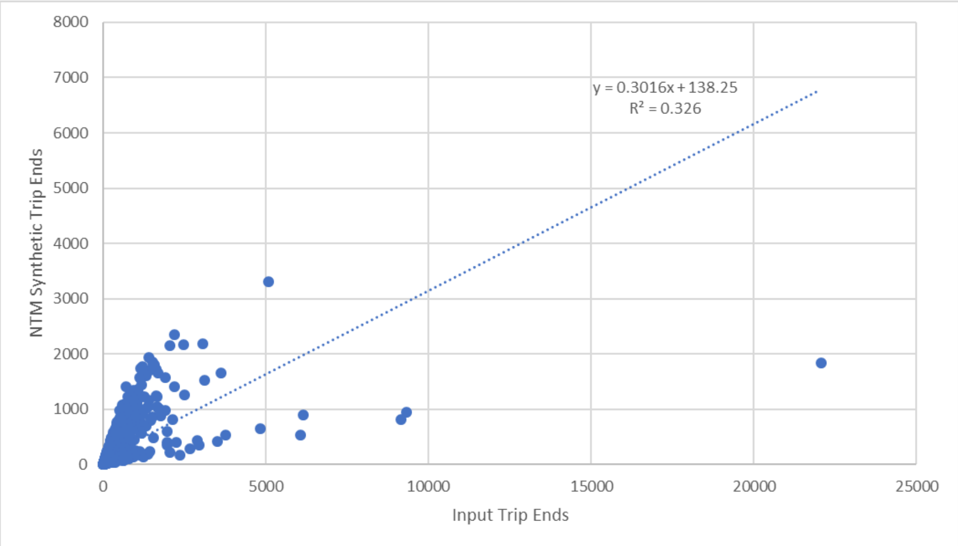


Figure 6.16: HB Employers' Business internal attraction zonal trip ends, input vs synthetic output for cars

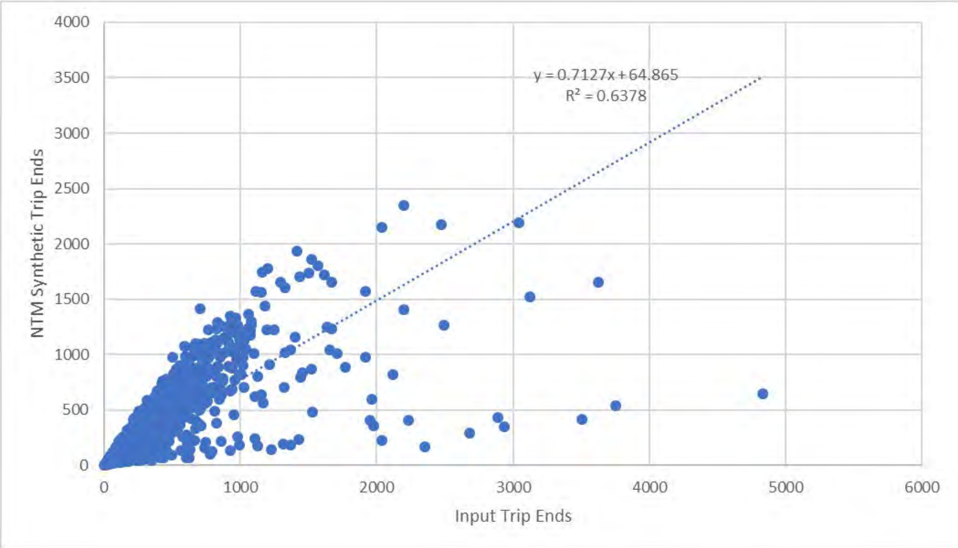


Figure 6.17: HB Employers' Business internal attraction zonal trip ends, input vs synthetic output for cars with input trip ends less than 5000

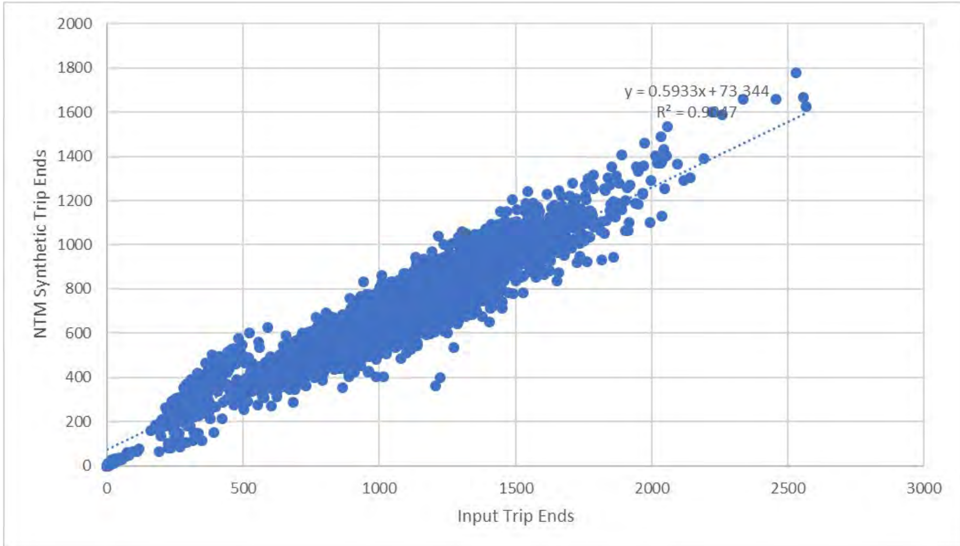


Figure 6.18: HB Shopping internal production zonal trip ends, input vs synthetic output for cars

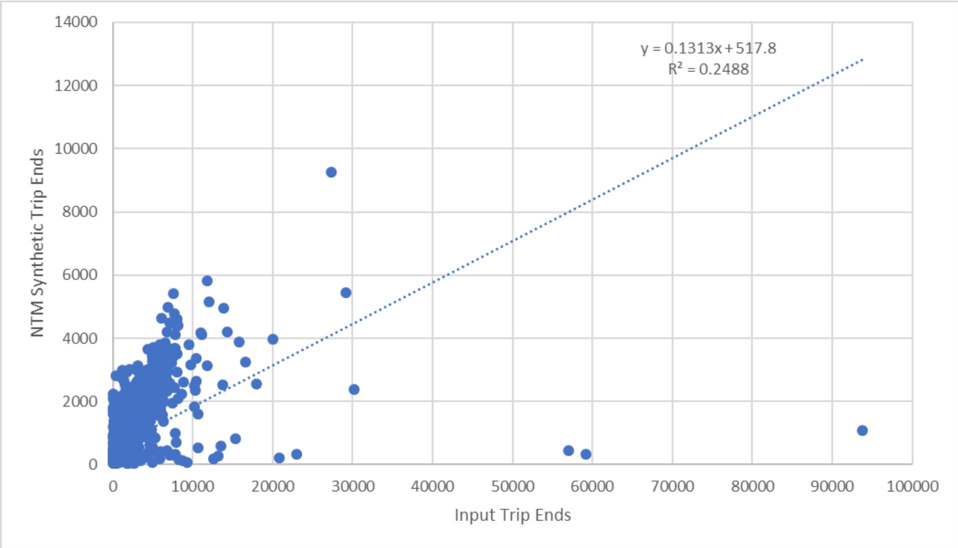


Figure 6.19: HB Shopping internal attraction zonal trip ends, input vs synthetic output for cars

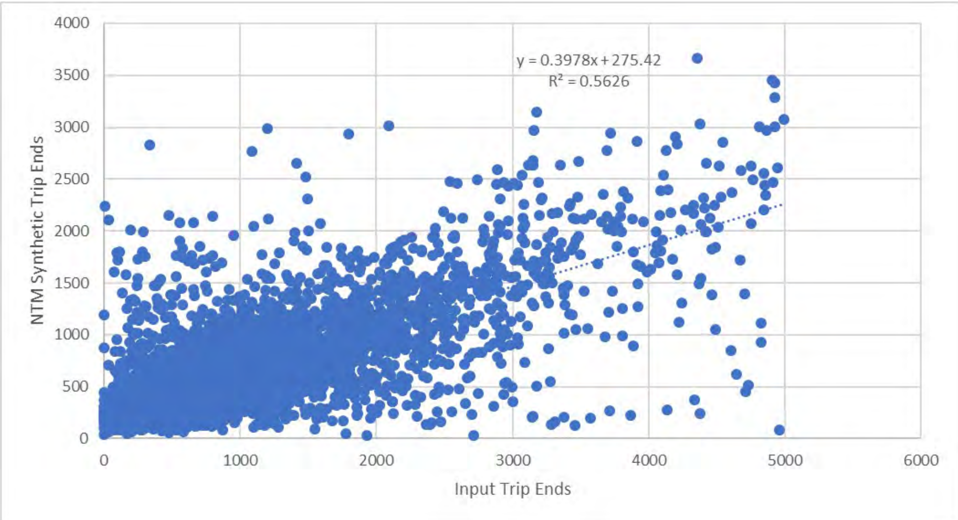
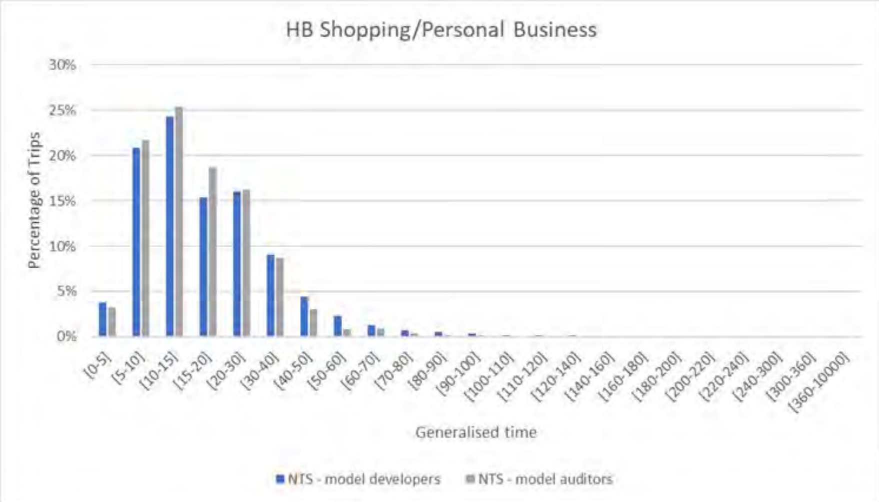


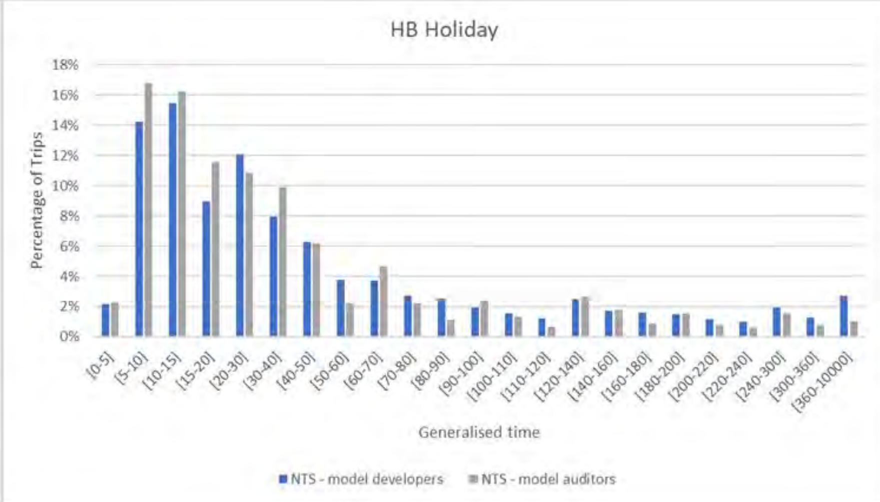
Figure 6.20: HB Shopping internal attraction zonal trip ends, input vs synthetic output for cars with input trip ends less than 5000

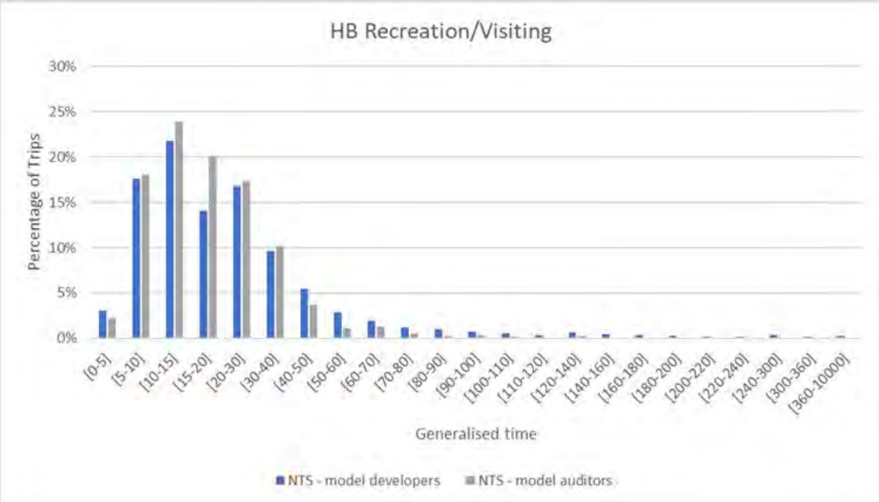
'NTM Dev Guide Vol2-BY Demand v2.0' describes the methodology used for calculating generalised time against which the synthetic matrices were optimised. While that is the case, the verification of the synthetic matrices reported by model developers are based on trip length distributions rather than generalised time trip distributions.

The NTS generalised time for predefined bands were provided by model developers and were compared with those extracted independently from the NTS for the purpose of model audit, for all HB purposes other than commuting and education. Generally, the generalised time distributions are consistent across the home-based purposes, as shown in **Figure 6.21**, with slight differences for the employers' business trips. These were calculated based on car from-home trips. The distributions are very similar even when considering both directions or car drivers only trips from NTS.

- The model developers need to be clearer on the data being extracted for each of the analysis reported, particularly: which mode was selected (car driver, passenger, or both) and which direction was selected (from-home or both directions).


HB Shopping/Personal Business
Percentage of Trips
Generalised time
NTS - model developers
NTS - model auditors


HB Holiday
Percentage of Trips
Generalised time
NTS - model developers
NTS - model auditors


HB Recreation/Visiting
Percentage of Trips
Generalised time
NTS - model developers
NTS - model auditors

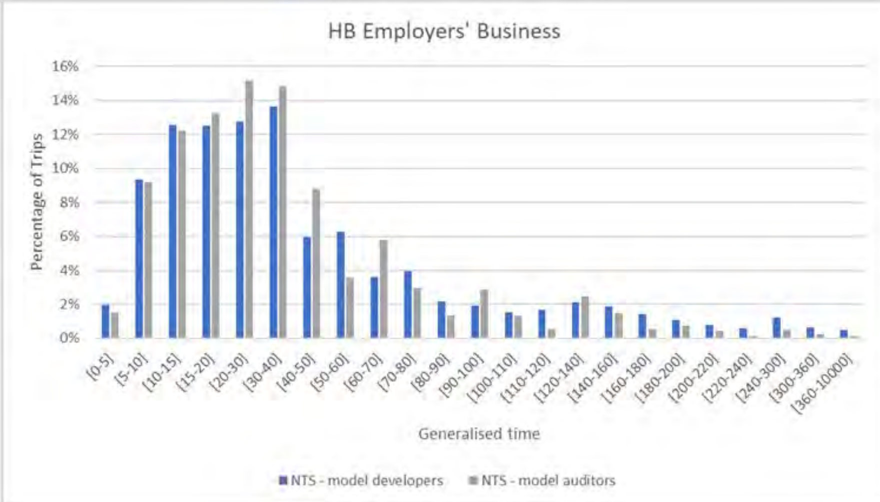

HB Employers' Business
Percentage of Trips
Generalised time
NTS - model developers
NTS - model auditors

Figure 6.21: Model developers vs model auditors generalised time distribution comparison for home-based purposes

The log files provided theoretical and empirical distributions as outputs from the 'kalibri' process. The 'kalibri' process shows a good fit of the modelled values for all purposes as shown in **Figure 6.22**. The most challenging optimisation was for the HB and NHB employers' business purposes, although the pattern is generally captured.

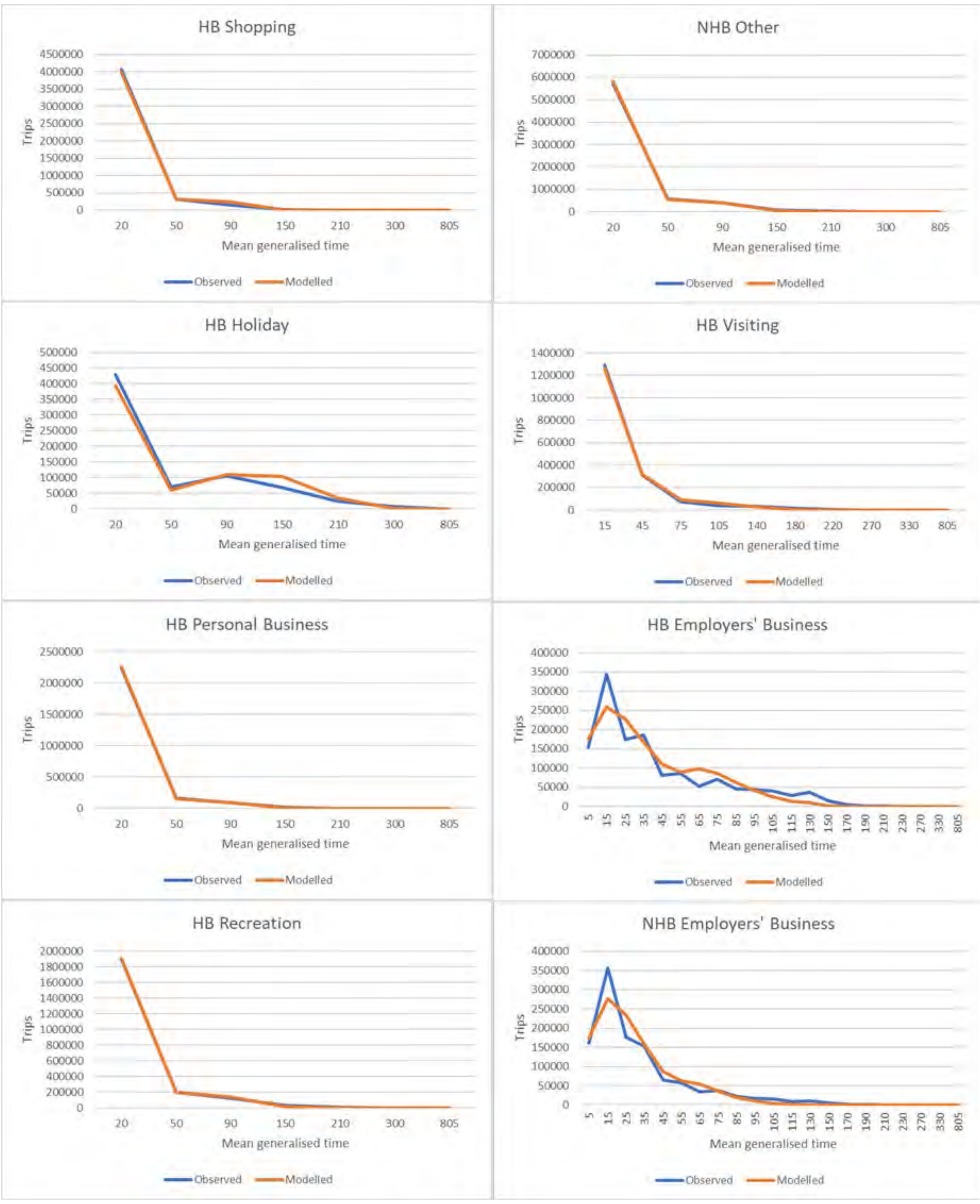


Figure 6.22: Observed vs. modelled generalised times derived from the log files

The final audit step of the synthetic matrices was comparing the trip length distribution from the observed NTS data with the final synthetic matrices. **Figure 5.7** and **Figure 5.8** in the 'NTM Dev Guide Vol2-BY Demand v2.0' shows a comparison of NTS TLDs with the synthetic TLDs for HB Holiday and HB Employers' Business. These figures are shown in **Figure 6.24**; Scenario k represents the final synthetic matrix for HB Holiday and Scenario N for that of HB Employers' Business. Similar figures were replicated and are shown in **Figure 6.23**. The NTS distributions are similar to those reported, but there are slight differences in the TLD built from the synthetic matrices. This is possibly attributed to the final distance skim being used in the process of developing synthetic TLDs. The NTS data used for this analysis was for cars and from-home only trips consistent with what was produced for the generalised time distribution analysis.

- Again, it is also recommended that the model developers are clearer on what NTS and the synthetic matrices for the different purposes represent, and their consistency with the input trip ends.

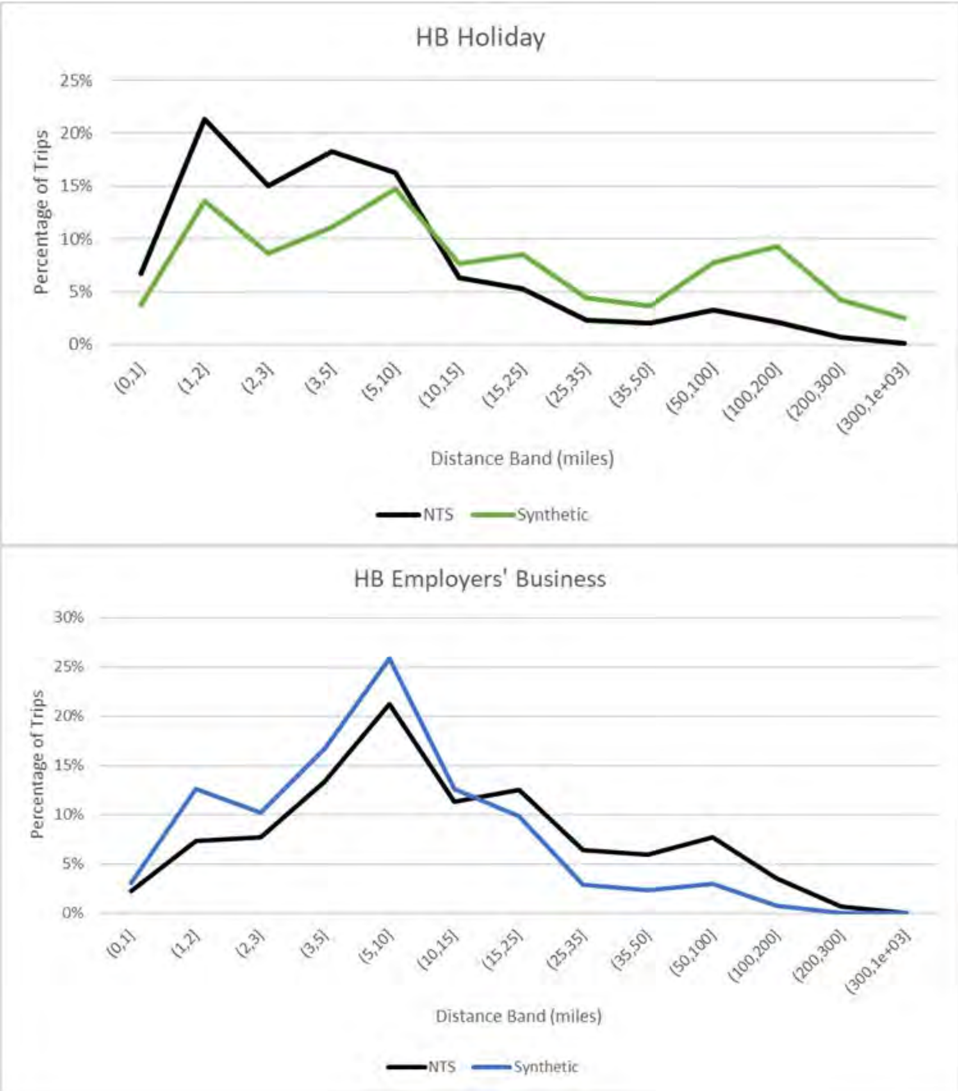


Figure 6.23: Model auditors - trip length distribution comparison for HB Holiday and HB Employers' Business (escort HB Employers' Business is included in the NTS values)

Figure 6.24: Model developers - trip length distribution comparison for HB Holiday and HB Employers' Business

6.2.2.2. Education Matrix Verification

The education census data were provided by the DfT in an aggregate form (in the 'PLASC_2011_v3_1 Arup AECOM.xlsx' spreadsheet). This contained number of trips by school type, NTMv5 home zone, and NTMv5 school zone.

The model auditors have followed the processing steps for the education census data as detailed in the 'NTM Dev Guide Vol2-BY Demand v2.0' document. These are:

- census data were subset into the NTMv5 modes (Car, Bus, Rail, Walk, and Cycle); and
- distribution pattern from the school census data were then applied to the education trip productions, from the 'tblAllDayPAs.csv' input file, providing an all mode education matrix.

The final steps involved a furnessing process to reconcile any discrepancies in education attractions, which the model auditors did not have access to, and defining final car matrix based on the mode share of the census data.

Using the distance skim extracted from the HAM *('CC AM Dist.mtx')*, an all-day education trip length distribution was produced based on the all mode matrix described above. This was compared with the reported NTMv5 education car matrix and NTS TLDs, extracted from figure 5.2 in the *'NTM Dev Guide Vol2-BY Demand v2.0'* document. **Figure 6.25** shows the comparison between the three education data sources.

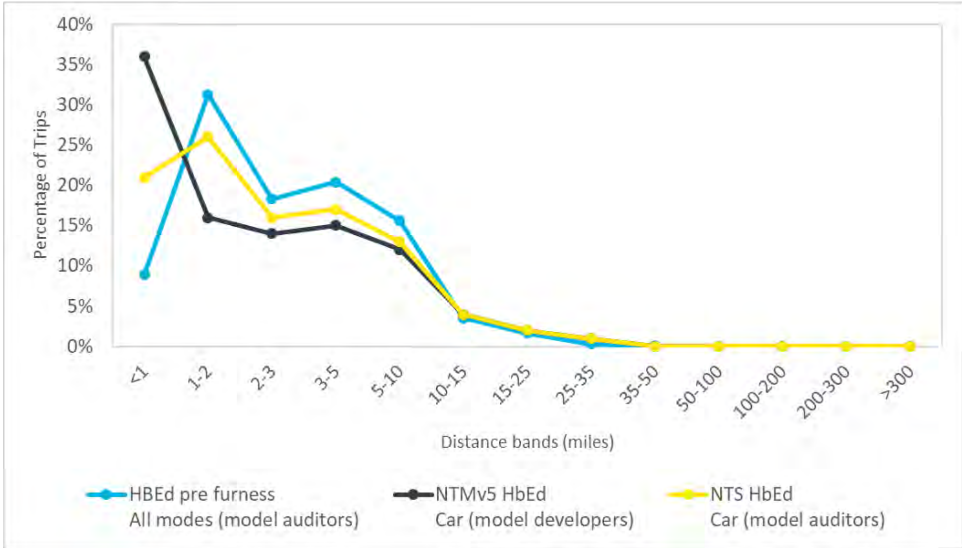


Figure 6.25: Education matrix TLD comparison

It can be seen that the furnessing process has a significant effect on the proportion of short distance trips, based on the two previously reported car TLDs. The all mode TLD reflects similar distribution of the NTS car TLD (excluding short trips). There will be differences due to the mode definitions and any issues in zone correspondences from the *'tblAllDayPAs.csv'* input file, as mentioned in section 6.2.1.1, but the process described produced sensible results in comparison to the available TLDs.

Other verifications of the education matrices would have been performed; however, the model auditors did not have access to the final education matrices or any other education-only matrices, hence these were excluded. These included:

- analysis of the trip distributions between the resulting education matrices and the underlying census data; and
- confirmation that the matrix totals were consistent with the input trip ends.

6.2.2.3. Commuting Matrix Verification

Similar to education matrices, commuting trips were also treated separately and were developed using JTW census data rather than the 'kalibri' process. The model auditors have access to the unprocessed JTW which is used to verify the main steps undertaken by the model developers. These steps were laid out in section 5.1 of the 'NTM Dev Guide Vol2-BY Demand v2.0' document. There are three main steps for treating internal zones from JTW data, and final two steps for treating the external zones of the commuting matrices. This section focusses on those related to the internal zones.

Table 6.7 shows a summary of JTW population data as reported in the *'NTM Dev Guide Vol2-BY Demand v2.0'* document, sourced from the full WU03UK dataset. **Table 6.8** shows the equivalent population summary independently sourced from the WU03EW (England & Wales) dataset used for the purpose of this audit for all the subsequent analysis. It can be seen that the number of England & Wales MSOAs and employed population is consistent between the two sources, and hence any discrepancies in the employed population totals were due to those residing in Scotland and working in Scotland or England & Wales.

Table 6.7: Total JTW population by home and work location, original

Area	Residence		Workplace	
	Employed population	**MSOAs**	**Employed population**	**MSOAs**
England & Wales	23,768,928	7,201	24,005,977	7,205
Scotland	2,222,323	na	1,985,274	na
Total	25,991,251	7,202	25,991,251	7,206

Table 6.8: Total JTW population by home and work location, new

Area	Residence		Workplace	
	Employed population	**MSOAs**	**Employed population**	**MSOAs**
England & Wales	23,768,928	7,201	23,743,129	7,205

The processes described in steps one to three of the commuting matrix development process by model developers were replicated based on the England & Wales JTW dataset.

The distribution patterns from JTW were calculated based on car driver and car passenger demand, and then applied to NTMv5 productions by zone. The average occupancy factor calculated based on the dataset available was 1.09. The developer guide does not provide the exact occupancies applied.

The NTMv5 prior matrices provided by Atkins *('CC_AM/IP/PM_M10j.mtx')* were converted to from home using the from home factors by distance band in the *'RHO Factors.*xlsm' spreadsheet and combined to form a 12-hour (7 AM – 7 PM) matrix. The TLD of the resulting matrix was derived, again using the distance skim from the HAM.

Figure 6.26 shows the resulting TLD comparison between the 24-hour commuting car matrix derived independently for the audit, and the 12-hour commuting car matrix derived by the model developers. It can be seen that the TLDs between the two sources are very similar, with some differences expected due to the missing data from the JTW dataset, and the zone correspondence discrepancies described earlier. This is not a direct comparison as the NTMv5 priors underwent sector-based adjustments and matrix improvements, as laid out in Section 6 of the *'NTM Dev Guide Vol3-HAM v2.0.pdf'*, yet the resulting TLDs are similar. This shows the process described in the *'NTM Dev Guide Vol2-BY Demand v2.0'* document is robust and it is an accurate description of the prior commuting matrix development process.

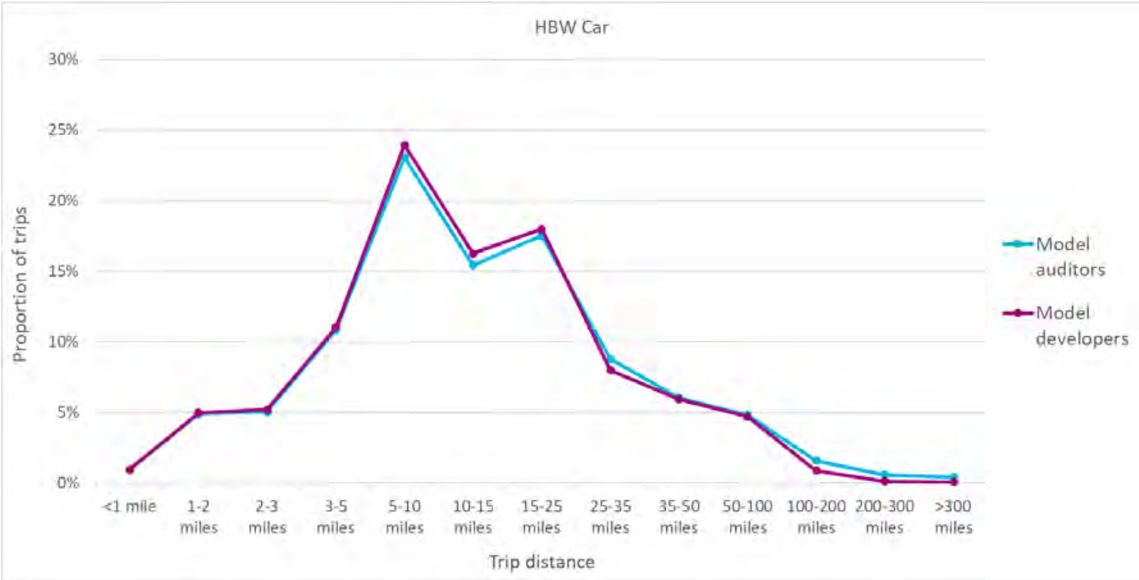


Figure 6.26: TLD comparison between the replicated car matrix and the original NTMv5 prior for commuting trips

The model auditors followed the steps of converting the 24-hour FH matrix to average hour OD using the from-home and to-home factors defined in Section 4.8.2 of the *'NTMv5 User Guide v4.0.pdf'*; full steps are outlined below.

- Distance bands were defined for each zone-zone movement in the 24-hour FH matrix, based on the bands defined in the '182 Distance Band Marker' matrix.
- AM, IP, PM, and OP FH matrices were derived from the 24-hour FH matrix based on the RHO FH factors by distance band[3], as defined in 'RHO Factors.xlsm' (procedure sequence 438-453).
- TH matrices by time period were calculated from the time period FH matrices using the PHI TH factors in the 'Activity Pairs.att' file (procedure sequence 455-460).
- Average hour OD were derived by combining the FH and TH matrices, then dividing by 3/6/3 for AM/IP/PM (procedure sequence 462-470).

Figure 6.27 shows the resulting AM zone-zone trip distribution for origins in the South East between the NTMv5 priors and what was subsequently derived by the model developers. Again, this is not a direct comparison as the NTMv5 priors underwent sector-based adjustments and matrix improvements, as laid out in Section 6 of the *'NTM Dev Guide Vol3-HAM v2.0.pdf'*, so details of the improvements would be required to assess if the matrices were reproducible at zone-zone level. The cream-coloured shading in **Figure 6.27** shows the region which was possibly affected by the adjustments which were not made by model auditors.

[3] Any zone-zone movement with a distance marker > 9 was given the time period specific RHO_{period}_BANDOTHER FH factor

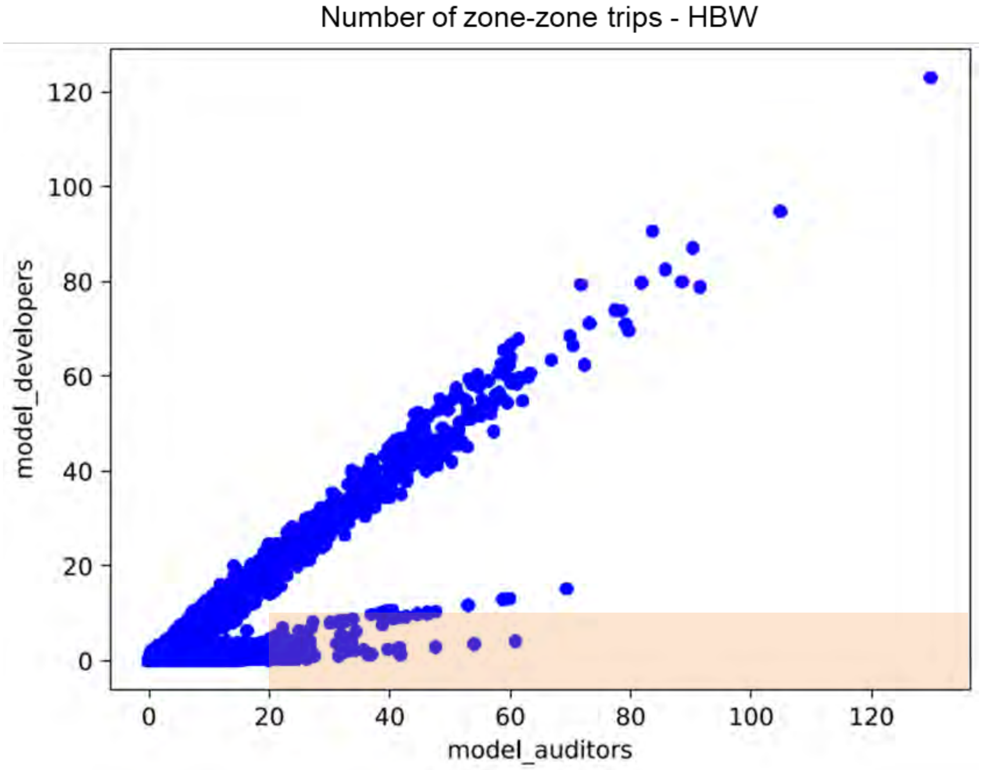
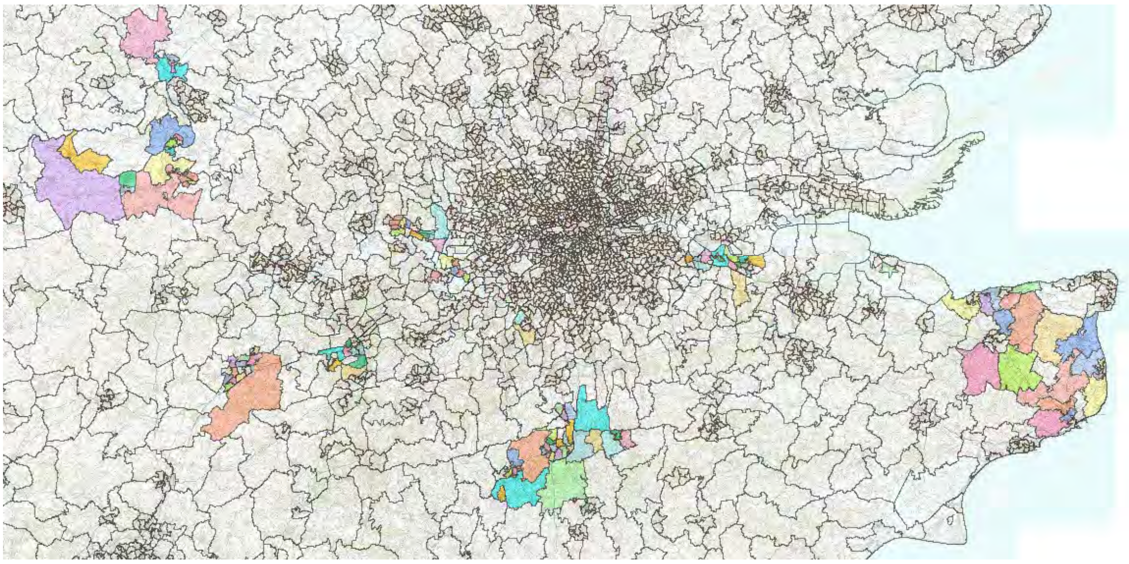


Figure 6.27: South East zone-zone trip distribution, model developers v model auditors

Figure 6.28 shows the NTMv5 origin zones from the shaded area of the plot above which are showing discrepancies at zone-zone level between the model developers and the model auditors' OD matrices. For simplicity, the zones shown highlight the areas where the model developers had fewer than 15 origin trips and the model auditors had greater than 20 origin trips in a zone pair, see the shaded region in **Figure 6.27**, indicating significant adjustments were made to these zone pairs under matrix improvements.



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.28: OD discrepancies between model developers and auditors

It can be seen the zones contributing to the differences are in fairly isolated pockets of the South East (particularly Kent) so the discrepancies could be the result of the sector-based adjustments outlined in Section 6.3.5 of the developer guide. The totality of sector adjustments is not laid out in the list provided in the developer guide, hence it is not certain these are the reason for the differences.

A number of queries were raised during the processing into average hour OD matrices as discussed below.

- The PHI factors were calculated as a proportion of the time period FH matrix, as opposed to 1 – FH, which suggested the original 24-hour PA matrix was also only FH. This was not clear or defined in the documentation.
- The PHI TH factors were defined and non-zero for all combinations of time periods (e.g. PM_AM, PM_IP, PM_PM, PM_OP) yet it is not clear what PM_IP, for example, represents. It was inferred that this represented trips with an outbound leg in the PM and a return leg in the IP, which does not make sense.
- In order to calculate 12-hour productions for the TLD above, the OD priors were converted to FH using the inverse of the TH function defined above. This resulted in, for each time period, FH = OD / (AM_phi + IP_phi + PM_phi + OP_phi + 1). It was not clear if this was the same method used to convert the matrices to PA in the VDM, so matrices of OD to PA factors could have been provided.

6.2.2.4. Freight Trips

The audit of the freight matrix development process was limited to reviewing the technical document “HGV & Van Origin-Destination Matrix Documentation” produced by MDS Transmodal (September 2019).

In general, the process used is considered to be transparent, robust, and designed to make the best use of available data. Nevertheless, it is important to note that general lack of data on freight demand does affect the quality of the final freight matrices.

For HGVs, the process heavily relies on the CSRGT data at aggregate level, used as constraints, with gravity models applied to estimate distribution by commodities at NTM v5 model zone level, based on zonal employee and land use data and estimates of tonnes generated and consumed by commodity per average employee. A single gravity model is used for each of the defined 6 stages of the logistics chain.

For LGVs, it is noted that even less reliable data is available. The process applied primarily relies on relatively old DfT van surveys. This has been used to generate control totals at aggregate level. Similarly, gravity models are used to generate synthetic van trip matrices at NTM v5 zone level.

Whilst the approach used is considered robust and suitable, the audit process has not verified the correct implementation of the methodology as the processes were not made available for review. Nevertheless, reflecting the quality of the source data used, the representation of freight demand in the model should be considered less reliable that cars and any use cases that relate to freight should be based on spatially aggregate forecasts.

6.2.2.5. Airport Trips

Both an Access and an Excel file of CAA data were provided as the base inputs for the audit of airport demand generation process. An R process and the output excel files were also provided. In order to audit the output of the R process, the prior matrices from Run202 were used, particularly: the nine matrices named ‘XX_YY_M10j.mtx’ where XX is the purpose and YY is the time period.

As a first step, the R process was run in order to ensure in runs without errors and to produce the airport leisure and business matrices by time period. A few issues were identified and were adjusted in order to produce the outputs as explained below:

- The R process loads a few R packages, one of which is called “RODBC”. This package only works for R version > 4.0.0, and so the process will crash if that was not the case.
- The process connects to the Access data base. In order for this to run successfully, Access and R bit versions must be compatible. If Access installation is 32-bit on the machine then R needs to be 32-bit as well.
- RStudio versions >1.2 does not support 32-bit R anymore, and as such for this process to run successfully, R.exe needs to be used directly rather than RStudio.

Once the version issues are resolved the R process will run successfully and produce the right output. There is only one coding problem that needs to be adjusted for:

- Any line in the code which has `data.frame(rbindlist(list(add_lines,dummy_df)))` will give an error and the run will crash. All these lines need to be adjusted to ` data.frame(rbindlist(list(add_lines,dummy_df)), use.names= FALSE)`

However, this issue is only related to the heading/title of the final data sets and so even if it is not corrected for, the process and the final numbers will be generated.

The process has a set of pre-defined parameters that the user can change if needed. The ‘NTM Dev Guide Vol2-BY Demand v2.0’ highlights some of these parameters and these are consistent with what is in the process. These parameters are:

- number of hours across which daily demand is split: this is 17 hours with business trips split into 60%, 20%, 20% in the morning, evening, and in-between. These are reported and are consistent with the process assumptions;
- assumed ratio of business trips that take place on weekdays which is 90% and is consistent with what is reported;

- Heathrow demand factor split across the three terminals which is consistent with the reported values of 45%, 13%, and 42% for T1-3, T4, and T5, respectively; and
- number of hours of the morning demand which lies in each time period and the in-between demand and is consistent with what is reported.

There are a number of parameters which do not appear to be reported in the CAA section 5.6.2 of the ‘NTM Dev Guide Vol2-BY Demand v2.0’. these are:

- number by which monthly data is divided to get a 'normal' weekday demand: 31 days but not reported in the guide;
- number of weekdays in March: assumed to be 22 days but not reported in the guide;
- percentage of demand for March 2015 figures were not reported but only referred to; and
- percentage of ‘no mode’ demand which was assigned to either car or taxis was mentioned in the report but not tabulated.

The final data sets are business, leisure, and total person trips at OD and PA level as well as summaries of person trips from/to each airport zone. The ‘NTM Dev Guide Vol2-BY Demand v2.0’ points out that occupancy i.e. the conversion to assignment level was not applied in the R process, but it provides the occupancy factors applied for each of the business, leisure, and total trips.

In order to audit the final summaries produced by the model developers, the auditors used the prior matrices provided for each of the time periods, and each of commuting, business, and other purposes and compared with the summary produced by the R process. An additional processing of the summaries was to apply the occupancy factors in order to match the unit of trips in the prior matrices.

The results for origin trips and destination trips are shown in **Figure 6.29** and **Figure 6.30**, respectively. It can be seen that the trends are generally reproduced with higher values for the model auditors. The main potential reason for these differences is the additional trips from/to the airport zones which do not represent airport passenger trips, noting that the three assignment prior matrices business, commuting, and other were used in this analysis.

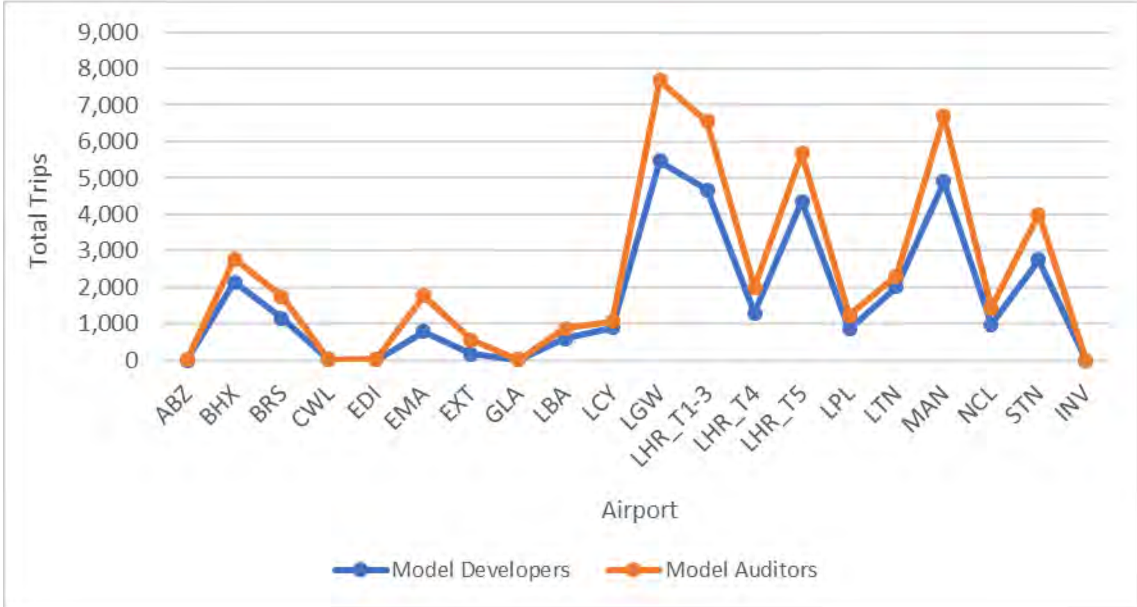


Figure 6.29: Comparison of airport origin vehicle trips at assignment level obtained by model developers vs model auditors

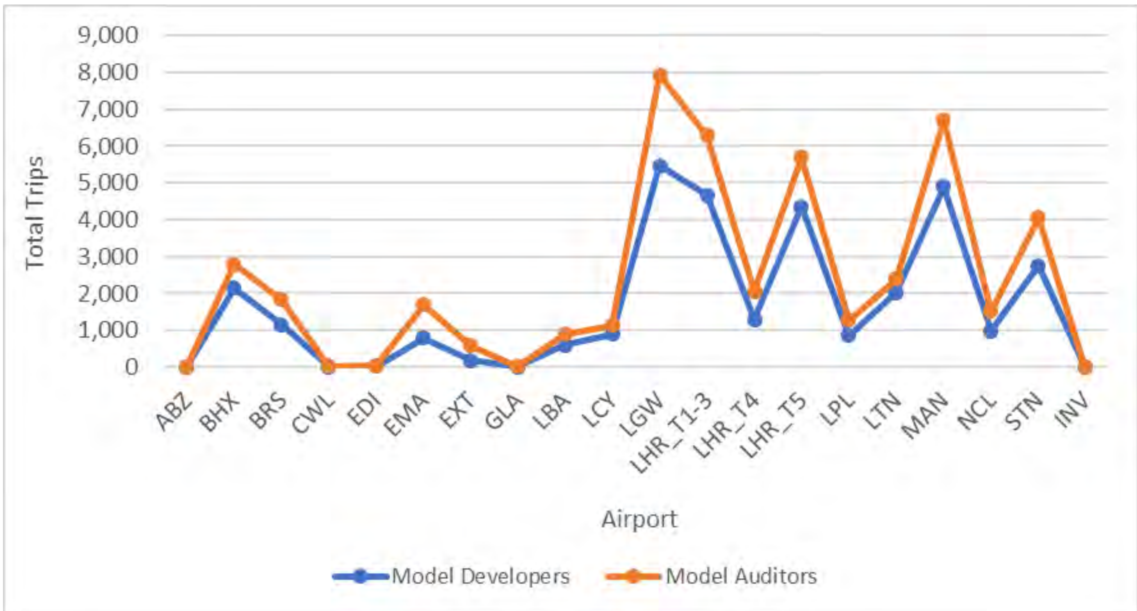


Figure 6.30: comparison of airport destination vehicle trips at assignment level obtained by model developers vs model auditors

6.2.2.6. Port Trips

The port surface access demand of the base year matrices is covered in section 5.7 of the Volume 2 Developer Guide. As part of the handover package, the VISUM version file has been received with the implementation of the matrix development for the ports demand.

Table 5.2 of section 5.7 in Volume 2 Developer Guide presents the annual cars trips to/from ports for year 2015. The table presents data for the 17 ports relevant to the study. However, when these ports were assigned to NTMv5 zones, it was noticed that two zones have combined two ports together. These were Fishguard and Milford Haven for zone 6838 and Cairnryan and Loch Ryan for zone 6863.

- It is recommended that the model documentation clarifies the reasons of combining these ports together in single zones.

Investigating the version file, it is concluded that the approach for the ports demand has been correctly implemented in VISUM and the right parameters were introduced to develop the matrices.

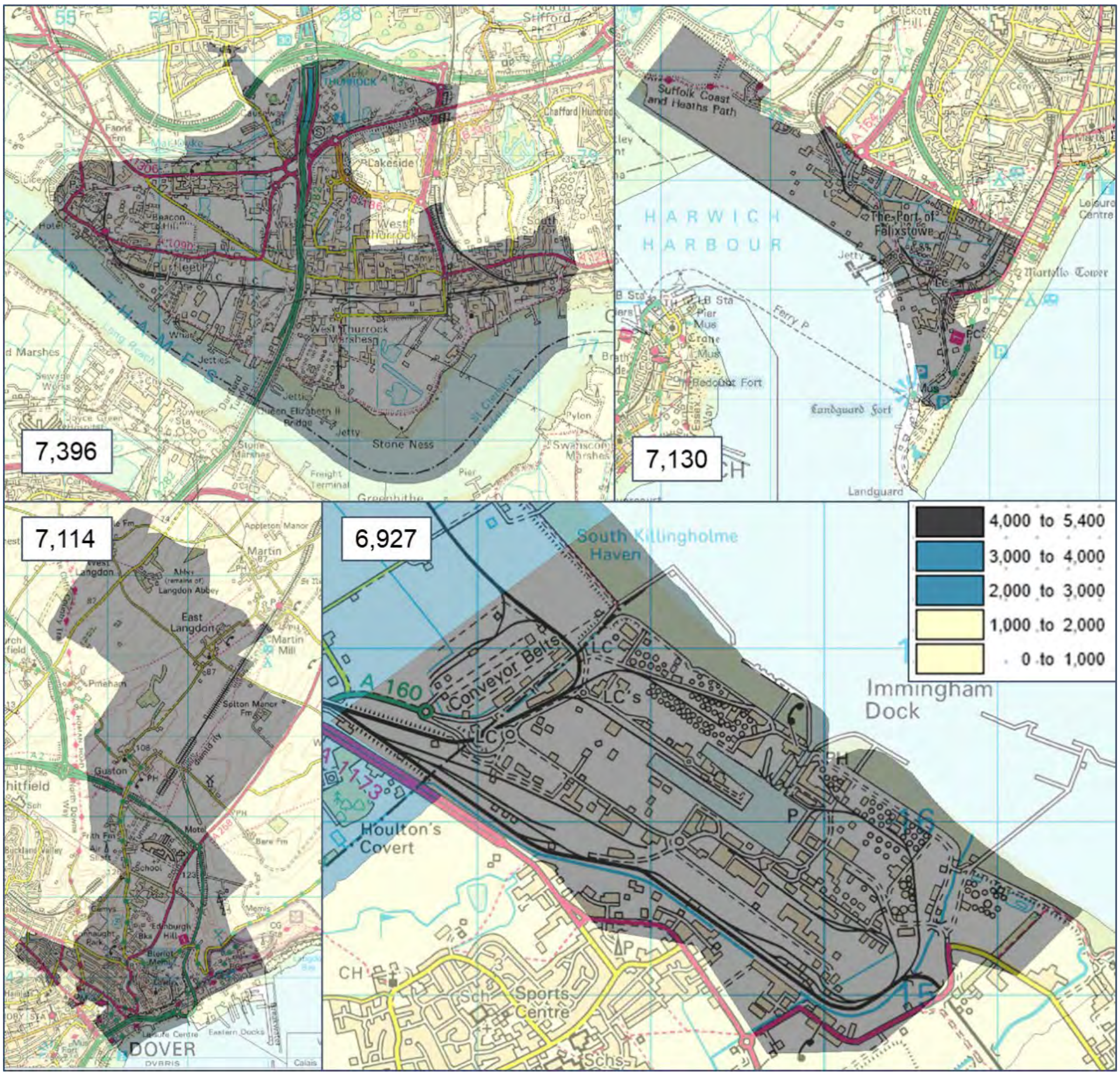
However, it is suggested to add more information in section 5.7 of the Volume 6 Developer Guide regarding the trip distribution approach followed to create surface access matrices for trips to and from the ports. In particular, it is mentioned in this report that a number of tests have been performed to balance the distance and population factors of the distribution model. The reference, though, of the outcome from these sensitivity tests is found to be very limited and not enough evidence has been presented in this section regarding the selection of the specific parameters for the distribution model.

Also, it is important to highlight that there are concerns over the time period factors being used to convert the annual port access matrix to average weekday peak hour matrices. As explained in the report, the factors were based on the ferry timetable data from the ports with the most trips, and specifically from the Dover and Holyhead ports.

This assumption should be based on more evidence from the other ports and not just from the fact that Dover and Holyhead are the busiest ports. In case of having significantly different time period factors by port, then the application of flat factors across the demand of all the ports might result in inaccurate and misleading average weekday peak hour matrices.

Figure 6.31 shows the four zones with the highest number of 12-hour HGV origin trips from the NTMv5 prior matrices. The zones are:

- Zone 7,396 – Purfleet Docks (4,982 origin trips);
- Zone 7,130 – Port of Felixstowe (4,661 origin trips);
- Zone 6,927 – Immingham Dock (4,077 origin trips); and
- Zone 7,114 – Port of Dover (5,398 origin trips).



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.31: Maximum HGV origin trip zones, HGV prior matrices

Figure 6.32 shows the number of HGV origin trips for Dover, and the neighbouring zones, from the NTMv5 priors provided by the model developers.

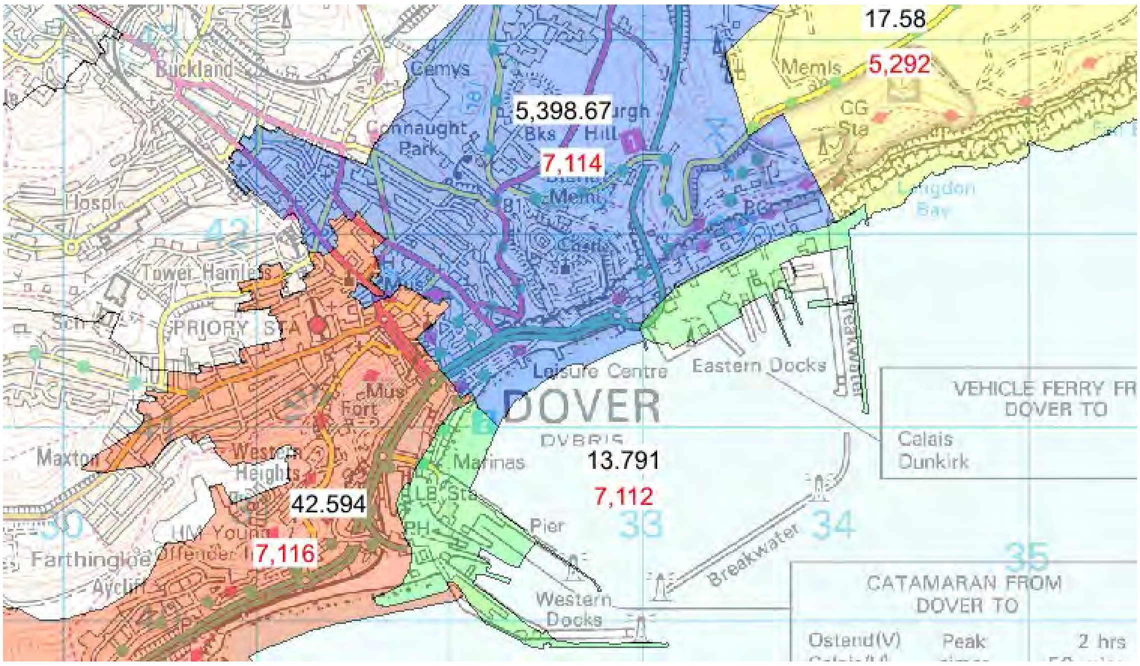
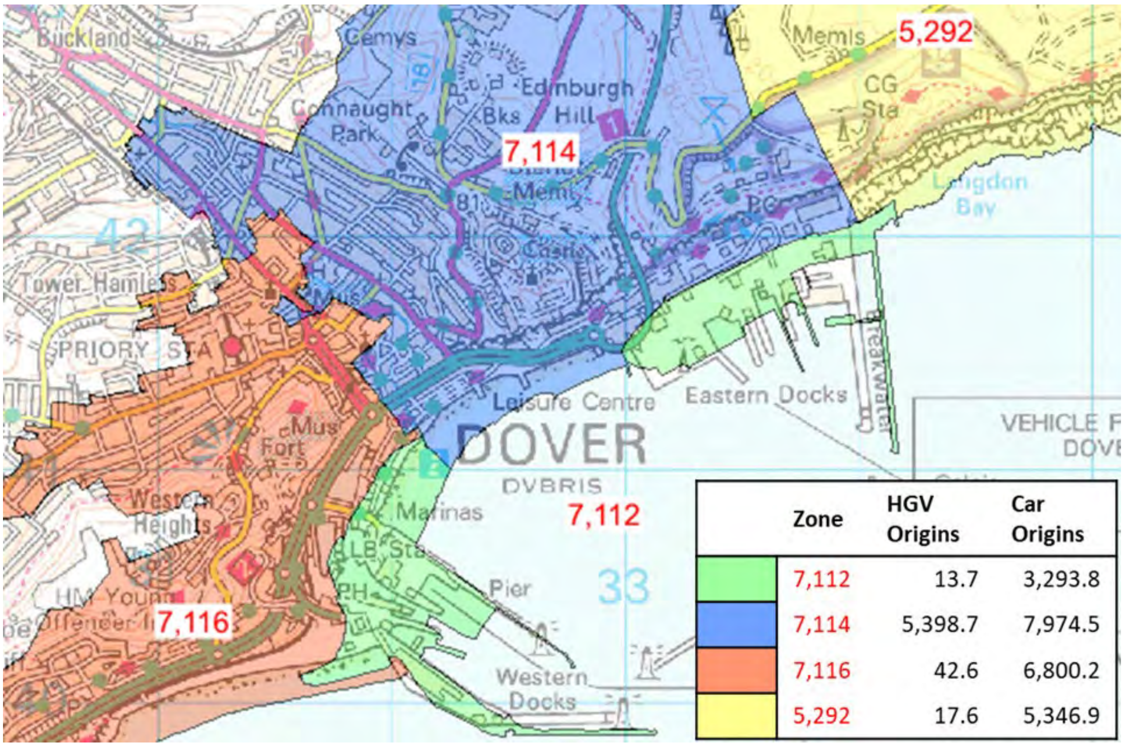


Figure 6.32: HGV origin trips, Dover port and neighbouring zones

It is not clear which zone loads the port trips onto the network, however the zoning definitions in *'NTMZonesSystem Spreadsheet v7.0.*xlsx' and the zoning GIS layer *'NTM_Polygons_v6.5'* defines zone 7,112 as "Dover Port" and 7,114 as "Dover 012", in which case it is likely there is an error in the Dover Port zone allocation.

Figure 6.33 shows the comparison of 12-hour car and HGV origins for the four Dover zones above. Interestingly the disparity between zones 7,112 and 7,114 is not seen in the car matrices, with ~3000 car origins coming from the port zone, and hence may only be a misallocation in the freight matrices.



Zone	HGV Origins	Car Origins
7,112	13.7	3,293.8
7,114	5,398.7	7,974.5
7,116	42.6	6,800.2
5,292	17.6	5,346.9

Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.33: Dover zones, HGV vs Car origins

6.2.3. Matrix Improvements

The model audit only had access to the final prior matrices, which were expected to include the matrix adjustments undertaken as set out in Section 6, Volume 3 of the NTMv5 Developer Guide. Therefore, the reviews undertaken thus far have been done with these adjustments in place and show the consistency of the resulting prior matrices with the source data.

Generally, more details/analysis can be added to Section 6 to improve the quality of reporting and for a better understanding by the reader. For instance, Section 6.3.3 of the developer guide states the occupancies for HBW, HB Employers' Business, and NHB Employers' Business were adjusted based on screenline performance. It also states that these were compared with different sources. A table of the resulting occupancies and their comparison by purpose could be provided to add confidence to the statements being made.

- It is recommended that detailed information is added to Section 6, Volume 3 of the NTMv5 Developer Guide on the source of data and graphs being produced to ensure transparency.

The model auditors verified the consistency of a selection of the adjustment factors described in Section 6.3 of the above developer guide.

Figure 6.34 shows the comparison of LGV proportion by distance between the model developers' report in the *'NTM Dev Guide Vol3-HAM v2.0.pdf'* and what was derived from NTS by the model auditors. The reported graph shows "van driver proportion", however it was not clear which NTS modes made up "van driver" and whether the resulting proportion was calculated from (van driver) / (car driver) or (van driver) / (car driver + passenger), for example. The model auditors' graph was calculated from (van driver) / (car driver + passenger) and shows a similar description of van driver proportion by distance.

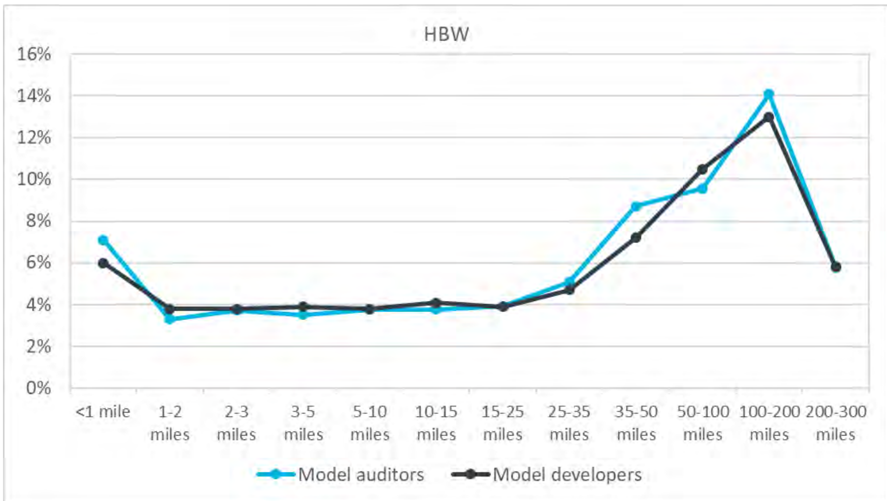


Figure 6.34: NTS LGV proportion by distance

In an attempt to verify the scaling factors used in Section 6.3.2 of the above developer guide, we assessed the trip length distributions of the HB Holiday synthetic matrix from the Kalibri process and NTS. **Table 6.9** shows a comparison of the two sets of scaling factors, with the auditors' factors being calculated as (NTS trip proportion / Synthetic trip proportion) for each distance band. Synthetic holiday trips were consistently high above 100 miles from both derivations, due to the allocation from the Kalibri process, however the model developers applied a reduction to trips between 25-100 miles which was not reflected in the NTS TLD that we independently derived. It was not defined which NTS modes or definitions were used to calculate these factors by the model developers, hence NTS car driver was used. The general trend of these two sources of factors is largely consistent, with significant reduction for trips over ~100km, so the differences seen are not thought to be a significant issue.

Table 6.9: HB Holiday scaling factors comparison

Distance band	Model developers' scaling factor	Model auditors' scaling factor
<1 mile	1	1
1-2 miles	1	1
2-3 miles	1	1
3-5 miles	1	1
5-10 miles	1	1
10-15 miles	1	1
15-25 miles	1	1
25-30 miles	0.8	1
35-50 miles	0.75	1.2
50-100 miles	0.6	1
100-200 miles	0.6	0.5
200-300 miles	0.6	0.3
>=300 miles	0.6	0.2

6.2.3.1. Matrix Estimation

Access to the final prior matrices enabled to assess the impacts of matrix estimation undertaken during the development of NTMv5. Detailed matrix estimation impacts are summarised in NTMv5 Quality Report v4.0, Appendix D. As part of the audit, a sample of checks were undertaken to replicate analysis from the appendix. Car/Light Vehicle matrices for the PM period were chosen for this assessment based on the matrix total size.

The first step was to verify that the matrix totals match between the actual matrices received and values reported in the documentation. It was confirmed that matrix totals matched those in Table D.1 in the Quality Report and it assumed that these matrices are appropriate for checking the impact of matrix estimation.

Matrix sparsity was evaluated using the Pre-ME and Post-ME matrices. **Table 6.10** below summarises matrix evaluation undertaken using histograms within Visum. Although the same segment thresholds were used as documented in the report (the lower limit is not included in the interval) there are noticeable differences when comparing the percentage distribution across the segmentation intervals. However, the shape and scale of change is comparable with the reported values. The analysis results could not be replicated and therefore the calculation to evaluate changes in sparsity of the matrices should be reviewed and changes to the process/documentation implemented where required.

- It is recommended that the calculation for assessing changes to Matrix Sparsity are reviewed and changes are made to the calculations and/or documentation where required.

Table 6.10: Impact of Matrix Estimation (Matrix Sparsity)

O-D Trips Lights		Share of O-D cells			% Volume of trips		
From	To	Prior Lights	Post Lights	Change	Prior Lights	Post Lights	Change
0	0	3%	3%	0.0%	0%	0%	0.0%
0	0.00001	1%	1%	0.4%	0%	0%	0.0%
0.00001	0.0001	13%	17%	3.8%	0%	0%	0.0%
0.0001	0.001	42%	41%	-1.1%	0%	0%	0.0%
0.001	0.01	28%	26%	-2.6%	1%	1%	-0.1%
0.01	0.1	9%	8%	-0.4%	3%	3%	-0.1%
0.1	1	3%	3%	-0.1%	10%	10%	-0.2%
1	3	1%	1%	0.0%	10%	10%	0.0%
3	5	0%	0%	0.0%	6%	6%	0.0%
5	10	0%	0%	0.0%	10%	10%	0.0%
10	MAX	0%	0%	0.0%	59%	59%	0.3%

Matrix zonal trip ends were also checked. **Figure 6.35** and **Figure 6.36** show the correlation between Pre-ME and Post-ME for the origin and destination zone totals respectively. The slope, intercept and R2 values calculated match exactly with those in Table D.9 of the Quality Report. The analysis results are deemed to be replicated and therefore the calculation process was assumed to be appropriate.

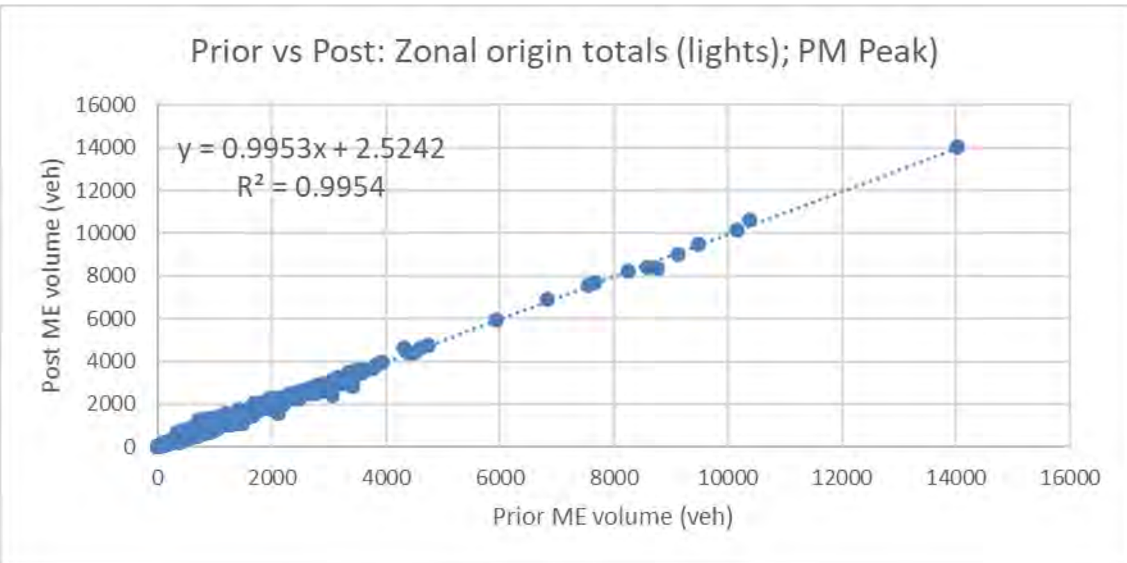


Figure 6.35: Impact of Matrix Estimation (Zonal Origin Totals)

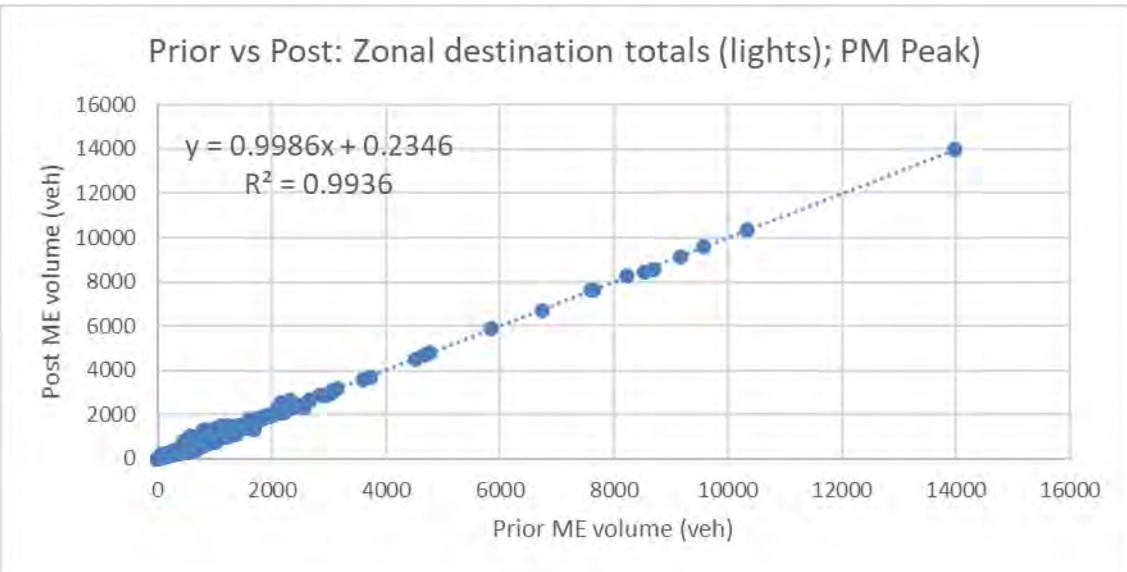


Figure 6.36: Impact of Matrix Estimation (Zonal Destination Totals)

Impact of ME on trip length distribution was evaluated and compared against values in Section D3 of the appendix It appears that figure references in some section of the appendix are incorrect and should be updated. The documentation does not state what assumptions were made in relation to distances used to classify each OD pair. For purposes of this assessment, final base distance matrix for Car Commute in the PM period was used. **Figure 6.37** visualises the changes in trip length distribution which compares well with the figure presented in section D3 of the appendix. The analysis results are deemed to be replicated and therefore the calculation process was assumed to be appropriate.

- It is recommended that the figure references in Appendix D of the Quality Report are updated.

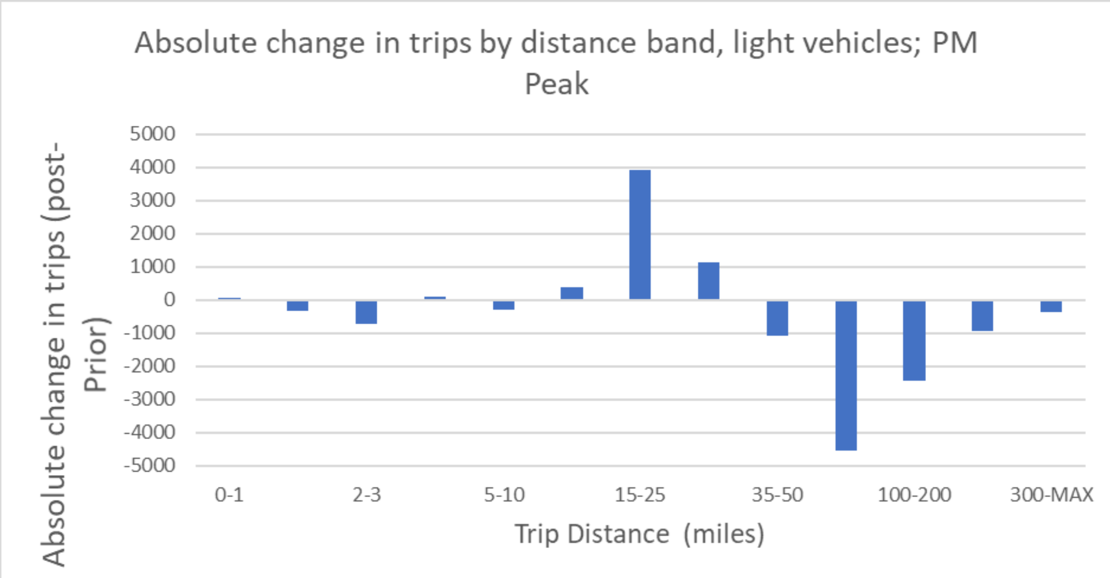


Figure 6.37: Impact of Matrix Estimation (Trip Length Distribution)

Lastly, changes related to the sector origin totals were evaluated. Map of the sector system used for this assessment is presented in in **Figure 14.4** of the Quality Report. It is not instantly clear which sector system was used (as implemented in the model), however considering the map in the report and number of sectors it was assumed that the "Screenlines" sector system was used which is implemented in the model using zone use-defined attributes. Although the segmentation of changes based on low/significant flows (as presented in Figure D6 of the appendix) was not replicated, the quantified changes and the shape of the chart compares well with Figure D6 and are shown on **Figure 6.38**. The analysis results are deemed to be replicated and therefore the calculation process was assumed to be appropriate.

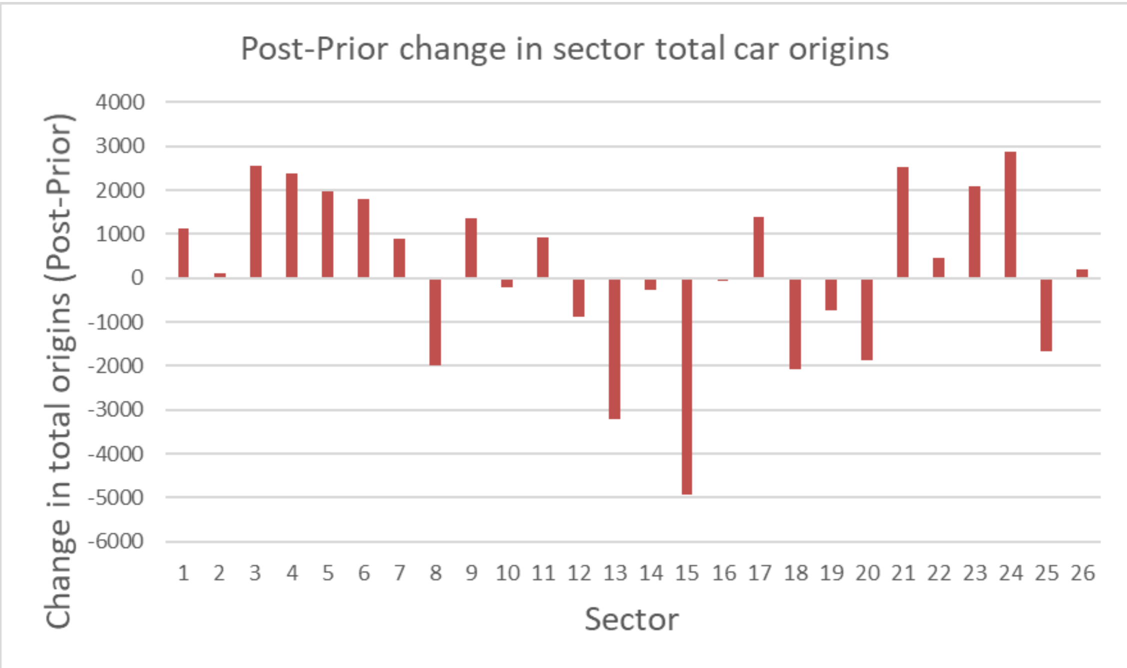


Figure 6.38: Impact of Matrix Estimation (Sector Car Origins)

6.3. Data for Calibration and Validation

Access to the source and processed traffic count and journey time data was provided and was audited accordingly. The audit process included:

- verifying the consistency of the screenline count data with counts processed by the RTM teams as provided;
- checking the processing of counts to form screenlines;
- reviewing the process to extract VISUM links corresponding to the journey time routes; and
- checking consistency with source Trafficmaster journey time data and verifying the process used to extract these for selected routes.

6.3.1. Counts and Screenline processing

Section 4 of ‘NTM Dev Guide Vol3-HAM v2.0’ focusses on the data for calibration and validation. Particularly, section 4.2 describes the traffic counts and the final counts and screenlines for NTMv5. Atkins/DfT provided the following for the model audit:

- shapefiles of the locations of counts for each of the five Regional Traffic Models (RTMs), with file names defined in **Table 6.11**;
- calibration and validation dashboard spreadsheet representing the aggregation of the counts to screenlines for each of the five RTMs, with file names defined in **Table 6.11**;
- a map for the NTMv5 screenlines (‘SL_and_MiniSL_screenline.shp’); and
- the calibration and validation spreadsheet representing NTMv5 screenlines (‘NTM_H-SLine_v2.0_Run203xlsm’).

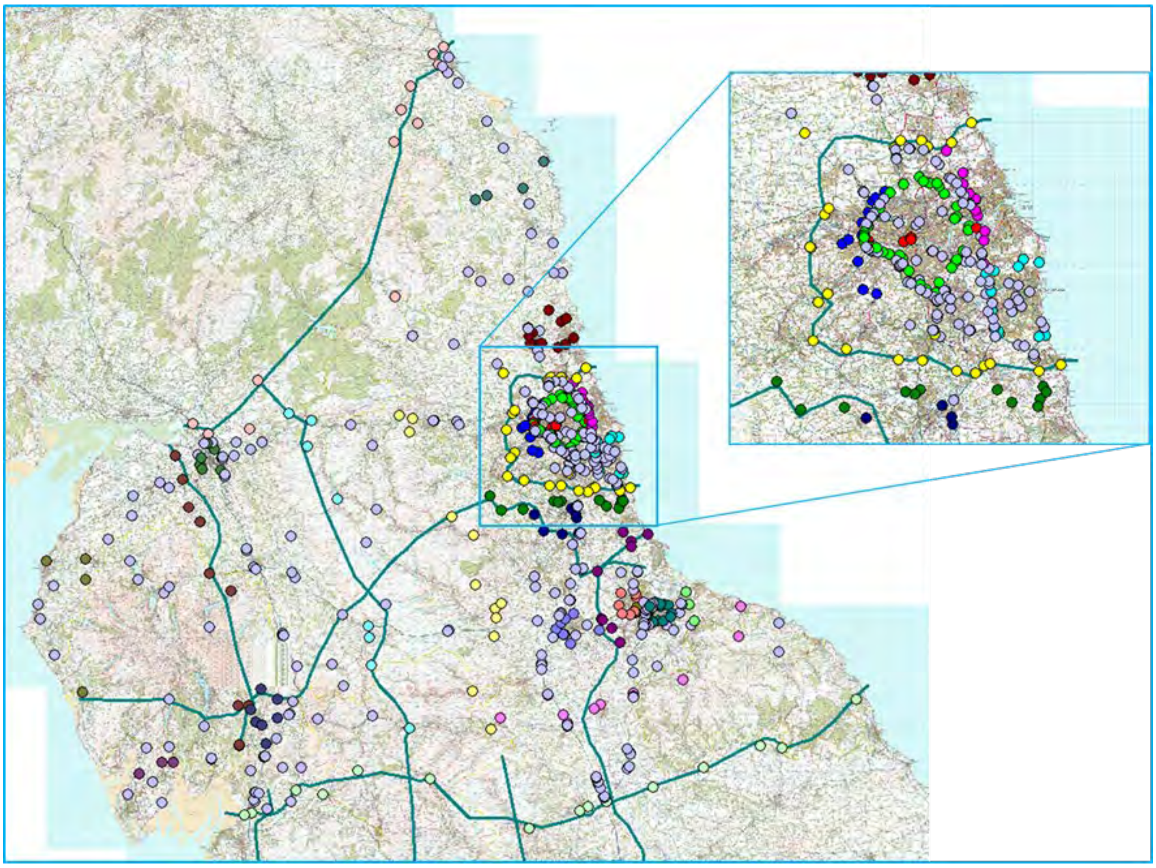
Table 6.11: RTM count location and calval spreadsheets file names

RTM	Data	File name
South West	Count locations	SW_b15_GIS_Counts_20160826.shp
South East	Count locations	CalibrationCounts_DF1_point.shp ValidationCounts_DF1_point.shp
Midlands	Count locations	MD_DF1_b15_net_v077a_MCCs.shp MD_DF1_b15_net_v077a_ATCs.shp
Trans-Pennine South	Count locations	TS_2015_TS1_net_P2_v033_Counts.shp
North	Count locations	NO_DF1_b15_GIS_Counts_v001.shp
South West	Calval dashboards	SWRTM_Dashboard_V4.15_RUN081_Post.xlsm
South East	Calval dashboards	RTM_Dashboard_Template_V4-1 DF3_Run 90-PostME (SERTM).xlsm
Midlands	Calval dashboards	MD_b15_CalValDashboard_Ass_v085.xlsm
Trans-Pennine South	Calval dashboards	RTM_Dashboard_Template_V4-1_TPS_v1.6_Assign26_Post.xlsm
North	Calval dashboards	NO_Dashboard_V4.11_Run027_Post.xlsm

In this section, the consistency of screenline counts provided in the RTMs calibration and validation spreadsheet is checked against the mapping of the counts on NTMv5 screenlines in GIS. The following steps were followed to audit the count locations and screenlines of NTMv5:

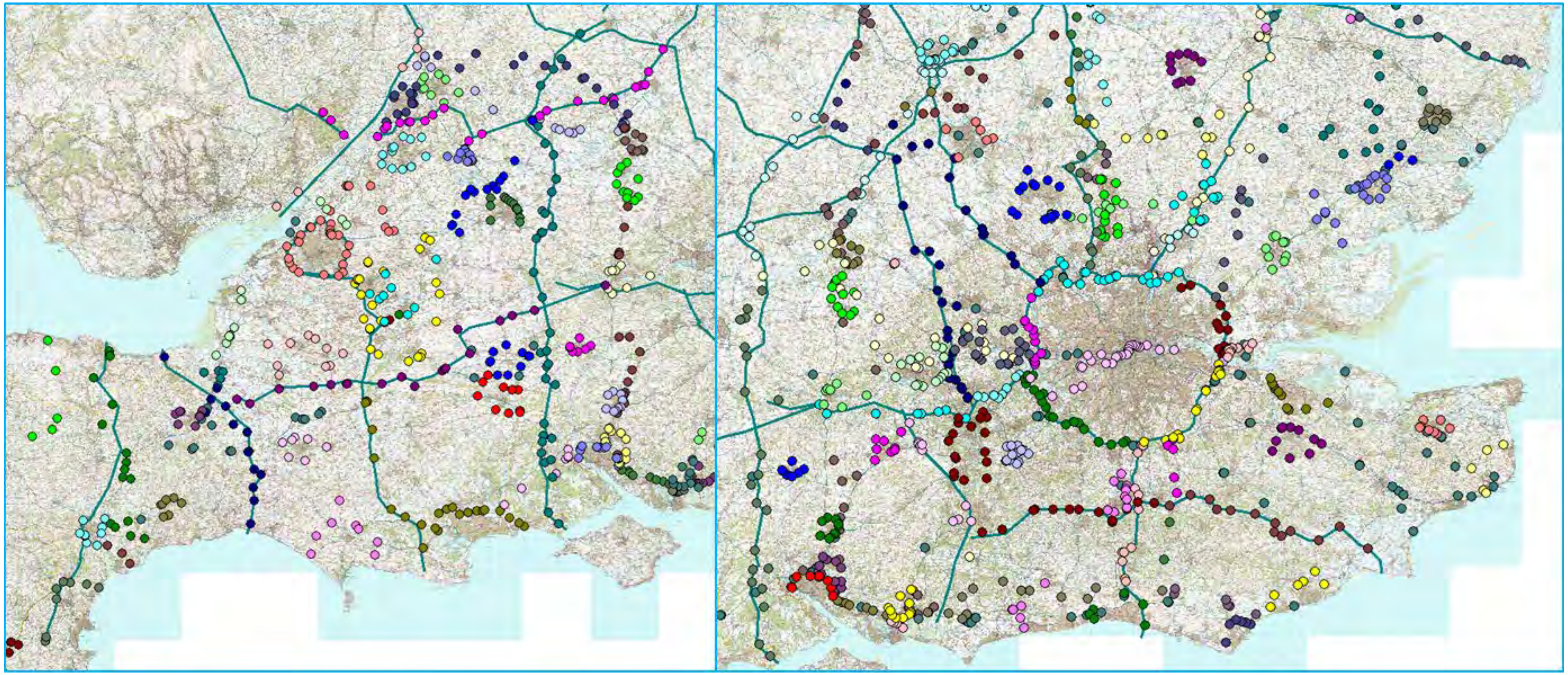
- all the RTM counts were overlayed on the NTMv5 screenline layer;
- 20 out of 32 screenlines of NTMv5 were selected randomly and overlaying RTM counts were extracted;
- counts from the calval spreadsheet of the corresponding RTM were extracted;
- counts from the two sources (RTM GIS layer and RTM dashboard) were compared and summarised to check for consistency between the two; and
- counts from the calval sheet of NTMv5 overlaying each selected screenline was extracted and compared with the corresponding RTM's counts.

Figure 6.39 through to **Figure 6.41** show the count locations of the five RTMs overlayed the NTMv5 screenlines. As expected, every screenline is represented by a number of counts allocated to it (points on the maps), with additional counts available across the entire internal area of each RTM which were not used as part of the NTMv5 screenlines.



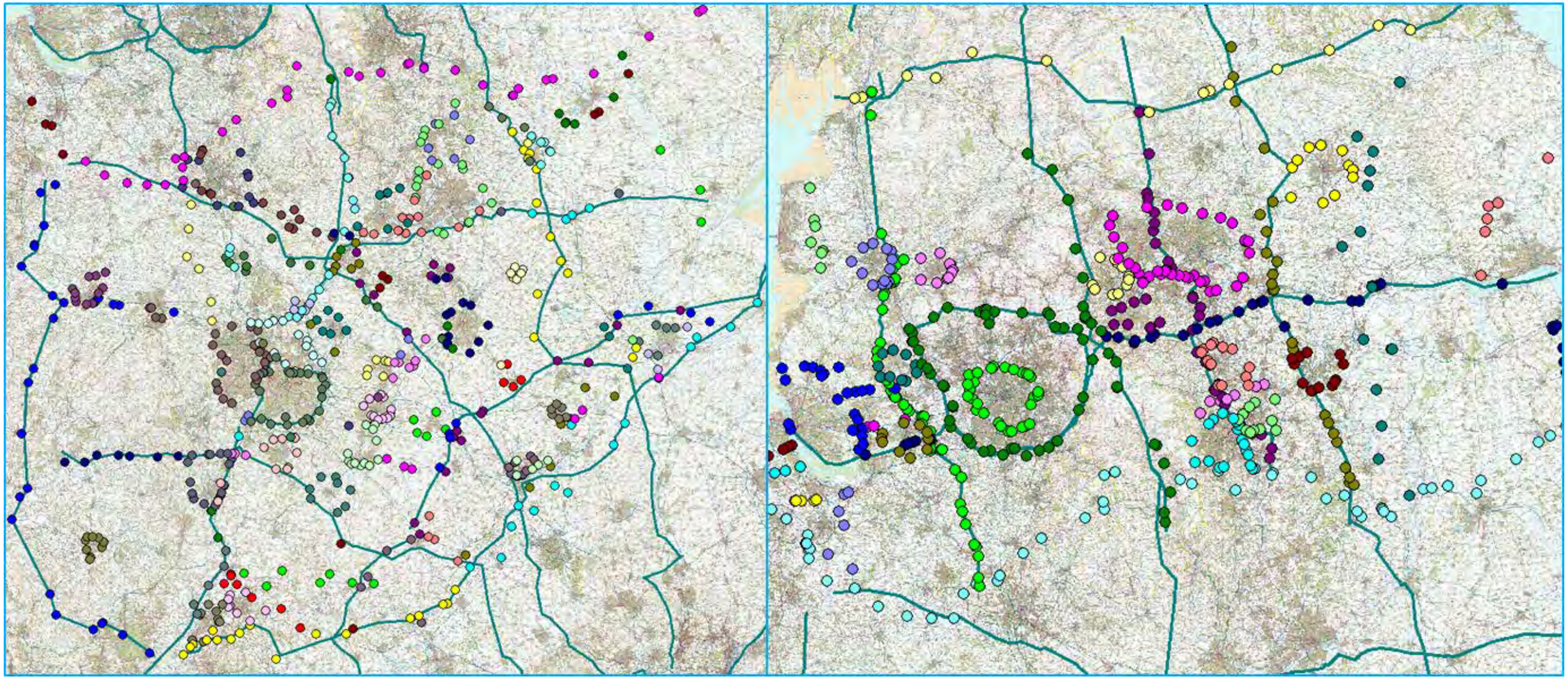
Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.39: North Regional Traffic Model's count locations



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.40: South West (L) and South East (R) Regional Traffic Models' count locations



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.41: Midlands (L) and Trans-Pennine South (R) Regional Traffic Models' count locations

Table 6.12 provides a summary of the review process for the 20 randomly selected screenlines. The summary provides the total number of counts for each screenline extracted from dashboards against those extracted from the GIS layers[4][5]. It can be seen that for 16 out of the 20 screenlines selected, the number of counts between the maps and CalVal dashboard are consistent (highlighted in green). There are 4 cases where the two sources are inconsistent, this is likely to be due to some locations being discounted prior to the CalVal stage but not being reflected in the maps, or that maps received are not the latest versions which have the final refinements.

Table 6.12: RTM screenline and counts consistency check

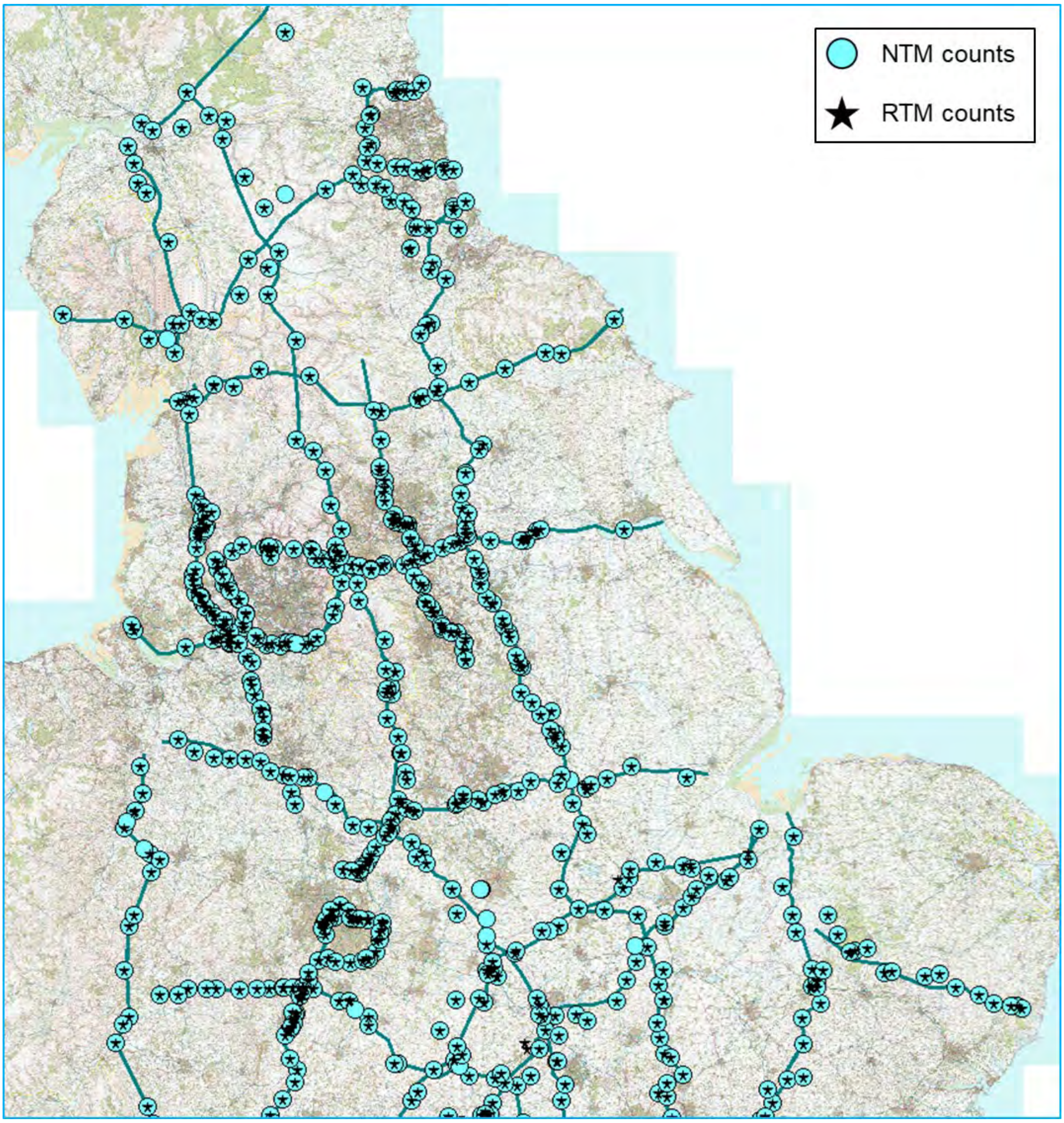
RTM	Screenline	RTM GIS Layers		RTM Dashboard	
		Count sites	Direction	Count sites	Direction
SWRTM	Bristol	26	IB/OB	23/23	IB/OB
SWRTM	Salisbury	13	IB/OB	11/11	IB/OB
SWRTM	Newquay	9/9	IB/OB	9/9	IB/OB
SWRTM	Barnstaple	6/6	IB/OB	6/6	IB/OB
NRTM	17. North East Western Boundary	12/12	EB/WB	12/12	EB/WB
NRTM	26. TPS Boundary	16/16	NB/SB	16/16	NB/SB
NRTM	05. Tyne and Wear Cordon	26/25	IB/OB	26/25	IB/OB
NRTM	25. Scottish Boundary	12/12	NB/SB	12/12	NB/SB
TPS	Sc_11	18/18	EB/WB	18/18	EB/WB
TPS	Sc_08	46/46	NB/SB	46/46	NB/SB
TPS	Sc_16	16/16	NB/SB	16/16	NB/SB
TPS	Co_07	41/41	IB/OB	41/41	IB/OB
MRTM	IS/11	16/16	EB/WB	16/16	EB/WB
MRTM	IS/22	26	EB/WB	23/23	EB/WB
MRTM	IC/303	28	IB/OB	36/36	IB/OB
MRTM	IC/10	12	IB/OB	12/12	IB/OB
SERTM	West Sussex-Surrey	24	NB/SB	12/12	NB/SB
SERTM	Bucks-Oxfordshire	38	EB/WB	19/19	EB/WB
SERTM	M25 Thames (Staines)-Godstone	40	IB/OB	20/20	IB/OB
SERTM	River Lea- River Ouse	48	EB/WB	24/24	EB/WB

Figure 6.42 and **Figure 6.43** show the count locations from the NTMv5 CalVal dashboard overlaid with the count locations from the five RTMs. A good location correspondence can be seen across the NTMv5 screenlines, with only minor discrepancies across the whole country, likely to be gaps identified in the data. This

[4] Where detail by direction was available in the GIS layers, counts have been defined by direction (e.g. 10 EB and 9 WB = 10/9, EB/WB)

[5] IB: Inbound, OB: Outbound, EB: Eastbound, WB: Westbound, NB: Northbound, SB: Southbound

suggests that the processed NTMv5 screenline counts are consistent with the source RTM count data.



Map contains Ordnance Survey data © Crown copyright and database right 2020

Figure 6.42: NTMv5 and RTM count locations (1)

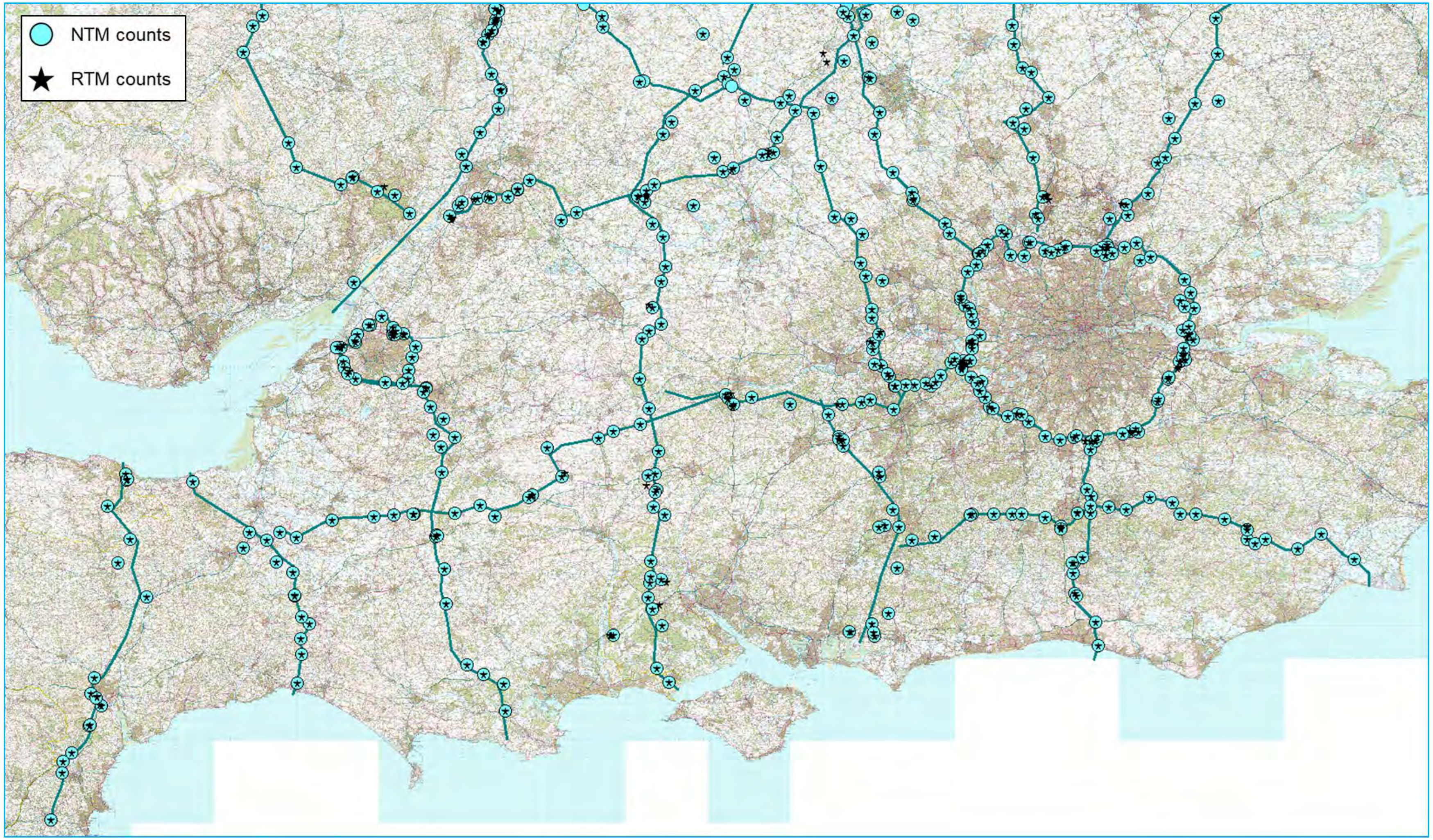


Figure 6.43: NTMv5 and RTM count locations (2)

6.3.2. Link Extraction

The journey time dashboard alongside NTMv5 network was provided and was used by the model auditors in order to verify the assigned links to each journey time route by the model developers. The files used were:

- NTM_H-JTVal_v2.0_NetV203.xlsm for the journey time routes; and
- NTMv5_Ver28.5.1_RunA244_Base Re-Issue.ver for NTMv5 network.

In total there exists 84 bidirectional routes covering a total of 13,307km. The model auditors have followed the below verification steps:

- selected four routes at random (~5% of the total number of routes);
- located the route on Google Maps using the origin and destination of each route;
- selected all the individual links of each identified route from Google Maps in VISUM using the Network Editor; and
- extracted all the individual links of each route and compared it with those set out in the journey time dashboard provided by the model developers.

The verified routes were:

- Route 31: Thrapston (A14) - Northampton (M1);
- Route 14: Eastbourne – Ashford;
- Route 43: Middlesbrough – Darlington; and
- Route 52: Grimsby - Hatfield (M18).

For each of selected routes, the links identified by the model auditors were the same as those identified by the developers. An example is shown below for route 52, showing the consistency of the results.

Table 6.13: journey time routes verification Route 52

Route link id	Audit		Model developers
	Start node	End node	Start_End node
52_EB_1	75354	72519	75354_72519
52_EB_2	72519	72606	72519_72606
52_EB_3	72606	72610	72606_72610
52_EB_4	72610	70407	72610_70407
52_EB_5	70407	72612	70407_72612
52_EB_6	72612	72620	72612_72620
52_EB_7	72620	70404	72620_70404
52_EB_8	70404	72658	70404_72658
52_EB_9	72658	72659	72658_72659
52_EB_10	72659	71238	72659_71238
52_EB_11	71238	70380	71238_70380
52_EB_12	70380	74159	70380_74159
52_EB_13	74159	74171	74159_74171
52_EB_14	74171	70321	74171_70321
52_EB_15	70321	74228	70321_74228
52_EB_16	74228	74230	74228_74230
52_EB_17	74230	74314	74230_74314
52_EB_18	74314	74321	74314_74321
52_EB_19	74321	74322	74321_74322
52_EB_20	74322	74291	74322_74291
52_EB_21	74291	75793	74291_75793

6.3.3. TrafficMaster Journey Time Data

In addition to the journey time spreadsheet audited, the model auditors were provided with the extraction process of the journey time data. Both were used in order to audit the journey time data in the spreadsheet, alongside what was reported in section 4.3 of 'NTM Dev Guide Vol3-HAM v2.0' on journey time data.

Teletrac Navman journey time data were processed using Python. For the purpose of this audit, the process provided by the developers was run in order to ensure that it runs without any errors. A number of issues were found and corrected for when running the script. These are listed below.

- The process requires an input file which is named wwMay_June2015_allClasses.csv, from the input received this file should be TM_May_June2015_allClasses.csv.
- There is a line of code which is deprecated in Anacanoda3 (64-bit) which is print '', the line should print('') instead. This error occurs only once in line 85.
- Three of the packages loaded in the python script are not required and one of which (cStringIO) is not available for installation in Anacanoda3 (64-bit). This was not an issue as it was not needed to run the code.
- There is a custom error class (raise duplicatedITN_error('ITN Toid link is not unique, please check')) which is not defined in the code provided. This was not an issue as the exception message was never raised.

In addition to the above, there is no cap imposed or analysis done on the sample size of the TrafficMaster data when averaging journey times over a month of data.

Links with zero observations are infilled with 'no_data'. The report suggests that these links alongside Trafficmaster links which were not snapped to the NTMv5 network links were infilled by average speeds across the corresponding journey time route. However, this infilling process is not part of the python script and is not provided or audited.

The python script produces four main output files of average journey times for each of the four time periods. These correspond for each AB nodes of the NTMv5 network in a journey time route. To audit these results, they were compared with those reported in the journey time dashboard.

Figure 6.44 shows a scatterplot comparison of the model developer journey times (i.e. from the dashboard) against the model auditors journey times (i.e. outputs of the provided python script) across all the AB nodes available (i.e. removing those which were infilled by the model developers). The results do not show a perfect match for three possible reasons listed below; however, we cannot independently verify this or rule out the possibility of errors in processing of journey time data.

- The input trafficmaster file to the python script is not the correct or final report (as a result of the different naming between the file the auditors received and that used in the python script provided, as noted earlier);
- The journey time dashboard is not the final dashboard representing the output of python script; and/or
- There exist intermediary steps alongside the infilling of 'no data' links or 'unsnapped' links involved in the processing of journey times which have not been documented in the 'NTM Dev Guide Vol3-HAM v2.0' document. If this is the case, then:

- ➢ It is recommended that a detailed reporting is provided of any intermediary steps undertaken to reproduce the results of those implemented in the journey time dashboard.

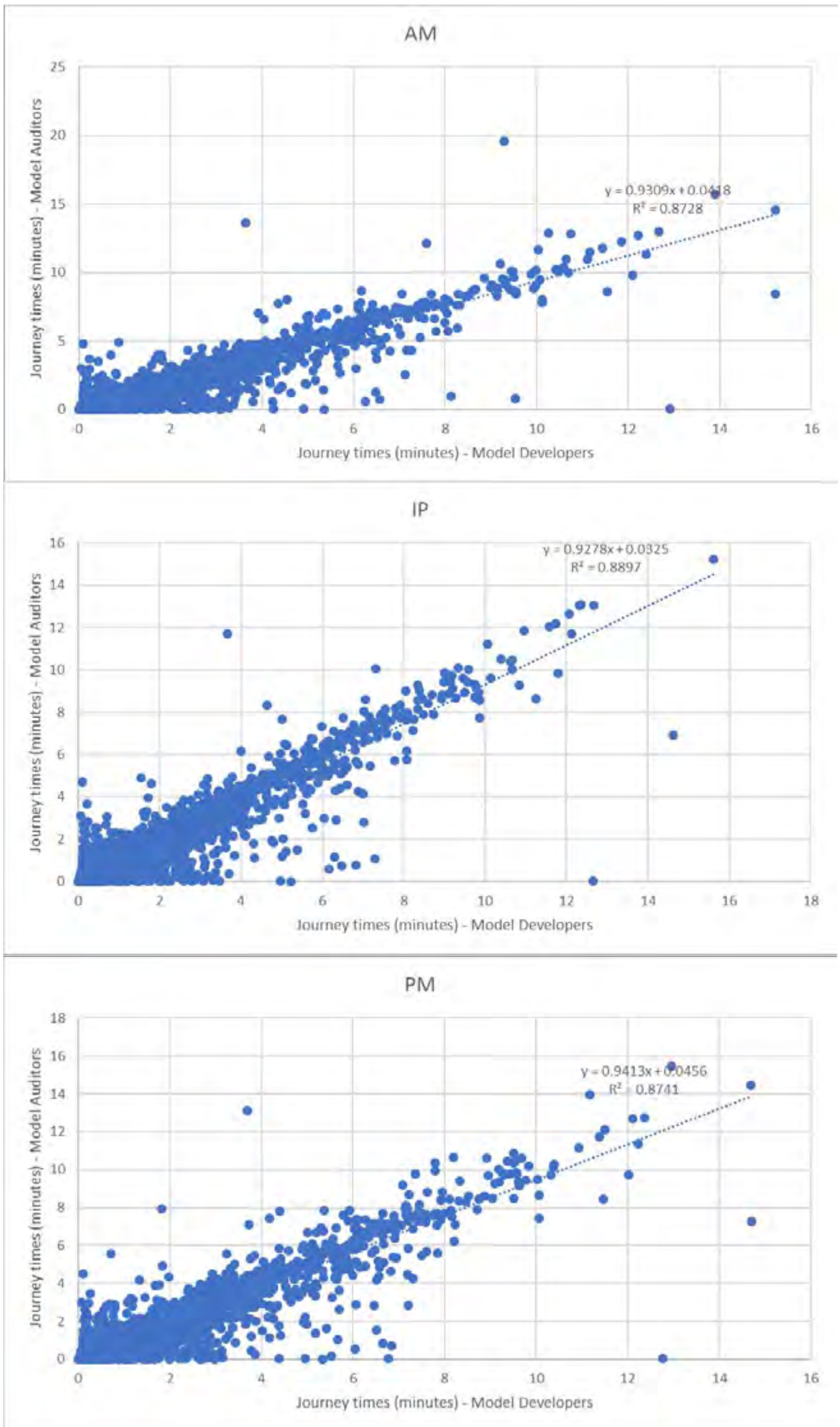


Figure 6.44: model developers vs model auditors journey times in minutes with missing values removed

6.4. Demand Model Development and Calibration

6.4.1. Data for Demand Model

In auditing the process of preparing data for demand model development, the following tasks were undertaken:

- random checks to verify accuracy and consistency of monetary costs with the documentation (as in Section 2, Volume 5 of the NTMv5 Developer Guide);
- random checks on level of service data to investigate if there are large errors; and
- verify consistency of attraction data in the model with source data / documentation.

6.4.1.1. Monetary Costs and Level of Service

Section 2.2 of 'NTM Dev Guide Vol5-Forecasting v2.0' documents the process of deriving monetary costs required as inputs for NTMv5. DfT have provided the auditors with the NTMv5 model parameters in an excel sheet: 'NTMv5 Model Parameters - Scenario Example v1.0.xlsm'. These were both used as part of auditing steps, summarised as follows:

1. VDM vehicle operating cost parameters were obtained by the model auditors from Dec2017 TAG databook (2015 values) and compared to those documented in Table 2.2 by the model developers extracted from the TAG databook;
2. the model auditors checked if the parameters in the spreadsheet are the same as those used in VISUM; and
3. the values were also checked if they were passed correctly in VISUM in the procedural sequence.

The parameter values from step 1 were consistent with what was reported. However, the 'a1' from TAG for non-work car was 4.144874 instead of zero. While the model developer explained in the spreadsheet the reason behind assuming the value to be zero, they have not done that in section 2.2.

> ➢ It is recommended that any assumption considered is described in the report as well as the spreadsheet.

As for steps 2 and 3, no issues were found. The parameters were found to have been implemented correctly and consistently with what is reported.

In addition to the above, average parking costs for all car trips presented in Table 2.5 by the model developers where verified by comparing them with those implemented in VISUM. These were consistent with what is reported.

The final audit undertaken under Section 2.2 was review of the VISUM procedure sequence behind the examples reported for car costs. These were also found to be consistent with what is reported.

6.4.1.2. Level of Service (LOS)

Model developers provided highway LOS data for each of the AM, IP, and PM time periods and three user classes (business, commute, and other). These include total distance, total journey time, and toll costs. As part of this audit, random checks were conducted to ensure consistency of LOS between different time periods. Filenames of the checked matrices are:

- PMtCur CB2.mtx (PM HAM LOS)
- 6 TTC (CB Employer Business)2.mtx (AM HAM LOS)
- 9 DIS (CC Car Commute)2.mtx (AM HAM LOS), and
- IPTrip distance CC2.mtx (IP HAM LOS).

The following checks have been made:

- A scatterplot of car commute AM vs IP distance costs for 1% of the sample ODs amounting for half a million of OD pairs;
- A scatterplot of car business AM vs PM journey time for 1% of the sample ODs amounting for half a million of OD pairs; and
- Coefficient of determination (R2) was calculated based on all OD pairs for the car commute and car business comparisons.

Figure 6.45 and **Figure 6.46** show the comparisons for journey times and distances of different time periods. As expected, AM distances are very close to IP distances with R^2 of 0.996, while AM journey times are close to PM journey times with differences attributed to potential different routing in different peak periods. The R^2 remains high with 0.93 for all the OD pairs.

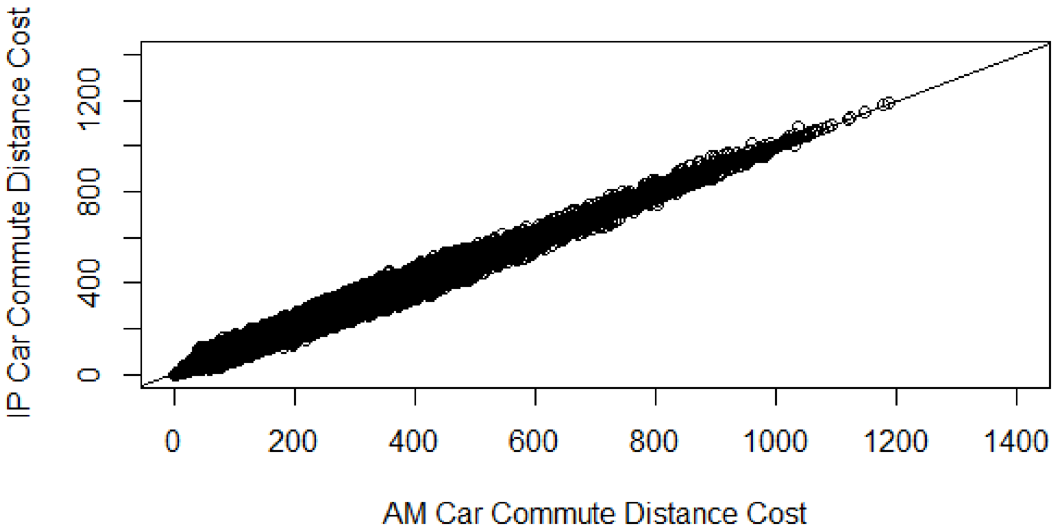


Figure 6.45: AM vs IP car commute distance costs

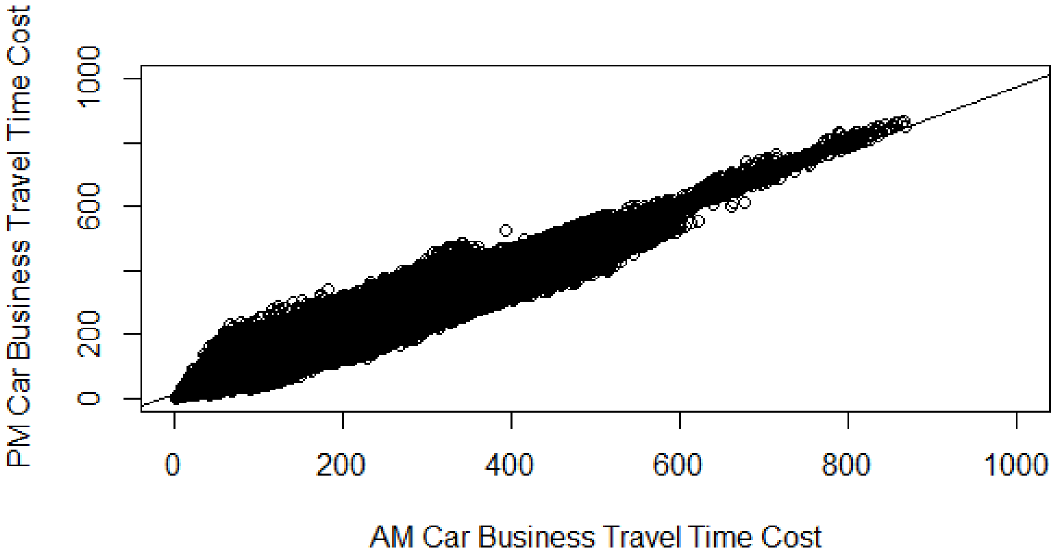


Figure 6.46: AM vs PM car business travel time costs

6.4.1.3. Attraction Data

Attraction data are used as input in the VDM process. Section 2.8 of ‘NTMv5 Dev Guide Vol5-Forecasting v2.0’ briefly lists the data which were used in model estimation in Table 2.9.

The model developers have also provided a draft spreadsheet under the attraction data ‘HSL QA Checking - Atkins draft spreadsheet.xlsm’. The spreadsheet contains zonal data on population and land use activities commissioned from HSL.

The spreadsheet takes as an input raw HSL data at MSOA level and produces a number of visualisations of the data at MSOA level and local authority level. There is not any intensive processing in the spreadsheet. One form of visualisation is scatterplots comparing different data types at MSOA level e.g. services employment versus full time university students. There is a minor error in that the y-axis of full-time university student is fixed while it should have been a drop-down menu. The other form of visualisation is barplots for all data types for each local authority chosen by the user. No other issues are found in these.

Generally, there is a lack of understanding of how the categories provided in this spreadsheet (total of 51 categories) had been aggregated to the 14 categories mentioned in Table 2.9. This is most probably a result of model auditors not being provided with all the processes involved in preparing the attraction data.

6.4.2. Choice Model Estimation

We did not have access to the process to prepare the data set used for demand model parameter estimation, or the code used to estimate choice model parameters. However, we had access to the source data used for these i.e. NTS, attraction tables, and level of service data, as well as technical notes describing this process. Therefore, we:

- reviewed specific technical notes describing the choice model estimation process;

- checked consistency of reported parameters against those implemented in the model; and
- used NTS data to reproduce a random selection of data tables in the corresponding technical note (i.e. OS12.2 NTS trip processing).

6.4.2.1. Estimation process

The choice models were estimated by RAND and documented in 'NTMv5_mode_destination_v13'. Section 3 of the 'NTM Dev Guide Vol5-Forecasting v2.0' discusses the general approach and refers to RAND's report for the details of the estimation. Section 5.5 checks and audits the implementation of VDM including the implementation of the choice model parameters and their consistency with what was reported in the developers' guide.

Due to the lack of availability of the processes involved in the estimation process, the audit process for the choice modelling estimation is partial. Ideally, the process for using the input data in calibrating the choice model parameters based on the reported models should be reviewed too; however this was not made available.

Rand's report provides a detailed description of the model specification, model results i.e. variables used and calibrated parameters obtained for each purpose, and model validation which included testing model elasticities, value of time, and predicted journey times.

The developers' guide summarised the results of the RAND's report with major tabulation being consistent between the two.

6.4.2.2. NTS processing verification

The *'NTM_OS12.2_NTS Trip Processing V1.0'* technical note contains the outline and assumptions used to process the NTS data for the NTMv5 demand model calibration. This section shows the outcome of reproducing a random selection of tables based on the processing steps outlined in this technical note.

In order to replicate the selection of results, key issues were identified in the audit process which can influence the quality of the results obtained. Particularly, the issues found were as follows:

- the distance property used to calculate trip length was not explicitly defined;
- it was not clear which, if any, trip weightings were applied to calculate total trips;
- some tables, which did not include escort purposes as separate segments, did not specify whether or not the escort purpose was absorbed into the main segment; and
- the time of trip was defined as the midpoint of the start and end times, however it was not clear which properties were used to define the start and end times.

6.4.2.2.1. Sample Size Analysis

Table 6.14 shows the reported sample sizes by model developers for the NTS data by purpose and mode. The modes have been recoded to represent the NTMv5 modes of interest, and the purposes are defined as likely segments to test sample sizes i.e. are not NTMv5 specific.

Table 6.14: Sample size (number of trips) by purpose and mode, model developers

Previously reported	Walk	Cycle	Car Driver	Car Passenger	Bus	Rail	Total
HB Work	6,078	4,231	74,354	10,908	8,133	10,415	114,119
HB Employers' Business	302	236	11,092	1039	661	1,519	14,849
HB Education	13,492	1,316	21,596	26,007	10,058	1,731	74,200
HB Shopping/Personal Business	13,129	1,464	64,443	36,178	13,946	1,800	130,960
HB Recreation/Social/ Visiting	6,825	1,483	39,198	28,901	6,025	2,272	84,704
HB Holiday/Day trip	13	1,254	7,237	5,484	644	682	15,314
NHB Employers' Business	546	128	10,254	1,041	403	700	13,072
NHB Other	10,746	1,278	69,957	39,274	6,461	3,782	131,498

Table 6.15 shows the same table derived by the model auditors for NTS data, as per the process defined in the technical note. It can be seen that these sample sizes are consistently larger than those reported by the model developers, despite ensuring the same years of data is being used (2010 – 2015 inclusive). It is possible that some geographic definition was used to derive the figures in the technical note, or some other restriction was used to subset the NTS data, however that is not detailed in the technical note and hence the figures could not be reproduced.

Table 6.15: Sample size (number of trips) by purpose and mode, model auditors

Newly derived	Walk	Cycle	Car Driver	Car Passenger	Bus	Rail	Total
HB Work	12,867	8,931	147,345	21,208	17,959	21,615	229,925
HB Employers' Business	704	502	25,155	2,191	1,412	3,186	33,150
HB Education	19,757	2,327	3,944	41,455	19,253	3,407	90,143
HB Shopping/Personal Business	26,707	3,334	147,907	73,280	32,682	4,061	287,970
HB Recreation/Social/ Visiting	17,604	3,390	100,760	77,249	14,695	5,674	219,371
HB Holiday/Day trip	72	2,735	15,487	12,085	1,495	1,427	33,301
NHB Employers' Business	2,033	360	24,844	2,251	918	1,498	31,904
NHB Other	7,739	863	50,816	29,423	4,887	2,431	96,158

6.4.2.2.2. Trip Length Distributions

Figure 6.47, Figure 6.48, and Figure 6.49 show the comparisons of NTS trip length distributions by detailed purpose, including escort purposes as separate segments, between what was reported in the model developers’ technical note and what has subsequently been derived based on the technical note.

It was not defined which modes the original TLDs were produced for, so they were subsequently derived for both ‘car’ and ‘all modes’, with ‘all modes’ being shown below. It can be seen that the TLDs for each purpose between the two data sources are very similar, if not identical, despite the differences seen in the sample sizes above.

In an attempt to reproduce the original TLD graph, the ‘trips’ calculation of the NTS data were defined as the sum of the ‘W5xHh’ property. However, the NTS trips should have been weighted using the ‘JJXSC’ grossing factor to account for short walks. Subsequently the distance property used excluded any short walks, and hence this may not need to have been considered.

The TLDs shown in **Figure 6.47**, **Figure 6.48**, and **Figure 6.49** show only very minor differences between the model developers’ and model auditors’ processing, and hence the differences seen are not thought to be a significant issue.

Figure 6.47: NTS TLDs (HBW, HB Employers' Business, HB Education, HB Shopping/HB Personal Business)

Figure 6.48: NTS TLDs (HBRecreation / HB Social /HB Visiting, HB Holiday, NHB Employers' Business, NHB Other)

Figure 6.49: NTS TLDs (HBW escort, HB Employers' Business escort, HB Education escort, HB Shopping/HB Personal Business escort)

6.4.2.2.3. Mode Share Analysis

Table 6.16 shows the mode split across all purposes as reported in the technical note by the model developers.

Table 6.16: NTS mode share by purpose, model developers

Previously reported	Walk	Cycle	Car Driver	Car Passenger	Bus	Rail
HB Work	5.7%	4.0%	63.9%	8.9%	7.7%	9.9%
HB Employers' Business	2.0%	1.6%	75.2%	6.1%	4.6%	10.6%
HB Education	19.9%	2.6%	4.3%	48.6%	20.7%	3.9%
HB Shopping/Person business	9.9%	1.2%	50.1%	26.0%	11.4%	1.5%
HB Recreation/social/visiting	8.1%	1.8%	46.3%	34.1%	7.1%	2.7%
HB Holiday/day trip	0.1%	8.2%	47.3%	35.8%	4.2%	4.5%
NHB Employers' Business	4.2%	1.0%	78.4%	8.0%	3.1%	5.4%
NHB Other	8.2%	1.0%	53.2%	29.9%	4.9%	2.9%
HB Escort Work	0.5%	0.2%	80.8%	18.1%	0.2%	0.2%
HB Escort Employers' business	4.0%	0.0%	58.9%	35.7%	1.1%	0.4%
HB Escort Education	15.9%	0.7%	61.9%	17.2%	4.1%	0.3%
HB Escort shopping/personal business	11.0%	0.3%	43.3%	39.0%	5.7%	0.7%
All purposes	8.8%	2.0%	51.5%	25.7%	8.0%	4.0%

Table 6.17 shows the mode split across all purposes, derived by the model auditors based on the processes described in the technical note. Small differences can be seen across all purposes, however the general splits are similar to what has been previously calculated, despite the differences in sample sizes, as shown above. **Figure 6.50** shows a summary of these results, where mode share patterns are consistent across all purposes between model developers figures and those of model auditors, and therefore the differences seen are not thought to be a significant issue.

Table 6.17: NTS mode share by purpose, model auditors

Newly derived	Walk	Cycle	Car Driver	Car Passenger	Bus	Rail
HB Work	5.6%	3.9%	64.1%	9.2%	7.8%	9.4%
HB Employers' Business	2.1%	1.5%	75.9%	6.6%	4.3%	9.6%
HB Education	21.9%	2.6%	4.4%	46.0%	21.4%	3.8%
HB Shopping/Person business	9.3%	1.2%	51.4%	25.4%	11.3%	1.4%
HB Recreation/social/visiting	8.0%	1.5%	45.9%	35.2%	6.7%	2.6%
HB Holiday/day trip	0.2%	8.2%	46.5%	36.3%	4.5%	4.3%
NHB Employers' Business	6.4%	1.1%	77.9%	7.1%	2.9%	4.7%
NHB Other	8.0%	0.9%	52.8%	30.6%	5.1%	2.5%
HB Escort Work	0.5%	0.1%	80.4%	18.7%	0.1%	0.2%
HB Escort Employers' business	3.0%	0.0%	58.3%	37.7%	0.7%	0.3%
HB Escort Education	16.9%	0.7%	60.9%	17.1%	4.1%	0.3%
HB Escort shopping/personal business	10.5%	0.3%	41.5%	41.4%	5.7%	0.6%
All purposes	9.0%	2.0%	51.3%	25.3%	8.6%	3.8%

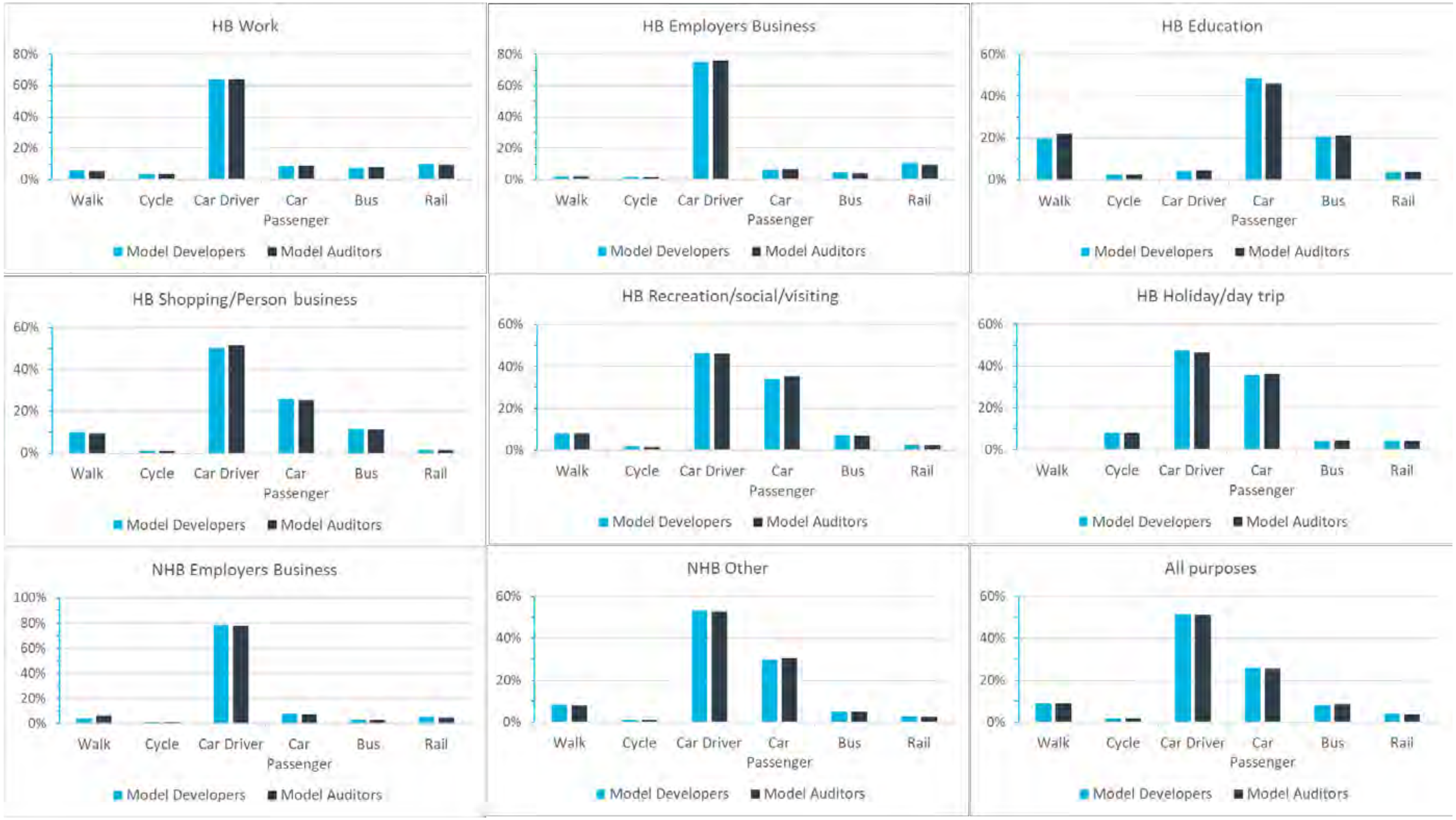


Figure 6.50: Summary of mode share changes by purpose

6.4.2.2.4. Time Period Split

Table 6.18 shows the time period proportions reported in the technical note by the model developers, with the highest period proportion highlighted for each purpose.

Table 6.18: NTS time period proportions by purpose, model developers

Purpose	Direction	AM	IP	PM	OP
HB Work	FH	64.0%	12.2%	5.2%	18.6%
HB Work	TH	4.1%	20.3%	59.4%	16.2%
HB Shopping/Person business	FH	24.0%	59.8%	12.0%	4.1%
HB Shopping/Person business	TH	5.4%	60.5%	25.1%	9.0%
HB Recreation/social/visiting	FH	14.4%	40.1%	27.5%	18.0%
HB Recreation/social/visiting	TH	1.8%	30.6%	26.4%	41.1%
HB Education	FH	78.3%	19.1%	2.2%	0.4%
HB Education	TH	15.4%	63.3%	20.0%	1.3%
HB Holiday/day trip	FH	18.6%	57.4%	15.3%	8.7%
HB Holiday/day trip	TH	7.3%	47.4%	31.5%	13.8%
HB Employers' business	FH	57.9%	23.8%	7.1%	11.2%
HB Employers' business	TH	3.5%	34.1%	46.4%	16.0%
NHB Employers' business	-	23.1%	59.4%	12.5%	5.0%
NHB Other	-	17.3%	54.3%	21.8%	6.6%
Total	-	23.5%	41.4%	22.4%	12.7%

Table 6.19 shows the time period proportions derived by the model auditors based on the processes reported in the technical note, with the highest period proportion highlighted for each purpose. Small differences can be seen across all purposes, and only one purpose and direction has changed the highest demand period (HB Recreation/social/visiting TH).

Table 6.19: NTS time period proportions, model auditors

Purpose	Direction	AM	IP	PM	OP
HB Work	FH	66.1%	11.9%	3.7%	18.4%
HB Work	TH	2.5%	20.7%	60.8%	15.9%
HB Shopping/Person business	FH	21.9%	61.8%	11.9%	4.5%
HB Shopping/Person business	TH	4.8%	61.7%	24.0%	9.5%
HB Recreation/social/ visiting	FH	13.6%	33.4%	31.1%	21.9%
HB Recreation/social/ visiting	TH	5.4%	38.9%	25.1%	30.6%
HB Education	FH	93.9%	5.2%	0.6%	0.3%
HB Education	TH	0.2%	73.5%	24.7%	1.7%
HB Holiday/day trip	FH	17.2%	58.2%	15.3%	9.3%
HB Holiday/day trip	TH	7.1%	47.3%	31.2%	14.4%
HB Employers' business	FH	57.5%	24.7%	6.7%	11.1%
HB Employers' business	TH	3.0%	33.7%	46.8%	16.4%
NHB Employers' business	-	39.2%	48.7%	8.2%	3.9%
NHB Other	-	13.1%	57.3%	23.9%	5.7%
Total	-	21.7%	41.9%	22.9%	13.5%

There may have been differences in the time definition between the two processes; the technical note highlighted the time period allocation was based on the mid time of the trip, hence for the new derivation that was taken as half way between the 'TripStartHours' + 'TripStartMinutes' and 'TripEndHours' + 'TripEndMinutes' properties. However, a number of other trip start and end time properties could have been used which could be causing some of the differences seen in the two tables. It was also not specified whether, for example, 'HB Education Escort' was absorbed into 'HB Education' for this table, which could be another source for differences. Considering the difference in sample size seen above, which could also be contributing to the changes, the trends seen between those derived by model developers and model auditors are largely consistent and therefore the differences are not thought to be a significant issue.

- It is recommended that the NTS trip processing technical note and/or the quality report is updated to better describe the processing assumptions of NTS trip data and add clarity to the definitions used in the analysis.

6.4.3. Non-Car Cost Matrices

This section focuses on the audits of the travel cost components for Non-Car modes: rail, bus and walking and cycling journeys, as detailed in NTMv5 Developer Guide Volume 4: Non-car modes and Section 7.8 of the NTMv5 Quality Report v4.0.

30 OD journey samples were obtained from the NTMv5 model to conduct the audit. The samples chosen aimed to represent journeys varying in distance, cost, directness and geographical location. Additionally, for the bus and rail samples, the OD pairs selected represent a mixture of service operators and include both single and cross-

operator journeys. These samples were used to validate fares and journey times for each mode and are displayed in Appendix 2.

Original TRACC models and other components of the process to develop non-car cost matrices were not available as part of this audit due to the size of the files. Instead, the non-car cost components were independently validated using bespoke processes. **Table 6.20** summarises the components checked along with the brief methodology adopted to replicate the cost values for the sample OD pairs selected.

Table 6.20: Summary of model components checked

Bus and Rail Journey Times	For the public transport journey time calculation, two multimodal models were built; one in Basemap's TRACC software and the other in Open Trip Planner (OTP). A smaller sample of 7 out of the 30 OD journeys were analysed using OTP as this was the total number of valid OD's within the parameters set.
Rail Fares	Rail fare data published by BR Fares[6] was used to compare current fares, factored to account for the inflation in ticket prices since 2015, with the NTMv5 model fare data.
Bus Fares	A subset of five journeys from the sample of 30 bus journeys were chosen to compare actual bus and coach fare information with the model data. The five journeys selected are varied in mode, distance and geographical location.
Walking and Cycling journey time	The OTP method was adopted to test the walking and cycling calculations.

6.4.3.1. Rail and Bus Fares

The assessment of rail fares found that the rail fares used in NTMv5 based on MOIRA2 data was consistently lower than actual fare data obtained from BR Fares, factored to reflect 2015 prices, for the sample dataset. This suggests that the existing approach used to generate fares in NTMv5 of using total revenue divided by number of tickets for each ticket type to determine fare costs is plausible as it takes into account the use of railcards and the mix of actual ticket products purchased (reflecting child fares or usage restrictions). In the absence of access to MOIRA or LENNON data, our check has had to use the published fares before any discounts are applied.

For zone pairs were data was not available an in-fill method has been used within NTMv5. To check this infill method the audit team developed a back-calculation approach beginning with the full rail dataset extracted from BR Fares. Values are summarised in **Table 6.21** and the resulting fare costs for the sample OD pairs are shown in **Figure 6.51**.

It was found that the cost per km assumptions used by NTMv5 to infill missing data entries were significantly higher than those (around double) obtained through back calculation within the audit. The audit back-calculated cost per km values produced more comparable fares with those in the MOIRA2 database.

[6] www.brfares.com An independent website that allows expert users to fully explore the variety of fares offered by the train companies in Great Britain, without having to plan a journey or specify times and trains.

Table 6.21: Cost per km comparison between existing model and back calculation method

Ticket Type	£ per km NTM	£ per km Audit
Full_Std	0.29	0.15
Reduced_Std	0.17	0.07
Season_Std	0.17	0.05

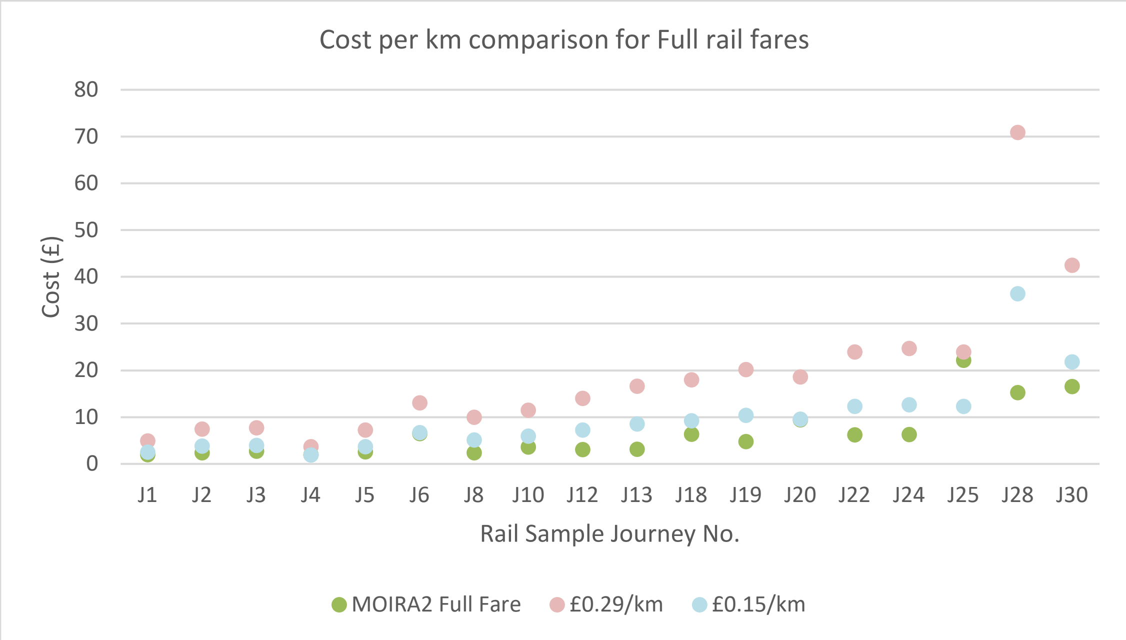


Figure 6.51: MOIRA2 Full Fares compared against £ per km factors using the existing model and back-calculation methods

> It is recommended that the methodology developed to infill missing entries in the MOIRA2 dataset should be revisited to ensure its validity across the whole dataset.

Comparing the model bus and coach fares with actual fares for a sample of 5 journeys, factored to reflect 2015 prices, showed that the cost function model used in the NTMv5 model may underestimate bus fares and overestimate coach fares. In particular, the 'fixed cost' aspect of the bus model may be too low. Further analysis will be needed to verify this since the sample size was very small.

To validate the cost function method used to infill unobserved entries within the NTMv5 model, the method was repeated for the sample 30 journeys. There were discrepancies in the fare cost when the methodology outlined in Volume 4 of the NTM Development Guide was repeated. 25 out of the 30 of the sample journeys recorded a model fare lower than the calculated fare, and across the sample, the model fare was on average 8% lower than the calculated fare.

> The application of the cost function model for the entire bus and coach dataset should also be validated as due to the discrepancies found when the method was repeated for 30 journeys.

6.4.3.2. Rail and Bus Journey times

The assessment found that total journey time for rail calculated an average 9% difference between NTMv5 model and the audit teams TRACC model. The total journey time for bus calculated an average of 28% difference between NTMv5 model and the audit teams TRACC model. Results are shown in **Figure 6.52** and **Figure 6.53**.

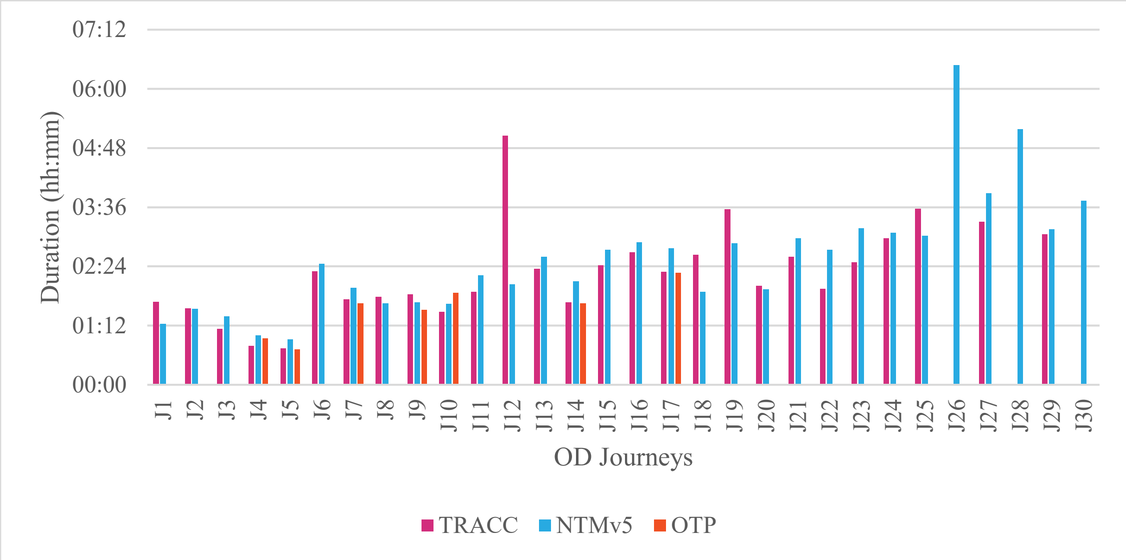


Figure 6.52: Total Journey Time by Rail

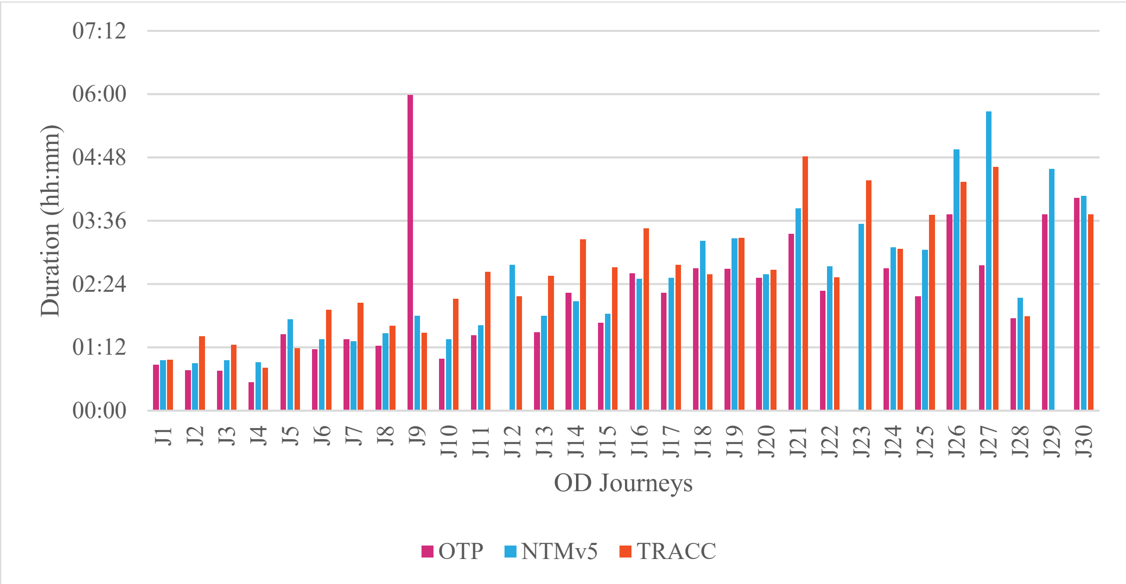


Figure 6.53: Total time by bus

When further analysing the individual components of the journey, there were wider gaps between the NTMv5 model, our TRACC and our OTP model. It is acknowledged that the results between NTMv5 and OTP will result in slightly different outcomes due to the difference in timetabling years.

However, the waiting time calculations for both rail and bus showed a large percentage difference, and it was unclear why this occurred due to the similar interchange stops recorded.

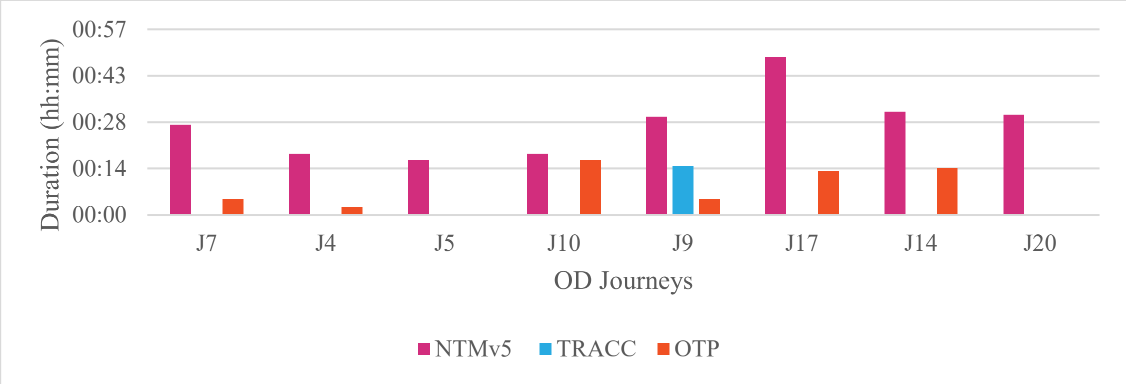


Figure 6.54: Wait time by Rail for the 7 OD pairs

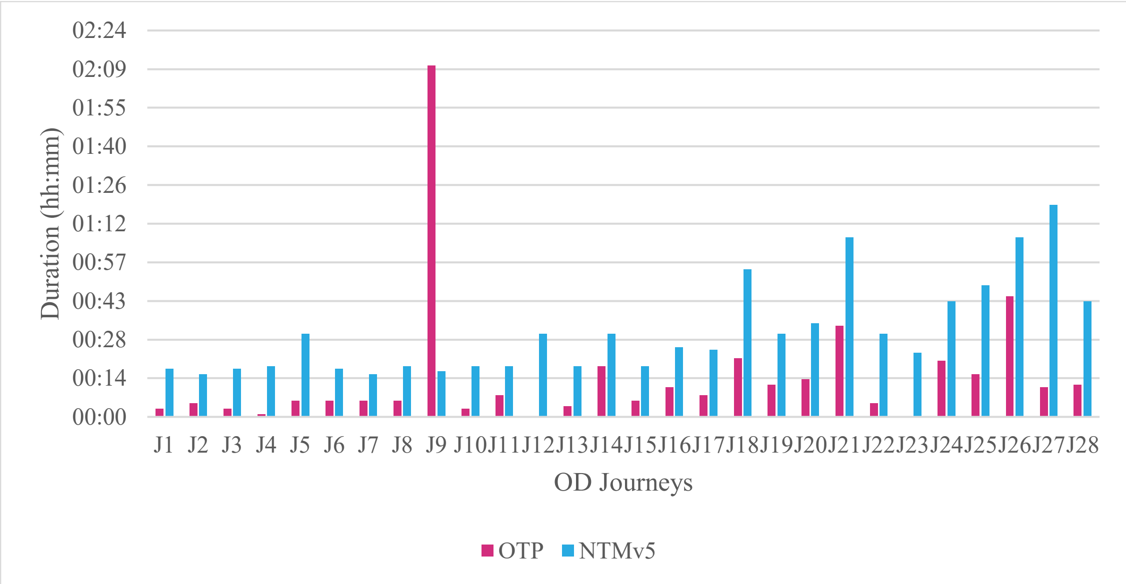


Figure 6.55: Wait Time by Bus

There were a couple of invalid journeys recorded from our TRACC model for bus. It is unclear which model outputs related to the different parameters tested during the development of the cost matrices for NTMv5 model to enable reproducing these results.

In summary, given that the audit team did not have access to the same data as was used to develop the journey times in NTMv5 it is concluded that the overall differences for rail journeys are reasonable as no overall bias could be found. However, with bus journeys, there are substantial differences in wait times across most bus journeys. Without comparable details, such as journey choice and itinerary, from NTMv5, it is not possible to understand the reasons behind these differences. The audit is therefore unable to conclude that no bias has been introduced into the parameter estimation process, and therefore provide assurance that the model is suitable to test a policy that effects level of service.

- It is recommended that further testing should be undertaken to make it clearer which NTMv5 OD pairs correspond to the different parameters tested. Further spot checks on bus route choice and wait time are also recommended to make sure they provide reasonable representation of actual journeys. This will allow a clear analysis of the individual journey components and help understand the gap between total journey times.

6.4.3.3. Walking and cycling journey times

It is acknowledged that this audit would result in slightly different walking and cycling journey times as those modelled in the NTM's TRACC model, due to the different road network data and routeing algorithms. For example, the OTP would avoid cycling journeys along steps and pedestrianised zones where cyclists are required to dismount.

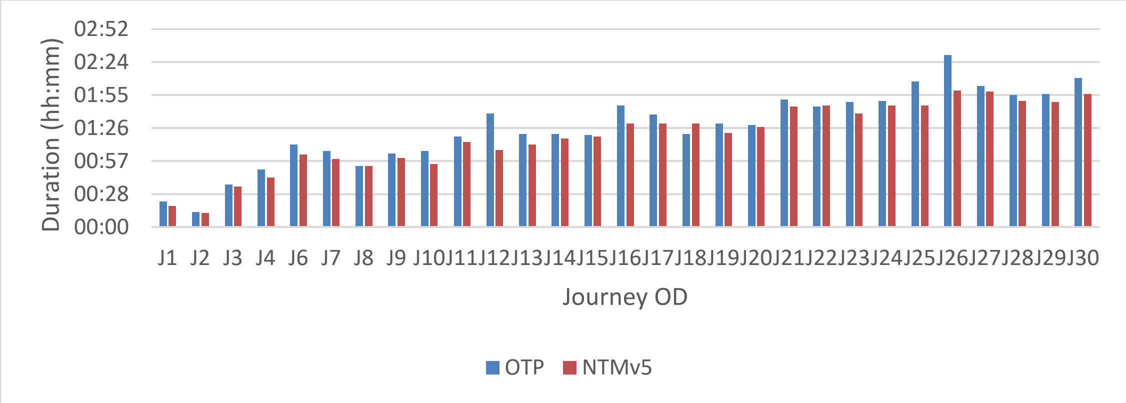


Figure 6.56: Total Walk Time

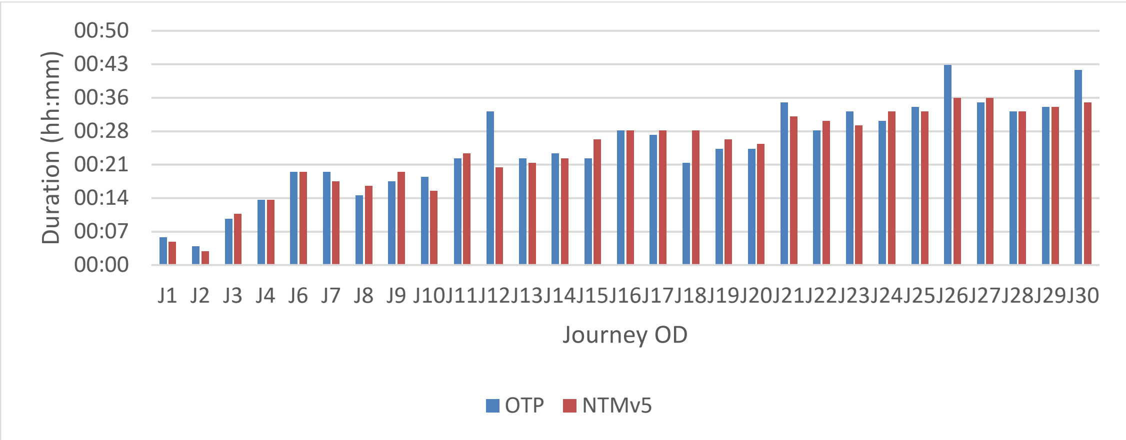


Figure 6.57: Total Cycle Time

In summary, the 30 sampled origin and destination pairs show an average difference of 9% amongst walking journeys and 8% amongst cycling journeys. The differences for most journeys are relatively small and considered negligible as being less than 5%. To give an independent view, further tests have been undertaken using GoogleMap direction for journeys with high differences. GoogleMap results for Journey 12 is found more similar to OTP as they both assume a route choice that avoids stairs and pedestrianised area that require cyclists to dismount. However, GoogleMap results for Journey 26 is found more similar to NTMv5 as they both have preference over a trafficked route than a cycle lane.

Therefore, the audit suggests that walking and cycling journeys can be very sensitive to the different approach in route choice. NTMv5 only considers the shortest path, which may provide incorrect results in places where access is restricted and the quality of routes varied.

6.5. Summary and Conclusions

6.5.1. Base Year Matrix Development Process

The demand data, matrix development process, and matrix improvements were audited as part of the base year matrix development process in sections 6.2.1, 6.2.2, and 6.2.3, respectively. The main conclusions, issues, and recommendations are provided below.

NTMv5 demand data were audited using secondary sources such as NTEM and NTS. Overall the results suggest the processes used to assemble the data and generate the trip ends produce outputs that are largely consistent with source data and independent verification sources at aggregate level. However, there exists some differences which prevented results to always be reproduced. The differences found can be explained by:

- the different planning data being used producing differences in trip ends at MSOA levels for a number of zones are near zero in NTMv5 but have large trip productions in NTEM, and vice versa;
- possible non-final versions of the input files such as the input trip ends where there is a discrepancy of 35 zones between it and the NTMv5 zoning;
- non-specified units of data being used in the calculations, specifically the use of cars vs car driver only data, and the use of from-home vs bidirectional data.

The main concern in the review of trip ends relate to large differences that were found between zonal trip ends in the NTM v5 and the NTEM. This suggests misallocations of trip ends between MSOAs within a district; alternatively, this may indicate statistical uncertainty in NTEM zonal trip ends. As a result, spatially disaggregate outputs from the model in terms of zonal trips should not be relied on and used without verification and possible correction for errors. Model outputs at aggregate levels (e.g. urban areas or districts) are expected to be suitable for use.

For the matrix development process, we were able to reproduce only some of the results provided in the documentation/technical notes following the processes explained and with the source data and the final prior matrices provided. The following lists the main findings from the matrix development audit.

- There is an apparent discrepancy in the input trip ends provided for the 'kalibri' process which was used for demand data audit as well as matrix development audit. This discrepancy is in the zoning system.
- There is an apparent lack of information on the details of the data i.e. whether trip ends, synthetic, and NTS data are from-home or both directions or car driver or cars. While it was mentioned that synthetic matrices have been produced for car drivers, the steps undertaken to convert car to car driver trip ends needs to be clear.
- TLD results for synthetic vs NTS data were reproduced and are generally close to what was reported. However, there is an inconsistency in the input trip ends and synthetic trip ends for all purposes, except for employer business. There is no clear reason behind such discrepancy, but it can be attributed to the discrepancy of zoning system of the trip ends.
- Correspondence for the external zones of JTW data (particularly for Scotland) has prevented the model auditors reproducing the commuting matrices for both internal and external movements.

- Airport demand was generally reproduced by the model auditors and was similar to that provided by the model developers. More information on how different business and leisure trips were assigned to the final three prior matrices is needed.
- The main recommendation from the review of Port trips was for the model documentation to clarify the reasons of combining a number ports together in single zones.

There is significant discrepancy between provided trip ends and synthetic matrices produced by the Kalibri process, with no information available to explain the reasons behind this. Whilst likely reasons for this have been discussed, we are unable to verify these, or entirely rule out the possibility of errors in the process of synthetic matrix development. Without further investigation, this is an area of risk (albeit considered low to moderate) affecting all model use cases.

The following actions are recommended:

- The documentation as well as scripts and excel files provided need to become more transparent to provide clarity in terms of units of data being used to avoid confusion for the user. Particularly, the modes and directionality of the matrix needs to be clear when comparing multiple sources of data.
- Processing documentation lacks some intermediary steps which could potentially explain some of the discrepancies that the audit has found. For instance, more information is required to understand how the outputs from the CAA process have reached the level of assignment matrices.

Generally, there were several key data sets and processes not provided for the model audit which have prevented a more complete audit of the base year matrix development process. For instance, commuting and education matrices were not provided at period person trips level, and intermediary matrices between the synthetic output and the final prior matrices were not provided which prevented a detailed review of the matrix adjustment processes described in the developer guide.

6.5.2. Data Processing for Calibration and Validation

Key calibration and validation data sets, journey time data sets, and essential GIS layers of counts and screenlines were provided which allowed a thorough audit presented in Section 6.3. The audit included:

- verifying the consistency of the screenline count data with counts processed by the RTM teams;
- checking the processing of counts to form screenlines;
- reviewing the process to extract VISUM links corresponding to the journey time routes; and
- checking consistency with source Trafficmaster journey time data and verified the process used to extract these for selected routes.

The following can be concluded from this audit.

- For the randomly selected screenlines (14 out of 35), there exists a number of discrepancies between the counts provided and those processed by RTM which could be justified by different versions of either maps or CalVal sheets.
- In general, the method of extracting VISUM links was considered adequate with 5% of journey times routes checked and verified against what was reported in the provided journey time dashboard for NTMv5.
- While the Trafficmaster journey time process ran without any significant issues, there were inconsistencies between the produced journey times and those

provided in the journey time dashboard. This is potentially a result of intermediary steps which were not documented properly nor processes behind them provided for this audit, or a result of a mismatch between the versions of input data and final dashboards; however, we cannot confirm this. There was also a lack of documentation on how Trafficmaster sample size data were used in processing journey times.

In order to have full confidence in the observed journey time data used for model validation, further investigation is required to confirm the reason for the discrepancy between the data in the provided journey time dashboard for NTMv5 and those produced independently for the purpose of this audit, as summarised in **Figure 6.44**. Whilst this is likely to be due to inconsistent data inputs with the process and / or intermediate processes and assumptions, this cannot be verified due to lack of information; hence, this is an area of moderate risk that should be considered in all model use cases.

6.5.3. Demand Model Data and Calibration

This section of the audit was divided into three main parts:

- auditing demand model data;
- auditing the choice mode estimation process and parameters; and
- auditing the NTS data processing technical note.

The model parameters relating to calculation of monetary costs were found to be consistent with the documentation and have been implemented correctly. The level of service and attraction data were also checked and verified against the documentation.

The detailed process of estimating choice model parameters could not be reviewed as no access was provided to the processes used for the estimation process.

As for the NTS data processing, it was found that the trends obtained from the model developers' NTS data processing is largely realistic and consistent with the results of the audit team following the process descriptions. Although the general patterns across trip lengths, modes, and time periods were largely reproducible, there were some discrepancies where the particular NTS properties used for the calculations have not been explicitly defined. In general, the main observation of the audit of NTS trip processing is lack of clarity in the documentation with regards to processing assumptions and definitions used.

In relation to non-car travel cost components there were a number of differences found between the data in NTMv5 and our own processing of what we believed to be the source data. Differences were found in the parameters used to infill missing rail fare entries, and in wait times across most bus journeys. Without more information on how the source data was handled within the development of NTMv5 the audit is therefore unable to conclude that no bias has been introduced into the parameter estimation process for rail fares, or bus wait time data, and therefore provide assurance that the model is suitable to test policy's that may affect public transport level of service at a local level.

7. Model Review- Model Use

7.1. Overview of User Interface and Approach

This section documents the audit of the model use in Visum undertaken as part of NTMv5 development. We first ran the VISUM version file of Run246, provided by DfT in the handover package, and reproduce the outputs of this model, following the instructions in the NTMv5 User Guide.

Using the VISUM version file of Run246 as the benchmark, we undertook five sensitivity tests, changing or updating some of the key components/inputs of this model run. The tests are:

1. Demand Growth;
2. Highway Network;
3. Public Transport Changes;
4. Economic Parameter Changes; and
5. Urban Area Strategy.

The sensitivity tests are designed in such a way in order to be able to audit the model usability of the potential NTM applications which were formed into the six use cases set by the DfT and mentioned in the NTMv5 Quality Report.

The model outputs from the five sensitivity tests are imported to the analysis spreadsheets provided in the handover package, following the instructions in the NTMv5 User Guide. Also, using the VISUM graphic parameters, we produce the relevant plots and maps to assess the outputs of the sensitivity tests.

Throughout this process, we carefully and meticulously review the model in terms of the usability, potential errors, ambiguities, robustness and transparency. We also suggest potential improvements to enhance the NTMv5 model use and advice for users of the model. In summary, the following questions are being answered through the review of model use and the five sensitivity tests:

- Is the model usable and well-documented?
- Are the analysis spreadsheets and other standard model outputs well-structured and documented?
- Does the model produce plausible forecasts?

7.2. Initial Testing

Initial model runs were undertaken by Arup and AECOM to test our system and model environment set up and reassure that consistency can be achieved for the same model runs undertaken independently in different environments.

An existing model run executed by the model developers was used intentionally, to ensure that inconsistent model use to the intended by the model developers is captured at the early stages of the audit and that subsequent model runs undertaken by the audit team are not impacted. Similarly, this allowed us to test the model handover process form the perspective of a new model user, identifying any issues that future users of the model are likely to experience solely relying on the model documentation.

VISUM version file of Run246 along with model run outputs, provided by DfT in the handover package, was used as a benchmark for the initial runs. Although model set up and use was not straightforward (as covered later in this section), upon completion of the model runs it was confirmed that the model outputs from the independent DfT, Arup and AECOM model runs were identical.

The following issues/observations were noted as part of this process:

1) Throughout the task it was noticed that a significant number of procedures and external scripts used by NTMV5 require user changes in the set-up process (input/output file paths, constant parameters etc.) prior to the model run. It is not clear to the model user which procedures need to be updated and failing to do so will cause the model run to crash or produce incorrect outputs.
   - It is recommended that the user guide clearly states which procedures and external scripts need to be updated by the user prior to the model run to avoid model run disruptions.
2) The initial model run was successfully completed after around 90 hours, which is somewhat higher than the reported time mentioned in the user guide (i.e. 60 hours). The relevant attribute files have been exported and the analysis spreadsheets mentioned in section 7.3 were updated. According to the "M-PSeq" spreadsheet, the commuting (HBW) and education (HbEd) choice models took a significant amount of time to be completed (see **Table 7.1**), much more than the choice models of the other demand segments. It is, also, observed that the run times increase noticeably with each iteration.
3) Almost half of the total run time is driven by the model assignments which might be reasonable. However, it should be clarified why the assignment run times, again, are increased between iterations. Neither in the user guide nor in any of the developer guide is there a reference to a potential progressive convergence set up, which might explain the increase in the run times.
   - Additional work inspecting and considering runtimes and possible improvements could be valuable for future use of the model.
4) **Table 7.2** presents the convergence of the assignments and the double-constraint process, both of which appear reasonable. However, it should be highlighted that there is no information about the convergence of the demand-supply loop; this is a significant concern.
   - It is important to highlight the fact that the total convergence of the model is not measured. This might be a weakness of the VISUM software; however, other alternative methods should have been applied. The lack of clarity in the overall model convergence is a significant issue for the credibility of the model.

It should be noted that the statements made above regarding the run times and convergence apply to all the sensitivity tests reported in the chapter.

Table 7.1: Run time of choice models for sensitivity test 1 according to "RunTime" tab of the "M-PSeq" spreadsheet

Group	Runtimes			
	Iteration 0	**Iteration 1**	**Iteration 2**	**Iteration 3**
Group 4a. HbW Choice Model	00:27:41	01:07:31	03:00:52	04:56:30
Group 4b. HbEd Choice Model	00:32:43	01:10:20	03:23:40	05:34:31
Group 4c. HbShopPB Choice Model	00:10:35	00:15:34	00:20:13	00:43:12
Group 4d. HbRecV Choice Model	00:08:06	00:12:02	00:21:41	00:28:58
Group 4e. HbHol Choice Model	00:04:18	00:07:01	00:13:04	00:16:47
Group 4f. HbEB Choice Model	00:06:34	00:08:21	00:15:05	00:21:35
Group 7a. NHbEB Choice Model	00:05:21	00:08:59	00:16:53	00:17:59
Group 7b. NHbO Choice Model	00:04:37	00:07:35	00:13:28	00:10:43
Grand Total	**10:25:49**	**14:02:08**	**25:28:40**	**32:22:12**

Table 7.2: Convergence measures of HAM and VDM for sensitivity test 1 according to "Convergence" tab of the "M-PSeq" spreadsheet

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2"># iterations</th><th colspan="3">Convergence</th></tr>
<tr><th>Setting (max)</th><th>Outcome</th><th>Tolerance</th><th colspan="2">Outcome</th></tr>
<tr><td colspan="2" rowspan="2">VDM</td><td>30</td><td>30</td><td>0.0001</td><td>HbW</td><td>0.48%</td></tr>
<tr><td></td><td></td><td></td><td>HbEd</td><td>1.68%</td></tr>
<tr><td colspan="2">PA-OD & Pivot</td><td colspan="5"></td></tr>
<tr><td rowspan="3">HAM</td><td>AM</td><td>100</td><td>11</td><td rowspan="3">Iterated - 10^{-3}
Final - 10^{-6}</td><td colspan="2">6.57E-07</td></tr>
<tr><td>IP</td><td>100</td><td>11</td><td colspan="2">5.06E-07</td></tr>
<tr><td>PM</td><td>100</td><td>12</td><td colspan="2">5.62E-07</td></tr>
</table>

7.3. Model Outputs

7.3.1. Analysis spreadsheets

The main outputs from the VISUM version files are exported in VISUM attribute format (.att) using .vbs scripts. The attribute files are imported into analysis spreadsheets for inspection and checks of the VISUM outputs.

The model outputs are broadly grouped into four categories:

- model diagnosis;
- VDM analysis;
- HAM analysis; and
- pivoting analysis.

Considering the model diagnostics, two spreadsheets exist to check that a model run has been completed successfully and to help finding errors before any further analysis is undertaken.

7.3.2. Matrix List

The "M-MatList" spreadsheet provides a high-level summary of the changes between a scenario run and one other comparator run (such as a base or do-minimum). The spreadsheet has been found to be well-structured and self-explanatory, and the instructions reported in section 9.2.2 are helpful and informative for the model output user to get familiarised with the spreadsheet.

However, it would be preferable to have functionality in the spreadsheet to automatically import the VISUM attribute files rather than importing them manually as the spreadsheet is currently designed. Also, it would be good to provide the opportunity to the model output user to compare all the iterations between the scenario run and any other comparator run. This is currently limited to a comparison of one single (final) iteration of the comparator run against all the iterations from the scenario run.

- It is recommended that the "M-MatList" spreadsheet is amended in order to import and compare all the iterations between the scenario and comparator run.

Also, in the "Cost Summary" tab of this spreadsheet, it is not clear whether the fuel cost is included - reference to this should be included either in the spreadsheet or in the user guide. Furthermore, in the "Avg Trip Cost Summary" tab, the "Deviation from Base Avg Trip Cost" table doesn't report the units of its values (see example in **Figure 7.1**). Since, this table shows the difference between the values which represent sterling pounds (£), the units are presumably sterling pounds (£) as well.

Car Driver Avg Trip Cost					
Purpose	**Base- Run246_3**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**
HbW	£1.23	£1.32	£1.25	£1.28	£1.28
HbEd	£0.48	£0.52	£0.50	£0.51	£0.51
HbShopPB	£0.65	£0.70	£0.67	£0.68	£0.68
HbRecV	£1.00	£1.07	£1.02	£1.04	£1.04
HbHol	£2.48	£2.63	£2.50	£2.55	£2.56
HbEB	£4.47	£4.70	£4.40	£4.53	£4.53
NHbEB	£2.66	£2.88	£2.59	£2.70	£2.71
NHbO	£0.73	£0.79	£0.75	£0.77	£0.77
Total	**£1.11**	**£1.19**	**£1.13**	**£1.15**	**£1.16**

Deviation from Base Avg Trip Cost					
Purpose	**Base- Run246_3**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**	**nA246_S1-Iteratio**
HbW	1.23	0.09	0.02	0.05	0.05
HbEd	0.48	0.04	0.02	0.03	0.03
HbShopPB	0.65	0.05	0.02	0.03	0.03
HbRecV	1.00	0.07	0.03	0.04	0.04
HbHol	2.48	0.15	0.03	0.07	0.08
HbEB	4.47	0.23	-0.07	0.06	0.07
NHbEB	2.66	0.22	-0.07	0.04	0.05
NHbO	0.73	0.06	0.02	0.04	0.04
Total	**1.11**	**0.08**	**0.02**	**0.04**	**0.05**

Figure 7.1: Example of "Deviation from Base Avg Trip Cost" from the "Avg Trip Cost Summary" tab of the "M-MatList" spreadsheet

There are other labelling issues. For example, the “Avg Trip Length Summary” tab has several tables labelled “Avg Trip Time”.

➢ It is recommended that the “M-MatList” spreadsheet is reviewed carefully to ensure all labels and units are correct, up-to-date and clear.

Considering more formatting issues of the “M-MatList” spreadsheet, it would have been preferable to replace the word “iteration” with “iter” in all the tables of the spreadsheet in order to fit the whole word in the table headers. As it stands now, the model output user has to expand the cells of the tables to be able to read the table headers (see example in **Figure 7.2**).

	Car Driver Min				
Purpose	**Base- Run246_3**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**
HbW	190,231,276	202,095,351	181,078,886	188,219,882	188,230,321
HbEd	24,298,383	25,119,367	23,120,544	23,696,599	23,717,669
HbShopPB	113,721,985	117,508,595	109,110,030	111,212,149	111,334,503
HbRecV	83,138,583	86,865,259	80,021,407	81,772,544	81,877,124
HbHol	30,849,980	32,513,631	29,761,553	30,474,324	30,513,646
HbEB	54,177,298	58,633,381	51,723,624	53,992,144	54,010,291
NHbEB	21,498,254	23,666,724	20,445,271	21,404,792	21,455,703
NHbO	95,023,826	99,603,270	92,131,283	94,002,753	94,104,725
Total	**612,939,585**	**646,005,579**	**587,392,597**	**604,775,186**	**605,243,983**
	Difference to Base Run				
Purpose	**Base- Run246_3**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**	**_nA246_S1-Iteratio**
HbW	190,231,276	11,864,075	-9,152,390	-2,011,394	-2,000,955
HbEd	24,298,383	820,984	-1,177,839	-601,784	-580,713
HbShopPB	113,721,985	3,786,610	-4,611,955	-2,509,835	-2,387,482
HbRecV	83,138,583	3,726,676	-3,117,176	-1,366,039	-1,261,459
HbHol	30,849,980	1,663,651	-1,088,428	-375,656	-336,335
HbEB	54,177,298	4,456,083	-2,453,674	-185,155	-167,007
NHbEB	21,498,254	2,168,470	-1,052,983	-93,463	-42,551
NHbO	95,023,826	4,579,445	-2,892,543	-1,021,073	-919,100
Total	**612,939,585**	**33,065,994**	**-25,546,988**	**-8,164,399**	**-7,695,603**

Figure 7.2: Example of “Time Summary” tab of the “M-MatList” spreadsheet

7.3.3. Procedure Sequence

The “M-PSeq” spreadsheet is used to check convergence levels achieved in the model run and to compare the runtimes against other model runs. A VISUM “protocol” file is manually input to the spreadsheet when the model run has completed. The protocol file is extracted manually from the VISUM version file; however, the user guide does not discuss how to extract this file. If this protocol file is not exported manually from the user, then the file is overwritten by a new model run.

➢ In order to make the process more user friendly and avoid confusion from the user, it is recommended to automate the process of exporting the relevant information for the run times and model convergence with the aid of the procedure sequence within VISUM.

7.3.4. VDM Analysis

With regards to VDM analysis, there are six related spreadsheets and one plot analysis.

The “V-TLD” spreadsheet analyses the trip-length distributions of the 24-hour P/A matrices output by the VDM for each model and purpose, along with mode share, average trip-length and intrazonal information.

Two issues have been found in the use of this spreadsheet. In the “Import” tab of the spreadsheet, the names of the VISUM attribute files used as inputs in the spreadsheet are inconsistent with the name of the version file. This results in the VBA macro used to import the inputs crashing.

- In order to address the issue, the name of the A12 cell in the “Import” tab should change, as the model output user should not type the version name but the name of the related attribute file names.

The second issue is linked with the formulas and the structure of the spreadsheet used to compare the scenario runs with the comparator run. In particular, the formulas in the F16,F17 & G16,G17 of the “RunIDs” tab are not working as expected, making it difficult for the model output user to compare two model runs.

- Hence, it is recommended that either these formulas are updated or add specific instructions in section 9.3.1 of the user guide to manually update the file paths and the model run names.

The main purpose of the “V-Sect” spreadsheet is to investigate the mode and distribution changes either within a certain area or between areas. The only observation from using this spreadsheet is related with the process of importing the necessary VISUM attribute files.

- Although there are adequate instructions in the user guide and the spreadsheet itself about how to manually import the inputs, it is recommended to have this process automated in order to avoid ambiguities and errors.

The “V-Prod” spreadsheet analyses the production trip end inputs from a scenario run, including the base values, growth inputs and resulting scenario productions for each demand strata. The inputs in the spreadsheet are imported manually with sufficient instructions in section 9.3.3 of the user guide. However, as mentioned above it is recommended to introduce an automated process to import the inputs, in order to avoid ambiguities and errors.

Also, an ambiguity has been identified in the “Summary by DStrata” tab of the” “V-Prod” spreadsheet. While in this tab, it is mentioned in the cover section of this tab (see **Figure 7.3**) that there are red boxes for self-checking, there are no such cells.

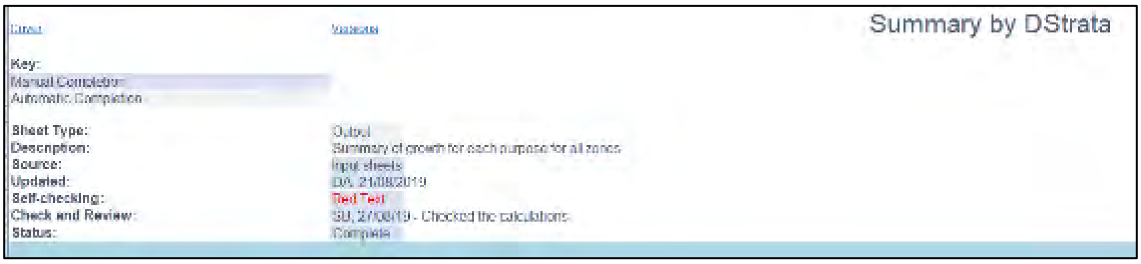


Figure 7.3: Cover of “Summary by DStrata” tab of the “V-Prod” spreadsheet

- Therefore, it is suggested to remove that reference for the tab.

The “V-Attn” spreadsheet works in the same manner as the “V-Prod” one. However, the VISUM version files included in the handover package, have no function in the procedure sequence to export the necessary inputs needed to update the “V-Attn” spreadsheet.

- Hence, the procedure sequence should be updated in order to export the following attribute files:

X V-Attn_Attns.att; and

X V-Attn_Inputs.att.

Likewise, the attribute files imported in the “V-AttCheck” spreadsheet are not exported in the received VISUM version files.

- ➢ Hence, the procedure sequence should be updated in order to export the following attribute files:

  X V-AttCheck_Inputs.att; and

  X V-AttCheck_Outputs.att.

The “V-TE_P” and “V-TE_A” spreadsheets analyse the production and attraction trip ends respectively from the VDM by mode and purpose for the scenario run and the comparator one. The spreadsheets work as expected and in line with the instructions reported in section 9.3.6 of the user guide, apart from two issues identified after their use.

First of all, as mentioned before, in the “Import” tab of both spreadsheets, the names of the VISUM attribute files used as inputs in the spreadsheet are inconsistent with the name of the version file. This results in the VBA macro used to import the inputs crashing.

- ➢ In order to address the issue, the name of the B22 and B30 cells in the “Import” tab should change, as the model output user should not type the version name but the name of the related attribute file names.

Furthermore, it is observed that in the “NTMv5 V-TE_P RunA246_vs_A244 v2.0.xlsm” spreadsheet, the status of the “PA Summary Tables” tab is mentioned as “To be checked” (see **Figure 7.4**).

Cover	Versions	PA Summary Tables
Key:		
Manual Completion		Created for OS17 Reporting, not finalised for general use.
Automatic Completion		
Sheet Type:	Output	
Description:	Summary tables by mode, purpose to go into Sensitivity Test Analysis note	
Source:	'Sector Summary' sheet	
Updated:	SFA, 19/07/19	
Self-checking:	Ran through existing spreadsheet to check values were following through correctly	
Check and Review:		
Status:	To Be Checked	

Figure 7.4: Cover of “PA Summary Tables” tab of the “NTMv5 V-TE_P RunA246_vs_A244 v2.0.xlsm” spreadsheet

This creates ambiguity to the model output user and confusion whether this tab is correct, and its results could be trusted. It should, also, be highlighted that there is no mention of this tab in the relevant section of the user guide.

- ➢ Hence, it should be made clear whether the “PA Summary Tables” tab has been checked and add a reference of this tab in the relevant section of the user guide.

In the pivoting analysis section of the model outputs, there are two related spreadsheets; the “P-TLD” and the “P-Sparsity” one.

The “P-TLD” spreadsheet includes comparison of the trip length distributions between the base, synthetic base, synthetic forecast, pivoted forecast and normalised forecast matrices by user class and time period. The spreadsheet works in a similar manner to the “V-TLD” one. Hence, the same issues are observed as in the “V-TLD” spreadsheet and mentioned above in this section.

The ”P-Sparsity” spreadsheet analyses the pattern of growth across sections of the base matrices, assessing the impact of additive growth. The spreadsheet works as expected and reported in the section 9.4.2 of the user guide. However, in the “Import” tab of the spreadsheet, the name of the version file is inconsistent with the VISUM attribute files, which imported as inputs in the spreadsheet. Hence, the model output user should not type the version name but the name of the related attribute file names, in order to import the files in the spreadsheet.

Also, it is noticed that the relevant VISUM attribute files are produced only for the final iteration of the model run and not for the rest. In the user guide, there is no reference to this fact, and hence an ambiguity is created to the model user whether this is as expected.

- It is recommended to add an explanation either in the relevant section of the user guide or in the cover page of the “P-Sparsity” spreadsheet why just the VISUM attribute files of the last iteration are imported.

7.3.5. HAM Analysis

In the HAM analysis section of the model outputs, there are two related analysis spreadsheets and four plots/maps-related analysis.

The ”H-VehKm” spreadsheet analyses the number of vehicle kms travelled on the network. It provides to the model output user the option to compare the scenario run against a comparator run (with the same issues identified and explained above). Also, it contains 2015 road traffic statistics, allowing the comparison of the modelled and observed flows.

However, the “RoadKMvsNationalStats” tab of the spreadsheet is not updated when new modelled data are imported. There is, also, no reference to this tab in the user guide and therefore, it is ambiguous to the model output user.

- It is recommended the “RoadKMvsNationalStats” tab to be linked to the imported data or removed. If the tab is needed, then more information should be provided in the user manual and a cover page should be added in the spreadsheet.

Finally, it has to be stressed that the inputs in the spreadsheet are imported manually. It would have been preferable to have an automated process, making the process more robust and less exposed to processing errors.

The ”H-Sect” spreadsheet analyses the sectored aggregations of the highway matrices by user class and time period. The spreadsheet works with exactly the same manner as the “V-Sect” one, and therefore, the same issues have been noticed for its use.

7.3.6. Map analysis

Regarding the plots/maps-related analysis, the volume/capacity ratio maps (H-VCMap) and the select link analysis plots (H-FlBnd) are considered to be straightforward for reproduction with useful instructions in the user guide being provided. The relevant graphic parameters are, also, being provided and imported in the VISUM interface in order to produce the plots/maps.

However, the instructions in the user guide related with the traffic flow maps (H-FlMap) and the speed maps (H-SPMap), are not adequate to produce the plots. Although the relevant graphic parameter files are available and provided to the model output user, there is not enough information on how to create version comparisons VISUM files.

- In order to produce the traffic flow and speed maps, more information is needed mainly regarding how the comparison version files should be created and which VISUM attributes should be considered.

Finally, regarding the plot of trip ends comparison in the VDM analysis, either the productions or attractions are being used. Although there are plots from previous runs and the graphic parameters file in the handover package, there is no reference for this plot or instructions on how to produce it in the user guide.

- Reference should be added in the user guide, regarding the trip end comparison plots and how they should be generated.

7.4. Future Year Trip-End Growth

In an attempt to produce a set of trip ends for 2040 using the NTMv5 trip end forecasting tool written in Python by the model developers, the model auditors were unable to run the process successfully due to two major errors in the process. A minor issue was initially fixed which has led to the other errors. These are the following:

1. An incompatibility in line 11 with the pyodbc.connect in section 2.1.2 of the Jupyter notebook. This is a result of incompatibility between Anaconda (Python) (64bit) and Microsoft Access (32bit) which was fixed by the model developers in order to continue with the running of the process. However, there are no instructions about the bit version of Anaconda (Python) and Microsoft Access either in the user guide (section 7.8.1) or in the Developer Guide Volume 5 (Section 6.14, 6.15).
2. An error in section 2.3.5 of the python code with an error message of: "Cannot operate inplace if there is no assignment". In the case of removing the argument "inplace=TRUE", the code runs until section 2.4.1, where an error is encountered again suggesting that removing "inplace=TRUE" is not the right approach as it does not allow to create new column/process the data appropriately to run the code.
3. A subsequent error in line 11 with the pyodbc.connect in section 2.1.2 of the Jupyter notebook. This might be related to the environment of Jupyter notebook. However, there are no useful instructions how to address this error either in the user guide (section 7.8.1) or in the Developer Guide Volume 5 (Section 6.14, 6.15).

As a result, producing a set of trip ends for 2040 using the process developed by the model developers has not succeeded.

7.5. Sensitivity Test 1- Demand Growth

As described in Section 7.4 it was not possible to re-run the python process and produce a set of trip ends for the future year 2040 based on NTEM. Hence, in this sensitivity test, the trip ends for the future year 2030 (i.e. the scenario year of the baseline model run) have been increased by 10%.

The trip end changes have been applied in the VISUM version file, increasing the growth factors by zone and purpose in the attribute list. However, it should be mentioned that there were no clear instructions either in the user guide or in the developer guides about the implementation of these changes in VISUM.

- It is recommended to add text in the relevant chapter of the user guide regarding the implementation of the trip end changes in the model.

Table 7.3 presents the trip changes between the baseline model run and this sensitivity test. As expected, across all modes there is an increase in trips of exactly 10% as the trip end increase in this model run. However, due to the congestion, the increase in the car driver and passenger trips is less than 10%. Hence, as a result of the mode shift in the VDM, the bus and rail trips are being increased by more than 10%.

Looking at the vehicle km differences (see **Table 7.4**), the outcome mentioned above is even more apparent, since the distribution model in VDM is more sensitive than the mode choice model. Hence, again because of the congestion, the car driver and car passenger vehicle km increase is less than 10% (and less than the trips increase), which the bus and rail vehicle km increase is more than 10% and slightly more than the trip increase.

Table 7.3: Trips changes between baseline and sensitivity test 1 model runs (final iteration) according to "Trip Summary" tab of the "M-MatList" spreadsheet

Purpose	All Modes	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	10.0%	8.9%	9.1%	12.9%	12.5%	12.8%	12.4%
HbEd	10.0%	9.2%	8.8%	10.8%	11.0%	10.9%	10.8%
HbShopPB	10.0%	9.6%	9.2%	11.3%	11.5%	11.3%	11.2%
HbRecV	10.0%	9.6%	9.2%	11.5%	11.7%	11.5%	11.4%
HbHol	10.0%	9.6%	9.3%	12.4%	12.6%	12.2%	12.1%
HbEB	10.0%	9.2%	8.6%	12.8%	13.5%	12.8%	12.5%
NHbEB	10.0%	9.5%	8.8%	11.5%	11.8%	11.6%	11.5%
NHbO	10.0%	9.8%	9.7%	10.4%	10.5%	10.4%	10.4%
Total	**10.0%**	**9.4%**	**9.2%**	**11.4%**	**12.0%**	**11.9%**	**11.0%**

Table 7.4: Vehicle kms changes between baseline and sensitivity test 1 model runs (final iteration) according to “Km Summary” tab of the “M-MatList”

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	7%	8%	13%	13%	13%	13%
HbEd	7%	7%	11%	11%	11%	11%
HbShopPB	8%	7%	11%	11%	11%	11%
HbRecV	8%	8%	12%	12%	12%	11%
HbHol	9%	8%	13%	13%	12%	12%
HbEB	8%	7%	13%	13%	13%	13%
NHbEB	8%	7%	12%	12%	12%	12%
NHbO	8%	8%	10%	10%	10%	10%
Total	**7.7%**	**7.6%**	**11.5%**	**12.1%**	**12.2%**	**11.1%**

The table shown in **Table 7.5**, which is extracted from the “V-Prod” spreadsheet, validates the fact that the sensitivity test has been set up correctly, since the growth factor between the baseline run and the sensitivity test, in both the internal and external area, is exactly 10% (there is a slight rounding error for non-home-based external trips).

Table 7.5: Trip productions in the baseline and sensitivity test 1 model run according to "Summary by Purpose" tab of the "V-Prod" spreadsheet

Purpose	All			
	Base Productions	**Scenario Productions**	**Diff**	**Growth Factor**
HbW	13,687,169	15,055,886	1,368,717	1.10
HbEd	11,410,290	12,551,318	1,141,029	1.10
HbShopPB	18,958,282	20,854,110	1,895,828	1.10
HbRecV	10,680,452	11,748,497	1,068,045	1.10
HbHol	1,733,436	1,906,780	173,344	1.10
HbEB	2,087,404	2,296,145	208,740	1.10
NHbEB	1,523,520	1,675,872	152,352	1.10
NHbO	16,206,478	17,827,125	1,620,648	1.10
Total 24hr Trips	**134,844,065**	**148,328,471**	**13,484,406**	**1.10**

In spite of the lack of specific documentation, this test was relatively simple to initiate and appears to work as the user would expect.

7.6. Sensitivity Test 2- Highway Network

As part of this sensitivity test, the speed limit on the M3 motorway was increased to 80mph. As suspected, there was no link type defined in the model for a motorway with 80mph speed limit. To avoid defining and coding a new link type with a corresponding volume delay function, a workaround was implemented to use the same link type (with the same volume-delay function) with the free-flow speed manually changed for cars to 80mph (129km/h as implemented in Visum using the correct units).

It is worth noting that the model developers have reserved few link type slots for future use in case of a requirement to model link types which were not defined in the model previously. However, the model documentation has very limited information to guide a model user through the process of adding a new link type and associated volume-delay function.

Table 7.6 and **Table 7.7** present the vehicle km and average trip speed changes, as reported in the "M-MatList" spreadsheet. As expected, since the scheme introduced in this sensitivity test is of smaller scale and more local than the schemes in the other sensitivity tests, the impact on the overall network is very small. Nevertheless, it is obvious that the changes are in the expected directions and of plausible scale.

Table 7.6: Vehicle kms changes between baseline and sensitivity test 2 model runs (final iteration) according to "Km Summary" tab of the "M-MatList"

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	0.04%	0.00%	0.00%	-0.01%	0.00%	0.00%
HbEd	0.03%	0.03%	0.00%	-0.02%	0.00%	0.00%
HbShopPB	0.04%	0.07%	0.00%	-0.01%	0.00%	0.00%
HbRecV	0.06%	0.08%	-0.01%	-0.02%	-0.01%	-0.01%
HbHol	0.08%	0.13%	-0.04%	-0.07%	-0.03%	-0.03%
HbEB	0.05%	0.06%	0.00%	-0.02%	0.00%	-0.01%
NHbEB	0.16%	0.19%	-0.02%	-0.04%	-0.01%	-0.01%
NHbO	0.06%	0.09%	0.00%	0.00%	0.00%	0.00%
Total	0.05%	0.08%	0.00%	-0.02%	-0.01%	0.00%

Table 7.7: Average trip speed changes between baseline and sensitivity test 2 model runs according to "Avg Trip Speed Summary(Kph)" tab of the "M-MatList"

Purpose	Car Driver	Car Pass
HbW	0.0%	0.0%
HbEd	0.0%	0.0%
HbShopPB	0.0%	0.0%
HbRecV	0.0%	0.1%
HbHol	0.1%	0.1%
HbEB	0.1%	0.1%
NHbEB	0.1%	0.1%
NHbO	0.0%	0.1%
Total	**0.0%**	**0.1%**

Table 7.8 and **Table 7.9** show the results of the vehicle km comparison between the baseline model run and this sensitivity test by Government Region for motorway and A roads respectively from the "H-VehKm" spreadsheet. This analysis spreadsheet can

provide more insightful results than the “M-MatList” spreadsheet which reports high level totals across the whole model.

As it is observed in **Table 7.8**, there is an increase in vehicle km for the South East region of about 2%. This is an expected outcome, since the network intervention of this sensitivity test is related with the M3 motorway is located in the South East of the country. In no other Government Region or A road (see **Table 7.9**), is a substantial difference in vehicle km observed.

Table 7.8: Vehicle kms comparison by GoR between baseline and sensitivity test 2 model runs for motorways, according to “Comparator” tab of the “H-VehKm”

Motorway	**246_3**	**246_3S3**	**Difference**
North East	2.71	2.71	0%
North West	45.39	45.39	0%
Yorkshire and The Humber	26.56	26.56	0%
East Midlands	20.05	20.05	0%
West Midlands	30.50	30.50	0%
East of England	23.40	23.40	0%
London	6.44	6.44	0%
South East	56.66	57.69	2%
South West	27.06	27.03	0%
England	**238.77**	**239.76**	**0%**
Wales	4.83	4.84	0%
Scotland	0.01	0.01	0%
Great Britain	**243.60**	**244.62**	**0%**

Table 7.9: Vehicle kms comparison by GoR between baseline and sensitivity test 2 model runs for A roads, according to "Comparator" tab of the "H-VehKm"

A Road	246_3	246_3S3	Difference
North East	26.73	26.73	0%
North West	52.86	52.86	0%
Yorkshire and The Humber	48.09	48.09	0%
East Midlands	61.29	61.29	0%
West Midlands	55.47	55.47	0%
East of England	73.38	73.38	0%
London	41.97	42.03	0%
South East	93.15	92.97	0%
South West	56.01	56.07	0%
England	**508.98**	**508.98**	**0%**
Wales	14.19	14.19	0%
Scotland	0.00	0.00	0%
Great Britain	**523.17**	**523.17**	**0%**

Finally, **Figure 7.5** and **Figure 7.6** illustrate in a map around the area of the scheme, the flow and trip speed differences between the baseline model run and this sensitivity. It is clear from these plots that there is an increase in the trip speed along the motorway M3 and subsequently an increase in the traffic flows along this corridor. There are also visible decreases along parallel corridors. These plots demonstrate that the sensitivity test has been performed as expected.

Some of the other noticeable differences in the traffic flow, not in close proximity to the scheme, may be a result of modelling noise in the highway model. Given there are two or three short sections of road with large flow differences (larger than on the M3 itself), this suggest that there may be convergence noise issues in these areas.

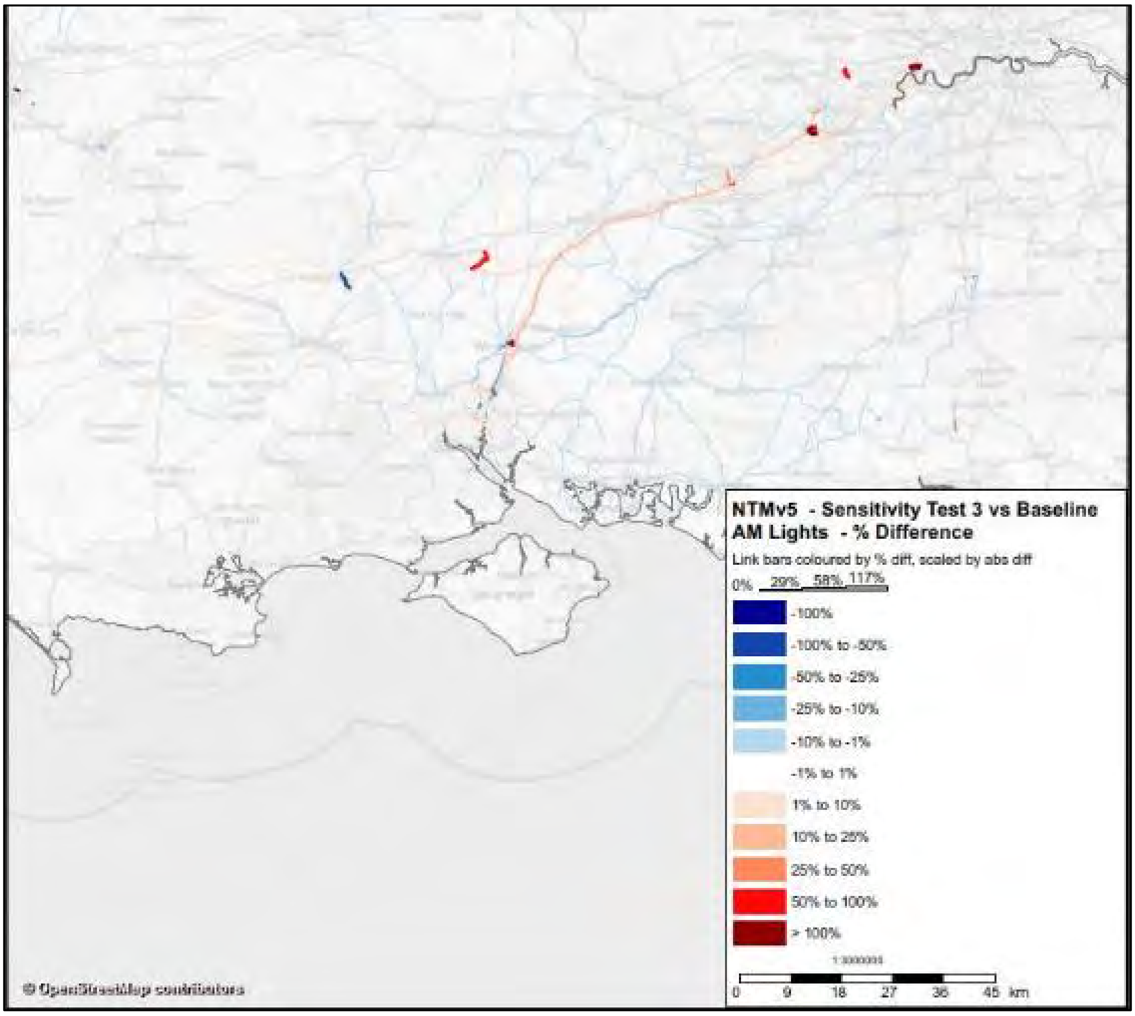


Figure 7.5: Flow differences in the wider area of M3 between the baseline run and the sensitivity test 2 model run

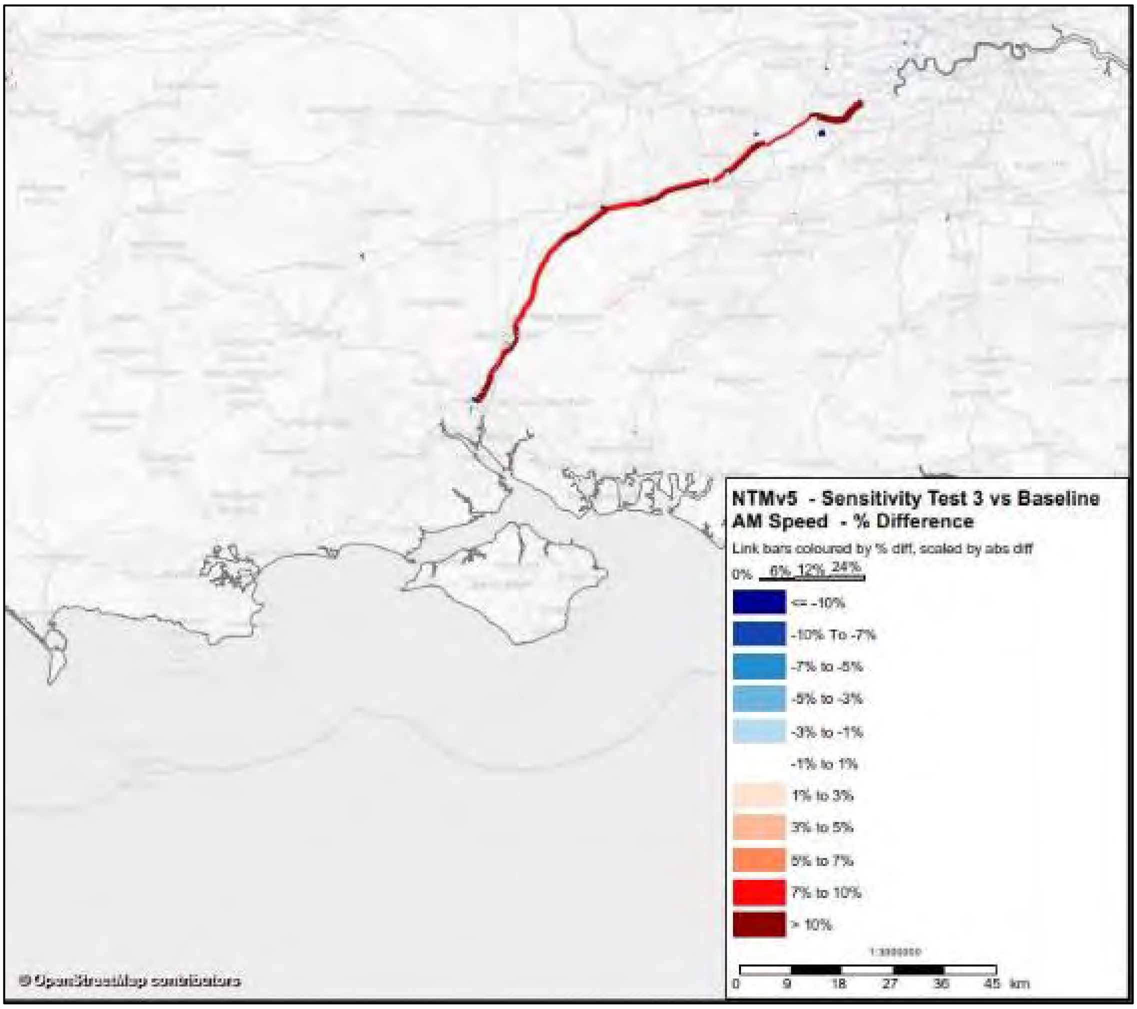


Figure 7.6: Speed differences in the wider area of M3 between the baseline run and the sensitivity test 2 model run

7.7. Sensitivity Test 3- Public Transport Changes

For this sensitivity test, the rail fare matrices have been halved while all the other model components remained intact. **Table 7.10** shows the rail fare matrices before and after the factor applied to them, as shown in the VISUM interface.

Table 7.10: Rail fare matrices in the original version file of Run246 model and in the sensitivity test 3 version file of Run246_S3 model

Rail fare matrices	Totals from Run246	Totals from Run246_S3
Rail AM OD Season	187,710,135,070	93,855,067,535
Rail AM OD Reduced	166,519,511,102	83,259,755,551
Rail AM OD Full	319,922,035,848	159,961,017,924
Rail IP OD Advanced	124,913,528,796	62,456,764,398
Rail IP OD Reduced	167,344,237,680	83,672,118,840
Rail IP OD Full	321,534,854,152	160,767,427,076

The matrix manipulations have been applied using the VISUM interface, being consulted by the VISUM manual. However, it should be noted that there were no instructions in the user guide or in the developer guides about how to update the rail fares in the model.

- Specific instructions should be provided to the model user about the rail fares and how they have been applied in the model. The detailed information should also include the format of the rail fares, since they could be either in a matrix format, as it is the case in NTM, or in a list attribute format.

The changes to rail fares have been applied in the baseline model run and the updated VISUM version file has been run to successfully produce this sensitivity test.

The first spreadsheet that the model output user should look at is the “M-MatList”, since it provides the high-level totals of the model run and compare them against the base one. **Table 7.11**, **Table 7.12** and **Table 7.13** provide the trip total, the average trip length and the average trip cost changes between the baseline model run and this sensitivity test as reported in this spreadsheet, respectively.

As expected, since there is no trip frequency response in the VDM, at all modes the trip totals remain the same. There is, also, a decrease in all other modes, except the rail trips which are being increased as a result of the mode shift response because of the significant reduction in rail fares.

Table 7.12 suggests that the average trip length for the rail trips has also been increased across all purposes, which is reasonable since the rail trips have become more attractive, increasing the willingness of the travellers to make longer rail trips since these trips are cheaper.

As shown in **Table 7.13**, the average trip cost changes are less than half, which is the rail fares reduction being applied in this sensitivity test. This is expected, since the average rail fare for every origin-destination (OD) movement has been halved, but also since the trips are now longer, the average cost across all passengers is less than halved.

Table 7.11: Trips changes between baseline and sensitivity test 3 model runs (final iteration) according to "Trip Summary" tab of the "M-MatList" spreadsheet

Purpose	All Modes	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	0.0%	-2.0%	-2.7%	-5.5%	23.5%	-5.6%	-3.7%
HbEd	0.0%	-1.4%	-1.4%	-3.6%	69.3%	-2.0%	-1.7%
HbShopPB	0.0%	-1.3%	-1.9%	-2.0%	98.3%	-2.1%	-2.0%
HbRecV	0.0%	-1.8%	-2.7%	-3.0%	72.9%	-3.0%	-2.9%
HbHol	0.0%	-3.4%	-4.1%	-4.3%	62.2%	-4.1%	-4.1%
HbEB	0.0%	-3.6%	-4.6%	-4.4%	32.1%	-4.4%	-4.1%
NHbEB	0.0%	-2.0%	-2.3%	-2.5%	38.3%	-2.5%	-2.5%
NHbO	0.0%	-0.4%	-0.3%	-0.3%	16.6%	-0.4%	-0.4%
Total	**0.0%**	**-1.5%**	**-1.8%**	**-2.9%**	**42.5%**	**-3.7%**	**-1.6%**

Table 7.12: Average trip length changes in km between baseline and sensitivity test 3 according to "Avg Trip Length Summary" tab of the "M-MatList"

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	-0.01	0.00	-0.06	3.42	-0.07	-0.02
HbEd	-0.04	-0.04	-0.06	21.82	0.00	0.00
HbShopPB	0.02	0.03	-0.01	1.79	0.00	0.00
HbRecV	0.02	0.03	-0.01	9.94	0.00	0.00
HbHol	-0.01	0.02	-0.05	21.68	0.00	0.00
HbEB	-0.13	-0.24	-0.04	19.80	-0.01	0.00
NHbEB	0.08	0.25	-0.01	4.23	0.00	0.00
NHbO	0.01	0.03	-0.01	6.80	0.00	0.00
Total	**-0.04**	**-0.03**	**-0.04**	**7.88**	**-0.04**	**0.00**

Table 7.13: Average trip cost changes between baseline and sensitivity test 3 model runs according to "Avg Trip Cost Summary" tab of the "M-MatList"

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	-0.4%	-0.3%	-0.6%	-43.9%	N/A	N/A
HbEd	-0.7%	-0.7%	-0.7%	-20.2%	N/A	N/A
HbShopPB	0.1%	0.2%	-0.1%	-47.4%	N/A	N/A
HbRecV	0.1%	0.1%	-0.1%	-38.1%	N/A	N/A
HbHol	0.0%	0.0%	-0.2%	-29.7%	N/A	N/A
HbEB	-0.5%	-0.8%	-0.3%	-23.2%	N/A	N/A
NHbEB	0.3%	0.5%	0.0%	-39.7%	N/A	N/A
NHbO	0.2%	0.3%	-0.1%	-40.7%	N/A	N/A
Total	**-0.6%**	**-0.3%**	**-0.4%**	**-37.5%**	**N/A**	**N/A**

For this sensitivity test, HAM results and the relevant spreadsheet are not very helpful since in this sensitivity test, a rail scheme has been implemented.

However, the TLD spreadsheet provide useful insights regarding the trip pattern changes in this sensitivity test. **Figure 7.7** and **Figure 7.8** show the trip length distribution of the rail trips for the HBW and HbEd purposes, respectively, as reported in the "V-TLD" analysis spreadsheet.

As it is observed from the figures below, the difference in the HBW trips, in terms of trip length, between the sensitivity test (246_3S2) and the baseline model run (246) is smaller than in the HbEd trips. In the education segment (see **Figure 7.8**), there is a dramatic increase in the very long-distance trips. This is slightly concerning; an increase of around 10 times in trips does not seem a plausible outcome of even so dramatic a reduction in fares as 50%. The increase is, however, still relatively small in absolute terms; the results may be robust for some purposes and it may respond more plausibly to smaller more likely fare policy changes.

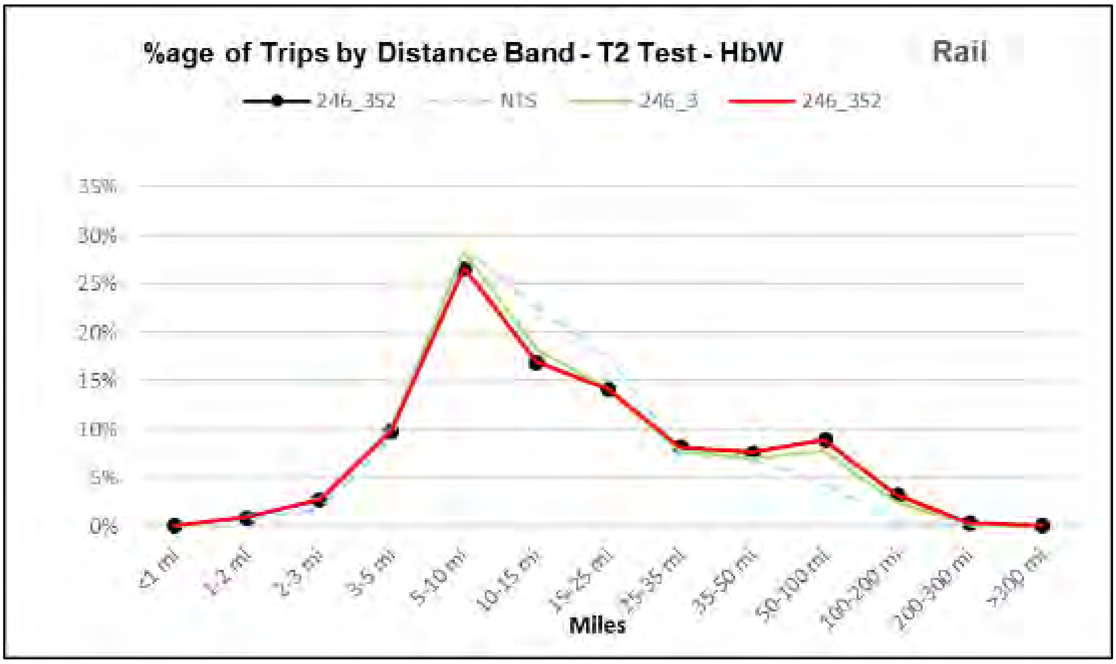


Figure 7.7: Rail HBW Trip Length Distribution of baseline and sensitivity test 3 model runs, according to "HbW" tab of the "V-TLD" spreadsheet

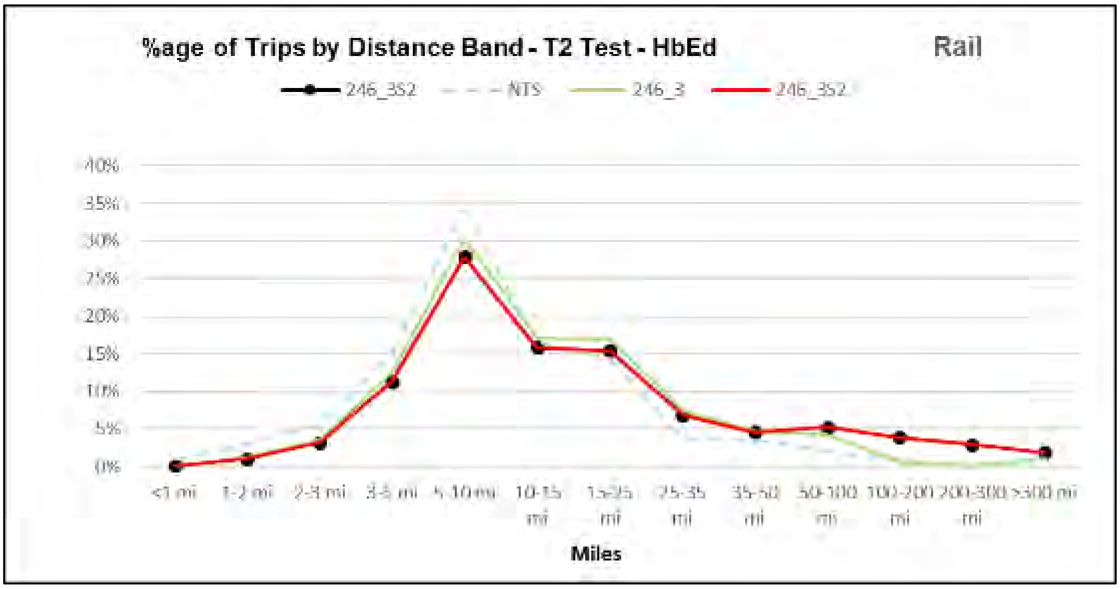


Figure 7.8: Rail HbEd Trip Length Distribution of baseline and sensitivity test 3 model runs, according to "HbEd" tab of the "V-TLD" spreadsheet

Although the instructions about how to set up this sensitivity test were relatively poor, the analysis spreadsheets have been found useful to understand the model outputs and the overall response in the scheme implementation.

7.8. Sensitivity Test 4- Economic Parameter Changes

As part of this sensitivity test, the economic parameters used for the version file of Run246 model and sourced from TAG databook of December 2017 was changed to use the TAG databook of May 2019.

The value of time and vehicle operating costs are being controlled through the "*NTM Model Parameters - Scenario Example v1.0.xlsm*" spreadsheet, which contains the relevant tables from the databook. Also, instructions on how to change the model parameters and use this spreadsheet are provided in the sections 4.8 and 7.10 of the NTMv5 User Guide.

The spreadsheet is well-structured; however, we have found that there are some ambiguities about its use. In particular, in the section 7.10.1.3 of the NTMv5 User Guide, it says that "*The VOC parameters for the VDM are updated by pasting the cells highlighted in blue and labelled 'Mode parameters' in the ActPair & Mode Output sheet into a mode list in Visum as described in Section 8.5.*". However, when the relevant tables are updated as part of the updates in the new databook of May 2019, the cells highlighted blue and labelled "Activity Pair Parameters" also change; these too should be imported in the VISUM version file. The user guide does not mention this tab.

- It should be made clear in the relevant section of the user guide which tables from the spreadsheet have to be imported in the version file when there are economic parameters changes. Based on the changes made in the "NTM Model Parameters - Scenario Example v1.0.xlsm" spreadsheet, both "Mode Parameters" and "Activity Pair Parameters" tables should be pasted in the VISUM version files.

Also, it is observed that when the databook tables are updated in the spreadsheet "*NTM Model Parameters - Scenario Example v1.0.xlsm*", the values of the highlighted blue sheets "*PerGrps Output*" and "*DStrata Output*" do not change (these represent fitted value from RAND's demand models).

- It would be helpful to mention explicitly in the user guide that the "PerGrps Output" and "DStrata Output" sheets do **not** need to be imported in VISUM when the TAG databook tables are updated.

Finally, in the sheet "HAM GenCost" of the spreadsheet "*NTM Model Parameters - Scenario Example v1.0.xlsm*", the growth factor for the future year 2030 is pasted "as value" without being able to trace its source in the spreadsheet. According to the spreadsheet, this factor exists in the spreadsheet "T1 Forecast VoT Factors v0.1.xlsm". However, this spreadsheet cannot be located neither in the handover package nor in any reference in NTMv5 User Guide.

- The "T1 Forecast VoT Factors v0.1.xlsm" spreadsheet is essential when the TAG databook tables are updated, hence it should be included in the handover package (ideally as part of the main NTM Model parameters spreadsheet) and linked to the calculations.

As part of this sensitivity test, the growth factor changes as the TAG databook tables are updated. Also, this factor affects the value of time (VoT) parameters by highway user classes introduced in the model. Hence, since there is no reference of this factor and its impact anywhere in the user guide or the handover package, the model user currently has to manually update it through the TAG databook spreadsheet.

- It is recommended to include specific instructions in the user guide about the growth factors and its impact in the model parameters.

The updated tables and parameters were added in the version file and the 2030 forecast year Run246 model has been run. **Table 7.14** and **Table 7.15** show the changes in value of time (VoT) and vehicle operating cost (VOC) parameters between the baseline model run and this sensitivity test. Also, **Figure 7.9** and **Figure 7.10** illustrate the resulting changes in mode and activity pair parameters input to VISUM.

Table 7.14: Changes of 2030 VoT parameters TAG May2019 minus TAG Dec2017

AUC	AM VoT (£/hr)	IP VoT (£/hr)	PM VoT (£/hr)
CC	-1.166%	-1.166%	-1.166%
CB	-1.166%	-1.166%	-1.166%
CO	-1.166%	-1.166%	-1.166%
LGV	-1.166%	-1.166%	-1.166%
HGV	-1.166%	-1.166%	-1.166%

Table 7.15: Changes of 2030 VOC parameters TAG May2019 minus TAG Dec2017

AUC	VOC (fuel)	VOC (non-fuel)	VOC (pence per km)	VOC (pence per metre)
CC	5.068%	N/A	5.068%	5.068%
CB	2.772%	-0.153%	1.062%	1.062%
CO	5.068%	N/A	5.068%	5.068%
LGV	4.278%	-0.153%	1.959%	1.959%
OGV1	-25.183%	-0.153%	-16.299%	-16.299%
OGV2	-18.902%	-0.153%	-11.668%	-11.668%
HGV	-20.673%	-0.153%	-12.928%	-12.928%

$VISION						
$VERSION:VERSNR	FILETYPE	LANGUAGE	UNIT			
10	Att	ENG	KM			
$MODE:CODE	FUEL_PARAM_A	FUEL_PARAM_B	FUEL_PARAM_C	FUEL_PARAM_D	NON_FUEL_PARAM_A1	NON_FUEL_PARAM_B1
Bus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CB	-40.46%	57.88%	163.00%	78.30%	-0.15%	-0.15%
CB_Pax	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CC	-40.46%	57.89%	163.00%	78.30%	0.00%	0.00%
CC_Pax	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CO	-40.46%	57.89%	163.00%	78.30%	0.00%	0.00%
CO_Pax	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cycle	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HGV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
LGV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rail	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Walk	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Figure 7.9: Changes of mode parameters between the baseline run and the sensitivity test 4 model run

$VISION					
$VERSION:VERSNR	FILETYPE				
10	Att				
$ACTPAIR:CODE	NAME	GEN_COST	GEN_LNCOST	U_CAR	U_RAIL
HbEB	Homebased Employers Business	1.07%	1.07%	0.00%	0.00%
HbEd	Homebased Education	1.07%	1.07%	0.00%	0.00%
HbHol	Homebased Holiday & Day Trip	1.07%	1.07%	0.00%	0.00%
HbShopPB	Homebased Shopping & Personal Business	1.07%	1.07%	0.00%	0.00%
HbRecV	Homebased Recreation/Social & Visiting	1.07%	1.07%	0.00%	0.00%
HbW	Homebased Work	1.07%	1.07%	0.00%	0.00%
NHbEB	Non-homebased Employers Business	0.00%	0.00%	-1.06%	-1.06%
NHbO	Non-homebased Other	1.07%	1.07%	0.00%	0.00%

Figure 7.10: Changes of activity pair parameters between the baseline run and the sensitivity test 4 model run

The VoT in this sensitivity test across all segments is lower that the baseline which means that the generalised costs are higher. The VOC are also higher in this scenario run for all the car user classes but not for heavy goods vehicles. Although the VOC for the HGV trips are lower, this change should not have any impact in the VDM since the HGV trips are frozen, according to the user guide.

In principle any change to the TAG databook that affects the model base year 2015 should necessitate re-running the base 2015 VDM to create an incremental adjustment point. As the base model changes are very small in this case, we did not do this; only the 2030 model was re-run.

- Specific advice in the user guide regarding when it is appropriate to re-run the base model, especially relating to changes in economic scenario, might be helpful.

Table 7.16 and **Table 7.17** present the trip changes and the vehicle km changes, according to the “M-MatList” spreadsheet, as a result of the updates in the model parameters.

As expected, the car demand (both car drivers and car passengers) has been supressed because of the increase in the generalised costs and the VOC. However, the total bus and rail trips are being increased. This might be reasonable, because of the mode shift caused by the significant increase in the VOC, which outweigh the very small changes in VoT (the larger car vehicle operating cost increases do not affect bus and rail, of course).

The active travel demand is being increased even further, since the changes in the model parameters do not affect the active modes at all and therefore cycle and walk trips are increased because of the demand response in all the other modes.

Investigating the trip changes by purpose, as expected, the reduction of VoT and VOC has less effect on the business and commuting car driver trips, since these demand segments have the highest VoT in the baseline, so they are less sensitive in these changes. On the other hand, the education and shopping trips are expected to be the most sensitive in VoT, since they had the lowest VoT in the do minimum scenario.

It is also notable that the reduction in car passenger trips is less than that of the car driver trips. This could be explained by the non-linear relationship between the VOC and the number of passengers in the vehicle which suggests that an increase in the VOC could result in an increase in the vehicle occupancy.

Considering the bus demand, the VoT decrease results in bus demand suppression, however this is outweighed by the significantly higher increase in car fuel cost. Hence, it is considered plausible the overall increase in the bus demand.

The overall rail demand is being increased slightly less than the bus demand, which can be explained by the fact that the rail fare is a larger component of rail cost than bus fare is of bus cost; this affect the perception of travel cost more than a change in VoT.

In the vehicle km summary (see **Table 7.17**), the decrease in car driver vehicle km is more than the decrease in trips, since the trip distribution response is considered bigger than the mode choice one in the VDM.

Although the bus trips are being slightly increased, the higher perceived cost of travel has shortened the bus trips, hence, the decrease in the bus vehicle km is believed to be reasonable. The same concept is also applied to the rail vehicle km response.

Finally, since there is no reason for a distribution response in the active modes, the changes in the vehicle kms are very similar with the trip changes.

Table 7.16: Trips changes between baseline and sensitivity test 4 model runs (final iteration) according to "Trip Summary" tab of the "M-MatList" spreadsheet

Purpose	All Modes	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	0.0%	-0.4%	0.5%	0.4%	0.2%	1.5%	1.4%
HbEd	0.0%	-1.7%	-1.1%	-0.7%	-0.7%	2.1%	2.0%
HbShopPB	0.0%	-1.3%	-1.3%	0.9%	0.5%	5.3%	5.2%
HbRecV	0.0%	-0.7%	-0.3%	0.3%	0.0%	2.2%	2.1%
HbHol	0.0%	-0.5%	0.3%	0.2%	0.2%	1.4%	1.4%
HbEB	0.0%	-0.1%	0.3%	0.1%	-0.3%	1.2%	1.2%
NHbEB	0.0%	-0.4%	0.6%	0.8%	0.4%	1.3%	1.2%
NHbO	0.0%	-0.3%	-0.2%	0.0%	-0.1%	0.5%	0.5%
Total	**0.0%**	**-0.7%**	**-0.6%**	**0.2%**	**0.1%**	**1.9%**	**2.1%**

Table 7.17: Vehicle kms changes between baseline and sensitivity test 4 model runs (final iteration) according to "Km Summary" tab of the "M-MatList"

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	-0.9%	0.5%	0.2%	0.1%	1.6%	1.4%
HbEd	-2.2%	-0.9%	-1.3%	-1.1%	2.2%	2.1%
HbShopPB	-1.8%	-1.4%	0.3%	0.4%	5.3%	5.3%
HbRecV	-1.4%	-0.5%	-0.2%	-0.3%	2.2%	2.1%
HbHol	-1.0%	0.1%	-0.2%	-0.2%	1.4%	1.4%
HbEB	-0.1%	0.4%	0.0%	-0.8%	1.2%	1.2%
NHbEB	0.2%	1.4%	0.8%	0.5%	1.3%	1.2%
NHbO	-0.8%	-0.4%	-0.5%	-0.4%	0.6%	0.5%
Total	**-1.0%**	**-0.5%**	**-0.3%**	**-0.2%**	**1.7%**	**2.1%**

7.9. Sensitivity Test 5- Urban Area Strategy Test

As part of this sensitivity test, the parking charges of three major metropolitan areas have been increased by £2. In particular, the changes have been applied to the variables shown in **Table 7.18**, for the metropolitan areas of Birmingham, Leeds and Liverpool.

Table 7.18: Parking Charges Variables in the Zone Attribute List

Attribute List Variables
HBEB_PARKING
HBED_PARKING
HBHOL_PARKING
HBRECV_PARKING
HBSHOPPB_PARKING
HBW_PARKING
NHBEB_PARKING
NHBO_PARKING

However, it should be mentioned that there was no information in the user guide about how to update the parking charges in the model. Although, there is a reference in the Quality report (see section 15.6.2) and the Developer Guide Vol6-Testing (see section 7.3) to parking charges, no specific instruction was provided regarding which variables the model user should change and how this could be done in VISUM.

- It is recommended to add either in the user guide or in the Developer Guide Vol6, detailed instructions to the model user about potential changes in parking charges (considering both the implementation in VISUM and the list of variables needed).

The updated zone attribute list was imported in the version file and the 2030 forecast year Run246 model has been run to generate the sensitivity test 5 model run.

As expected, an increase is observed in the bus and rail demand of a larger scale than the decrease of the car demand (see **Table 7.19**). Likewise, similar conclusions are drawn for the vehicle km (see **Table 7.20**), except for the car passengers, which might also be explained by increased car-sharing due to the increase of parking charges.

The average speed of the car trips is also increased (see **Table 7.21**), which is reasonable since there should be a congestion relief in the city centres because of the decrease of traffic caused by the increase of the parking charges.

As a general comment, the smaller the scheme, the more difficult might be for the model run to converge. This will be particularly true if the effect is small, but global (e.g. a 1% increase in bus fares). Small localised schemes may return robust results within the local area.

Table 7.19: Trips changes between baseline and sensitivity test 5 model runs (final iteration) according to "Trip Summary" tab of the "M-MatList" spreadsheet

Purpose	All Modes	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	0.0%	-0.4%	0.0%	1.1%	0.6%	1.1%	0.8%
HbEd	0.0%	-1.3%	-1.2%	0.9%	0.9%	1.3%	1.1%
HbShopPB	0.0%	-0.8%	-0.9%	1.9%	2.0%	2.2%	1.9%
HbRecV	0.0%	-0.4%	-0.3%	1.0%	0.7%	1.1%	0.9%
HbHol	0.0%	-0.2%	0.0%	0.5%	0.4%	0.5%	0.4%
HbEB	0.0%	-0.1%	0.0%	0.3%	0.2%	0.4%	0.3%
NHbEB	0.0%	-1.1%	-0.1%	3.9%	1.5%	3.2%	3.2%
NHbO	0.0%	-0.3%	-0.2%	0.4%	0.5%	0.4%	0.4%
Total	**0.0%**	**-0.5%**	**-0.6%**	**1.3%**	**0.7%**	**1.0%**	**1.0%**

Table 7.20: Vehicle kms changes between baseline and sensitivity test 5 model runs (final iteration) according to "Km Summary" tab of the "M-MatList" spreadsheet

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	-0.3%	0.1%	1.2%	0.6%	1.2%	1.0%
HbEd	-0.5%	-0.5%	0.8%	0.4%	1.3%	1.3%
HbShopPB	-0.3%	-0.2%	1.8%	1.5%	2.3%	2.3%
HbRecV	-0.3%	-0.1%	0.9%	0.6%	1.1%	1.1%
HbHol	-0.1%	0.1%	0.5%	0.4%	0.4%	0.5%
HbEB	0.0%	0.1%	0.3%	0.2%	0.4%	0.4%
NHbEB	1.5%	1.7%	2.6%	2.2%	3.0%	3.2%
NHbO	0.2%	0.3%	0.5%	0.4%	0.5%	0.4%
Total	**-0.1%**	**0.0%**	**1.2%**	**0.6%**	**1.0%**	**1.2%**

Table 7.21: Average trip speed changes between baseline and sensitivity test model runs according to "Avg Trip Speed Summary(Kph)" tab of the "M-MatList"

Purpose	Car Driver	Car Pass	Bus	Rail	Cycle	Walk
HbW	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
HbEd	0.2%	0.1%	-0.1%	-0.2%	0.0%	0.1%
HbShopPB	0.1%	0.2%	-0.2%	-0.2%	-0.1%	0.2%
HbRecV	0.1%	0.1%	-0.1%	0.0%	0.0%	0.1%
HbHol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
HbEB	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NHbEB	0.4%	0.2%	-0.4%	0.4%	0.0%	0.1%
NHbO	0.1%	0.1%	0.0%	-0.1%	0.0%	0.0%
Total	**0.1%**	**0.1%**	**-0.1%**	**-0.1%**	**0.0%**	**0.1%**

Table 7.22 shows the sectored car trip changes between the baseline and the sensitivity model run. As expected, the increase of the parking charges in the metropolitan areas of Birmingham, Leeds and Liverpool resulted in a significant reduction of car trips produced in the sectors of West Midlands, W Yorks and Cheshire and Merseyside respectively.

Table 7.22: Car trip changes at sector level for sensitivity test 5 according to "Productions-Trips" tab of the "V-Sect" spreadsheet

Production Zones	Grand Total Trip Change
7001 Northumbria and Tees	121
7002 Cumbria and Lancs	277
7003 Manchester	596
7004 Cheshire and Merseyside	-60,347
7005 N and E York and N Lincs	162
7006 S Yorks	143
7007 W Yorks	-85,186
7008 Derbyshire and Notts	145
7009 Leics and Northants	251
7010 Lincolnshire	-12
7011 Hfordshire, Worcs and Warks	383
7012 Shrops and Staffs	251
7013 West Midlands	-130,534
7014 Norfolk and Suffolk	-34
7015 Cambs, Pborough and Beds	-45
7016 Essex and Herts	103
7017 Inner London	34
7018 Outer London	238
7019 Berks, Bucks and Oxford	-1

It is observed from **Figure 7.11**, **Figure 7.12**, **Figure 7.13** and **Figure 7.14** a decrease of car flows in the metropolitan areas of Birmingham, Leeds and Liverpool. This outcome is plausible and as expected because of the increase in parking charges in the city centre of these areas. Also, an increase is noticed in other corridors which might be a result of rerouting because of the traffic flow reduction in the main roads crossing the city centres.

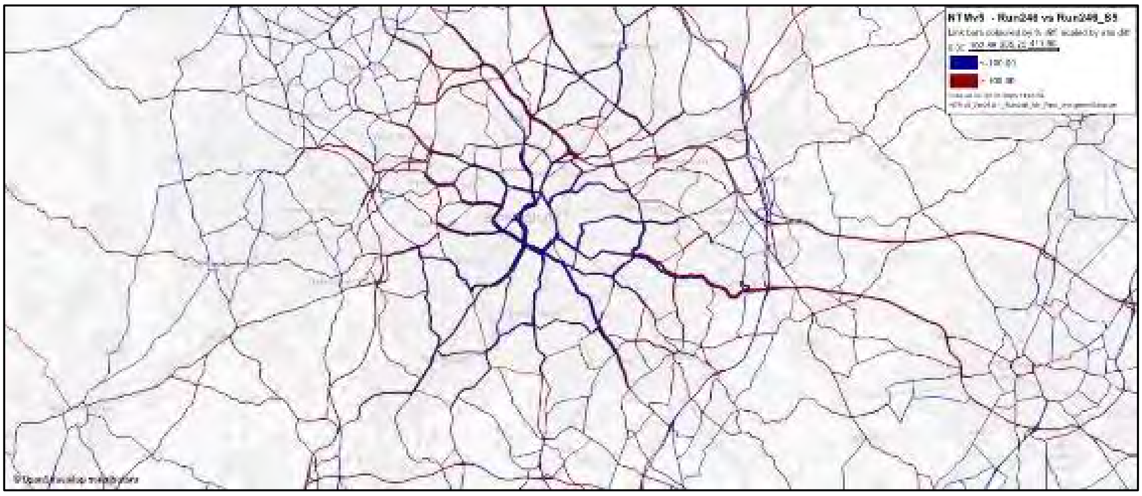


Figure 7.11: Flow differences in Birmingham between the baseline run and the sensitivity test 5 model run

Figure 7.12: Flow differences in Leeds between the baseline run and the sensitivity test 5 model run

Figure 7.13: Flow differences in Liverpool between the baseline run and the sensitivity test 5 model run

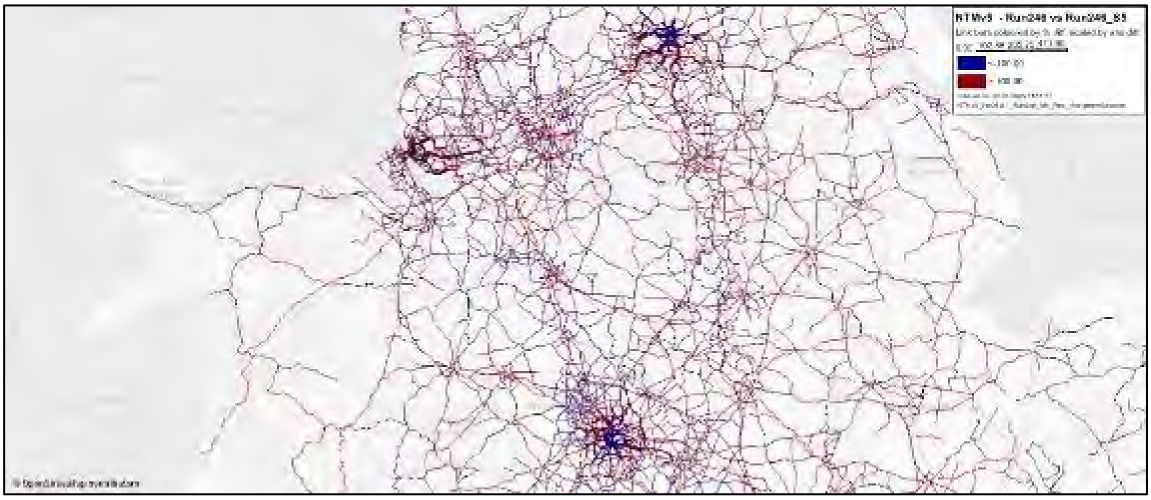


Figure 7.14: Flow differences in the wider area of Birmingham, Leeds and Liverpool between the baseline run and the sensitivity test 5 model run

7.10. Realism Testing

The VDM itself appears, on the basis of the reported realism test results to respond at the required sensitivity, both for highway and public transport cost changes. This is reassuring.

Unfortunately, the overall model elasticities, at the level of the actual traffic in the highway assignment matrices, are too high probably by around a third. This is because of inconsistencies in trip-length profiles, especially for very long trips, between the VDM demand and the base assignment demand.

Depending on the scenarios being tested, this could easily result in over-sensitive responses being derived.

- This discrepancy between VDM and calibrated assignment demand sensitivities needs to be carefully considered, and either appropriate advice given to users, or adjustments made to the model.

Users may need to consider running sensitivity tests with reduced demand model sensitivity, where appropriate.

7.11. Summary and Conclusions

As part of the audit of the NTM model use in VISUM, five sensitivity tests have been performed covering the following areas which are related with DfT's use cases:

1. Demand Growth;
2. Highway Network;
3. Public Transport Changes;
4. Economic Parameter Changes; and
5. Urban Area Strategy.

It is concluded that across all the sensitivity tests, there is often insufficient detail in the relevant chapters of the user guide and the developer guides regarding how to implement these and similar tests in VISUM. Hence, it is recommended to include specific instructions in the reports about the necessary inputs needed to run the sensitivity tests and how the inputs should be introduced in VISUM. The user guide could be updated "in use" as tests are required- this will ensure that it remains relevant to the actual use of the model in practice.

The fact that the model use section is not well-documented, is believed to be an important issue since NTM is a complicated model with more than 850 procedure sequences in VISUM. Therefore, with the lack of instructions and well-written documentation, it is difficult for the model user to use the model and apply the necessary changes for each scenario test.

Another significant issue which has been highlighted in the model use sections above is the model convergence, which is not measured. Although this might be a weakness of the VISUM software, the lack of evidence for the overall model convergence (i.e. the supply-demand iterations in NTM) leads to a lack of credibility for the overall model performance and subsequently for the outputs and insights derived from the model.

The run time of the suite as a whole and specifically of the HBW and HBEd choice models raise concerns for the model, particularly if tighter convergence is deemed necessary. In particular, the run times of these models are not only significantly higher than in any other demand segments, but also are being increased as the number of the supply-demand iterations is being increased. This is presumably related to the double-constraint process, but it is not clear why runtimes for these segments approximately double in each iteration of the demand-supply loop.

The available analysis spreadsheets and map analysis tools were updated, investigated and reviewed as part of the implementation of the sensitivity tests. Overall, the spreadsheets provide very useful information on the model outputs. However, some issues are noted in the sections above regarding errors in importing the data in the spreadsheets, spelling mistakes, missing units and inconsistencies between the instructions within the user guide and the analysis spreadsheets.

Apart from correcting these errors in the spreadsheets, it is recommended to automate all the functions in order to avoid errors and ambiguities.

Regarding the map analysis, although it is considered very useful to assess the plausibility of the forecasts, the available instructions in the user guide could be improved. While the graphic parameters are being provided as part of the NTM handover package, in order to produce the necessary plots and maps, the map analysis heavily depends on the VISUM experience of the model output user.

Furthermore, it is worth mentioning that two analysis spreadsheets could not be updated since the relevant attribute files are not exported from the procedure sequence of the VISUM version files which are included in the handover package.

The final aspect of the model use audit is related with the plausibility of the model forecasts from the five sensitivity tests. The model outputs have been imported in the available analysis spreadsheets and relevant plots have been generated. Investigating these results, it is concluded that the sensitivity tests have been set up as expected and the model forecasts from all the sensitivity tests are in line with inputs of the scenario tests and the changes applied to the baseline model. However, it should be highlighted that since the review of forecasts plausibility is not the primary purpose of this review, a thorough investigation of all the outputs and model components have not been undertaken.

Additionally, the NTMv5 trip end forecasting tool could not be run due to a number of issues in the code which would require fixing to generate the output. Potentially additional errors could come up once these are corrected.

8. Audit Conclusions

This chapter contains our recommendations from the audit of NTMv5.

8.1. Advice for the Department

8.1.1. Model Implementation

In terms of network coding it is recommended that the department consider a review of the junction coding. A number of inconsistencies were found around the coding of junctions which would be likely to affect the detailed distribution of delay across the network. No specific consideration has been given to delays at dual carriageway merge nodes whilst inconsistencies were found in the coding of Urban Area Speeds including where junction delay coding had been included in these fixed speed areas, potentially double counting delay. It is difficult to quantify the level of possible distortion of network delays at a local level caused by these issues as the journey time calibration that has been achieved is based on very long routes. It is therefore possible that different local errors cancel each other out in the strategic context.

It is suggested that as part of any future model update the department considers a review of the zone loading. The audit raised a number of questions regarding how the zones were connected to the network, such as connectors being connected to motorways and A roads, more than one zone being loaded to the same point on the highway network, and crow fly distances being used for connector lengths. In order to remedy the issues, it is suggested a general review of zone loading is undertaken. Within this it is suggested that principle of attempting to load connectors on a secondary network (i.e. away from the SRN and MRN) is worth pursuing. This would provide the model user with the assurance that there is a higher order road network on which the flow and delay representation is likely to be of a higher standard. This would strengthen the model application across all use cases.

Until these issues are investigated further, or remedied, it is suggested that this model should not be used to consider local investment (UC3) without the need for bespoke local review by the model user. For use cases concentrating on the SRN (UC1), or those considering aggregate outputs (e.g. UC5) then the effect of these issues would be less significant, although it would still be recommended that results are considered at a suitably aggregate scale.

A numerical error that we recommend be fixed immediately has been found in the implementation of the incremental modelling and VDM-HAM linkage: it is critical that the script converting LGV synthetic future matrices for the IP period to IP average hour is corrected from 1/3 to 1/6.

The implementation of the VDM has been applied in an acceptable manner. There is no cost-damping applied to time or distance components of cost, except for non-home-based business trips. This was slightly concerning to us in a model covering the whole country and full range of trip-lengths; However, we have undertaken a sensitivity test in which speed changes are made to the whole network to explore this. The resulting changes in vehicle distance and trip-lengths do not appear unreasonable, so we are content that this is not a critical problem.

Gap calculation for the purpose of understanding model convergence is present in the procedure sequence but disabled. It is recommended that a manual implementation of the calculation should be attempted. We would advise that care is taken to explicitly inspect the convergence and stability of any conclusions regarding any use case.

It is recommended that to improve consistency of outputs, and to improve model accuracy consideration be given to removing the final assignment from the procedure sequence. The current approach saves run time in the VDM loop but adds an extra set of assignments at the end of the model run that could potentially be avoided. In this regard, a number of potential solutions have been suggested that could be investigated that may improve model convergence and/or reduce model run times, including the use of a warm start, tightening of convergence criteria incrementally within each run or implementing the latest Visum software upgrades.

8.1.2. Data Analysis

As noted earlier in Section 6.1, the audit of data processing element of NTMv5 model development was limited by lack of access to some of the key processes and the data used in the model development process. This is partly due to the fact that some of the model components and tools used to process the data are not owned by the Department. As a result, the processing used to develop the NTMv5 Base Year model cannot be fully traced and repeated, and the Base Year model cannot be rebuilt or updated without significant effort and cost to the Department.

Overall, it was found that processes used to assemble the data and generate the trip ends produce outputs that are largely consistent with source data and independent sources at spatially aggregate level. There were however discrepancies found and possible reasons behind them were discussed.

The main concern in the review of trip ends relate to large differences that were found between zonal trip ends in the NTM v5 and the NTEM. This suggests misallocations of trip ends between MSOAs within a district; alternatively, this may indicate uncertainty in NTEM zonal trip ends. As a result, spatially disaggregate outputs from the model in terms of zonal trips should not be relied on and used without verification and possible correction for errors. Representation of trips at aggregate levels (e.g. urban areas or districts) are expected to be adequate.

The process of developing matrices could only be partially reviewed and verified as many of the intermediate processes and files were not available. Whilst some of the results provided could be reproduced and verified, it is likely that most of the discrepancies found in the matrix development are due to lack of clarity in the documentation and gaps in the inputs provided rather than serious errors in the data processing. However, we are unable to confirm this; therefore, without further investigation this is an area of low to moderate risk that should be considered in model use cases.

A general observation in reviewing the matrix development process was lack of clarity in model documentation. There are a number of assumptions which are not adequately documented; these are discussed and recommendations are made to improve the documentation in Sections 4.3 and 6.2.

No significant issue was found in processing of count data to prepare the calibration and validation data set; they were generally found to be consistent with the source data as provided. However, the audit process was not able to reproduce the observed journey times sourced from Trafficmaster data. Whilst this is likely to be due to inconsistent input files, or intermediate processes and assumptions that were missing in the audit process, this cannot be verified due to lack of information; hence, without further investigation to verify this, this is an area of moderate risk that should be considered in all model use cases.

Bespoke validation criteria were defined to help ensure efficient use of the resource available to ensure a consistent quality of model performance was achieved across the country and in particular to place emphasis on the need to ensure that matrix estimation processes did not distort the prior demand matrices. The audit concurs with the importance of this focus. The documentation provided does not however provide the user with an understanding of how to interpret the accuracy of the model outputs. The ‘relaxed’ standards define a greater error tolerance. The user will need to consider the implication of these. It would be beneficial if the Department could set out the implications for different use cases; it is likely that the errors are random rather than bias and if so it is likely to be feasible to provide guidance on the level of aggregation at which model outputs should be used for different purposes.

Checks were undertaken to verify accuracy and consistency of monetary costs, parking costs, level of service data, and attraction data with the source data and the documentation. The parameters were found to have been implemented correctly and consistently with the documentation describing them. The detailed process of estimating choice model parameters could not be reviewed as no access was provided to the processes used for the estimation process. It was found that the trends obtained from the model developers’ NTS data processing is largely realistic and consistent with the results of the audit team following the process descriptions. In general, the main observation of the audit of NTS trip processing was lack of clarity in the documentation with regards to processing assumptions and definitions used.

8.1.3. Model Use

There are serious concerns about the overall supply-demand model convergence and the fact that this is not measured in any of the available analysis spreadsheet. Hence, detailed and specific criteria should be used and reported in order to provide enough evidence for the model convergence. The existing convergence criteria include only the doubly constrained distribution models and the highway assignment which are alone insufficient to inform the user fully about confidence that can be placed in outputs and insights derived from the model.

Also, it is important to mention that the user guide and the relevant developer guides should be enriched with more detailed instructions about how to implement changes in the NTM such as those covered by the sensitivity tests reported in chapter 7. The most practical approach may to be to update the user guide as applications arise; the application modellers will note any omissions or ambiguities in the user guide and updates can be targeted on the tests actually being run.

Furthermore, it is recommended to update some of the available analysis spreadsheets, not only to correct errors being noted in section 7.3 but also to automate the import of VISUM files to a greater degree.

There is critical issue with the running of NTMv5 trip end forecast tool which would allow producing trip ends for future years. To reproduce the forecast trip ends, DfT needs to ensure the reproducibility of the forecast tool provided and to ensure they have enough support from the documentation to resolve any potential issues.

Finally, it is suggested that the department investigate other ways of calculating the demand-supply gap for the model; the native VISUM module having failed to work. It may be possible to undertake a “manual” matrix calculation within the procedure sequence rather than using the explicit %Gap calculation procedure. It would highly desirable to understand how well NTMv5 does converge.

8.2. Advice for Users of the Model

As discussed in 5.4.3 users should ensure that VOC values are updated within any future year model run. This is easily achievable within the model, making refence to the TAG Databook, however the process is currently missing in the documentation in relation as to how so to do.

As described in 5.7.1 the model user should only run the model once within the procedure sequence to avoid any unintended errors arising in users model runs caused by the GV/PSV growth factoring. If the model procedure sequence is run multiple times, the effects of PSV factors will be combined and not reversed to the original values. Similarly if the model user runs the model multiple times but assumes that the importing of data was undertaken at the previous model run and does not need to be undertaken again, values of the freight matrices will not be restored, and the same factors will be applied multiple times.

As mentioned in section 7.3.4, the attribute files related with the analysis spreadsheets "V-Attn" and "V-AttCheck" are not exported from the procedure sequence which is included in the VISUM version files being received by DfT. Hence, changes in the procedure sequence by the model users should be made in order to export the relevant outputs from VISUM.

As detailed in section 7.4, model users need to ensure that the python scripts created are generic and / or provide enough guidance in the documentation on how to set up the environment for python scripts to run properly. This especially related to the forecast trip ends tool developed.

If undertaking a scenario or policy test at all similar to one of the sensitivity tests undertaken for this audit, consulting the relevant section of this report may be helpful in addition to the user guide.

Users should be wary both of model convergence, and sensitivity of long-distance trips, especially to time. Explicit review of model stability and robustness is advised for all applications. This might involve comparing the final and penultimate iterations of the NTM and considering whether differences between them are material relative to the conclusions being reported.

In the case of interventions likely to affect travel times across a very wide area, sensitivity testing of the model sensitivity (a suggestion would be to consider a 33% reduction) may be valuable, especially if the impact on long-distance trips seems excessively large.

8.3. Advice for Users of Model Outputs

It is recommended the model output users to be cautious regarding the overall model convergence and not rely just on the reported convergence of the double constrained mode choice model and the highway assignment convergence. Users of model outputs should take advice from the modellers at what level model outputs should be considered robust and be wary of drawing conclusions from other figures reported by the model that might not be robust or stable.

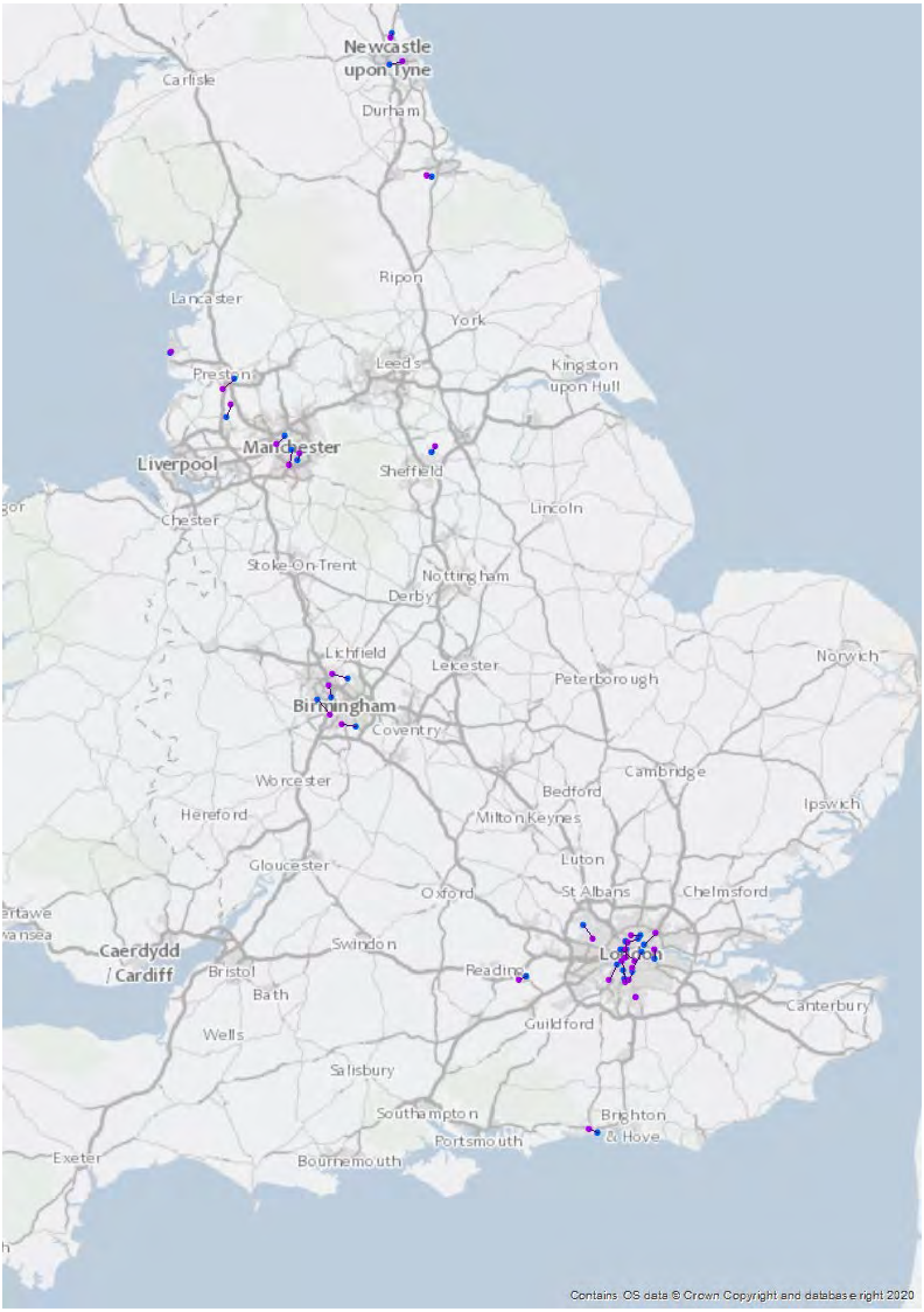
Also, it should be highlighted that in scenario tests with relatively local model interventions, some of the analysis spreadsheets being available are not granular enough to describe the model outputs. Additional effort is needed by the model outputs users to investigate the results at a more granular level. A suggestion could be to manipulate the exported attribute files in order only to keep the data related with the area of interest and then import these files to the existing analysis spreadsheets. Any “local” application is likely to require work in extracting and interpreting appropriate outputs.

APPENDICES

Appendix A– OD Pairs for Non Car Costs

Rail OD Samples

Bus OD Pair Samples



Walk and Cycle OD Pair Samples