Department for Transport

National Transport Model - Analytical Review

Moving Britain Ahead

December 2020

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Foreword

It is vital to have a robust understanding of the impacts that transport investment has so that we can make the best investment decisions. The appraisal framework of the Department for Transport (DfT) aims to provide a full assessment of the impacts transport has on the economy, environment and society. It needs to keep pace with any changes in the appraisal environment and ensure our guidance remains relevant and robust in an ever-changing world. The Department therefore launched its Appraisal and Modelling Strategy (AMS) in April 2019.

The primary aim of the AMS is to provide robust, flexible and easy to use modelling and appraisal tools that can be used to inform the critical policy decisions that the Department and wider transport community will be making over the next five years.

The strategy includes consideration of potential alternative techniques and innovations which might enhance the existing tools and our scheme appraisal guidance, and one of the main themes of the strategy is to ensure that all the tools remain fit-for-purpose, relevant and evolve in line with best practice.

A key part of achieving this is through opening up our national models and we are keen to set an example in this regard. This will allow full and widespread understanding of our model methodologies, the data that underpins them, their performance and their use in forecasting and analysis.

Therefore, having recalibrated our National Transport Model in 2018, we have undertaken a workstream targeted at illuminating the characteristics and performance of the new model to achieve these transparency objectives.

Within this workstream, we explored the suitability of the model for its main purpose of forecasting traffic and emissions by using a range of stress-type tests and an innovative backcast of the model for the year 2003.

This report presents the analysis of results from the above workstream. It forms the major part of a range of descriptive and technical documentation, including a peer review carried out by external transport modelling experts, being published.

We feel the publication of this report and the peer review represents a major step forward in openness and in meeting our transparency objectives and provides assurance of the suitability of the latest version of the National Transport Model in the production of national road traffic forecasts and strategic policy analysis.

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Executive summary

Background

For many years the UK Department for Transport (DfT) has been at the leading edge in terms of its transport scheme appraisal and the methods, tools and guidance that underpin this and in April 2019 published its latest Appraisal and Modelling Strategy (AMS) designed to keep guidance relevant and fit for purpose over the coming years.

The strategy, which includes looking at innovative or new techniques, also stresses the importance of being transparent in our approach and opening up our national models where possible to allow stakeholders to gain a full understanding of the methodologies and data that are being used.

Therefore, when the National Transport Model (NTM), which has been used for many years in the provision of traffic forecasts and policy assessments, was re-calibrated, we took the opportunity to perform some additional analysis designed to expose and explain the model behaviour to a wider audience of stakeholders. This report, which contains this analysis, is being published alongside a peer review and a model overview, which provides a more detailed description of the model structure and the recent update. These are intended to provide that deeper understanding of model structure and performance and also meet our transparency objective for this model.

The NTM was first developed in 2001 and since then its data and assumptions have been updated regularly. It is a multi-modal[1] model of land-based transport in Great Britain and enables the Department to estimate the impact of a transport policy or a change in forecasting assumption on key travel indicators such as the levels of traffic, congestion and vehicle emissions.

To ensure that transport models remain fit for their purposes it is important for them to be updated to keep pace with changes relating to travel behaviour, innovative transport technologies and socioeconomic trends. This most recent update of NTM involved the recalibration of the model to a 2015 base year and the new model (named NTMv2R) was delivered for use in 2018.

Summary of Approach

Since this latest model version was delivered, it has been through a rigorous series of sensitivity-type tests that allowed it to be used with confidence in the production of the latest Road Traffic Forecast (RTF18) scenarios. Whilst the RTF18 report included some information about the model's performance, the Department also published the model implementation and calibration reports[2] which included details relating to updating the latest version of the model together with the realism test results.

[1] This includes the six modes of walk, cycle, car driver and car, bus or rail passenger.
[2] All these reports are fully referenced later in this report.

Since then we have undertaken this further analysis, designed to provide a wider understanding of the model's behaviour and methodologies, through the performance of a range of model stress tests and development of a backcast model.

The stress tests were designed to reveal how the model responds to changes in some of the key drivers or inputs that are often used in producing the traffic forecasts or policy analysis for which the model is used.

The analysis starts with presenting the results of the model realism tests, which test the model responses to changes in fuel prices, car journey times and public transport (bus and rail) fares. The realism tests provide results for the model base year of 2015 and provide confidence that the basic model form is satisfactory. Further, more stretching tests, have then been performed involving larger changes in fuel costs, gross domestic product (GDP), the interaction of these as well as changes to the capacity of the road network in the forecast years of 2030 and 2050.

The analysis considers several NTM outputs, such a trips and traffic (by journey purpose), speeds and congestion (by area and road type), which are used to derive base and forecast year elasticities[3] where appropriate. The results from the tests are compared against the RTF18 scenario 1 which is being taken as the Reference case (Core scenario).

The stress tests only analyse the car travel data. The performance of the LGV model, the Great Britain Freight Model (GBFM) and PSV forecasts, which are used to provide forecasts of light and heavy goods and public service vehicles (buses), are not covered by this work and a mixture of historic data and core forecasts will be used for these as appropriate. The vehicle-specific models behind these data have not been changed in the NTMv2R recalibration exercise and therefore have not been included in this analysis.

We have also developed an innovative backcast of the model in order to help evaluate the quality of the model as a forecasting tool. This represents the first successful attempt of developing a backcast using the NTM and this has been made possible due largely to availability of sufficient data.

The previous version of the NTM (Version 2) had a 2003 base year and included the actual traffic data for that year. Thus, 2003 was selected as the backcast year due to both the availability of this good quality traffic data as well as a number of series of historic data covering network capacity, fuel costs, GDP, value of time (VoT), rail and bus fares.

The main challenge of this work was to determine the correct level of demand for 2003 and six backcast scenarios were developed, each of them with a plausible level of travel demand in 2003. The traffic levels from each backcast scenario were then compared with actual traffic data for 2003 and one of the above six scenarios was selected as the best representation of the out-turn 2003 demand.

[3] An elasticity here is defined as the rate of change of one item in relation to the rate of change of another.

Summary of Results

Stress Tests Results

The results from the various stress tests demonstrate that the model is performing well and behaves as expected. The model's elasticities, which were derived from the realism tests, lie within the recommended range as described in Transport Analysis Guidance[4] (TAG) and provide a high level of confidence in the model's performance and robustness. The resulting car journey time and fuel elasticities mean that increases in journey time or fuel cost decreases the numbers of car trips whilst increasing the numbers of rail and bus trips with the opposite result being observed when Public Transport fares increase. The model reaction to the tests of much larger changes to capacity and fuel costs are also consistent with expectations and the convergence tests showed that, when operating under reasonable assumptions, the model converges well.

Backcast Results

The backcast scenario that was developed incorporates travel demand data of 2003 derived from NTEM version 6.2, the actual population figures for 2003 and the reduced trip rates for that year which were observed as occurring between 2003 and 2010 in the National Travel Survey data (in 2012-2013).

The analysis of the backcast model outputs related to travel by the different journey purposes and traffic by road types and area types. These showed that the model validates well to the actual traffic levels of 2003. The distance travelled in the backcast is 3.7% lower compared to the actual traffic levels, and this highlights the capability of the latest model (NTMv2R) at projecting a backcast year. These results indicate that the latest model version (NTMv2R) has performed well in projecting the backcast year.

Conclusions

The successful performance of the model in both the stress tests and the backcast scenario has demonstrated the high quality of the model and reflects favourably on its ability to produce the National Road Traffic Forecasts and help decision making through strategic policy analysis and appraisal. It is concluded that this latest version of the National Transport Model is a tool that is sufficiently fit for these purposes.

This document, which details the analytical review of the NTM, and its publication alongside a more detailed description of the model and an independently-authored peer review fulfils one of the AMS objectives related to opening up our national models and should promote a full and widespread understanding of both the model's methodologies and its behaviour.

[4]TAG website: https://www.gov.uk/guidance/transport-analysis-guidance-webtag

1. Introduction

1.1 Background – History

1.1 The National Transport Model was originally developed to meet the commitments made in the Department's Ten-Year Plan for Transport (July 2000). This plan included a range of policy interventions across all motorised modes of transport. Following the successes achieved in the analysis which underpinned the plan's objectives, the Department committed to develop a national tool which could monitor the progress of its plans and assess the impacts and value of different policy options. Thus, the first National Transport Model (NTM) was developed in 2001 with a Base Year of 1998.

1.2 The Department acknowledges the importance of updating its models to keep pace with the evolution of travel behaviour and technology and the first update to the NTM (Version 2) occurred quite quickly in 2003. Since then, although the model structure has remained largely unchanged, the model inputs and data have been continuously updated as the model has been used for a wide range of policy analysis and forecasting projects.

1.3 More recently, in 2015 we decided to improve our strategic modelling capabilities with the development of a new, more spatially detailed version of the model, whilst also taking into account of the latest changes in travel behaviour that had been observed in the Departments National Travel Survey (NTS) data over recent years.

1.4 It was also decided that, as part of this wider NTM update programme, the NTM version 2 model should be updated and recalibrated to cater for this latest travel behaviour and the ensuing demand data, as provided by the Department's National Trip End Model (NTEM) dataset.

1.5 This approach would provide an improved model for use in the medium term whilst the more spatially detailed model is being developed.

1.6 Thus, an updated version of the NTM (NTMv2R) with a base year of 2015 has been developed over the last two to three years and this model has successfully incorporated recent transport trends and is able to make use of the updated NTEM version 7.2 trip end data.

1.2 Purpose of NTM

1.7 This section describes the main purpose of the model, its use in various workstreams in the Department and some limitations of the model that are expected to be overcome in the new version of the National Transport Model.

1.2.1 Main purpose of the model

1.8 The main purpose of the NTM in the Department is to provide:

- An evidence-based forecast, to government and external bodies, representing the department's best estimate of the future direction of the main road transport indicators such as road traffic, congestion and vehicle emissions;
- Credible and relevant projections exploring the variations of road traffic demand, including uncertainty around how it may evolve, to influence policy and strategy development;
- A policy and scenario testing tool used to estimate the impact of a transport policy scenario or a change in forecasting assumption on the key transport indicators above.

1.9 The model results or outputs are therefore used as a critical input in policy Impact Assessments and underpin the calculations of costs and benefits attributed to the overall levels of demand. These benefits include time savings impacts, environmental benefits (CO_2, NO_x, PM_{10}), indirect tax and any other potential revenues.

1.10 Additionally, the models results feed into the calculation of the Marginal External Congestion Costs (MECCs) which are presented in the TAG data-book. These costs data, which provide an estimate of the economic impact of removing a vehicle from the road network, are used in a wide range of local scheme appraisals including cycling and sustainable travel as well as in economic assessments of rail schemes and freight grants.

1.11 The model therefore plays an important role in helping to determine policy and since its development, the NTM has contributed to a wide range of policy analysis projects. This has included:

- Road Pricing Feasibility Study (2003),
- The Eddington Transport Study (2006);
- Advanced motorway signalling and traffic management feasibility study (2008);
- Speed Limits Analysis for Motorways and HGV's on A roads (2010-12);
- Analysis behind National Networks National Policy Statement (2014);
- 2014 Roads Investment Strategy (RIS) Strategic Business Case (2014);
- Impacts of Policies on CO_2 (2017);
- National Road Traffic Forecasts (2018 and previous years).

1.2.2 Model's limitations

1.12 The model inputs and assumptions are routinely updated to ensure the model remains fit for the main purposes above. However, this is a national model designed to test national policies in a strategic and not local level, hence there are some model limitations that do not allow us to test every policy.

1.13 These limitations are mainly related to the representation of non-car modes of travel such as rail, bus and cycle where the Department uses its bespoke, mode-specific models for policy analysis in such areas.

1.14 On the roads side, the model can include schemes that result in explicit changes to road capacity such as:

- Road widening and dualling;
- Smart Motorways;
- Some local by-passes and some junction improvements.

1.15 However, there is a range of local schemes that cannot be assessed in the model. These schemes include:

- New roads, major by-passes, road closures and diversions;
- New junctions and detailed junction improvements;
- Overtaking or climbing lanes and HOV/HOT Lanes;
- Local pinch points and bottlenecks;
- Cordon or area based charging and local tolls;
- Safety schemes and accidents.

1.2.3 New National Transport Model

1.16 Some of the limitations, mentioned in the previous section, are expected to be overcome with the development of the more spatially detailed version of the NTM, details which will be published over the coming months.

1.17 In particular, this completely new NTM model version will include a more detailed road network, allowing the Department to test detailed road network changes in Regional and National strategic road corridors across England.

1.18 The model includes a much more disaggregate zoning system where each MSOA (middle super output area) is represented within the mode as an individual zone. This will allow the testing of transport policies at a local level and hence, this next NTM version will add to our existing capabilities and allow the assessment of a range of transport policies that we are not currently able to assess in the current NTMv2R version.

1. 3 Purpose of this document

1.19 In 2018, the new recalibrated version of the National Transport Model (NTMv2R), was tested through a rigorous series of acceptance tests and sensitivity-type tests that allowed it to be used with confidence in the production of the latest Road Traffic Forecast[5] (RTF18) scenarios.

1.20 The RTF18 report included some information on the model's performance and details relating to the up-dating of the NTMv2R model have also been published in the model implementation and calibration reports[6].

1.21 However, as the Department is keen to set an example in being open about the performance and capabilities of the NTM, including any potential shortcomings, it commissioned an in-house work stream designed to illuminate the model's

[5] Available at: https://www.gov.uk/government/publications/road-traffic-forecasts-2018
[6] These reports are available on the Departments web site at: https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools

performance and provide assurance that the recalibrated NTMv2R model is fully fit for the policy and forecasting type work that it is intended to be used for.

1.22 The focus of this work has been to test the model through a series of stress tests and the development of a model backcast. These have all been designed to explore the behaviour of this newly-calibrated version of the model with the intention of sharing the results with stakeholders in order to improve model transparency for a wide-ranging audience.

1.23 The results of this workstream, demonstrating the model's performance to some large changes to several of the key drivers of transport demand, is now presented in this report and enables us to share this knowledge with stakeholders.

1.24 First, in Chapter 2 we present an overview of the structure of the model and the data that has been up-dated in the re-calibration exercise.

1.25 This is followed by Chapter 3 of where we present the results of a series of model stress tests. These tests were designed to expose the detailed behaviour of the model and enable us to better understand the strengths and weaknesses of the model and ultimately assure us that the model is fit for the analytical purposes for which it is required.

1.26 Chapter 4 discuss the results of a backcast of the model to 2003. Whilst often mooted as an ideal method of helping to assure the quality of models, the performance of model backcast is always difficult and rarely successful. The results of the innovative analysis that we have performed is presented here builds on the results of the stress tests.

1.27 Finally, Chapter 5 is designed to provide an overall summary with a discussion of our findings and our conclusions about model performance and includes an extended summary of the stress test and backcast methodological decisions of the previous chapters.

1.28 With the publication of this package of testing and detailed analysis we aim to provide an improvement in the transparency of the current version of the National Transport Model and reassurance to our stakeholders of the model’s performance and its fitness for purpose.

2. National Transport Model Overview

2.1 Background of the Model

2.1 The Departments National Transport Model (NTM) is an analytical and policy-testing tool used to provide road traffic forecasts and a systematic means of comparing the national consequences of alternative national or widely applied local transport policies. This is done against a range of background scenarios, taking into account the major factors affecting future patterns of travel.

2.2 The NTM is a highly disaggregated multi-modal model which covers land-based transport in Great Britain[7]. It is made up of a collection of different models that have been specifically designed and combined to enable the NTM to forecast the changes to traffic on the road network stemming from all vehicle types. This is both the model's main purpose and the focus of its results.

2.3 The traffic on the road network is made by a combination of the personal trips made by individuals and the traffic from goods and public service vehicles. For each of these, the NTM uses the results of a number of bespoke models. These include the Great Britain Freight Model (GBFM) for freight (heavy goods) vehicles, a separate light goods vehicle model for vans and the personal travel demand model which covers six different modes of travel. These are car driver, car passenger, rail, bus, walk and cycle and this enables the model to look at mode switching.

2.4 The model's main personal travel demand component uses what is known as a four-stage behavioural modelling approach to forecast the demand for travel. This method estimates the demand for travel from the bottom up and is behaviour led.

2.5 Firstly, it estimates the numbers of trips people make. The frequency of trip making is known to vary according to factors such as household structure, car ownership, employment etc.

2.6 Secondly, it allocates those trips to journeys made between specific origins and destinations. This is undertaken by comparing the attractiveness of different destinations with the costs of getting there.

2.7 Thirdly, it allocates those journeys to specific modes. This is done by comparing the relative costs of travelling by different modes.

2.8 Finally, for car travel, it allocates the journeys to specific routes across the road network. This route choice includes the impact of any congestion.

2.9 The results from these models are then combined with a range of other exogenous inputs (including costs, fares and demographics etc.) which are used to forecast personal travel and to provide the best possible estimates of all road

[7] Although, the NTM is a model of land-based transport in Great Britain, forecasts are generally presented at the England level. Domestic air travel is not currently modelled however, only around 1% of total distance travelled within Great Britain is by air.

traffic. Non-transport related inputs such as oil prices and GDP assumptions are agreed with other Government Departments such as ONS, HMRC and OBR.

2.10 It is important to represent all surface modes of transport in the demand model in order to predict and quantify changes in travel demand resulting from a change in the transport system. Thus, the main demand model for personal travel includes Bus and Rail travel, however, it does not include aviation or any maritime/inland waterways travel.

2.11 The number of trips involved in Rail and Bus modes is far less than the numbers of car trips and the Department has bespoke models and tools that are designed to produce forecasts and analysis for these specific travel modes. These are used instead of the NTM, which is mainly used for assessing highway policies.

2.12 Whilst the NTM forecasts demand for all land-based modes it only forecasts costs for passenger cars on the road network. Costs relating to other modes and traffic growths for certain vehicle types are taken from other models used in the Department and the range of models used by the NTM includes:

- Rail Model - MOIRA[8] is used to predict railway flow volumes and revenues based on the 2015 National Rail timetable. The forecasted result provides updated rail journey characteristics (average interchange time, waiting times and journey time etc) in the model base year.
- GBFM freight model (for Heavy Goods Vehicle traffic growth)
- LGV model[9] (for Light Goods Vehicle or Van traffic growth)

2.13 As the light and heavy goods vehicle models have not been changed during the updating and recalibration of the latest NTMv2R model, the performance of these models is unchanged. A review of these models is therefore not included in this analysis which is focussed on the update, recalibration and performance of the main personal travel demand model and the resulting car traffic.

2.2 How the Model Works

2.14 The NTM demand model that is used to determine personal travel behaviour combines data and information that derive from a wide range of sources. It uses data from the National Travel Survey (NTS), Car ownership model (NATCOP) and the National Trip End Model[10] (NTEM) where the combination of the above data along with estimates of housing, population and employment provide spatially detailed travel demand in terms of trip-ends (these are the origins and destinations of trips) in local areas.

2.15 These trip ends, which are determined by the travel patterns of people in Great Britain, form part one of the four stage approach and represent the key input of travel demand into the NTM. Although some of the details of the subsequent demand model have changed over the years, the basic structure of the main components has remained the same. The recent recalibration exercise has not resulted in any changes to the basic NTM version 2 structure.

[8] MOIRA is owned by the Passenger Demand Forecasting Council (https://www.raildeliverygroup.com/pdfc/about-the-pdfh.html) of the Rail Delivery Group (RDG: TOCs and Network Rail).
[9] The original in-house LGV model was updated in 2015. Details of the up-dated model have also been published alongside this report
[10] Guidance on the use of NTEM and its sub-models is available at: https://www.gov.uk/government/publications/webtag-si-ntem-sub-models-july-2016

2.16 Table 1 and Table 2 below present the total numbers of trips for each mode by distance band and journey purpose in 2015. There is a total of 142,945,384 trips per average day in the base year and the percentages give an indication of the relative importance of modes on the overall results. These figures are derived from the base year model, which has been calibrated to match the 2015 NTS data to within 1% or 2% at the lowest level[11] of detail.

Table 1 Proportion of Trips by Distance and Mode

Distance Band	Walk	Cycle	Car Driver	Car Pas	Bus	Rail	Total
<1 mile	13.40%	0.30%	2.40%	1.50%	0.20%	0.00%	17.70%
1-2 miles	5.00%	0.60%	7.20%	4.20%	1.20%	0.10%	18.30%
2-3 miles	0.70%	0.30%	6.40%	3.60%	1.50%	0.10%	12.60%
3-5 miles	0.20%	0.30%	8.40%	4.60%	2.20%	0.40%	16.20%
5-10 miles	0.03%	0.23%	9.50%	4.90%	1.80%	0.90%	17.30%
10-15 miles	0.00%	0.05%	4.00%	1.90%	0.50%	0.70%	7.10%
15-25 miles		0.03%	3.10%	1.50%	0.20%	0.50%	5.30%
25-35 miles			1.10%	0.60%	0.10%	0.20%	2.00%
35-50 miles			0.70%	0.40%	0.00%	0.20%	1.30%
50-100 miles			0.70%	0.50%	0.00%	0.20%	1.40%
100-200 miles			0.27%	0.22%	0.02%	0.09%	0.60%
200-300 miles			0.05%	0.06%	0.01%	0.04%	0.20%
>300 miles			0.02%	0.01%	0.00%	0.01%	0.00%
All Distance Bands	19.3%	1.8%	43.80%	23.90%	7.70%	3.40%	100.00%

Table 2 Proportion of Trips by Journey Purpose and Mode

Purpose	Walk	Cycle	Car Driver	Car Pas	Bus	Rail	Total
1. Home-Based Work (HBW)	1.9%	0.6%	11.2%	2.0%	1.5%	1.5%	18.7%
2. Home-Based Employers Business (HBEB)	0.1%	0.0%	1.7%	0.3%	0.1%	0.2%	2.4%
3. Home-Based Education (HBEd)	4.9%	0.2%	2.5%	3.1%	1.4%	0.2%	12.3%
4. Home-Based Personal Business/Shopping (HBPB)	6.7%	0.3%	12.3%	7.6%	2.8%	0.4%	30.1%
5. Home-Based Recreation/Visiting friends (HBRec)	3.5%	0.3%	8.9%	6.5%	1.3%	0.6%	21.1%
6. Home-Based Holidays/Day trips (HBHol)	0.0%	0.3%	1.7%	1.5%	0.2%	0.2%	3.9%
7. Non-Home-Based Employers Business (NHBEB)	0.2%	0.0%	1.1%	0.1%	0.0%	0.1%	1.5%
8. Non-Home-Based Other (NHBO)	2.0%	0.1%	4.4%	2.8%	0.4%	0.3%	10.0%
All Purposes	19.3%	1.8%	43.8%	23.9%	7.7%	3.5%	100.0%

2.17 Car trips are almost 68% from the total number of trips with a further 9.5% of trips being road-based journeys using either bus or cycle. Of the remaining trips almost 20% of them are walking whilst the Rail mode only represents 3.4% of trips.

[11] The limit depends on sample size with 2% only allowed for certain small sample size combinations of mode/purpose/distance band.

2.18 The trips made by active modes are mainly for short distance trips. Trips by other modes, such as car, bus and rail attract both short and longer distance trips. The long-distance trips are mainly made by both car and rail.

2.19 Table 3 shows the proportion of travelled distance by mode and journey purpose. An important highlight is that longer trips made for recreational (HBRec) and holiday (HBHol) purposes mainly use car and rail modes.

Table 3 Proportion of Distance Travelled by Journey Purpose and Mode

Purpose	Walk	Cycle	Car	Car Pas	Bus	Rail	Total
1. Home-Based Work (HBW)	0.3%	0.3%	14.0%	2.0%	1.1%	3.4%	21.0%
2. Home-Based Employers Business (HBEB)	0.0%	0.0%	5.0%	0.6%	0.1%	1.5%	7.3%
3. Home-Based Education (HBEd)	0.5%	0.0%	1.3%	1.5%	0.9%	0.4%	4.7%
4. Home-Based Personal Business/Shopping (HBPB)	0.7%	0.1%	8.6%	6.4%	1.6%	0.7%	18.0%
5. Home-Based Recreation/Visiting friends (HBRec)	0.4%	0.1%	10.7%	9.0%	1.1%	2.1%	23.5%
6. Home-Based Holidays/Day trips (HBHol)	0.0%	0.2%	4.6%	6.4%	0.6%	1.4%	13.3%
7. Non-Home-Based Employers Business (NHBEB)	0.0%	0.0%	2.0%	0.3%	0.0%	0.3%	2.6%
8. Non-Home-Based Other (NHBO)	0.2%	0.0%	4.8%	3.7%	0.3%	0.6%	9.6%
All Purposes	2.1%	0.7%	51.0%	30.0%	5.8%	10.4%	100.0%

2.20 The Rail share of 3.4% of all trips has increased to 10.4% of the total distance travelled but the significance of the 19.3% of walk trips has diminished to represent only 2.1% of the distance of all trips. Car Driver and passenger now accounts for over 80% of trip distance with Busses adding a further 6% of trips distance to the road network. The total average daily distance travelled by all modes is modelled as 1,173.4 Million Miles/Day.

2.21 The increasing importance of the Rail and Car modes when looking at distances travelled (as opposed to trips), highlights that the trips undertaken on these modes are of much longer distances than those on the other modes.

2.22 When compared to the numbers and lengths of car trips, the relatively small numbers of trips involved in active and public transport modes tend to change quite rapidly due to small changes to the numbers of car trips. Whilst the focus and primary purpose of the model is on forecasting cars, the inclusion of different modes and their responses to change is important for the overall levels of demand forecasting. However, these mode shares are subject to some uncertainty when forecasting, particularly at lower levels of disaggregation, and therefore the shares should not be used for other mode specific purposes. We have a range of specialist models or tools focused on these modes which are used to produce more accurate mode specific forecasts for them.

2.2.1 Summary of NTM Components and Functionality

2.23 The two main components of NTM which are described below form the Demand Model component (Pass1) and the Highway Assignment component (FORGE[12]) which is proxying the assignment process. The Pass1 model represents stages two and three of the classic four stage approach whilst FORGE represents the fourth. During an NTM iteration Pass1 estimates the mode split and the trip distribution and feeds FORGE with the car traffic growth. FORGE then fits the car

[12] FORGE acronym stands for: Fitting On Regional Growth and Elasticities

traffic growth onto the road network and returns the resulting congestion impacts to the Pass1 model.

2.24 The new traffic speeds change the car journey times and therefore costs and this results in a new estimate of car driver demand. This exchange of feedback iterates until convergence is achieved between the supply and demand components of the NTM.

2.25 At the end of the convergence process we have two distinct model outputs stemming from the two components and these are:

- Average daily trips, disaggregated by their mode, journey purpose, origin and destination zone type and length (by distance band) produced by the Pass1 model and
- Traffic (vehicle km) and its speed on the road network disaggregated by Region, area type, road type, vehicle type (including journey purpose for cars) and time period (within a week) from the FORGE model.

2.26 The traffic and speeds information from FORGE is then used to create a number of other model outputs such as a range of congestion metrics, vehicle operating costs, fuel consumption, tailpipe emissions, and the marginal costs associated with adding extra traffic.

2.27 These outputs can be fed into a special welfare model which, when compared to a suitable reference case scenario, can be used to calculate the benefits of a modelled change in policy or assumptions.

2.28 The key input assumptions which are used in these main NTM components (Pass1 and FORGE) are the trip ends (demand) from NTEM, rail and bus fares, income (GDP), average fuel cost, traffic growth for bus and good vehicles, speed flow curves and emission curves, base year traffic data and road policies.

2.29 Figure 1 summarises the key input assumptions used in Pass1 and FORGE. The wider range of inputs and functionality of the combined NTEM and NTM models is described in Figure 2.

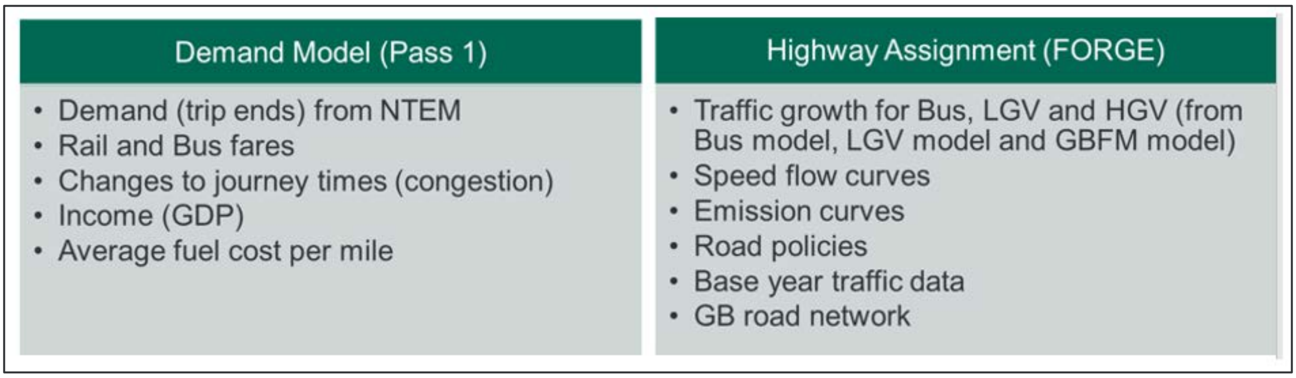

Figure 1: Pass1 and FORGE model inputs

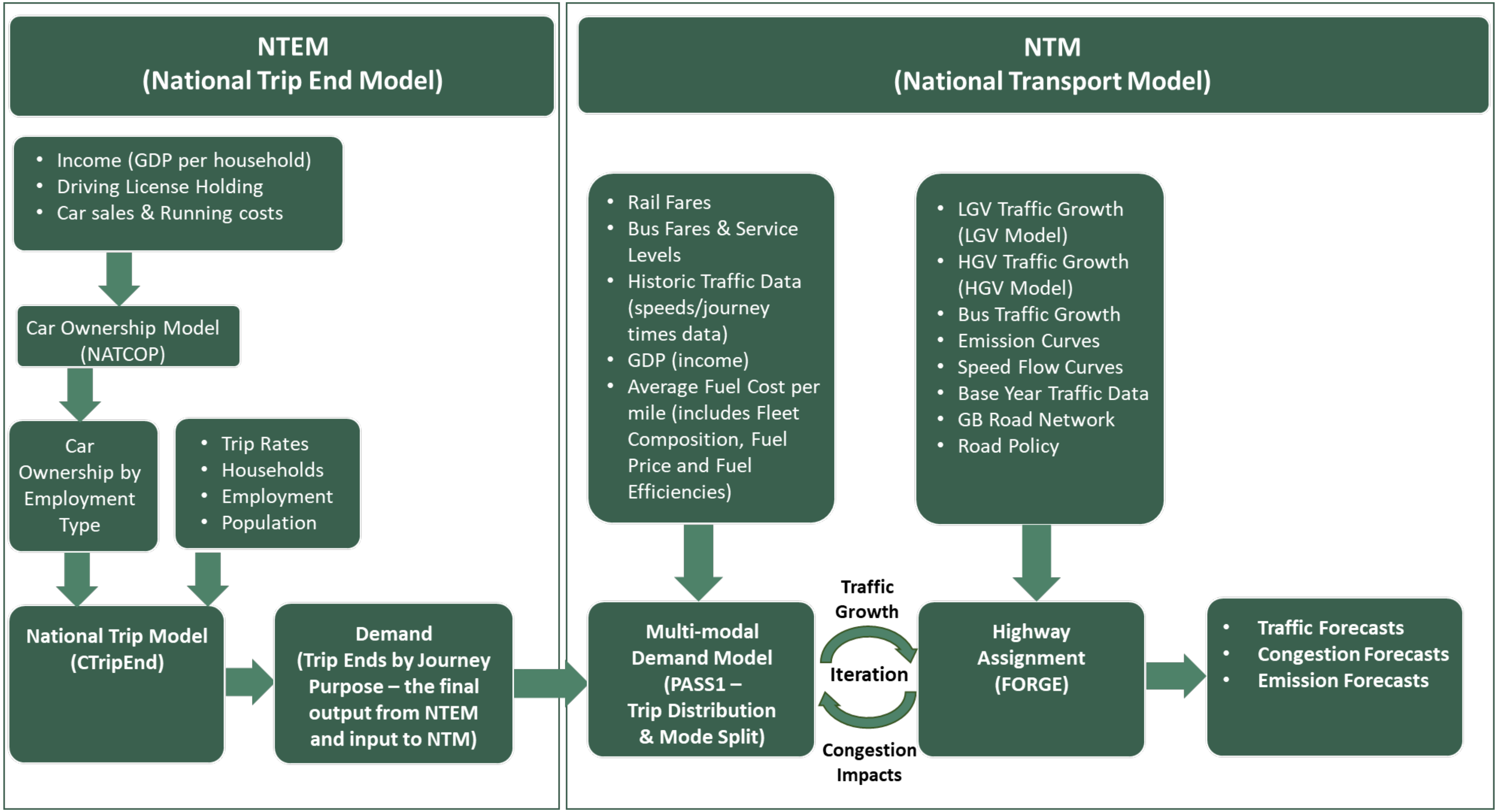

Figure 2: Inputs and Connectivity of the National Trip End Model and National Transport Model

2.3 The Four Stage Modelling Approach in the NTM

2.30 Figure 3 below illustrates the data flows of a four-stage approach to modelling travel behaviour and each of these stages is discussed in the following sections in relation to how they are performed in the NTM.

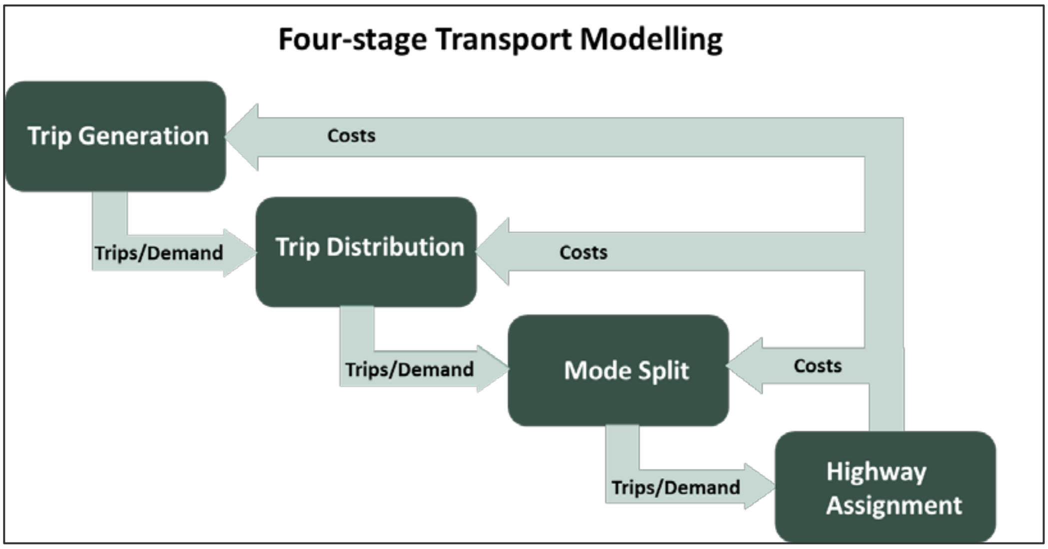

Figure 3: Diagram of four-stage Modelling Approach

2.31 This is then followed by a brief discussion of how the light and heavy goods vehicle models interact with the NTM to enable it to provide forecasts for all the main road based vehicle types.

2.3.1 Stage 1: Whether to travel (Trip Generation)

2.32 Trip generation is determined by the decision of making a trip (e.g. to work, the shops or to visit friends) and the range of different journey purposes used in the NTM are shown in Figure 4 below and also listed in Annex A (section A5).

2.33 This decision determines the total number of trips and is performed in NTEM which forms an input to the NTM. The decision is based on trip rates which are founded on National Travel Survey data and which vary for each of the different traveller types. Whilst trip productions are based on the populations of zones (ie, where people start their journeys), the choice of where to travel to (the attractions) is determined and constrained by the distribution of destinations or where to travel to by the location of jobs, schools and shops etc.

2.34 The NTEM dataset and its suite of component models provides a forecast of travel demand in terms of these “trip ends” for each year and this is based on:

- Numbers of households (by size) for the base and each forecast year;
- Population by gender and age for each control area in each forecast year;
- Employment (jobs) by industry, gender and working status in the control area for each forecast year;
- Car Ownership (NATCOP) by household type based on licence holding, income, population, car costs and employment;
- Trip rates which vary for each of the model segments described below.

2.35 These inputs and associated personal travel characteristics are founded on the same NTS survey data that was used in constructing the model base year (2015). The personal demand element of the NTM is highly dis-aggregated and the personal trips are split in 105 demand-segments by journey purpose, person type and household type (shown in Figure 4). This disaggregated approach for the demand segments enables the NTM to perform a wide range of policy work and assess how different policies impact on different population groups.

Purpose	Person Type	SEG / Income	Household: 1 adult / 0 car (1)	Household: 1 adult / 1 car (2)	Household: 2+ adult / 0 car (3)	Household: 2+ adult / 1 car (4)	Household: 2+ adult / 2+ car (5)	All
HB Work (1)	Full time employed (2)	High	1	2	3	4	5	
		Medium	6	7	8	9	10	
		Low	11	12	13	14	15	
	Rest of population (2)	All	16	17	18	19	20	
HB EB (2)	Full time employed (2)	High	21	22	23	24	25	
		Medium	26	27	28	29	30	
		Low	31	32	33	34	35	
	Rest of population (2)	All	36	37	38	39	40	
HB Education (3)	Child (0-15) (1)	All	41	42	43	44	45	
	Full time employed (2)	All	46	47	48	49	50	
	Other (16-74) (3)	All	51	52	53	54	55	
	Pensioner (4)	All	56	57	58	59	60	
HB PB / Shopping (4)	Child (0-15) (1)	All	61	62	63	64	65	
	Full time employed (2)	All	66	67	68	69	70	
	Other (16-74) (3)	All	71	72	73	74	75	
	Pensioner (4)	All	76	77	78	79	80	
HB Rec / Visiting friends (5)	Child (0-15) (1)	All	81	82	83	84	85	
	Full time employed (2)	All	86	87	88	89	90	
	Other (16-74) (3)	All	91	92	93	94	95	
	Pensioner (4)	All	96	97	98	99	100	
HB Hols / Day trips (6)	All persons	All						101
NHB EB (7)	All persons	High						102
		Medium						103
		Low						104
NHBO (8)	All persons	All						105

Figure 4: Segmentation of Car Trips by Journey Purposes and Traveller Type

Spatial Disaggregation of the NTM

2.36 NTEM is based on a geographic zoning system which aligns with the Middle Super Output Are[13] (MSOA) definition and therefore the model outputs trip ends for 7201 GB zones.

2.37 In order to allow feasible run times of the model, the base trip data from NTEM is aggregated into the model zone types as presented in Annex A (section A1). These zones align with the more generic Area Types, which are based on the population size of settlements. The NTM zones are shown in Figure 5.

2.38 The NTM zones are grouped into the regions and area types which are described in Annex A (section A2). The urban zone types are founded on the urban polygon-based NTS area type definitions overlaid onto the NTEM7 (MSOA-based) zones whilst the London and conurbation boundaries are those of the Greater London Authority and (old) metropolitan councils.

2.39 The zone types are thus distinguished by local administrative boundaries and size of population. This approach leads to the grouping together of places where personal travel behaviour and the opportunities to use different modes are broadly similar. The zone types also divide the country into North and Eastern, North and Western and Southern regions providing some alignment with the main rail corridors.

2.40 The towns and cities that comprise the different zone types for the current version of the model (NTMv2R) are listed in Annex A (section A3). These are based on the 7,131 MSOA level zones in NTEM version 7.2 and are slightly different to those in the earlier model. This is due to changes in the population and zoning systems as the earlier versions of NTM (and NTEM) were based on 2,496 zones.

2.41 The zone types also make up the more generic area types (numbered 1-10), which are disaggregated by the eleven Government Office Regions and are used by the supply model FORGE in its processing and outputs.

[13] MSOA is a standard geographic level of detail which is defined on the Office for National Statistics (ONS) website.

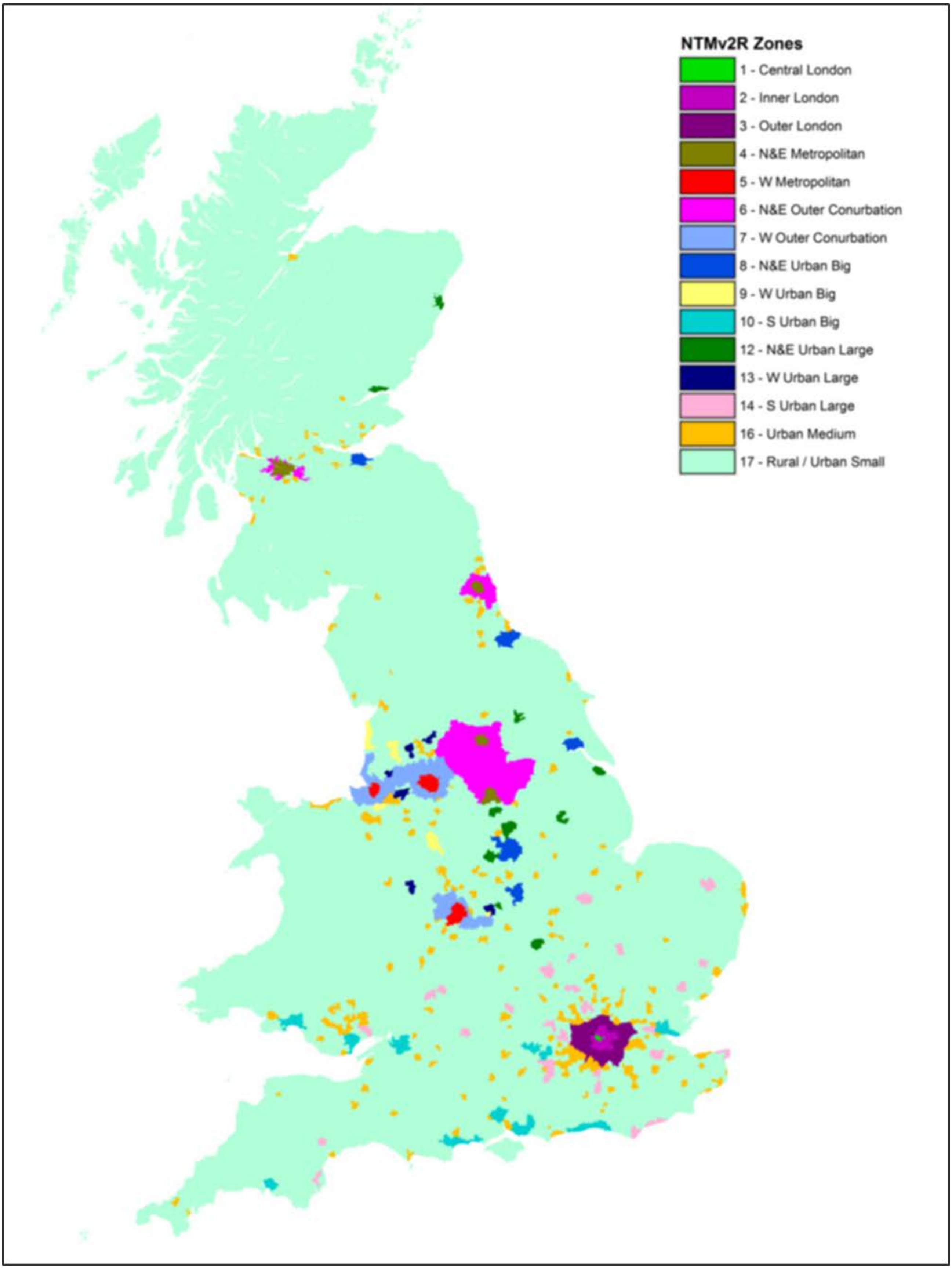

Figure 5 Map of NTM Zones

2.3.2 Stage 2: Where to travel to (Trip Distribution)

2.42 Having aggregated all the trip ends from NTEM into the NTM's zones, next stage in the modelling process is to decide where to travel to. This stage is termed Trip Distribution and in the NTM this process is performed by the Pass1 model.

Demand Model in NTM (Pass1)

2.43 The Pass1 demand model performs the distribution and modal split stages of a conventional four stage transport model as shown earlier in Figure 4. It includes a high degree of traveller segmentation to enable a wide range of policies to be tested and takes as input the total trip productions and attractions by purpose and traveller type from NTEM, which performs the initial Trip Generation stage.

2.44 The demand model aims at explaining where the trips from each of the origin zones go to, in terms of the NTM zones, and which modes they use. The demand model operates with production and attraction (PA[14]) trips for a single time period to reflect an average day (full week / 7). The total travel demand, in terms of trip ends, are taken directly from NTEM dataset for the year of interest.

2.45 The trips are grouped into the fifteen different NTM zone types but remain disaggregated by the 105 different journey purposes and traveller types (person and household types) as described in the trip generation section above.

2.46 Although the NTM's geography has been highly aggregated, an innovation in the original NTM methodology included the use of distance bands to help further segment the distribution of trips across the fifteen NTM zones.

2.47 The distribution module of the demand model splits the trip productions into distance bands and allocates them to aggregate attraction zones to match a set of specified trip attraction constraints based on data from the NTS.

2.48 There are 13 distance band categories and these each span a range covering trips of less than a mile up to trips of 300 miles or more. The bands are described in detail in Annex A (section A4) and are used to allow travellers to change their destination choices based on the costs of alternatives.

2.49 Travel costs used in the distribution model are taken from the linked modal split model which divides the trips (segmented by traveller type, purpose and distance band) into the different modes of travel.

2.50 The components of these travel costs vary for the different modes and are either derived from other models, published data or, for roads-based travel, the journey times of travel on the road network.

Demand Model Choices

2.51 There are three choice mechanisms that operate within the demand model; the choice of distance band, choice of destination zone type and choice of mode of travel (in two layers). The choices are all modelled using absolute logit choice models. Figure 5 below describes the choice hierarchy.

[14] Definition for PA (Productions and Attractions) in NTEM guidance: http://assets.dft.gov.uk.s3.amazonaws.com/tempro/version7/guidance/tempro-important-information.pdf

2.52 The operation of the logit models is best described as an “S” shaped function which will return a choice between two possible alternatives. The choice is based on the cost of each of the alternatives so that, if costs are below a certain threshold one choice is made whereas higher costs will result in the other. The shape of the logit curve, in terms of its steepness, determines how sensitive the different choices are to costs and the parameters which define these characteristics are set during the model calibration process.

2.53 In order to make these choices the model uses a property called the disutility to travel and this is based on the concept of generalised time. A more detailed description of the composition or formulation of generalised time is presented in Annex B and is also included in the separate “NTMv2R Overview of Model Structure and Update to 2015” which is published alongside this report.

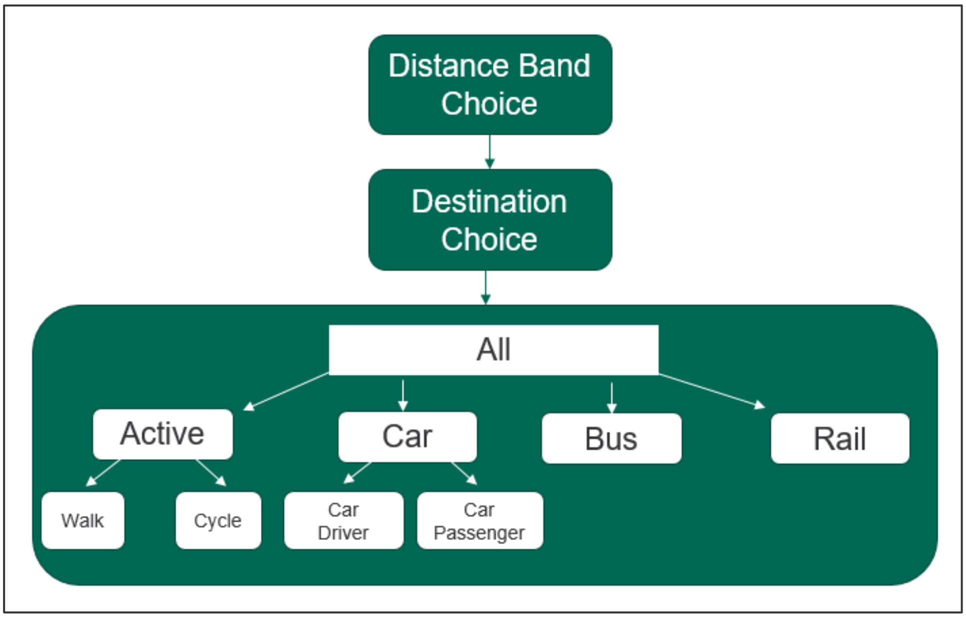

Figure 6: Diagram of the NTM choice model

2.54 The distance band choice model is embedded within the trip distribution model. The trip productions by purpose and traveller type for each zone are inputs to the model. These trip ends are then split into the distance bands with the proportion being calculated using a logit segmentation function based on the relative disutility of travel from each production zone for the different distance bands. The travel disutility is calculated by the mode choice model and applied over all modes and attraction zones.

2.3.3 Stage 3: Which transport mode to travel by (Mode Choice)

2.55 The mode choice model is a hierarchical logit model for each of the trip purpose, traveller type, zone type and distance band combinations output from the distribution model. Walk and cycle are sub modes of the “active” or non-mechanised mode, while car trips are subsequently split between drivers and passengers as shown in Figure 5. The personal trips from NTEM are allocated to one of the six passenger transport modes of car driver, car passenger, rail, bus, walk and cycle.

2.56 This allocation considers the time and monetary costs of travelling by each of the different modes and distributes the trips according to the application of logit functions that are calibrated in the model base year to match the travel choices shown in National Travel Survey (NTS) data. Thus, the modal trips, $Tijlm$, from zone i to zone j by distance band l, are calculated from the trip productions by distance band for the zone $Tijl$ as:

$$T_{ijlm}{=}T_{ijle}(-\lambda M_{uijlm})\Sigma exp(-\lambda M_{uiJlM})M$$

2.57 Where, λM is the lambda (sensitivity) parameter for mode choice, M is the full set of modes and $uijlm$ the disutility of travel associated with each zone pair and distance band (ijl) is calculated from input characteristics to the demand model for mode m.

2.58 For active modes, such as walking and cycling, the only cost component is the trip journey time. Car driver costs also include petrol, parking (search time and cost) and any charges whilst public transport trips additionally include mode access and egress times, wait and interconnect times as well as fares[15].

2.59 Travel characteristics (costs, times and disutility/generalised costs) are derived from input parameters and these are applied to a pseudo network which is comprised of links representing all mode, zone and distance band combinations.

2.60 Not all combinations of mode and distance bands are available, for example, walk and cycle trips only occur in the shorter bands extending up to 15 and 25 miles. More details of the make-up of the disutilities of each mode and the operation of the Pass1 demand model can be found in the “NTMv2R Overview of Model Structure and Update to 2015” report.

2.3.4 Stage 4: Which route to be assigned to (Highway Assignment)

2.61 This process considers the time and monetary costs relating to route choice and calculates updated journey times based on road capacity, forecast demand levels, speed-flow curves and a comprehensive database of actual base year traffic data. In the NTM, this process is handled by FORGE, the Highway Assignment component of the model.

2.62 The car driver trips split by origin and destination zone and distance band produced by the Pass1 model are first converted to traffic occurring in FORGE based in regions, area types and road types by means of a number of mileage profiles. These profiles are essentially a database which was originally derived from a full network assignment of the original version of the NTM model during which the regions, road and area types each of the Pass1 trip types used was assembled.

2.63 Comparing base and forecast year traffic files derived from the above process thus produces traffic growth varying by journey purpose, region, FORGE area type and road-type.

2.64 The FORGE model applies the growth in car travel demand to the traffic data across the 19 different time periods which encompass an entire week. The 19 different time periods are described in Annex A (section A7). Although the same average daily growth rates (from Pass1) are applied in each of the periods, the splitting out of peak, interpeak, off-peak and weekend hours within FORGE

[15] Full details of the components of travel time, and any special weights that are applied to them, are provided in the “NTMv2R Overview of Model Structure and Update to 2015” report which is being published alongside this report.

results in a highly disaggregated range of responses to the changes in congestion. These changes are derived from the new levels of demand, the link capacity and a series of area and road type specific speed flow curves which reflect the performance of roads at different congestion levels.

2.65 The FORGE model applies a range of elasticity-driven responses which cover route switching, time period switching and trip suppression/shortening to changes in costs (generalised time) occurring between the model base and forecasts years and it also iterates within itself until the different responses have converged.

2.66 At the end of the reassignment processes in FORGE, a reversal of the mileage profile technique is performed to create changes to Origin-Destination zone and distance band car journey speeds, suitable for re-application in Pass1. The model then recalculates travel costs of car driver and passenger trips as a result of the new congestion levels and returns these to the Pass1 demand model for the recalculation of trip destinations and modes.

2.67 This process is continued until a certain level of tolerance is reached between the levels of demand suggested by the Pass1 model and the travel costs that have been assumed in calculating that level of demand. This process is known as convergence. To achieve equilibrium, it is important to ensure that the model noise is kept to the minimum level. A model that does not reach convergence may provide significantly different traffic results depending on which iteration it stops. A converged model can be trusted and used with confidence as an appraisal tool.

2.68 More detail about the original NTM version 2 model and the FORGE model is available on the National Archives website[16].

2.4 Public Transport and Active Modes

2.69 Although the NTM's multimodal demand model incorporates the mode choice between car driver, car passenger, walk, cycle, bus and rail, the main purpose for representing all modes in the NTM, and not just cars, is to ensure that the relative attractiveness of all those modes is captured in the demand model.

2.70 This ensures that the response to changing costs and levels of congestion that lie behind the forecasts for cars are as robust as possible. The Department has a number of other specialist models that are more detailed and appropriate for forecasting demand for those specific modes.

2.71 The demand for bus trips and the provision of buses is a complex relationship. Thus, the forecasts of bus service levels from the Department's bus modelling tool are input directly into FORGE, (along with HGV and LGV traffic). This ensures that any resulting impacts of buses on congestion are captured.

2.72 Similarly, relationships describing the impact of cycling and motor cycling on road capacity and congestion are complex and not directly transferrable for this modelling application at the national level. Thus, these modes are not included in the traffic database and the trips cannot be assigned to the NTM road network. Whilst Cycling is included as a mode in the demand model, motor cycle trips are included with cars.

[16] https://webarchive.nationalarchives.gov.uk/20110202223628/http://www.dft.gov.uk/pgr/economics/ntm/

2.73 The model includes the impact of costs for public transport and active modes such as ride times, access/egress assumptions and public transport fares and service levels and these data can be changed within the model if required.

2.74 Cycling and walking comprise the active modes in NTM. The NTMv2R model assumes walk trips occur within the first six distance bands (up to 15 miles) and cycle trips within the first seven distance bands (up to 25 miles). These two modes have no monetary costs associated with them and their disutilities are based solely on an assumed speed and hence travel time.

2.75 The assumed walking speeds in the model are.

- 2.8 miles per hour for trips to / from larger urban areas (zones 1-11)
- 3.5 miles per hour for trips to / from smaller urban and rural areas (zones 12-17)

2.76 The assumed cycling speeds in the model are:

- 8 miles per hour for trips to / from larger urban areas (zones 1-11)
- 9 miles per hour for trips to / from smaller urban and rural areas (zones 12-17)

2.77 Trips between zones with different assumed speeds use an average of the two times (i.e. an average of the inverse speed) (3.11 mph for walking and 8.47 mph for cycling).

2.78 In addition, the main cycle trips also have a weight to increase the time component of the generalised cost which is set to 2 (for walk trips is set to 1).

2.5 HGV and LGV Forecasting

2.79 Heavy Goods Vehicle (HGV) and Light Goods Vehicle (LGV) forecasts are generated by two separate sub-models within the NTM suite. These models take account of the key drivers of demand for their respective vehicle types and the resulting traffic growth is fed into the FORGE so that the impact of these vehicles on congestion is included in the calculation of car journey times.

2.80 The Great Britain Freight Model (GBFM)[17] is a freight transport demand model, developed by MDS Transmodal, for forecasting HGV traffic growth based on fuel costs (price and efficiencies) and the manufacturing index which provides forecasts of tonnes lifted of manufacturing outputs by sub-sector based on GDP and terms of trade. The manufacturing index is calculated by the Department for Business, Energy and Industrial Strategy (BEIS) in their Energy Demand Model.

2.81 The model produces separate growths for Rigid and Articulated vehicles disaggregated by FORGE-based area and road types however, to overcome discrepancies between the NTM and GBFM models, the growths are combined into a single HGV growth for application by FORGE.

2.82 This combined HGV growth on individual area and road types is further aggregated into up into 12 different growths per Government Office Region. These combinations are the conurbation, urban and rural area types for motorway, trunk, principal and minor road types. Note, London area types are covered separately as they also represent a region.

[17] For details of GBFM see: https://webarchive.nationalarchives.gov.uk/20110202223628/http://www.dft.gov.uk/pgr/economics/ntm/

2.83 LGV traffic growth is projected by the LGV Model. This is a regression-based model that forecasts LGV traffic using three main inputs; LGV lagged traffic (past two years' traffic figures for LGVs), GDP per capita and fuel price.

2.84 The LGV model is a series of regional models and these models produce disaggregated growth for Rural and Urban area types for each of the three road types Motorway, Major (A) roads and minor (all other) roads.

2.85 There are no congestion feedback mechanisms for the light and heavy goods vehicle models and therefore the elasticity based "volume response" is used in FORGE to take account of congestion impacts experienced by these vehicles.

2.86 Details of the LGV model are also being published alongside this report.

3. Model Stress Tests

3.1 Purpose and Scope of Model Stress Tests

3.1 This section presents the results from a series of realism and stress tests. The realism tests involve the changing of a selection of input variables in turn and checking that the model responses lie within a certain expected range whilst the stress tests involve significantly larger changes to inputs to test the resilience of the model in extreme conditions.

3.2 The tests have been specifically designed to enable an assessment of the model's robustness and its suitability for the purposes of modelling and forecasting. They focus on the model's performance in response to changes to some of the key model inputs such as fuel costs and road capacity and taken together the tests are designed to expose both the performance of the model under normal conditions as well as indicate a safe working range for the model.

3.3 Analysis will consider a number of NTM outputs, such as trips and traffic (by journey purpose), speeds and congestion (by area and road type) and will be used to derive base and forecast year elasticities where appropriate. The focus of the analysis of each test will depend on the nature of the test being performed.

3.4 The stress tests only look at car travel. The performance of the LGV model, the Great Britain Freight Model (GBFM) and PSV forecasts, which are used to provide forecasts of goods and public service vehicles (buses), are not being covered by this work and a mixture of historic data and core forecasts will be used for these data as appropriate. These vehicle-specific models have not been changed in the NTMv2R recalibration exercise, which only affects personal trips and travel derived from NTEM.

3.5 All the tests reported here are founded on the RTF18 Scenario 1 (Reference scenario of RTF18) which is also used as a comparator for the stress tests results. Whilst the NTM covers Great Britain, some of the input data is only available for England (e.g. National Travel Survey) and therefore most of this analysis will only look at England.

3.2 Details of Model Stress Tests

3.6 The stress tests have been grouped into five sections as briefly described below.

- Section 3.3 Realism Tests Analysis presents the results of three tests which separately increased fuel prices, public transport fares and car journey times by 10% in the model base year of 2015. The tests have been used to derive the base year elasticities presented in 3.3.5 Elasticities from Realism tests.

- Section 3.4 Fuel Cost Test Analysis presents the results of further tests performed in forecast years and analyses the interaction of the resulting fuel cost elasticity with assumed changes in GDP.
- Section 3.5 presents the estimated GDP elasticity of the new model whilst Section 3.6 discusses the results from further tests on GDP which also assess the impact of moderate and extreme fuel cost changes to trips and mode shift.
- Section 3.7 Capacity tests Analysis presents results showing the impacts of some large network capacity changes on trips and mode shift.
- Section 3.8 Convergence Test Analysis presents results showing how the model convergences between iterations for a range of scenarios.

3.7 The comparison of the above tests will be made against the RTF18 reference scenario, either in the Base year or for the forecast years 2030 and 2050. The fuel cost and GDP tests will be used to derive elasticities for a series of forecast years where possible.

3.8 As noted in previous section, the NTM is used primarily for road traffic and policy analysis and therefore the focus of the stress tests is on traffic results for the car mode. It is however important to maintain realistic assumptions and behaviour for all the other modes and any significant impacts seen occurring on these in any of the stress tests are also reported. However, as the department has other models designed to cover these modes their performance is not particularly assessed.

3.3 Realism Tests Analysis

3.3.1 Background to Realism Testing

3.9 The National Transport Model is based on the concept that travellers make their travel decisions by trying to minimise the cost or inconvenience (called disutility) of their journeys. To achieve this, the NTM is based on a quantity termed "Generalised Time" in which all the monetary costs (petrol, fares etc.) are converted to units of time (minutes) by dividing by the traveller’s value of time. This is a rate of monetary cost per hour (£/hour) which is based on survey data. The converted monetary costs are added to a traveller's journey time (walking, queuing and bus, train of car ride time etc). Once all potential options for journeys have been converted to the single "Generalised Time" metric, the model is then able to select the destination and mode of travel for the required journey based on the traveller’s preferences.

3.10 This is the same technique as used in "Generalised Cost" models in which journey time-based components are converted to units of cost, again using the value of time, to allow selections to be made on costs units instead of time.

3.11 The NTM uses the generalised time metric because, if there are no other changes, increasing wealth (as reflected in the values of time) will result in more travel and this fits better with historic economic evidence than the generalised costs approach.

3.12 Further details about the components of "Generalised Time" for the different modes can be found in the model overview report published alongside this review and although we may refer to model performance in terms of costs, the actual metric is time.

3.13 Having assembled all the travel choice data for all the possible modes of travel into time units, the model's parameters are then calibrated so that the travel choices given by the model match those of real travellers in the model base year (the NTM's base year is 2015) as recorded by the National Travel Survey. A report on the model calibration entitled ″NTMv2R Demand Model Calibration and Validation″ is available on the Department's website[18] and the process is also described in the accompanying model overview paper.

3.14 Once a demand model has been constructed, it is essential to ensure that it behaves 'realistically', and this is done by changing components of travel costs and times and checking that the overall demand response accords with evidence as described in our modelling and appraisal guidance (TAG).

3.15 This is achieved through checking the resulting model elasticities that derive from changing different costs. Any component of cost or travel time can be used to calculate demand elasticities; however, they are not all independent so that there may be little point in checking all of them separately.

3.16 Also, in the calculation of the generalised costs, different components can have different weights applied to them (e.g. waiting time is weighted more than in-vehicle time). Thus, if one weighted component always accounts for twice as much as another in the total cost, the elasticity of demand relative to it will always be twice as much. Nevertheless, it is desirable to test the more important components in this way to ensure that the formulation of generalised cost in the model is correct.

3.17 Whilst the model calibration and overview reports mentioned above include brief discussions of the realism testing performed as part of model acceptance testing (in accordance with our Transport Appraisal Guidance (TAG)), the tests are also explained in this section in a little more detail.

Realism Test Scenarios

3.18 The primary realism tests as specified in TAG require that car fuel cost and public transport fare elasticities lie within specified bands (as set out in Table 4).

3.19 Car fuel cost elasticity tests are required in all cases where a highway model is used for road scheme or policy analysis and public transport fare elasticity tests are required when changes in public transport generalised costs (including changes in fares) are modelled. Car journey time elasticity tests are also required as these will similarly affect the model results in relation to the choice of mode.

3.20 Table 4 below summarise the recommended elasticities that should be achieved by the realism tests (TAG unit M2-Variable Demand Modelling) whilst Table 5 presents the elasticities derived from the NTM realism tests.

Table 4 Recommended Elasticities

Elasticity	High	Low
Car Journey Time (trips)	No stronger than -2.0	
Average Fuel Cost (kms)	-0.35	-0.25
PT Main Mode Fare (trips)	-0.9	-0.2

[18] Calibration Report is available at: https://www.gov.uk/government/collections/transport-appraisal-and-modelling-tools

Table 5 Elasticities from Realism tests (per mode)

Elasticity/Mode	Walk	Cycle	Driver	Passenger	Bus	Rail
Car Journey Time	0.11	0.49	-0.20	-0.12	0.60	1.21
Fuel Cost	0.09	0.35	-0.32	-0.19	1.19	1.26
PT Fare	0.06	0.24	0.07	0.17	-0.98	-0.58

3.3.2 Car Journey Time

3.21 The Car Time test includes a journey time increase of 10% on trips made by private vehicles. An increase of journey time for such trips is immediately related to a decrease to the number of private vehicle and passenger trips and a shift to other non-car modes.

3.22 The percentage difference, in number of trips, from the reference case is shown in Figure 7. As expected the car trips related to the trips by Driver and Passenger modes are lower due to the increase of the journey time. A proportion of car trips are shifted to other modes with more trips made by Bus and Rail modes followed by Cycle and Walk modes.

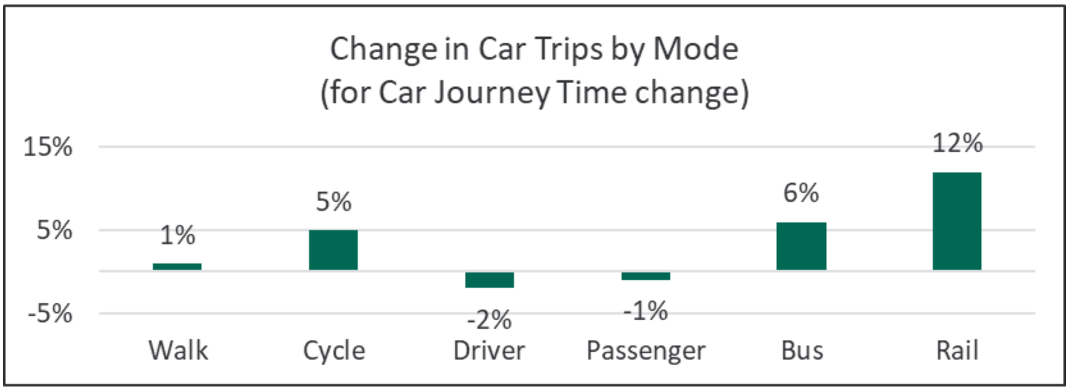

Figure 7 Change in Trips by Mode – For Car time change

3.23 Figure 8 shows a greater mode shift to public transport is observed in the longer distance trips. These are trips of 35 miles or more and the modal switch proportion increases with increasing trip length. The switch to long distance bus is particularly noticeable and this is consistent with the large elasticities reported for these in the calibration report. However, the numbers of trips involved in these modes and distances are very small compared to that of car driver. The proportion of all trips in the long-distance bus and rail categories are less than 0.01% and 0.05% respectively. For shorter trip lengths (up to 25 miles) the switch to public transport modes is much less and this is replaced by shifts to cycling and walking for such trips.

3.24 It is also interesting to note that the overall response of car passengers is half that of car drivers. Whilst car passengers do not experience the full costs of travel, they do experience the full impacts of delays and this time component therefore makes up a larger portion of their total disutility. This will be particularly true for the longest trips as time is by far the greatest component of total disutility and this is where we see the greatest switch away from car passenger. Analysis by trip purpose (Figure 9) shows that the most elastic trips are holiday trips and, since these tend to be the longest distances, is consistent with our expectations.

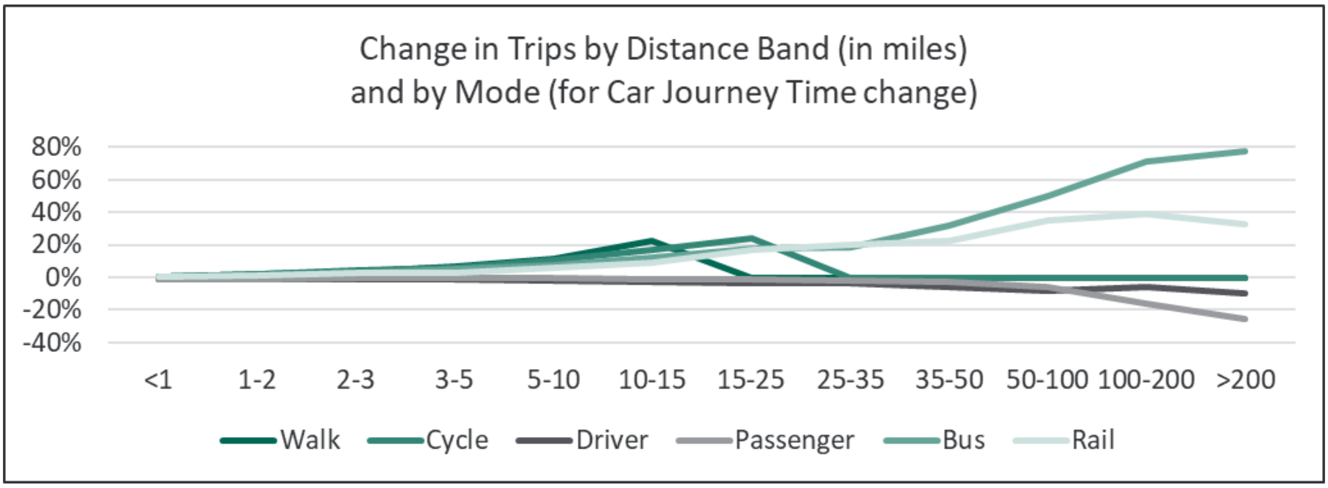

Figure 8 Change in Trips by Distance Band - Car time change

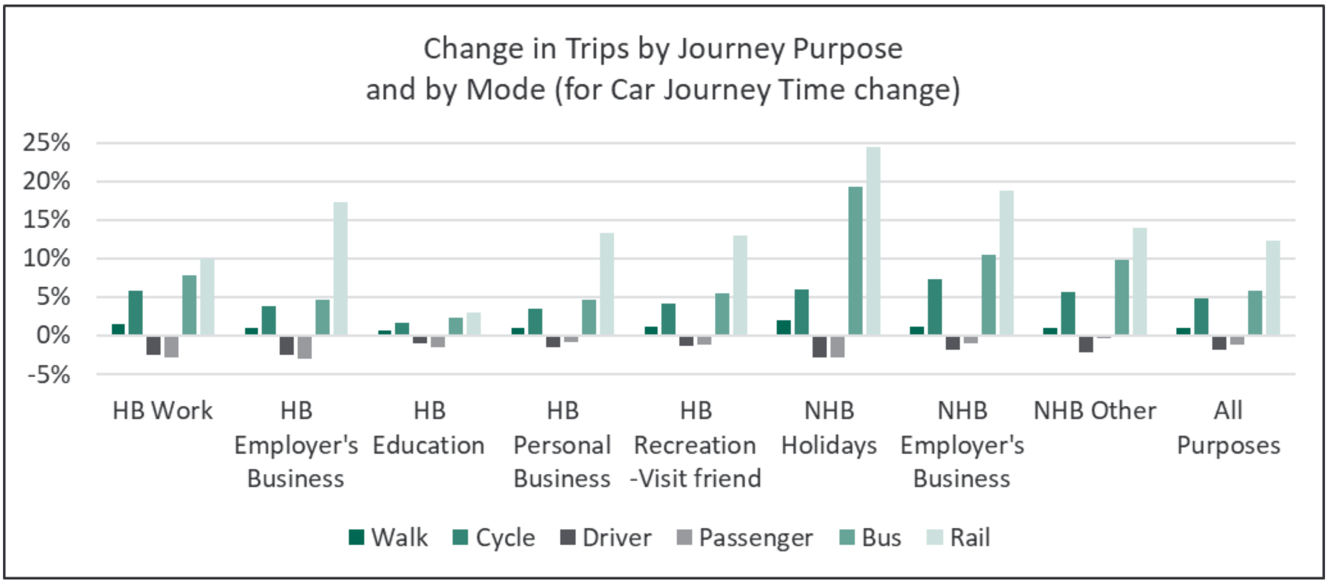

Figure 9 Change in Trips by Journey Purpose - Car time change

3.3.3 Car Fuel Price

3.25 The Car Fuel Price test includes an increase of 10% on the fuel price paid by private vehicles. An increase in fuel price is related to a decrease of trips with private vehicles and a shift of these trips to other modes. The difference in distance travelled is shown in the figures below. As expected, the distance travelled by car is less due to the increased price of fuel. A proportion of car trips is shifted to other modes with more trips made by Bus and Rail modes followed by Cycle and Walk modes.

3.26 Again, a greater mode shift to public transport is observed in long distance trips, starting from 50miles and this effect increases with increasing trip lengths. For shorter trips (up to 25m) there is mode shift to Cycle and Walk modes. When compared to the test which increased Car Journey Times (above) the generally lower impacts show that the model is more sensitive to time than costs and that, as expected, the changes in cost impact most on the lower value of time and more discretionary trip purposes.

3.27 Similarly, whilst the switch to making more long-distance trips by rail or bus is less pronounced than when the car journey time is increased, the impact on distance travelled is again far greater than the changes in the numbers of trips (Figures 10, 11 and 12). This effect is consistent with the greatest impacts being seen for the longer and most discretionary purposes with holiday trips showing the largest response.

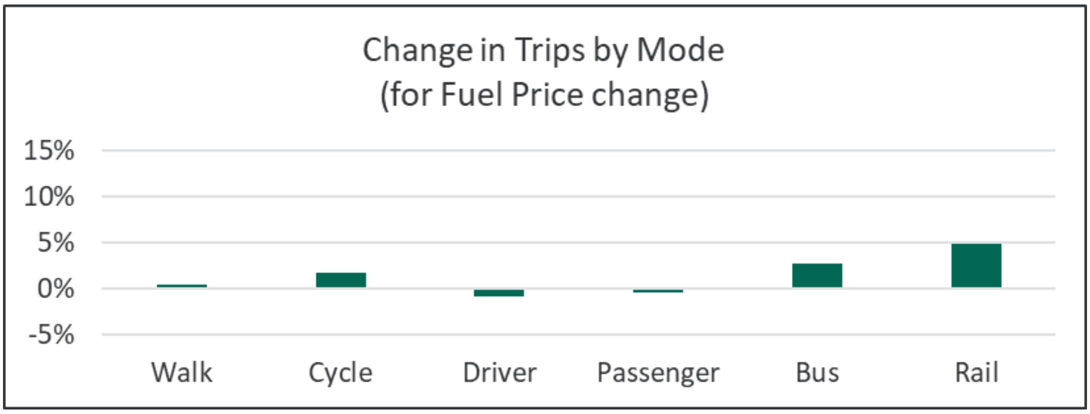

Figure 10 Change in All Trips by Mode in response to Car Fuel price change

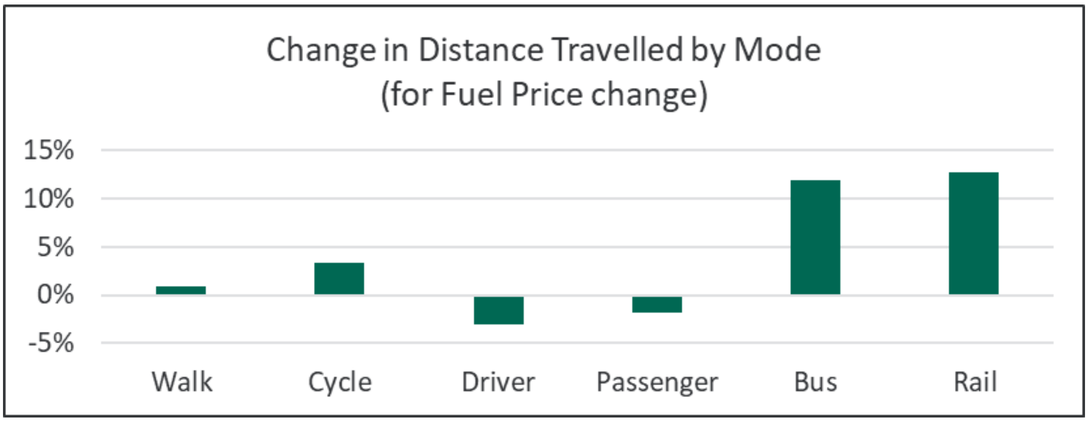

Figure 11 Change in Total Distance Travelled by Mode in response to Car Fuel price change

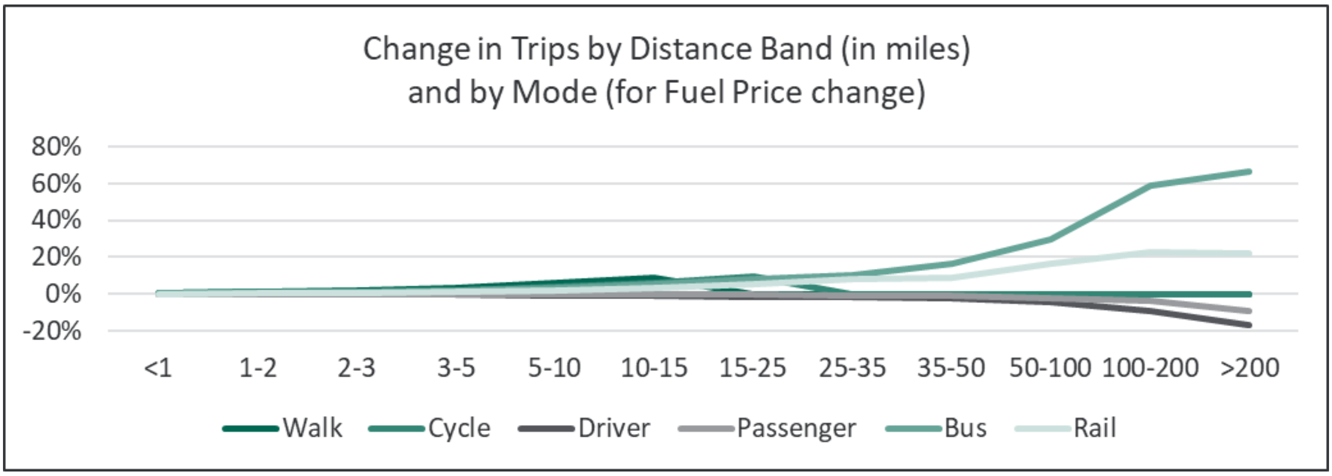

Figure 12 Change in Trips by Distance Band - Fuel price change

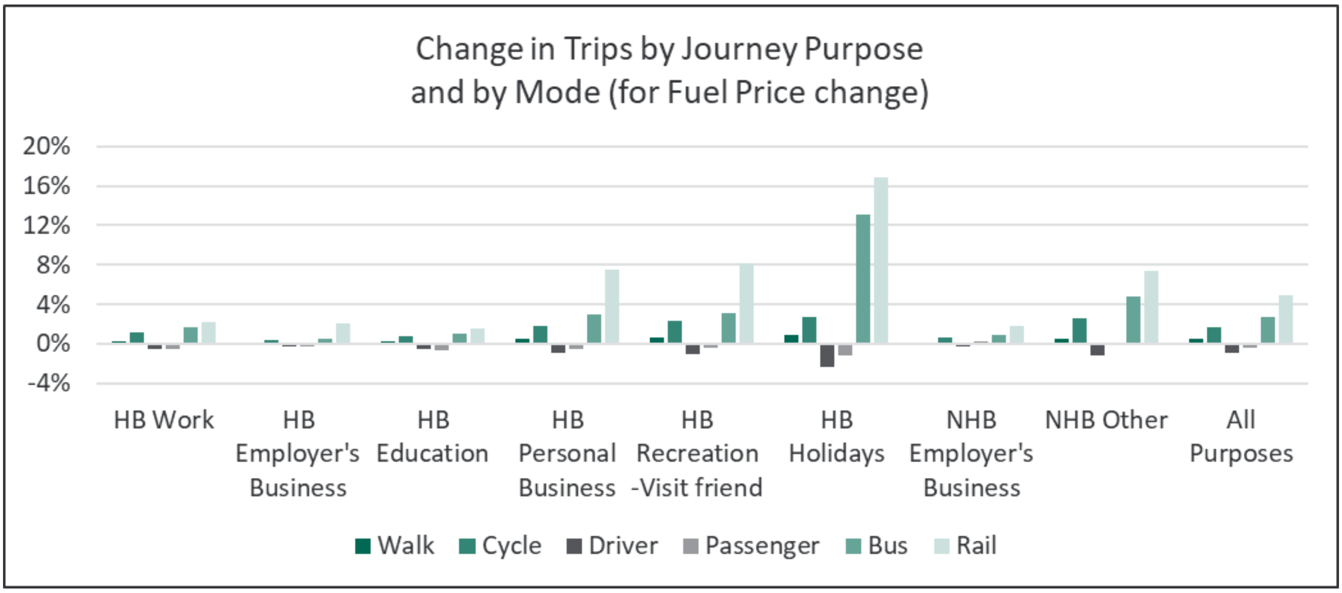

Figure 13 Change in Trips by Journey Purpose – Fuel price change

3.28 The percentage change in car passengers is less than that of car drivers as these travellers do not fully experience the cost of the fuel price change. However, to ensure the model responds in a sensible manner, passengers are assumed to experience costs through a "guilt factor" which was set at a rate of 87% of the costs felt by the car driver as part of the NTMv2R calibration.

3.3.4 Public Transport Fare Price

3.29 The PT Fare Price change includes an increase of 10% on the fare price of rail and bus trips. An increase in fare price is related to a decrease of trips on public transport modes and a shift of these trips to other modes. The difference in the number of trips is shown in the figures below. As expected, Rail and Bus trips are reduced due to the fare increase having switched trips to other modes.

3.30 A greater shift to Car mode is seen in long distance trips starting from distances of 35km and this effect again increases with increasing trip lengths. For shorter trips (up to 25km) there is mode shift to Cycle and Walk modes. Comparing the results of this test to those of the Car based tests above shows that the responses are somewhat lower. Thus a 10% change to monetary costs for these travellers is having a smaller impact than the case for car costs. This will be partly because the monetary component of the total disutility is less for PT trips, due to longer journey times and access and egress times but may also be because the value of time for Rail passengers tends to be higher and this makes rail passengers less sensitive to costs.

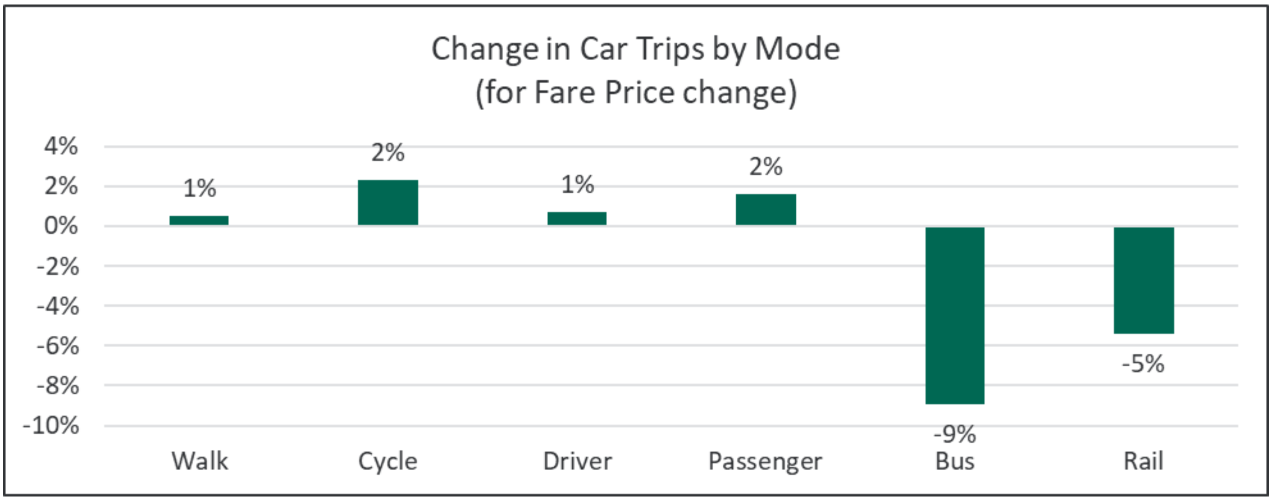

Figure 14 Change in Trips by Mode - Fare price change

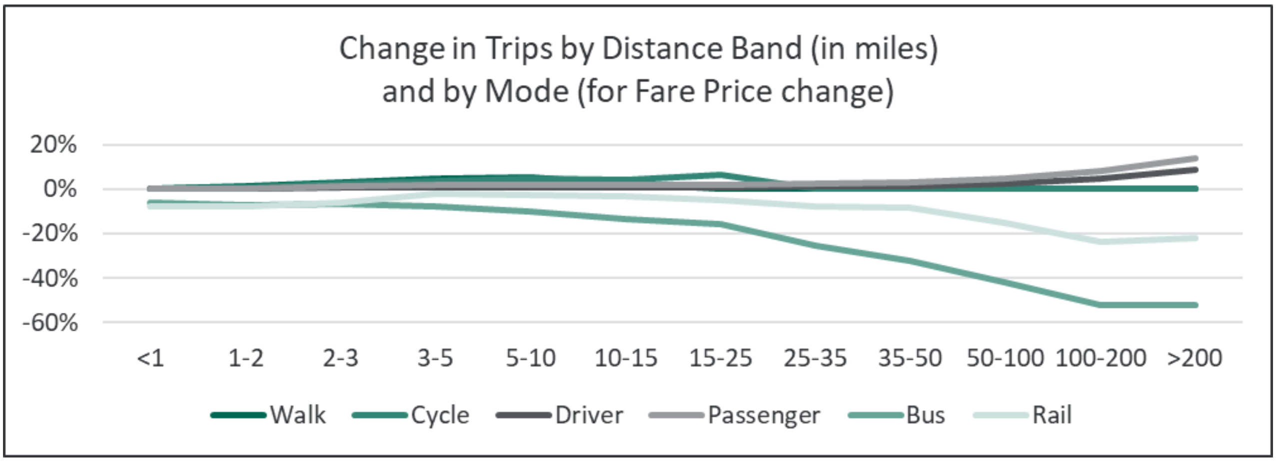

Figure 15 Change in Trips by Distance Band and Mode - Fare price change

3.3.5 Elasticities from Realism tests

3.31 Figure 16 summarises the percentage difference in number of trips by mode for the three different tests that comprise the Realism tests. The percentage changes in trips for each mode are used to calculate the Car Journey Time Elasticity and the Fare Elasticity whereas the Fuel elasticity is calculated from the difference in distance travelled by each mode rather than trips. Figure 17 shows the elasticities resulting from the Realism tests.

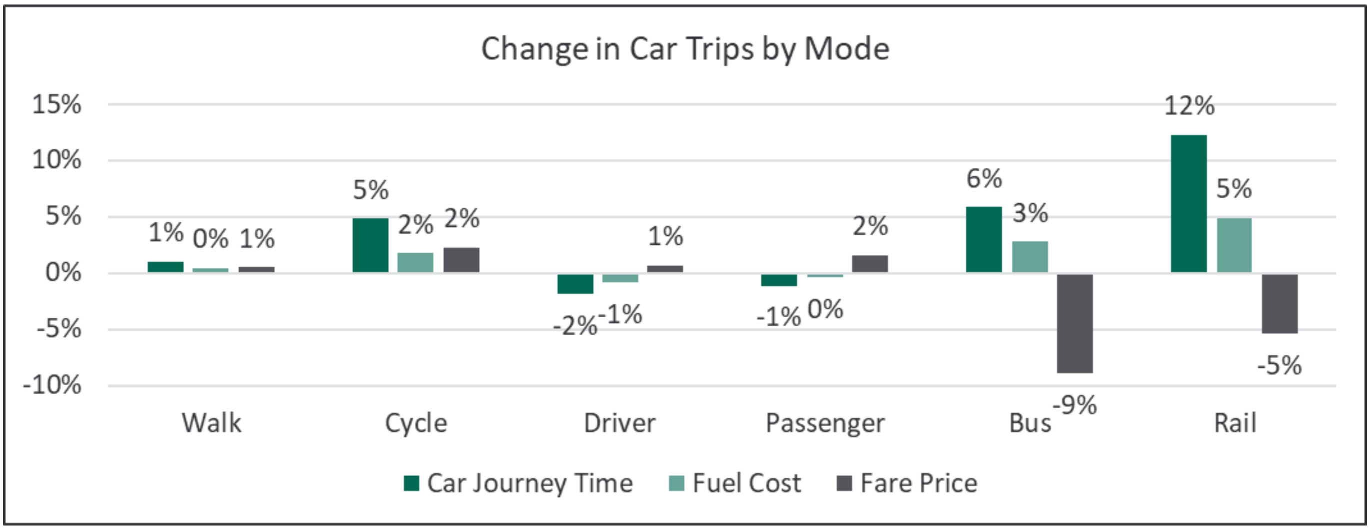

Figure 16 Change in Trips by Mode from Realism tests

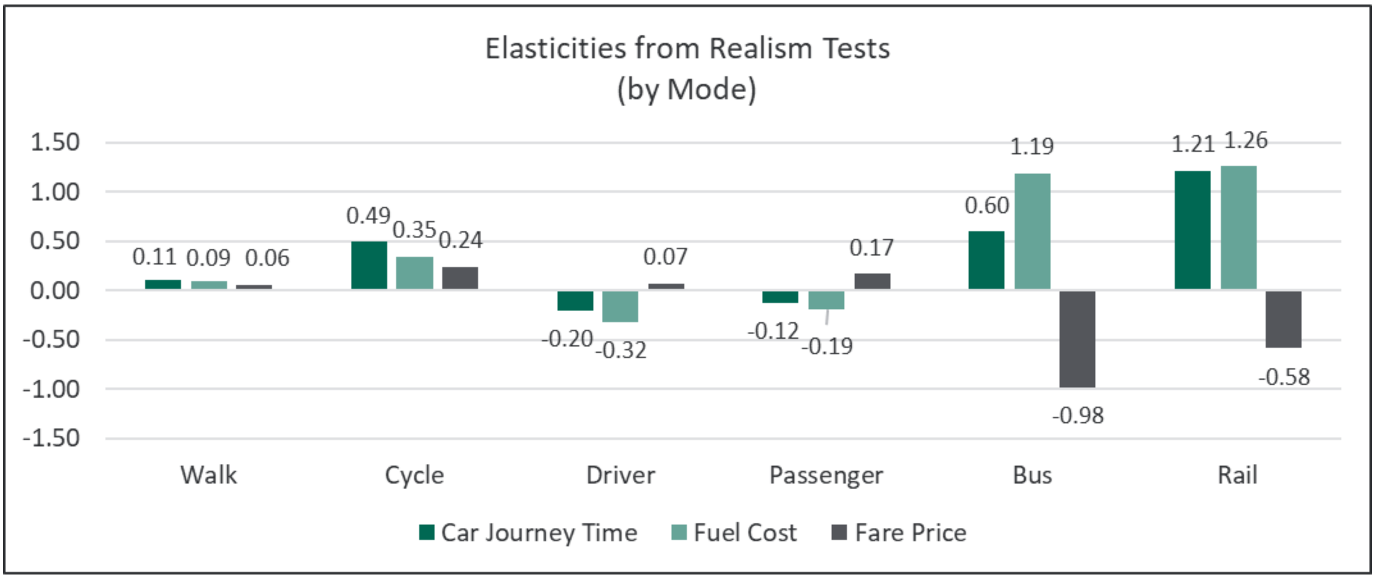

Figure 17 Elasticities from Realist tests by Mode

3.32 All the elasticities lie within the recommended range as described in TAG and this provides confidence in the model's performance and robustness. The Car Journey Time and Fuel Elasticities show that any increases in these items result in decreases in car trips and significant increases in rail and bus trips. However, the elasticities for rail and bus trips are higher with the fuel cost increases indicating that the switching traveller types value money costs more importantly than time. This suggests that the impacts are more from lower value of time travellers or purposes. The Fare Elasticities show that rail and bus trips are significantly affected by any change in fare prices although this doesn't make a significant change in the number of car trips. This is due to the relatively small number of rail and bus trips in the 2015 base year when compared to car trips.

3.4 Fuel Cost Test Analysis

3.33 This section presents the results of a series of tests designed to check how the fuel cost elasticity varies in forecast years under the influence of different GDP growth assumptions. The first set of tests, presented in section 3.4.1, show the fuel cost test results compared to the RTF18 reference scenario. These are followed in section 3.4.2 by the results of the same fuel price scenarios but using a different GDP assumption in order to show how varying rates of GDP can impact on the resulting fuel price elasticity.

3.4.1 Fuel Cost change by 10%

3.34 The fuel cost tests include scenarios with a 10% increase and 10% decrease in the fuel cost for the two forecast years 2030 and 2050. The model outputs show the effects on both the total number of trips travelled by each trip purpose and the total impact on car traffic. The results from the two tests of a fuel cost change of ±10% for 2030 follow the same pattern as those for 2050 discussed below. The figures below show the number trips and the distance travelled (billions Km) by car journey purposes in 2050.

Results of Fuel Cost change by ±10% for 2050

3.35 A decrease of fuel costs by 10% affects the number of car trips and produces an increase in distance travelled on the road network which varies for each of the six trip purposes. The trips for the "other purposes" (HB-Other and NHB-Other) are the most significantly affected by the fuel cost change and these are followed by the education and personal business trips. The commuting trips (HB-Work) and business trips (HB-EB and NHB-EB) have the smallest variations resulting from the fuel cost change. The modelling results for the test with 10% decrease on fuel cost are shown in Figure 18 and Figure 19.

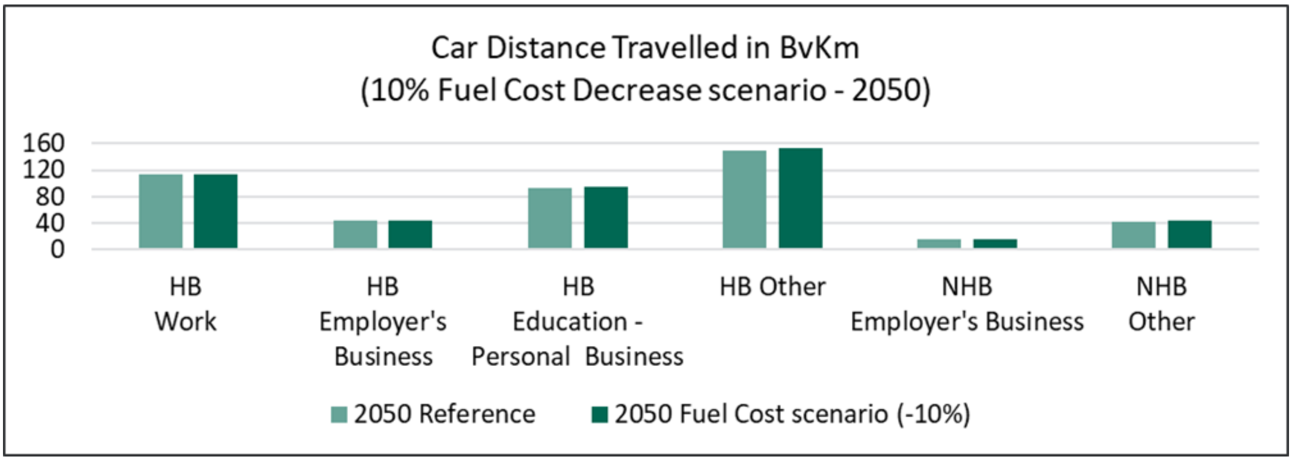

Figure 18 Car Distance Travelled for 10% Decrease in Fuel Cost - 2050

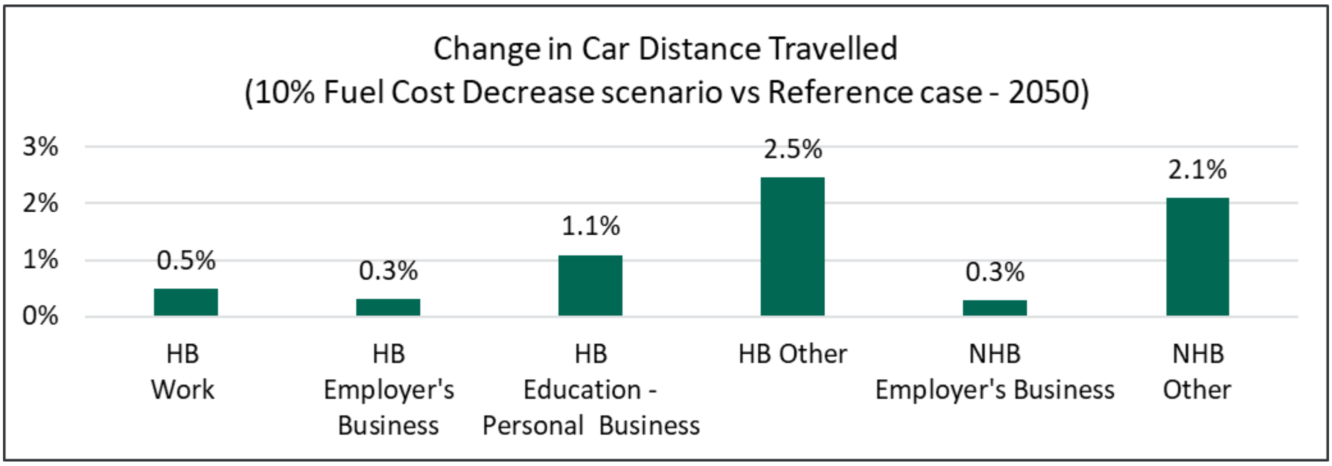

Figure 19 Change in Car Distance Travelled from Reference case for 10% Decrease in Fuel Cost - 2050

3.36 An increase of fuel cost by 10% has the opposite effect in the number of car trips and provides less car distance travelled and the results from both changes (±10%) in the fuel cost follow the same pattern but in the opposite direction. Again, the increase of fuel cost has more significant effect on the HB-Other and NHB-Other trips, a moderate effect on the HB-Educ/PB trips and less significant effect on the higher value HB-W and HB-EB trips. The modelling results for the test with 10% increase on fuel cost are shown in Figure 20 and Figure 21.

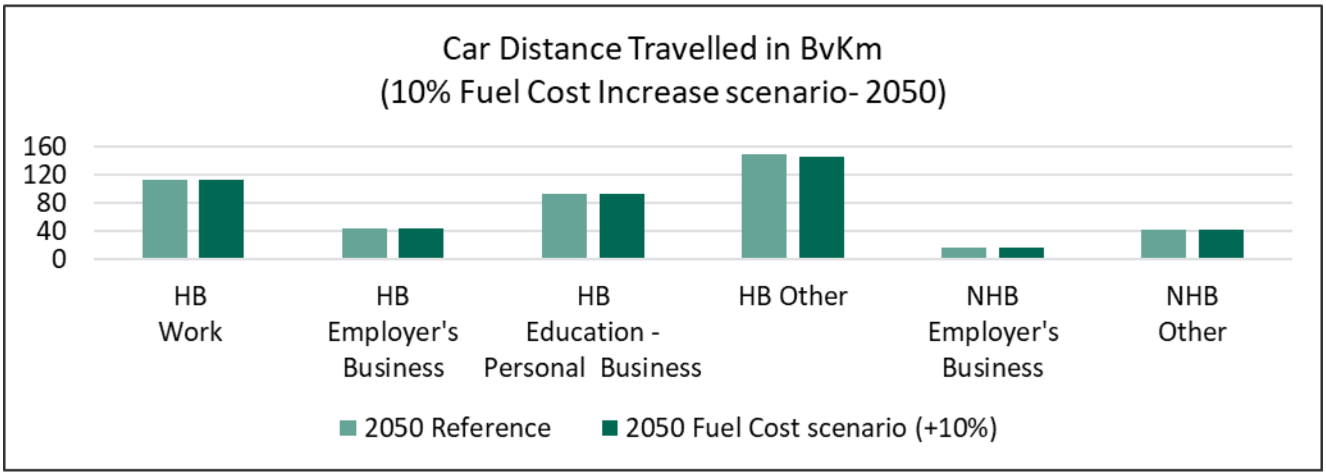

Figure 20 Car Distance Travelled for 10% Increase in Fuel Cost - 2050

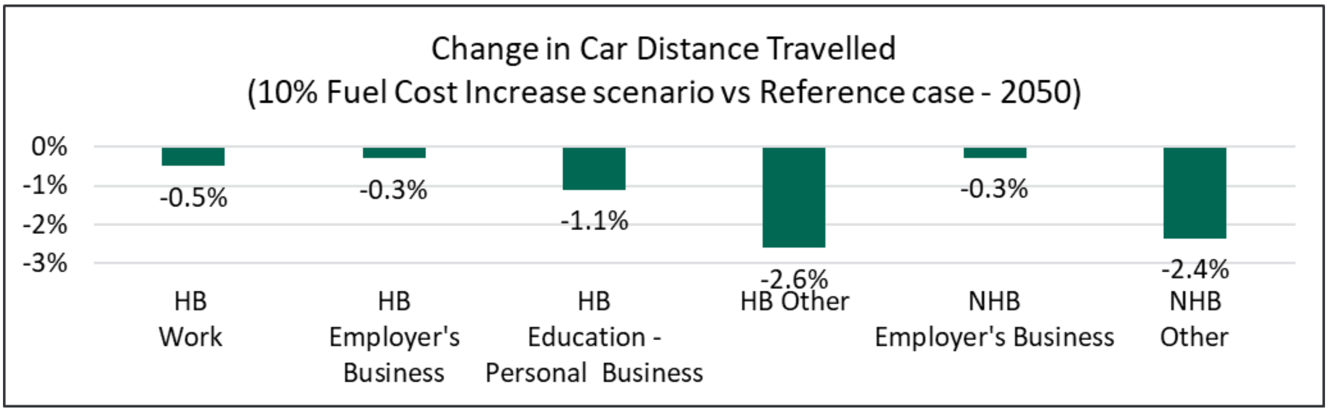

Figure 21 Change in Car Distance Travelled from Reference for 10% Increase in Fuel Cost – 2050

3.37 The results from these tests are in line with expectations and justified as:

- Commuting trips (HB Work) and business trips (HB-EB and NHB-EB) place a higher importance on the value of time for their journey rather than the monetary cost of their journey thus they are less affected by fuel changes.
- Education and personal business trips (HB-Educ/PB) assume travellers have a lower value of time than commuting and business trips and therefore the fuel change has somewhat larger effect on these trips.
- Other trips (HB-Other, NHB-Other) are more discretionary and are therefore the most sensitive of the travel purposes to both changes to costs as well as time. The category of trips includes holiday and recreational trips which, as well as being more discretionary are generally longer in distance, so the resulting impacts on traffic tends to be even higher than that of trips.

Fuel Cost Elasticities for 2030 and 2050

3.38 The total difference of car distance travelled that derive from the above four scenarios has been used to calculate the fuel elasticities presented in Table 6. The values show that the model is slightly less sensitive to the fuel cost decrease than the increase and, as they have declined quite markedly to 2030, they have fallen outside of the recommended range in TAG (-0.25 to -0.35). The decline increases again to the year 2050 but at a much slower rate.

3.39 The phenomenon of declining price elasticities is not surprising and is regarded a feature of models founded on the principal of "generalised time". It is a result of the modelled GDP growth per capita increasing the value of travel time through time (i.e. in forecast years) resulting in monetary costs becoming a smaller component of the overall generalised time. The smaller the monetary cost element, the smaller the impact on price changes will be and thus the resulting price elasticity will be lower.

3.40 Compared to the base year elasticity of -0.32 the car driver fuel price elasticity has declined by a range spanning from 41% in 2030 to 60% in 2050. This reduction was also a feature of the earlier NTMv2 model and in order to mitigate these impacts the NTM reference scenario applies a factor of 0.5[19] to the GDP (VOT) growth rates, and this factor has again been included in this scenario.

Table 6 Reference Scenario Fuel Elasticities (2030 & 2050)

Year	Fuel Cost	Change on Total Car	Change on Fuel	Elasticity
2030	-10% fuel cost	1.75%	-0.10	-0.16
2030	+10% fuel cost	-1.82%	0.10	-0.19
2050	-10% fuel cost	1.38%	-0.10	-0.13
2050	+10% fuel cost	-1.46%	0.10	-0.15

3.4.2 Fuel cost change by 10% with GDP factor equal to 1

3.41 The purpose of this test was to investigate the potential impact of the use of the GDP Growth factor on both the fuel cost elasticity and the reference scenario that was developed for RTF18. The test included the same fuel cost changes of ±10% as in the previous test but using a GDP growth factor equal to 1 rather than 0.5 used in the earlier Reference scenario. The scenarios were again run for the years 2030 and 2050 and included a new Reference case scenario with the factor set to 1 for use as a comparator.

Model output for Fuel cost change by 10% for 2050

3.42 The figures below show car distance travelled (billion Km) by journey purpose in 2050 for the 10% decrease and increase in fuel cost compared to the Reference (Core) scenario in which all have the GDP growth factor equal to 1.

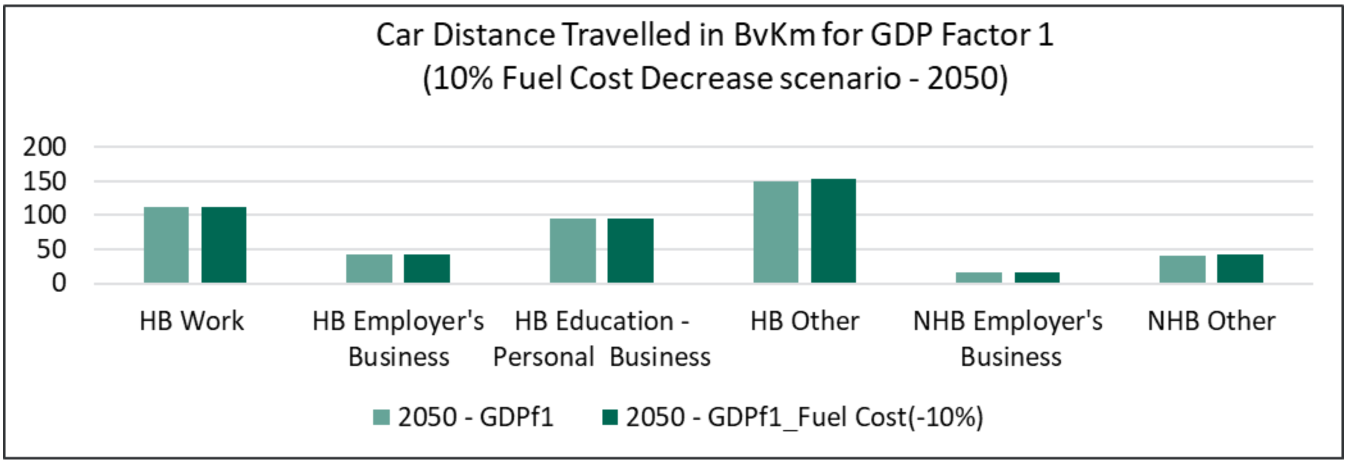

Figure 22 Car Distance Travelled for 10% Decrease in Fuel Cost – 2050

[19] A GDP factor of 0.5 has historically been used in the NTM to help reconcile the economic evidence of the impact of GDP on values of time with empirical evidence that suggests the fuel price elasticity has remained constant around the figure -0.3 for many years. Use of the factor reduces the rate of decline in the fuel price elasticity.

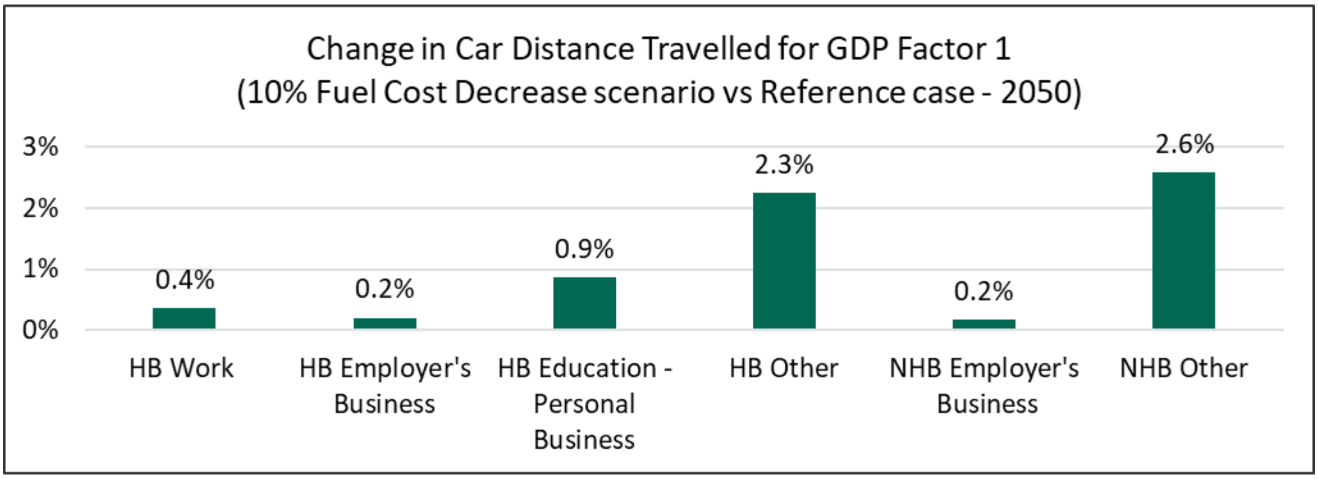

Figure 23 Change in Car Distance Travelled from Core for 10% Decrease in Fuel Cost - 2050

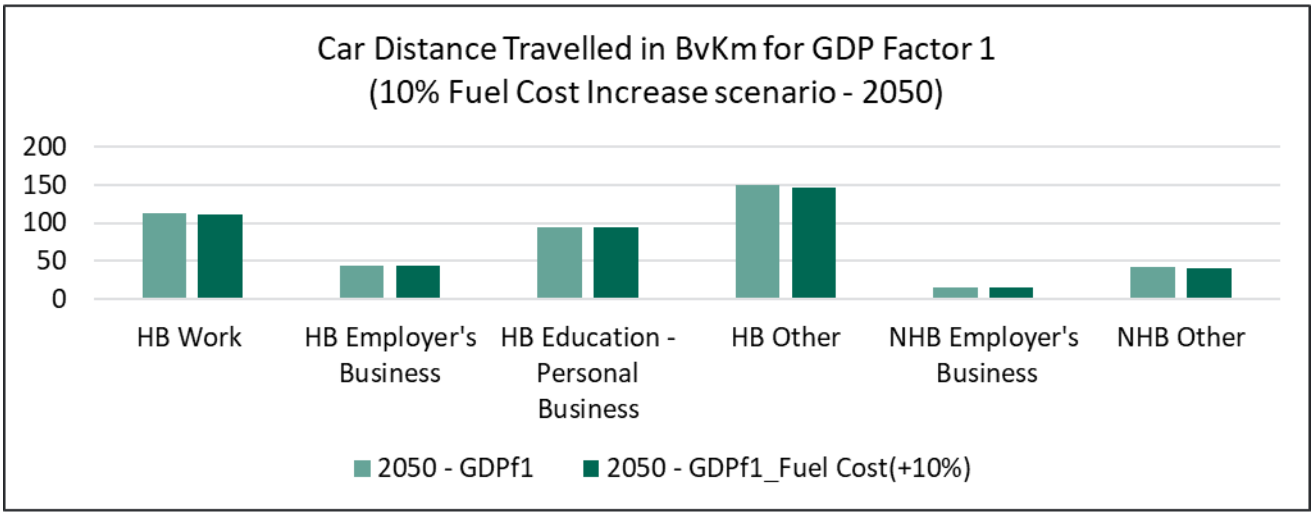

Figure 24 Car Distance Travelled for 10% Increase in Fuel Cost - 2050

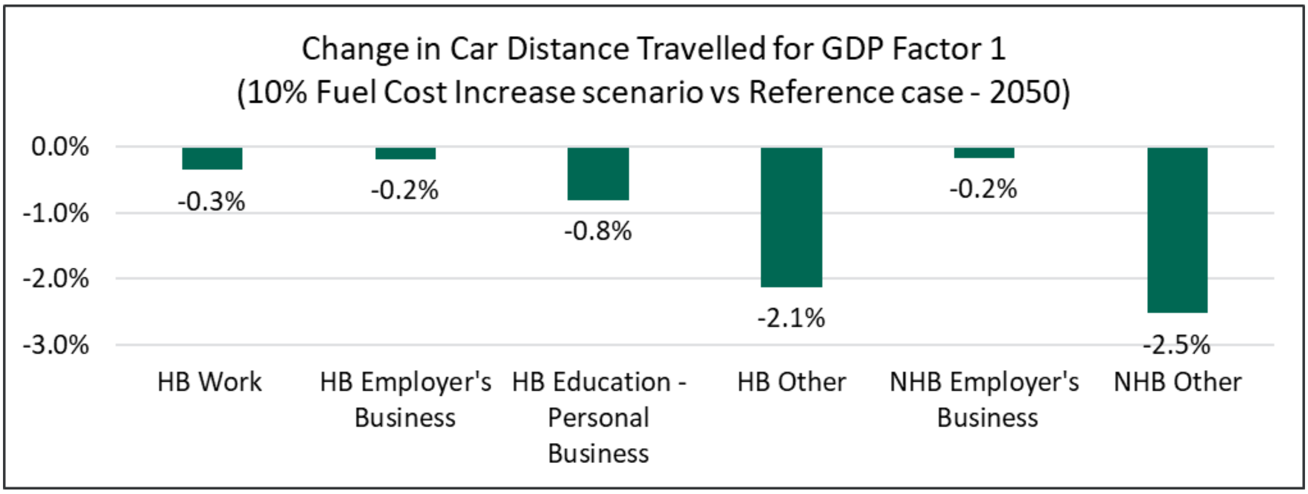

Figure 25 Change in Car Distance Travelled from Core for 10% Increase in Fuel Cost - 2050

3.43 The results for both the 2030 and 2050 scenarios show the same patterns as seen in the earlier fuel cost test scenario with the more discretionary home based other (holidays and leisure) trips responding the most and the higher value business trips responding the least. As expected, the responses in the earlier test are greater than those from the GDP factor of 1 scenario as this has acted to further reduced the significance of the monetary fuel cost component.

Fuel Elasticities for 2030 and 2050 with full GDP growth

3.44 Table 7 shows the Fuel Elasticities in 2030 and 2050 for the full GDP scenarios. The elasticities are again fairly symmetric and are again lower in 2050 than in 2030. Compared to the base year elasticity of -0.32 they have declined by a range spanning from 44% in 2030 to 63% in 2050 which is a few percent more than found in the original scenario.

Table 7 Fuel Elasticities (2030 & 2050 from Core scenario with GDP growth factor =1)

Year	Fuel Cost scenario	Change on Total Bvm Car travelled	Change on Fuel Cost	Elasticity
2030	-10% fuel cost	1.66%	-10%	-0.16
	+10% fuel cost	-1.68%	10%	-0.18
2050	-10% fuel cost	1.26%	-10%	-0.12
	+10% fuel cost	-1.20%	10%	-0.13

3.45 Table 8 presents a comparison between the scenarios with GDP growth factors equal to 0.5 and 1. The fuel price elasticity declines significantly in forecast years in both sets of tests and whilst this decline has increased with increased GDP the difference is not as large as anticipated and it is also interesting that the figures are not as symmetric as might be expected. The differences involved in the ±10% change in fuel costs are having as much impact on the outturn elasticity as the impact of the GDP factor itself and this would imply that the assumption about GDP growth is having a much smaller monetary impact than the change in costs used in the elasticity test.

Table 8 Elasticities comparison for GDP Growth factors of 0.5 and 1

Year	Fuel Cost scenario	Elasticities GDP Growth factor 0.5	Elasticities GDP Growth factor 1
2030	-10% fuel cost	-0.16	-0.16
	+10% fuel cost	-0.19	-0.18
2050	-10% fuel cost	-0.13	-0.12
	+10% fuel cost	-0.15	-0.13

3.5 High GDP Test and Analysis

3.46 Given the fairly small impacts from varying GDP in the fuel price tests, a further test was run with a larger increase in GDP to investigate the size of any outturn GDP elasticity. This test involved assuming higher GDP (growth factor = 2.5) compared to the standard reference scenario which has the GDP growth factor equal to 0.5.

3.47 The only difference between the two scenarios is the GDP value, which essentially means just the Value of Time which changes over time. A full GDP test in the NTM would also include people's travelling characteristics, income and car ownership as modelled in NATCOP, but this additional step was not performed for the scenarios tested here. Figure 26 and Figure 27 show the car traffic results by journey purpose and the difference for the two runs.

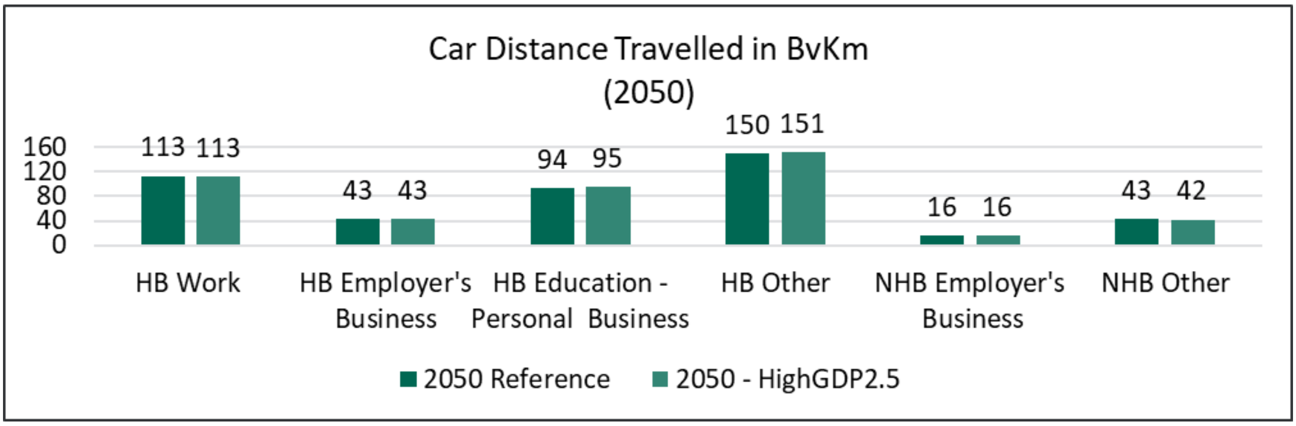

Figure 26 Car Distance Travelled for Core and High GDP scenarios - 2050

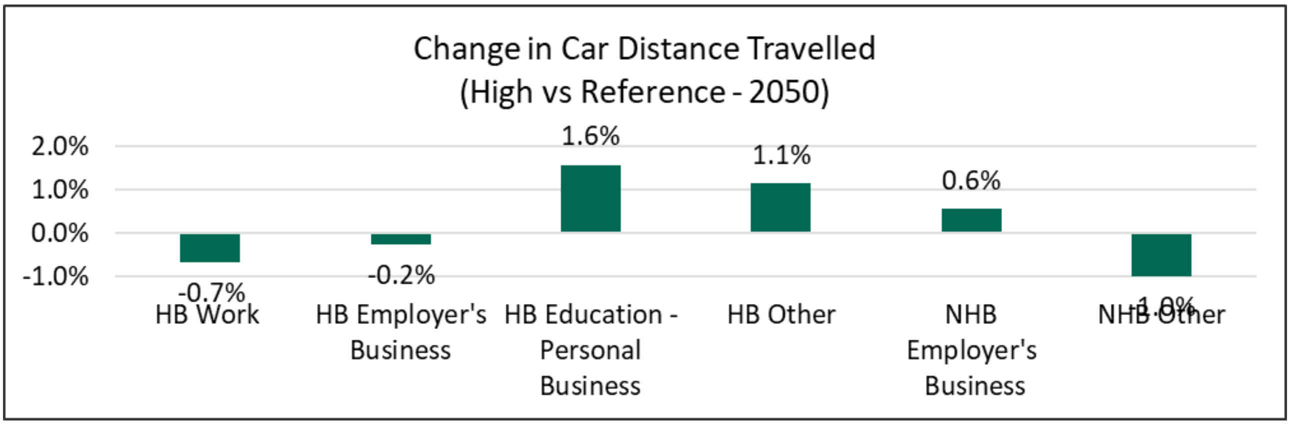

Figure 27 Change in Distance Travelled High vs Reference GDP scenarios - 2050

3.48 It can be seen that increasing GDP by a factor of 2.5 has made only a very small difference in traffic levels in 2050. The difference of 0.4% is fairly insignificant when compared to the 35% traffic growth forecast in the reference scenario in 2050 and it is noticeable that increasing GDP has resulted in falls to each of home based work (commuting), employer's-business and non-home based other trips.

3.49 Further investigation of the effects of increasing GDP revealed a more complex interaction between the different modes as shown in Table 9 below in which the overall scale of the GDP effect on travel remains small and increases slightly over time (from 0.15% to 0.2%) but that the impact on car driver trips declines from 0.84% in 2030 down to 0.3% in 2050.

Table 9 Change in Distance travelled by Mode and Year from Increased GDP (with respect to Reference case)

Mode	2030	2035	2040	2045	2050
Walk	-3.10%	-3.85%	-4.57%	-5.26%	-5.92%
Cycle	-9.72%	-12.00%	-14.16%	-16.03%	-17.75%
Driver	0.84%	0.79%	0.68%	0.52%	0.30%
Passenger	-3.04%	-3.42%	-3.84%	-4.24%	-4.65%
Bus	13.54%	16.88%	20.98%	25.33%	29.51%
Rail	2.26%	3.00%	3.54%	3.76%	4.07%
Total	0.15%	0.16%	0.17%	0.19%	0.20%

3.50 These effects for car trips are however small compared to what is seen to be occurring on other modes. There are large percentage increases in both Rail and particularly Bus traffic and these impacts are offset by decreases in walking, cycling and car passenger trips as shown in Figure 28.

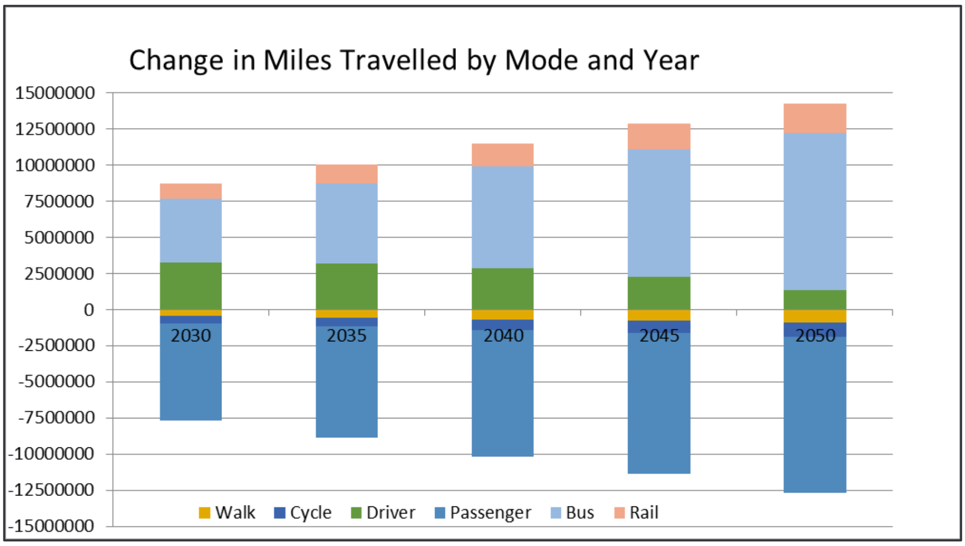

Figure 28 Change in Distance travelled by Mode and Year from Increased GDP

3.51 Looking at the percentage changes by distance band, in Figure 29, this clearly indicates that the biggest impacts are occurring at the longest distances, which are for coach travel. Although some of the changes are large, the actual numbers of trips affected in the longer distance bands will be quite small as in Figure 30.

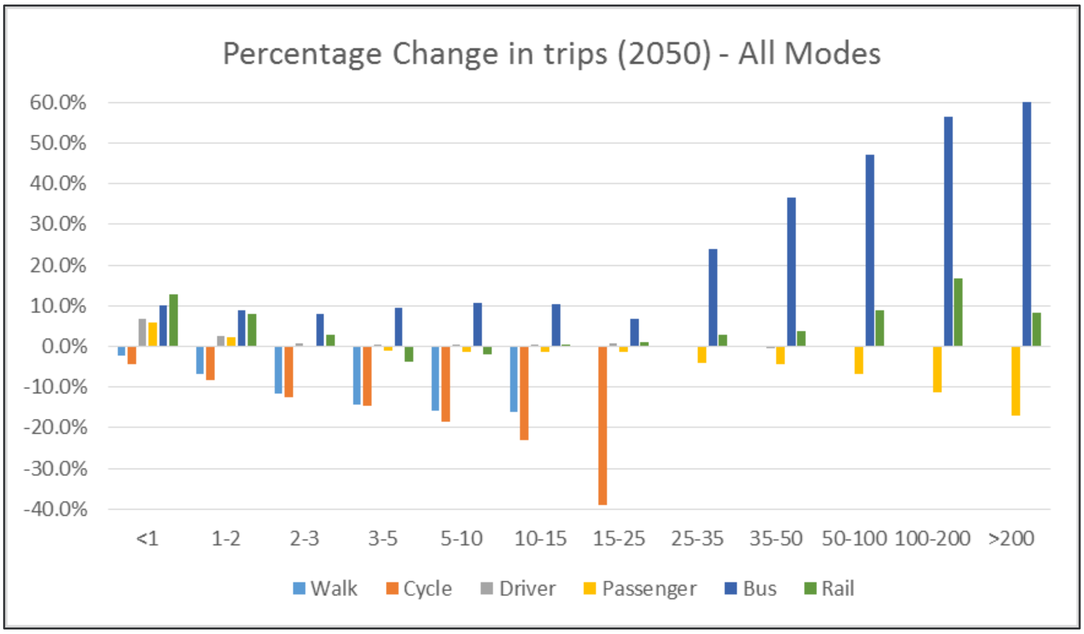

Figure 29 Percentage Change in Trips by Mode and Distance Band in 2050

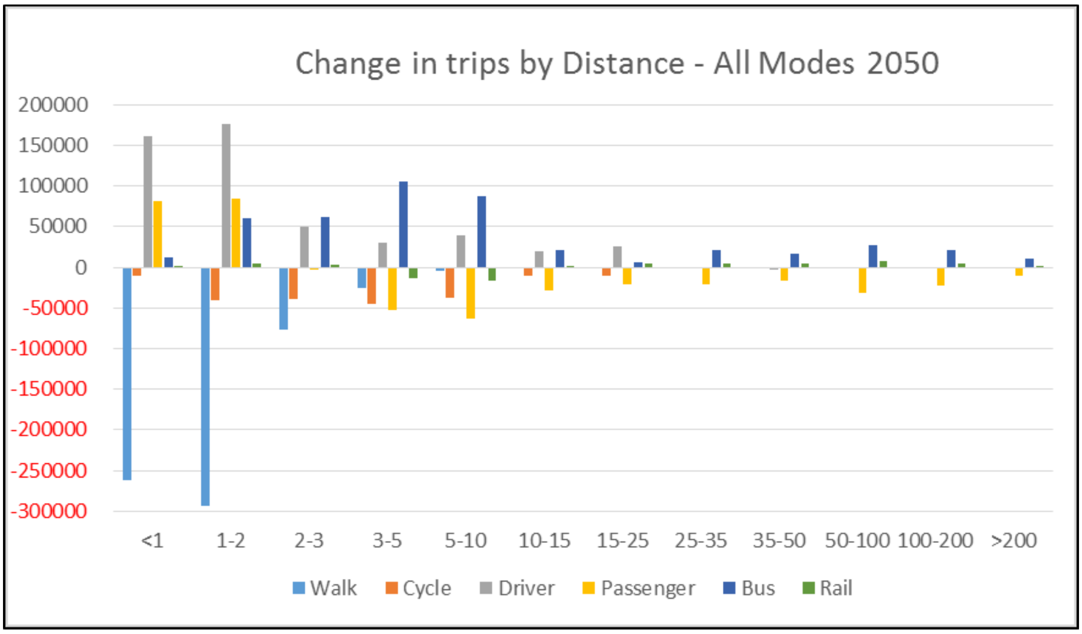

Figure 30 Change in Trips by Mode and Distance Band in 2050

3.52 Looking at the changes in the actual numbers of trips by distance band, the impact is largest in the shorter distances where a large number of walk and cycle trips are switching to car passenger and driver. The picture changes as distances increase but for the longest trips there is a marked switch from car passenger to bus. Whilst the numbers involved here are relatively quite small, the percentage changes are quite large with an approximate 10% decline in car passengers swapping to create 60% and 10% increases in Bus and Rail trips respectively.

3.53 To analyse this phenomenon, we investigated the way that the total disutility and component time and money costs are changing for each of the modes through time. As with the earlier NTMV2 model, the total travel disutility in the model is expressed as Generalised Time and is formed as described by the equation:

$$\text{Generalised Time} = \text{Travel Time}(\text{min/km}) + \text{Travel Cost}(£/\text{km})/\text{VoT}(£/\text{km})$$

3.54 Travel time is made up of mode specific access and egress times, wait and interconnection times (for public transport), parking search times (for cars) as well as the actual journey times. Many of these time components remain constant but the increasing congestion levels experienced by car travel mean that Travel Time per km is increasing through the forecast years for Car mode. However, as there are no crowding or congestion feedbacks for other modes in the model, travel time remains constant for these alternative modes.

3.55 Whilst public transport fares are increasing throughout time, the fuel cost for car travel decrease for all trip purposes over the forecast years as shown in Table 10. Trips for HB-Work and HB-Other have the same fuel costs but these are higher than the fuel cost for HBEB trips. Fuel cost for HBEB trips in the model are lower as the business trips can reclaim VAT and therefore they only experience 80% of fuel cost compared to other car trips.

Table 10 Forecast Changes in Fuel Costs from 2015

Journey Purpose	2020	2025	2030	2035	2040	2045	2050
HBW	-8%	-10%	-12%	-15%	-16%	-17%	-17%
HBEB	-8%	-10%	-11%	-14%	-15%	-16%	-16%
HBEO	-8%	-10%	-12%	-15%	-16%	-17%	-17%
HBDO	-8%	-10%	-12%	-15%	-16%	-17%	-17%
NHBEB	-8%	-10%	-11%	-14%	-15%	-16%	-16%
NHBO	-8%	-10%	-12%	-15%	-16%	-17%	-17%

3.56 Car fuel costs are expected to fall by 8% by 2020 and continue to fall declining by a further 8% by 2040 after which they decline at a lower rate reaching a total fall of 17% compared to the 2015 base year in 2050. This reduction is driven by assumed fuel efficiency improvements and a switch to electric vehicles. All the other monetary cost components remain constant in all the analysed scenario.

3.57 The monetary costs of car journeys are therefore diminishing for all journey purposes in the core scenario, shown in Figure 31. This is especially true for the lower value of time "Other" purposes as the fuel costs here make up a greater proportion of their overall disutility and therefore the effect of the lower fuel costs and a higher VOT through time will be proportionally larger.

3.58 With the faster increases in VOT in the high GDP the decline in the monetary component is even more significant, as shown in Figure 32.

3.59 In the calculation of full disutility these falls in the monetary components are being offset to some extent by slower (more congested) journeys and the combination of these effects means that the monetary component the total disutility of car journeys is diminishing even further as shown in Figure 33.

3.60 The monetary component of bus and rail costs however are increasing because of fare increases and, as there are no congestion-type feedbacks for these modes, the time component of Public transport trips remain constant. This leads to the monetary component of the overall disutility increasing for bus and rail as shown in Figure 33.

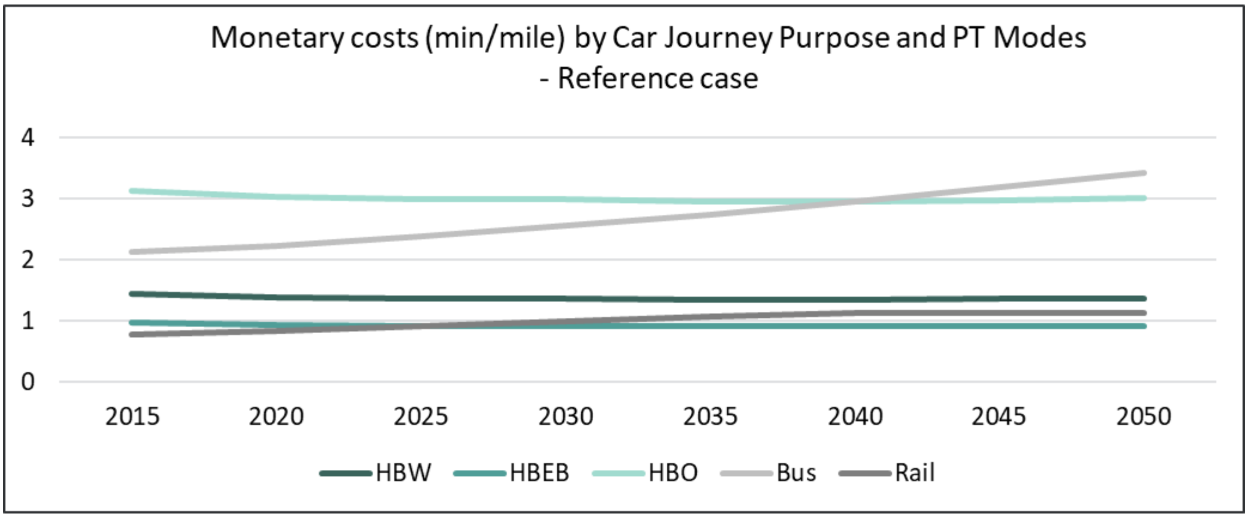

Figure 31 Monetary Costs in min/mile – Reference case

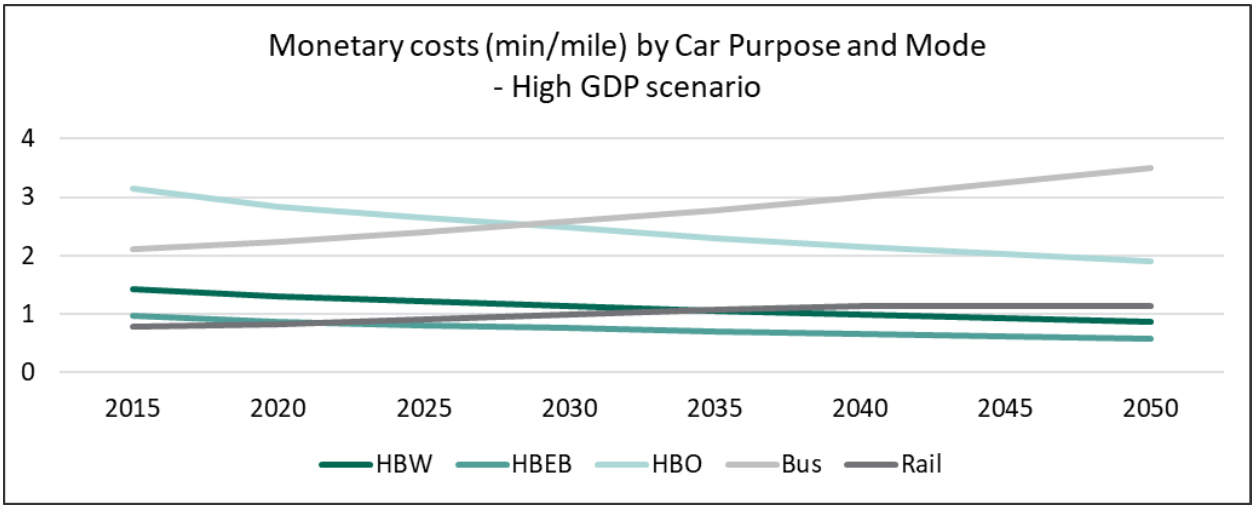

Figure 32 Monetary Costs in min/mile - High GDP scenario

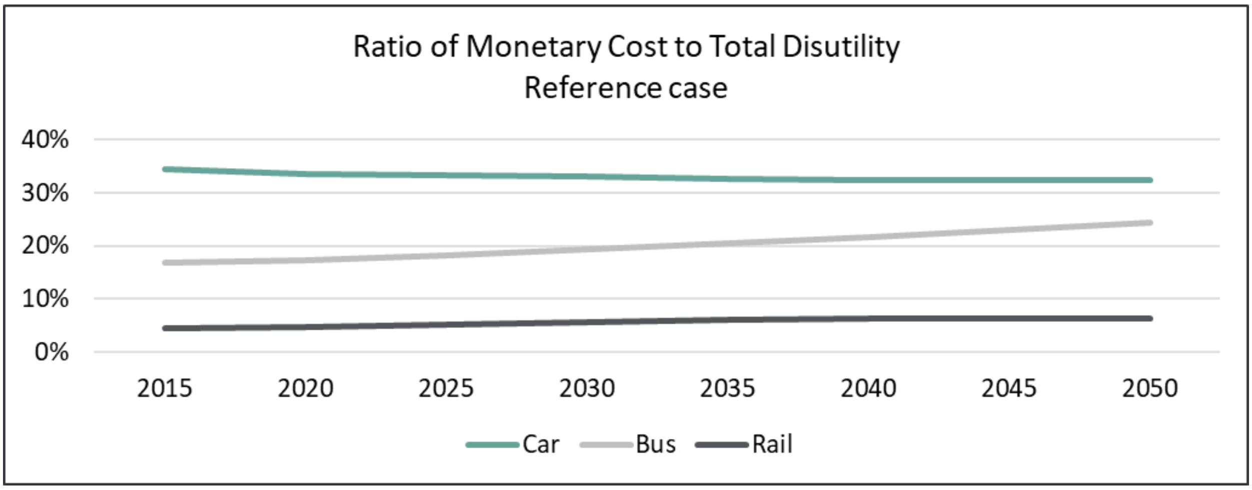

Figure 33 Ratio of Monetary Costs to Total Disutility – Reference case

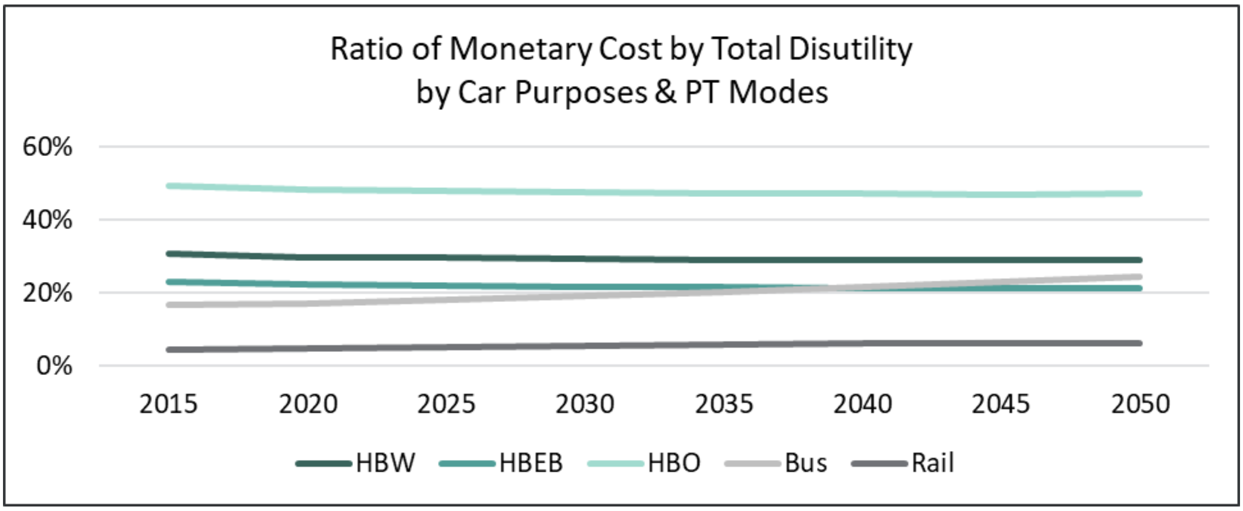

Figure 34 Cost in Minutes as Percentage of Total Disutility

3.61 In the case of bus and rail travel, the monetary component has increased by over 40% although for rail the monetary component still represents only a small portion of the overall disutility. Increasing the rate at which the VOT increases in the High GDP scenario has made a small change to the car fuel component but made a much larger impact on the monetary component of bus trips - which is now markedly less. This has resulted in a similarly large change to the disutility of bus trips and generated the large switch from car to bus as shown in figures above.

3.6 Combined GDP and Fuel Costs Analysis

3.62 In order to confirm that the smaller than expected impacts in car travel resulting from increasing GDP are indeed a result in the declining importance of monetary costs, a series of tests were performed in which GDP is varied under scenarios where car fuel costs had been greatly increased from the original reference case values. In these tests the GDP scenarios were rerun, but fuel costs were increased by 40% and then 80% in both cases. Again, the only difference between the reference and the high GDP scenarios is the rate of GDP growth and thus the value of time.

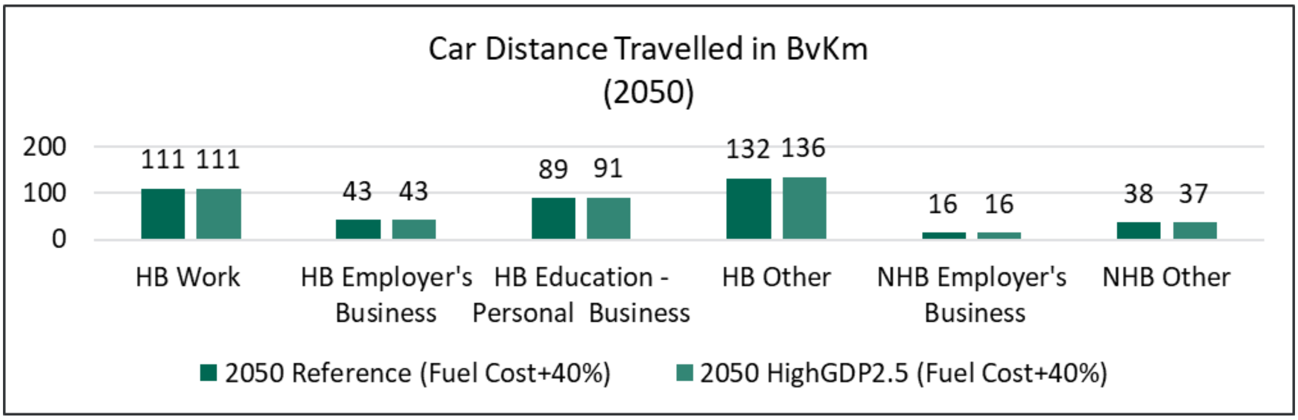

Figure 35 Car Distance Travelled in High and Reference scenarios (both with +40% fuel cost)

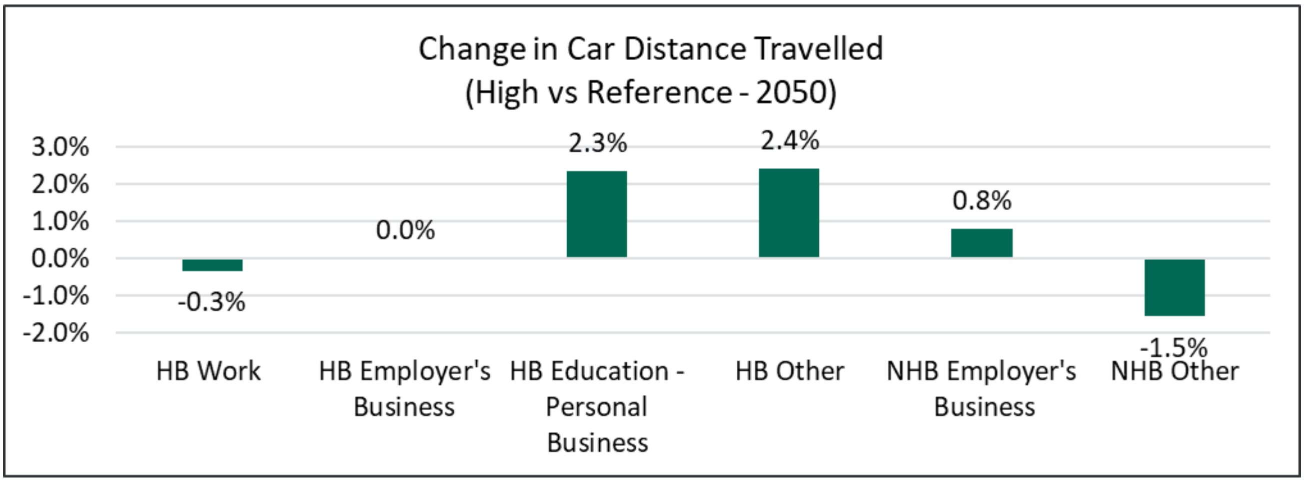

Figure 36 Change in Car Distance Travelled High vs Reference scenarios (both with +40% fuel cost)

3.63 In the +40% fuel cost scenario, increasing the car fuel costs in both the reference and High GDP scenarios has resulted in a much larger increase in car traffic compared to the earlier high GDP test. The impact has increased from 0.4% to 1%, however the size of the overall impact remains small. Whilst employer's business trips are now static, there are still falls in home-based work (commuting) and non-home based other (leisure) trips stemming from the higher VOT assumption. The non-home-based other trips are falling although many of the home-based trips purposes that these trips are associated with are increasing. The decline suggests that many of these trips are either linked to commuting or there has been significant mode switch away from car, or both. Figure 37 and Figure 38 below show the differences between the reference scenario (Core) and high GDP scenarios but with fuel costs increased by 80%.

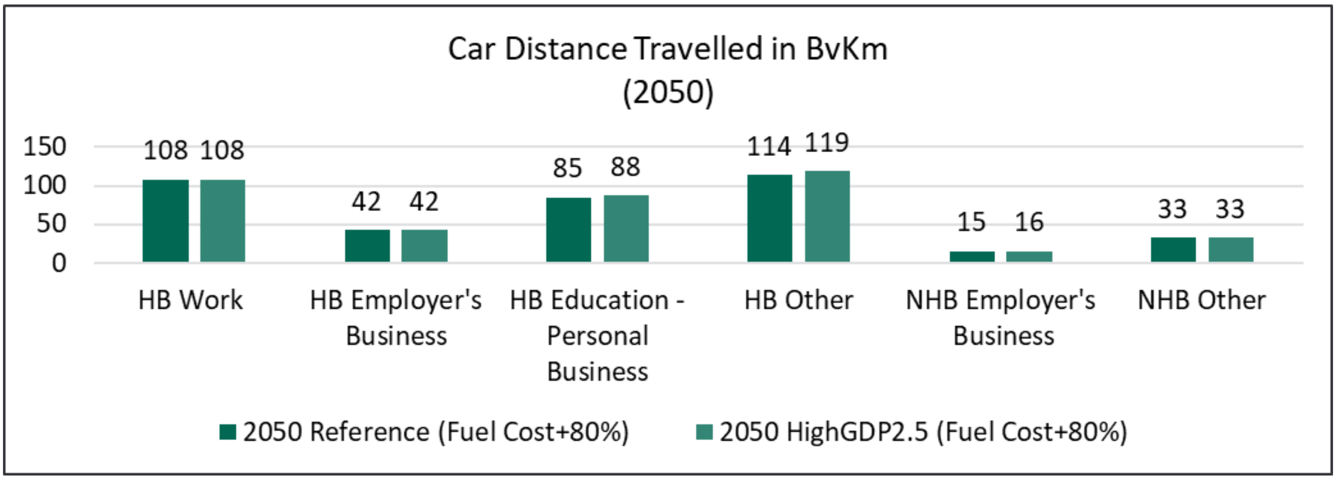

Figure 37 Car Distance Travelled for Reference and High scenarios (both with +80% fuel cost)

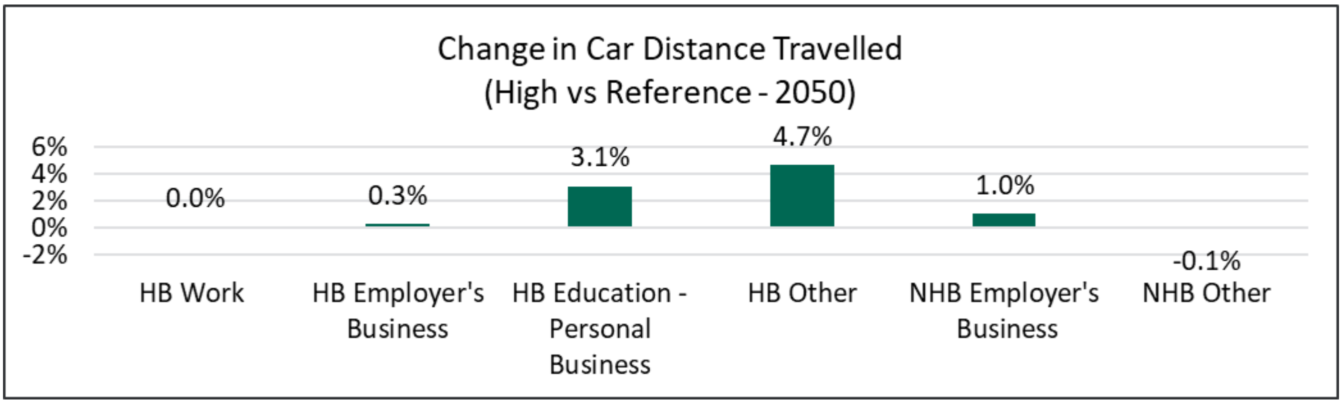

Figure 38 Change in Distance Travelled for High vs Reference scenarios (both with +80% fuel cost)

3.64 Increasing the car fuel costs by 80% in both the reference and High GDP scenarios has resulted in a further doubling of the earlier impact with a resulting increase in car traffic of just over 2% compared to the reference case test. Most journey purposes now show increases with only non-home based other (leisure) trips falling slightly from the increase in VOT.

Comparison of scenarios with different GDP and fuel cost increases

3.65 As shown above, the model reacts differently in each of the GDP scenarios when a fuel cost change is applied. The effect of the fuel cost increase in the model for the Reference GDP and a High GDP scenario are summarised as:

- Fuel costs become a larger component of the car disutility, which is also increasing
- There is less distance travelled when VoT remains unchanged (as per elasticities).

3.66 Changing GDP has an impact on the monetary cost components of the six different modes of travel in different proportions. Whilst there are some more macro level changes to distance travelled, this masks some much larger mode switching impacts seen on individual modes.

3.67 High GDP scenarios result in:

- More car distance travelled in each of the scenarios
- More car distance travelled in the High scenarios (when GDP is higher) for the Education/Personal and Other trips (HBEd/PB and HBO).
- A negligible change on the distance travelled for the Commuters and Business trips (HBW, HBEB).
  The negative values for changes in HBW and HBEB trips are diminishing and heading to positive values as the increased fuel costs form a larger part of the overall costs.

3.68 Figure 39, Figure 40 and Figure 41 show the total distance travelled (in billion Km) for each scenario and the percentage differences in total car traffic between a High GDP scenario and the Reference case scenario for each of the three fuel price assumptions in 2050.

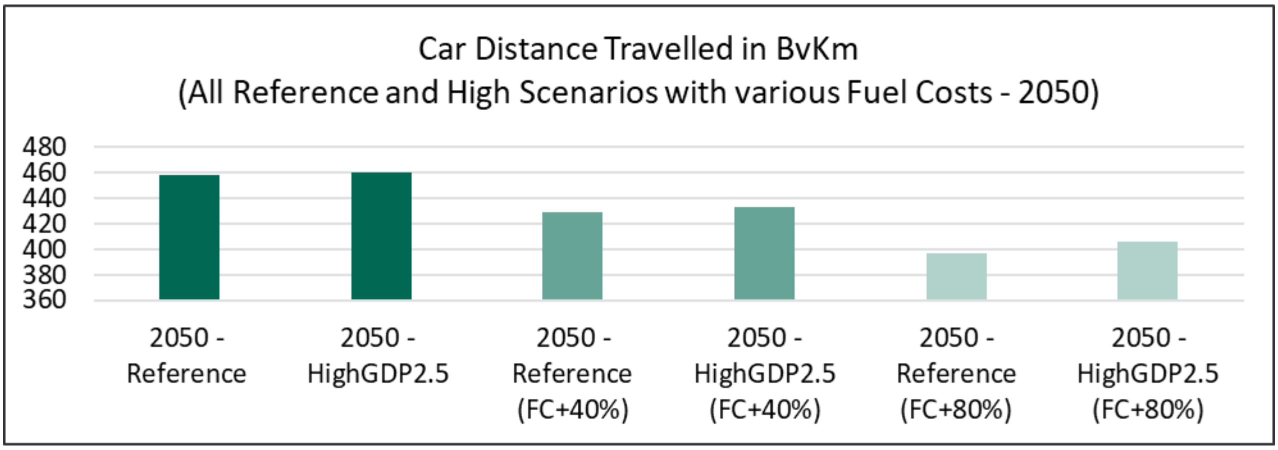

Figure 39 Car Distance Travelled for all Reference and High scenarios - 2050

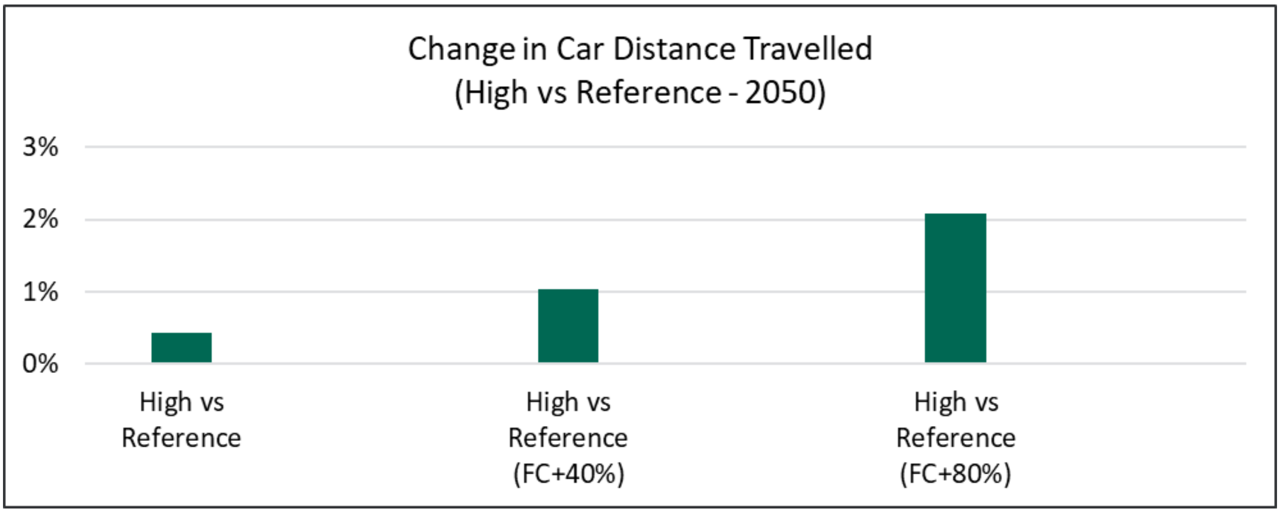

Figure 40 Change in Car Distance Travelled for all Reference and High scenarios (2050)

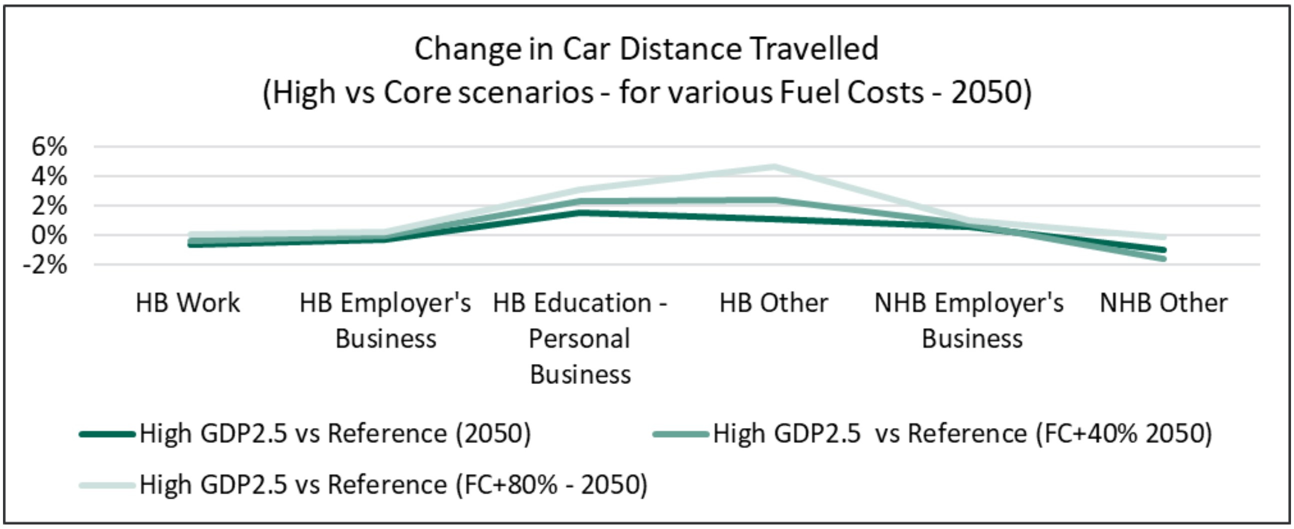

Figure 41 Change in Car Distance Travelled for High vs Reference (for different fuel cost changes) – 2050

3.69 This highlights that the largest impacts are associated with the purposes which are the most discretionary and also associated with the highest elasticities. The response of non-home-based trips to higher GDP in the 40% fuel price increase scenario (compared to the Reference scenario) seems low but no reason has been found for this. Non-home based other trips represent about 10% of the total distance travelled and a very large proportion of this mileage (almost 90%) is by car drivers or passengers, so other modes will only be having a small impact on results.

3.70 The model reaction to the different fuel cost increases is consistent with expectations and gives confidence that the model is performing well. The GDP effect on the model is higher when the fuel cost and hence the monetary component of costs is higher, and this is also in line with expectations.

3.71 This effect was seen earlier in Figure 33 which shows how the monetary costs of modes is changing over time. Whilst car monetary costs fall between 2015 and 2050, monetary costs for rail and bus are constant or rising. This resulted in GDP having a proportionately larger impact on those modes and made them more attractive. The increases in fuel costs tested here have tended to reduce that disparity and resulted in increasing GDP leading to increased car travel as well.

3.7 Capacity tests Analysis

3.72 It is recognised that the capacity of the road network and the presence of congestion plays an important role in influencing travel making decisions. Additionally, the provision or re-allocation of road space also plays important part in both local and national government transport policy and It is therefore important to understand the impact that changes to road capacity have on model responses and any resulting traffic forecasts.

3.73 A change in the network capacity is expected to change the number of car trips and hence the distance travelled for all the trip purposes across the road network. In order to test the model's responses an identical set of tests were performed in each of the 2030 and 2050 forecast years and included:

- Scenario 1: Capacity increase of urban roads by 50%
- Scenario 2: Capacity increase of rural roads by 50%
- Scenario 3: Capacity increase of all roads by 50%
- Scenario 4: Capacity decrease on urban roads by 50%
- Scenario 5: Capacity decrease on rural roads by 50%
- Scenario 6: Capacity decrease on all roads by 50%

3.74 Although each of the scenarios nominally increased or decreased the capacity of the road network in the FORGE model by the percentages, since the quantities or actual lengths of road that exist in the Rural and Urban area types are different, the traffic results in absolute terms can also be expected to be different. Of the total 395,700 Km of road comprising the GB network, just over a third or 147,400 km is classed Urban whilst the remaining 248,200 km are Rural.

3.7.1 Increasing Capacity by 50%

3.75 Table 11 below shows the absolute traffic and congestion results from increasing capacity on the different road types in 2030 and 2050 whilst Table 12 shows the results of all scenarios as a percentage change from the 2015 model base year.

3.76 As expected, the scenarios have generally resulted in increased traffic across all road types with the largest impacts occurring on the most congested road types in the year 2050. In both years, the increase in Urban roads capacity has resulted in increased traffic on Principal A and minor roads with relatively small increases on the strategic network.

3.77 The biggest increases in the Rural scenarios were on all purpose Trunk roads and again on minor roads whilst, compared to the Reference scenario, traffic on Principal Rural A roads has decreased slightly.

Table 11 Traffic and Congestion Impacts due to Increasing Capacity

Traffic per Road Type	Base Year	2030 Ref	2030 Urban	2030 Rural	2030 All	2050 Ref	2050 Urban	2050 Rural	2050 All
Motorway - Car Traffic Bvkm	78.85	97.04	95.97	96.80	95.04	113.47	114.36	113.95	113.88
Motorway - Congestion s/km	2.73	3.33	2.78	1.71	1.05	5.77	4.98	2.60	1.55
Motorway - Speed Miles/Hr	65.34	64.27	65.51	67.39	68.99	60.07	61.47	65.66	67.86
Trunk - Car Traffic Bvkm	49.86	60.72	61.14	61.44	61.69	70.16	71.19	72.04	72.69
Trunk - Congestion s/km	8.07	8.14	5.34	7.01	4.17	10.27	6.68	9.03	5.37
Trunk - Speed Miles/Hr	46.21	46.26	49.08	47.34	50.34	44.38	47.76	45.46	49.09
Principal - Car Traffic Bvkm	127.59	146.70	150.28	144.35	150.92	166.57	170.81	164.21	171.72
Principal - Congestion s/km	12.28	14.92	9.81	12.86	8.99	18.85	11.84	15.88	10.90
Principal - Speed Miles/Hr	34.34	33.00	35.53	34.15	36.01	31.22	34.46	32.66	34.98
Minor - Car Traffic Bvkm	142.35	163.32	166.37	168.11	166.46	186.65	190.52	192.50	190.57
Minor - Congestion s/km	12.57	14.03	10.24	10.61	9.90	15.38	11.33	11.60	10.93
Minor - Speed Miles/Hr	24.21	23.82	24.75	24.58	24.84	23.49	24.45	24.31	24.55
Total Traffic - Car Traffic Bvkm	398.64	467.79	473.77	470.70	474.11	536.84	546.88	542.70	548.86
Total Traffic - Congestion s/km	9.97	11.33	7.96	9.00	7.09	13.76	9.56	10.66	8.24
Total Traffic - Speed Miles/Hr	33.55	33.12	34.67	34.10	35.13	32.05	33.97	33.36	34.67

Table 12 Changes in Traffic and Congestion from Base year 2015 due to Increased Capacity

Traffic per Road Type	2030 Ref	2030 Urban	2030 Rural	2030 All	2050 Ref	2050 Urban	2050 Rural	2050 All
Motorway - Car Traffic Bvkm	23.07%	21.72%	22.77%	20.53%	43.90%	45.03%	44.52%	44.43%
Motorway - Congestion s/km	21.81%	1.69%	-37.39%	-61.57%	111.29%	82.47%	-4.97%	-43.11%
Motorway - Speed Miles/Hr	-1.64%	0.26%	3.14%	5.58%	-8.06%	-5.92%	0.50%	3.86%
Trunk - Car Traffic Bvkm	21.80%	22.64%	23.24%	23.75%	40.73%	42.80%	44.50%	45.80%
Trunk - Congestion s/km	0.81%	-33.87%	-13.16%	-48.31%	27.26%	-17.24%	11.92%	-33.53%
Trunk - Speed Miles/Hr	0.11%	6.23%	2.45%	8.96%	-3.96%	3.36%	-1.62%	6.24%
Principal - Car Traffic Bvkm	14.98%	17.79%	13.14%	18.29%	30.55%	33.88%	28.70%	34.59%
Principal - Congestion s/km	21.52%	-20.15%	4.70%	-26.77%	53.49%	-3.60%	29.30%	-11.21%
Principal - Speed Miles/Hr	-3.89%	3.46%	-0.55%	4.86%	-9.07%	0.36%	-4.88%	1.86%
Minor - Car Traffic Bvkm	14.74%	16.88%	18.10%	16.94%	31.12%	33.84%	35.23%	33.88%
Minor - Congestion s/km	11.67%	-18.48%	-15.53%	-21.23%	22.41%	-9.81%	-7.68%	-13.04%
Minor - Speed Miles/Hr	-1.61%	2.23%	1.52%	2.61%	-2.98%	1.01%	0.41%	1.43%
Total Traffic - Car Traffic Bvkm	17.35%	18.85%	18.08%	18.93%	34.67%	37.19%	36.14%	37.68%
Total Traffic - Congestion s/km	13.63%	-20.15%	-9.70%	-28.85%	38.04%	-4.11%	6.99%	-17.35%
Total Traffic - Speed Miles/Hr	-1.29%	3.35%	1.65%	4.71%	-4.48%	1.25%	-0.57%	3.34%

3.78 On Motorways, the congestion increases seen in the reference scenarios have been greatly reduced or reversed however they have been accompanied with very small increases in traffic and slight reductions for 2030. The traffic reductions are due to changes in costs that occurred on other road types being large enough to result in re-assignment of traffic to them from Motorways.

3.79 The slight reduction in Motorway traffic may also be due to the use of fixed speed flow curves in the model which imply that traffic on less congested roads is forced to travel at faster (and potentially free flow) speeds. This is particularly the case on Motorways where the increased fuel costs that result from the higher speeds may no longer be optimal for the lower value of time journey purposes. As an example, the value of the time saved from increasing speeds is less than the cost of the additional fuel consumed. As fuel prices decline in the future the effect is less apparent in 2050.

3.80 More generally, when compared to the reference scenarios the increases in capacity have only resulted in traffic levels of 2% or 3% more than the Reference scenario for each year as shown in Table 13. At the same time, congestion and journey times are returned to levels lower than those in the 2015 base year for all but one of the six capacity increase scenarios. The exception, where congestion and journey times remain above 2015 levels (speeds are slower) is the 2050 50% Rural Road increase scenario.

Table 13 Changes in Traffic and Congestion with respect to the Reference Scenarios from Increasing Road Capacity by50%

Traffic per Road Type	% Change of 2030 scenario with 50% increased capacity vs Reference year 2030	% Change of 2050 scenario with 50% increased capacity vs Reference year 2050
Urban Roads - All Traffic	1.90%	2.60%
Urban Roads - Car Traffic	2.10%	2.90%
Urban Roads - Congestion s/vkm	-36.30%	-38.30%
Urban Roads - Congested Traffic	-48.90%	-50.30%
Rural Roads - All Traffic	0.60%	1.40%
Rural Roads - Car Traffic	0.70%	1.70%
Rural Roads - Congestion s/vkm	-44.60%	-49.20%
Rural Roads - Congested Traffic	-69.20%	-77.70%
All road types - All Traffic	1.20%	1.90%
All road types - Car Traffic	1.40%	2.20%
All road types - Congestion s/vkm	-37.40%	-40.10%
All road types - Congested Traffic	-53.40%	-58.20%

3.81 The next section looks at the impacts of increased road capacity for the two area types on the different journey purposes in 2050 and are again in comparison to the applicable Reference case scenario. Similar impacts were also observed in 2030 although they were proportionally smaller than those seen in 2050 due to the lower traffic and congestion levels present in the 2030 Reference case.

3.82 Figure 42 shows the impacts for each of the journey purposes are in line with their values of time. Employer's business trips, having the highest values of time, respond the most, followed by commuting trips, educational, personal business and other trip purposes. This is consistent with the results of the earlier realism tests and is entirely expected as higher value of time travellers are, by definition, more sensitive than others to changes in journey time or congestion.

3.83 For each of the purposes the increase to Urban road capacity is having a larger impact than the increase to Rural capacity, even though the network is only about a half the length of the Rural network. This impact is due to the large reductions in congestion that the Urban capacity scenario is generating on the existing high levels of congestion that generally prevail in such areas.

3.84 The size of the combined impacts due to increasing the capacity of all roads is not the sum of the impacts of the increases to the separate Urban and Rural networks. There are thus few or no synergy effects and the responses seem to be governed by the capacity available on the Urban networks. This seems appropriate as most journeys start and end in Urban areas and any increases in traffic due to increased Rural capacity will be constrained by the high levels of Urban congestion.

3.85 Although employer's business trips are experiencing the greatest impact from the increase in capacity on Rural and All road types, Home Based work (or commuting) trips show the largest increase when only Urban road capacities are increased. This is consistent with the relatively higher value of time and longer (more Rural) nature of business trips compared to most commute trips which are generally less than 15 miles and often both start and finish in Urban centres.

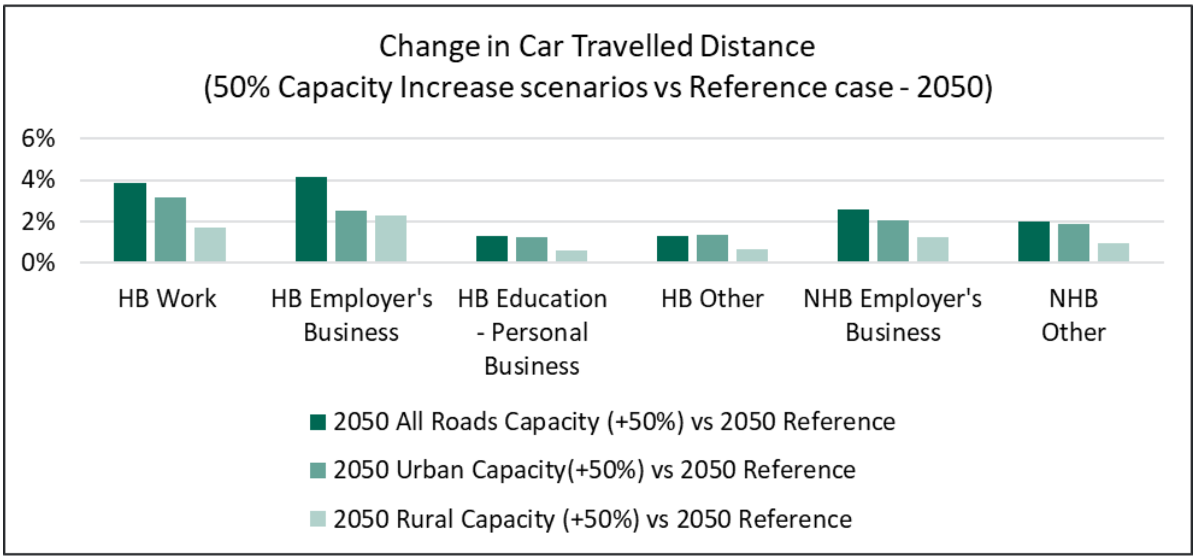

Figure 42 Change in Car Traffic compared to Reference for 50% Capacity Increase - 2050

3.86 For the 50% increase in capacity across all roads scenario, the size of the traffic impacts, compared to the 2050 Reference case, range from +4% for business and commute trips to +2% for other purposes and results in a traffic increase of only +3% overall. This is alongside congestion falling by 40% and national average speeds increasing by 8% from 32 to 34.7 miles/hr. The impact on traffic growth is small in comparison to the 34.7% increase in the 2050 reference scenario (from 2015 base) and would suggest that growth is not being particularly constrained by congestion.

3.7.2 Decreasing Capacity by 50%

3.87 Whilst the three reduced capacity scenarios initially appeared to be producing plausible results, subsequent examination of the resulting large traffic reductions, which in one case reduced traffic to 39% below the base year level, revealed that the model had not properly converged. Non-convergence was a particular problem in 2050 where all three scenarios were affected and also, to a lesser extent, the two 2030 scenarios which involved reduced urban road capacities.

3.88 Analysis of the convergence characteristics of the 2030 50% Reduction in Urban capacity run is presented in Annex C and whilst traffic in the two 2030 reduced Urban capacity scenarios was oscillating by a few percent in most areas, London traffic levels were changing by over 40% and levels of Motorway traffic were also variable with changes of 13% between iterations.

3.89 Given the size of the capacity reductions attempted in this test, and the resulting congestion and delays that would ensue on roads operating well beyond their theoretical capacity, it is encouraging to see that the model was still attempting to converge and it may well have achieved this if permitted to continue.

3.90 The test has highlighted areas where convergence might become a problem in extreme conditions, however the variation in the results has meant that, whilst trips were seen to be behaving in a broadly similar pattern to those for the 50% reduction in Rural capacity described below, it is not possible to draw any further insights from the results.

3.91 Table 14 below presents the traffic and congestion impacts for the successful reduced Rural road capacity by 50% in 2030 scenario. This run converged well and both National and Rural car mileage changed less than 0.1% between the final two iterations with London changing only slightly more by 0.15%.

3.92 The largest traffic responses of -12.5% are associated with Rural Motorway and Trunk roads and Motorways also experience a large increase in congestion. As expected, the impacts on the less congested local rural road types are not as large as on the strategic road network (Motorway and other Trunk roads). The impact across all Rural road types together is an 8.4% reduction is traffic resulting from a 20.6% reduction in speed (27% increase in journey time).

Table 14 Percent Change in Traffic and Congestion from capacity reduction in Rural roads for 2030

Traffic per Road Type	London	Conurbation	Urban	Rural	All Areas
Motorway - Cars	-14.47%	-5.70%	-	-12.36%	-11.01%
Motorway - Congestion s/vkm	-50.19%	-23.71%	-	780.51%	558.66%
Motorway - Average V/C	-8.93%	-3.35%	-	67.36%	49.47%
Motorway - Congested Traffic	-65.08%	-18.95%	-	918.49%	628.85%
Motorway - Speed km/hr	1.97%	0.71%	-	-43.03%	-35.76%
Trunk roads - Cars	-	-3.84%	-5.60%	-12.64%	-10.85%
Trunk roads - Congestion s/vkm	-	-6.69%	-7.99%	140.76%	48.97%
Trunk roads - Average V/C	-	-2.32%	-3.09%	71.30%	43.52%
Trunk roads - Congested Traffic	-	-8.67%	-7.68%	698.79%	126.56%
Trunk roads - Speed km/hr	-	1.47%	2.38%	-18.24%	-12.09%
Principal - Cars	-9.47%	-1.24%	-2.52%	-7.32%	-5.11%
Principal -Congestion s/vkm	10.20%	-1.39%	-3.36%	139.31%	21.93%
Principal -Average V/C	-4.92%	-0.67%	-1.62%	71.90%	20.35%
Principal -Congested Traffic	-13.35%	-0.25%	-3.49%	801.12%	60.43%
Principal -Speed km/hr	-8.61%	0.40%	0.55%	-12.96%	-5.72%
Minor - Cars	-8.72%	-0.93%	-1.84%	-1.69%	-2.02%
Minor - Congestion s/vkm	1.42%	-0.56%	-1.37%	62.72%	2.80%
Minor - Average V/C	-6.56%	-0.49%	-1.08%	95.78%	20.64%
Minor - Congested Traffic	-22.59%	-0.66%	-1.96%	2021.76%	52.05%
Minor - Speed km/hr	-0.38%	0.08%	0.21%	-2.60%	-0.27%
All roads - Cars	-9.61%	-2.36%	-2.49%	-8.37%	-6.00%
All roads - Congestion s/vkm	6.75%	-1.38%	-3.11%	286.06%	48.40%
All roads - Average V/C	-5.57%	-1.74%	-1.98%	69.49%	30.83%
All roads - Congested Traffic	-14.53%	-4.96%	-5.60%	860.21%	181.74%
All roads - Speed km/hr	-4.92%	-0.44%	0.39%	-20.55%	-9.27%

3.93 London is the most sensitive of all the area types and the large traffic response is because its roads are the most congested and near to capacity for the most time. The response also suggests that there are many trips coming from and going to the surrounding Rural areas which are being primarily impacted by the test. The traffic and congestion results however for London are not intuitive and whilst reductions in London Motorway traffic are accompanied by reduced congestion and increased speeds, this is not true for the other road types.

3.94 For principal and minor roads, reductions in traffic are accompanied by increased congestion and lower average speeds. This effect can be a result of changes to the daily traffic distribution caused by different sized reductions in the different journey purposes. If the purposes that are reducing most travel at less congested times of day, then the congestion metric, which is based on average delay (given by delay divided by traffic) can rise even though total traffic falls.

3.95 The congested traffic metric, which is based on the quantity of traffic flowing in congested conditions[20] and the average volume to capacity measures both reduce in line with the reduction in car traffic as would be expected.

3.96 Conurbations and other Urban area types are behaving similarly to each other with both these area types showing traffic reductions of about 2.5%. Whilst the reduced traffic has generally resulted in less congestion and faster speeds, the speeds of all traffic in Conurbations has fallen whilst the speed for each of the individual road types has increased. This again is a distributional effect and has been caused by the remaining journeys using a higher proportion of slower (probably minor) roads in comparison to the Reference scenario. This is consistent with the largest reductions in journey purposes being associated with holiday/leisure trips (see Table 15), which tend to be longer than average and therefore make more use of the major road networks.

3.97 Rural Trunk roads have experienced the largest traffic reduction, which at 12.6% is slightly larger than the 12.4% reduction in motorway traffic. The congestion impacts on Rural road types are however very different with Motorways experiencing an increase of 780% compared to the much smaller increase of 140% seen by both the Trunk and Principal road types. The smallest increase in congestion is found on minor roads and at 63% this pattern seems align with actual conditions.

3.98 The standard Congestion metric, which is based on journey times compared to “free flow” conditions, can show large increases where speeds are low because as speeds reduce, the journey times increase exponentially. This means that, at low speeds a small speed reduction can result in a large increase in congestion.

3.99 For minor roads the congestion result seems to contrast to the quantity of congested traffic, which has increased by over 2000%. This is due to the different definition and a relatively large increase in a very small quantity of traffic (0.2%) which is experiencing congested conditions in the Reference scenario.

3.100 Volume to capacity ratios of Rural roads have increased by 70% which is consistent with a loss of half the network capacity and the accompanying reduced traffic levels. Whilst the results can all be related to the prevailing congestion levels on these road types, they are also a result of the most sensitive trip purposes being the longest and therefore more likely to spend much of their journey duration on Motorways. Minor roads traffic will be comprised of a wider representation of all trip purposes and journey distances.

3.101 A decrease in network capacity affects the journey times of all the different trip purposes in a similar manner. However, the different purposes make different use of the more local Urban and Rural road types and whilst the impact on each of the purposes increases with trip length, reducing network capacity in Rural

[20] defined as where the volume to capacity ratio of traffic is 0.8 or more

areas has the most significant effect on reducing HB-Employee Business trips and subsequently NHB-Employee Business trips as well. These trips seek alternative ways of travelling as their higher value of time means that they are more affected by increases to journey times than costs. Home based holiday trips show the next largest response, particularly for the longer distances, and as these trips are more discretionary this response is to be expected.

3.102 The responses of HB-Work and both HB and NHB-Other trips are very similar to each other whilst the education and personal business trip purposes are the least affected by the increased congestion. These results are consistent with the decreasing values of time and lower response elasticities of the different purposes. Table 15 below shows the variation of traffic (shown here as trips multiplied by distance band mid-point) from the reference case for each journey purpose and distance band for the 50% Reduced Rural road capacity scenario.

Table 15 Traffic Change - Reduced Rural Capacity Scenario vs Reference Case

Distance Band	HBW	HBEB	HBEd	HBPB	HBRec	HBHol	NHBEB	NHBO	All
<1 mile	-0.10%	-0.10%	-0.10%	-0.20%	-0.10%	0.00%	-0.10%	-0.10%	-0.10%
1-2 miles	-0.20%	0.00%	-0.20%	-0.20%	-0.20%	-0.10%	-0.20%	-0.30%	-0.20%
2-3 miles	-0.20%	-0.10%	-0.10%	-0.20%	-0.20%	-0.30%	-0.20%	-0.30%	-0.20%
3-5 miles	-0.30%	-0.10%	-0.10%	-0.20%	-0.20%	-0.40%	-0.40%	-0.40%	-0.30%
5-10 miles	-0.90%	-0.70%	-0.50%	-0.70%	-0.80%	-1.40%	-1.00%	-1.20%	-0.90%
10-15 miles	-1.30%	-1.00%	-0.90%	-1.30%	-1.30%	-2.30%	-1.40%	-1.60%	-1.30%
15-25 miles	-2.00%	-1.80%	-1.20%	-2.00%	-1.90%	-4.10%	-1.80%	-2.30%	-2.10%
25-35 miles	-5.90%	-3.20%	-3.30%	-4.20%	-2.90%	-6.20%	-2.30%	-4.90%	-4.60%
35-50 miles	-12.70%	-4.70%	-4.30%	-5.20%	-3.50%	-6.30%	-4.20%	-6.30%	-7.40%
50-100 miles	-22.10%	-8.40%	-5.10%	-7.70%	-5.00%	-10.20%	-8.70%	-11.70%	-10.60%
100-200 miles	-49.00%	-28.10%	-10.60%	-7.80%	-1.10%	-20.00%	-30.40%	-18.80%	-17.70%
200-300 miles	-56.40%	-43.70%	-19.70%	-9.50%	-0.30%	-35.40%	-40.60%	-44.30%	-26.50%
>300 miles	-86.40%	-67.60%	0.00%	-15.90%	-5.10%	-10.60%	-70.90%	-11.60%	-22.40%
All Distances	**-6.10%**	**-14.90%**	**-1.50%**	**-1.90%**	**-1.90%**	**-13.90%**	**-10.20%**	**-6.20%**	**-6.20%**

3.8 Convergence Test Analysis

3.8.1 Number of Trips

3.103 The convergence test consisted of two model runs each comprised of a different number of iterations between the main demand and network supply models:

- Run 1: includes 6 iterations (iteration A to F) - for 2030 and 2050
- Run 2: includes 10 iterations (iteration A to J) - for 2030 and 2050

3.104 The model has been seen to be converging well in all the tests and the Run 2 tests, replicated the results for the Run 1 tests in the first 6 iterations as expected. In both analysis years the difference in number of trips between the last two iterations (E and F) in Run 1 is significantly higher (around 10 times) that the difference between the two last iterations of Run 2 (iteration I and J). However, the differences in the numbers of Car Drivers trips are small in all cases with the differences in Run 1 (6 iterations) being less than 0.1% in both years and the differences for Run 2 (10 iterations) being less than 0.01% for both years.

Table 16 Difference in Number of trips between two last iterations for Run 1

Trips in Year	Run 1 - Iteration E	Run 1 - Iteration F	Iteration F-E Difference	Iteration F-E Difference (%)
Trips 2030	39305940	39303488	-2452	-0.01%
Trips 2050	44382468	44347292	-35176	-0.08%

Table 17 Difference in Number of trips between two last iterations for Run 2

Trips in Year	Run 2 - Iteration I	Run 2 - Iteration J	Iteration J-I Difference	Iteration J-I Difference (%)
Trips 2030	39304212	39304152	-60	0.00%
Trips 2050	44362356	44358388	-3968	-0.01%

3.105 The percentage differences for each of the runs has increased slightly in 2050 going from almost zero in 2030 up to -0.08% for Run 1 and -0.01% for Run 2 and this is due to the larger numbers of trips and higher costs in the 2050 Reference scenario. However, the model has clearly converged well in both tests and as the convergence behaviour of car driver trips in both years are similar the more detailed analysis of trips shown in the figures below (figures 43, 44 & 45) is only presented for 2050.

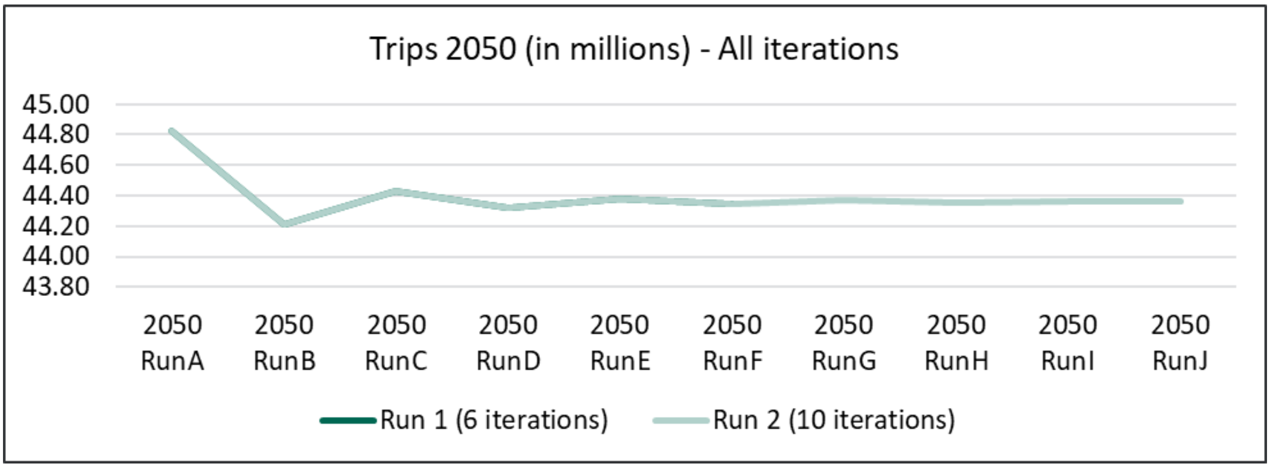

Figure 43 Number of Car Driver trips in each iteration (Average daily Million Vehicle Km) - 2050

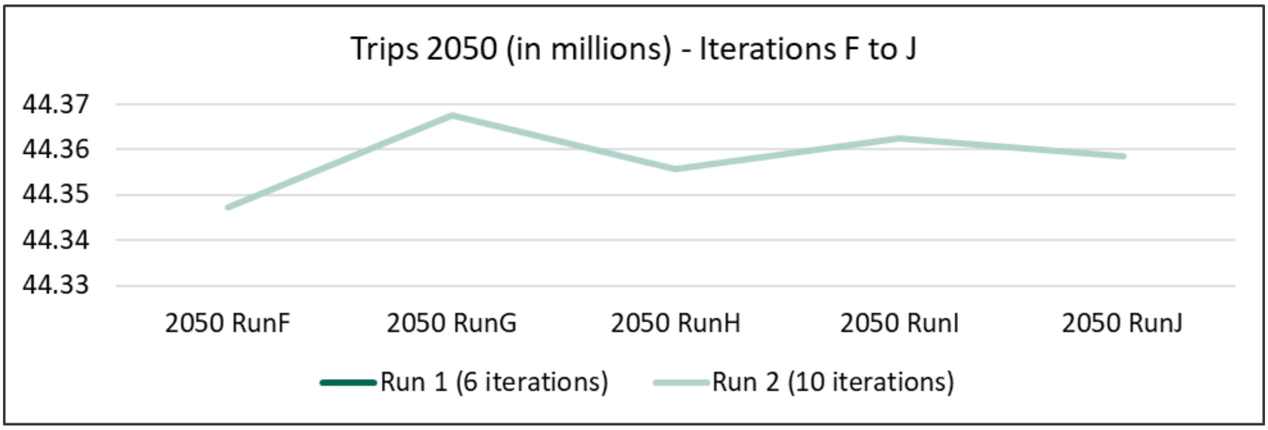

Figure 44 Number of Car Driver trips in each iteration (Average daily Million Vehicle Km) - 2050

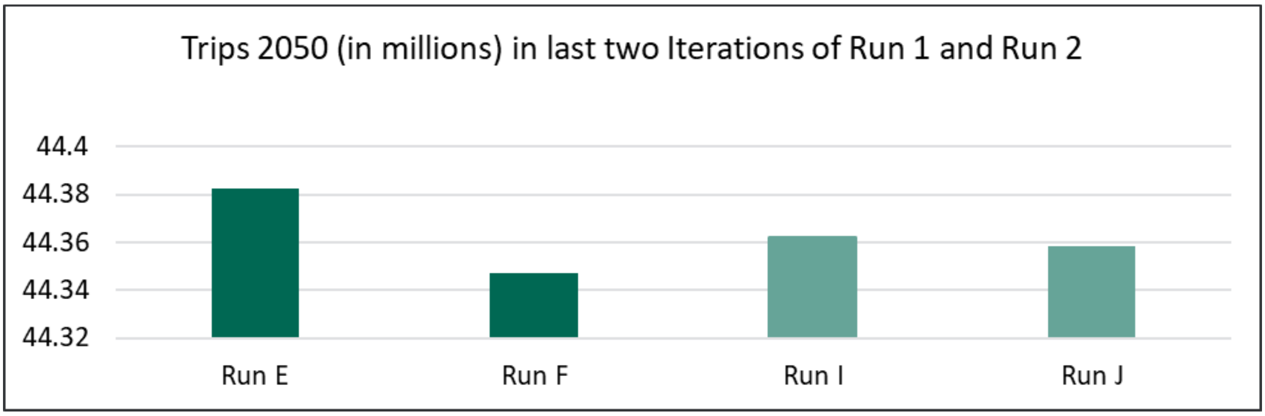

Figure 45 Number of Car Driver trips in last two iterations in both runs (Average daily Million Vehicle Km) - 2050

3.106 Although the model has converged well, the difference in the numbers of Car Driver trips between the final iterations of each of the runs (Iterations F and J) is 11096 as shown in Figure 45 above. Whilst there are more trips in the 2050 reference scenario this still represents only a 0.025% difference between the results and means that we can confidently use the lower number of iterations of Run 1 for routine analysis in 2050.

3.8.2 Car Distance travelled

3.107 The difference in distance travelled between the last 2 iterations of the runs shows larger differences for both runs than trips. These are shown in figure below and are 0.116% for Run 1 and -0.013% for Run 2. The larger differences here would suggest that the un-converged trips are to some extent longer than the average trip and this is likely to represent long distance rail trips, which historically have always been more variable in the NTM. However, the difference in distance travelled between runs F and J still only represents 0.036% of all car driver distance travelled and using the 6 iterations of Run 1 will again be suitable for most strategic forecasts and analysis.

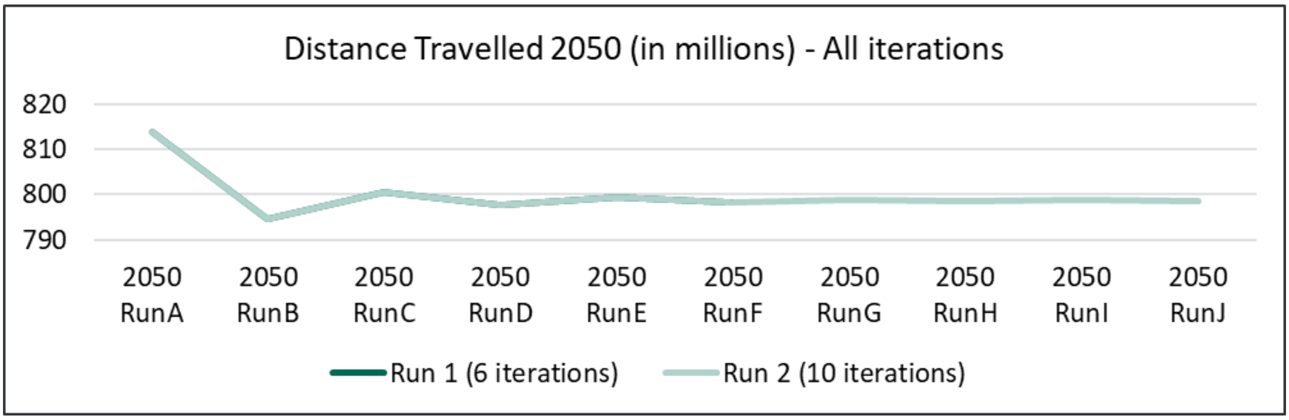

Figure 46 Distance travelled in each iteration (Average daily Million Vehicle Km) - 2050

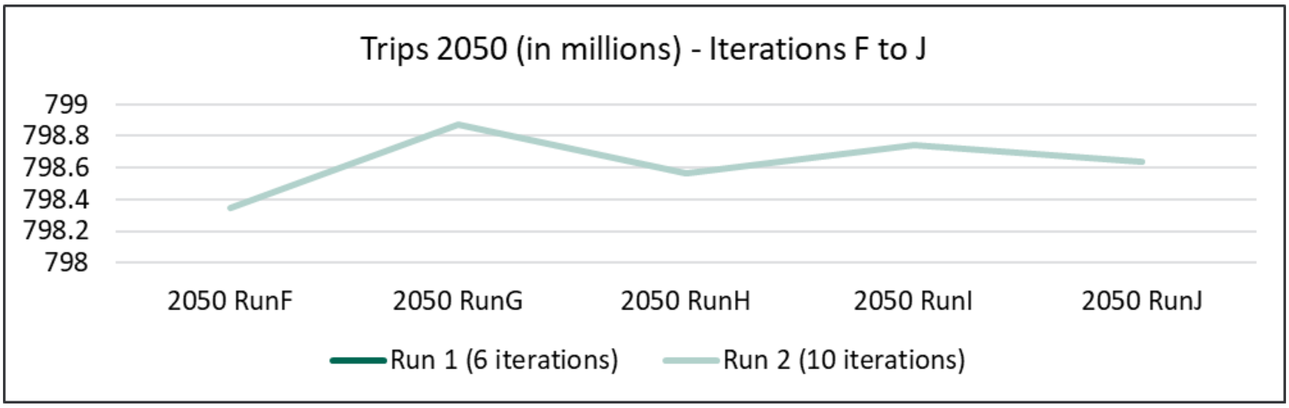

Figure 47 Distance Travelled in each iteration (Average daily Million Vehicle Km) - 2050

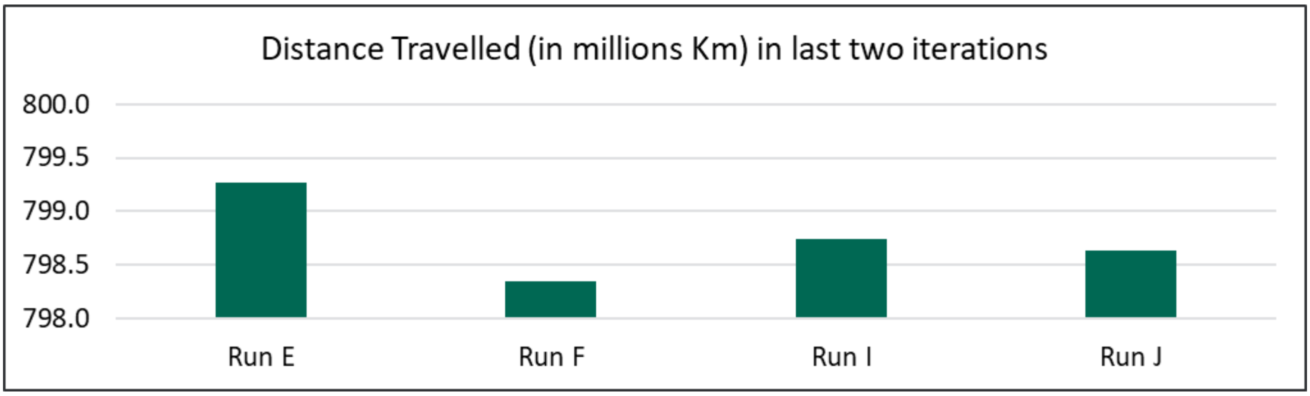

Figure 48 Distance Travelled in last two iterations in both runs (Average daily Million Vehicle Km) - 2050

3.108 The largest variations in this car driver mileage are found on trips either starting or finishing in London. Mileage into Central London from all other origins changed by 2.5% and mileage to all other destinations from Central London changed by 4.5%. Across all origins and destinations, the largest changes in mileage are seen in trips between Central and Outer London and these are approximately 5.5% in each direction, with trips between Central and Inner London being slightly less variable and changing by approximately 4.5%.

3.109 The variation in distance travelled for the different journey purposes and distances are more in keeping with the overall convergence levels with mileage changing by less than 0.2% in most journey purpose and distance band combinations. The largest changes for all purposes combined are of 0.21% occurring in the middle-distance bands and within these by far the largest changes are for holiday trips which are changing by 0.5% between iterations.

3.8.3 Convergence of Non Car Modes

3.110 In order to confirm that the model had sufficiently converged in all aspects, the changes in the numbers of trips on other modes was investigated. The figures below are also derived from comparing iterations 5 and 6 in Run 1 for year 2050. Walk trips were the most stable with numbers changing by only 0.03% whereas rail trips were the most variable changing by almost 1.2%. Car passenger trips were performing similarly to Car Driver trips discussed above and Cycle and Bus trips changed by 0.2% and 0.27% respectively.

3.111 For origins and destinations across all modes, the greatest variation was again found amongst the London area types with both bus and cycle mileage being most variable between the Inner London and Rural area types. Here the mileage changed by 3.5% in each direction for bus and 4.8% for cycling with all other combinations outside of London changing by less than 0.1% for both modes. In outer London the greatest variation in Bus mileage (1.6%) was on trips to Rural areas but for cycling the greatest variation (2.5%) was with the adjacent Central and Inner London areas. Rail mileage changed by 1% and within this the most variable destinations were again Inner and Outer London which both changed by approximately 2.5% on trips from all origins. Central London was however more stable with mileage changing only by 0.5% from all origins. A similar pattern in seen on trip origins whereby trips stemming from Inner and Outer London varied by 2.0 % and 1.8% respectively across all destination areas.

3.112 The greatest variations between individual areas also occurred on trips between inner and outer London where the rail mileage changed by 2.8% in each direction between the two iterations. Outside of the three London area types the largest difference in rail travel between different areas was only 0.2%. The variation in rail trips by purpose and distance was the greatest for medium length trips (15-25 miles) and the mileage of all purposes changed by 1.9%. Within this band the most sensitive purpose is NHBEB trips which varied by 4.6%. Given the planned use of the model, the relatively small differences noted here for all the non-car modes are considered acceptable and the analysis has confirmed the robustness of the model in normal use.

4. Backcast Development

4.1 Introduction

4.1 As part of the transparency workstream, a backcast model has been developed by the Department to help evaluate the performance of the NTM. This represents the first successful attempt of developing an NTM backcast and it has been made possible by the availability of data.

4.2 The performance of a model backcast is described in literature as an excellent method of evaluating a model's quality (Gunn et al. 2006, Sammer et al. 2012). To develop a backcast model it is required to have an established model, historic data for both model input and validation of the backcast results and to select a backcast year more than 10 years prior to the model base year. This is to ensure that modelled systematic changes are much larger than random variation or “model noise”. The selected backcast year is 2003 due to both the availability of data and the number of years between this and the Base year of 2015 of the current NTM. A series of historic data was used to represent the 2003 backcast year such as network capacity, fuel costs, GDP, value of time, rail and bus fares, traffic levels and travel demand.

4.3 As a result of the travel behaviour changes that occurred over the backcast period (2003 to 2015), the biggest challenge was to determine the travel demand in the backcast year. Six different demand scenarios were developed to explore this, each of which used otherwise identical input data for travel costs etc. The first three scenarios used pre-existing demand files for 2003 from earlier versions of NTEM and two of these did not validate well, with the third being fair. Three further scenarios were developed with corrections on the differences between NTEM6.2 assumptions and 2003 outturn data. These differences relate to population and trip rates which had been observed to be declining in the National Travel Survey (NTS).

4.4 Two of the adjusted scenarios performed satisfactorily, validating the historic 2003 traffic data; Scenario 4 and Scenario 6 with the latter one seen to have performed better. However, we have designated Scenario 4 the "Preferred Backcast Scenario". Scenario 4 was preferred as it incorporates more actual historic data and is therefore based on fewer assumptions. The preferred scenario incorporates the travel demand that derives from NTEM6.2, with a factor to represent the actual population figures for 2003 and incorporates the declining trip rates trend that was observed to be occurring between 1998 and 2010 in the National Travel Survey (in 2012-2013). The car distance travelled in 2003 (for Cars) in the backcast scenario is only 3.7% less than the actual distance travelled for the same year. A further analysis of the backcast related to traffic levels, journey purposes, road types and area types, showed similar results which demonstrates the capability of the latest model version (NTMv2R) in projecting a backcast year.

4.5 The sections in this chapter describe the requirements and the methodology used to develop a backcast, the six different backcast scenarios and the selection of the preferred backcast scenario. The final section includes the comparison between the preferred backcast scenario with the Reference case. This Reference case is a scenario of the earlier NTM version (NTMv2) with a 2003 base year which represents the actual 2003 traffic count data. The comparison between the backcast 2003 and the Reference case 2003 is made for the same model outputs; total distance travelled, distance travelled by area type, by road type and by journey purpose.

4.2 Background

4.6 We have attempted backcast testing on earlier versions of the NTM but it failed due to the unavailability of enough historic data. Fortunately, last time the NTM was calibrated (to 2003) all the data was preserved, so a new backcast test could be attempted. The publication of results from the backcast model is also considered an excellent way of enhancing transparency on the capabilities and robustness of the latest NTM version.

4.3 Requirements for Developing a Backcast

4.7 Although the value of performing model backcasting is well understood, there is very little published literature available to help in developing a backcast and only a few limited examples in the transport sector (Roorda et al., 2008). However, one important study called "QUALIVERMO" (Sammer et al., 2010) suggests that the development of a model backcast requires the three elements below:

- **An established model** - that has passed all relevant model steps such as model calibration and sense checks;
- **Sufficient available data** - for model input and validation of backcast results;
- **A backcast year more than 10 years** to ensure that systematic changes are much larger than random variation and 'model noise'.

4.8 The following analysis shows that the above three requirements are met, thus a viable backcast model can be developed for the new NTMv2R model version.

4.3.1 Established Model

4.9 As demonstrated in the previously published calibration reports, the 2018 Roads Traffic Forecasts paper and this publication, the current model version NTMv2R is a model that has been calibrated, has passed a range of sensitivity tests, stress tests and it also uses actual traffic data for the 2015 base year.

4.3.2 Sufficient Available Data

4.10 The biggest challenge in meeting the above three requirements is to gather all the required historic data and changes that represent the backcast year (model input and demand). To determine whether there is sufficient available data it is required to determine these two sets of data; traffic data for validation and model input data representing the change from base year to backcast year.

Traffic data for validation of the assignment results

4.11 The previous version of the model (NTMv2) had a Base Year of 2003. This earlier model version is also an evaluated model that used actual traffic data based on the Traffic Database that the Department holds. The results from the earlier model version can be used to validate the results from the backcast of the new model as they are also based on actual traffic data. The existence of this earlier version and data led to the Backcast year being set to 2003, the Base year of the earlier model.

Model input data that are required to represent the changes through years

4.12 A variety of model input data is required to assess any year. Such data often varies by year and having selected the old NTM's base year as the backcast year, helped to ensure that all the required data is available. The required model input data falls into the two main categories as described in Figure 49; Demand data and other data.

Required model input for 2003

- **Demand**
- **All other changes**
- Fuel costs for 2003 (fuel prices, efficiencies and petrol/diesel mileage split)
- The Traffic Database of link based traffic counts for 2003
- Changes in road lengths and capacity between 2003 and 2015 (Backcast and Base years)
- Bus Fare Growth between 2003 and 2015
- Rail Fare Growth between 2003 and 2015
- Bus, LGV and HGV traffic growths between 2003 and 2015
- Speed versus Flow Curves for 2003 if different
- GDP for 2003
- Value of Time (VoT) for 2003

Figure 49 Model Input Required to Develop a Backcast

4.3.3 Backcast Year of more than 10 years difference

4.13 Having all the available data for the year 2003 convinced us to select year 2003 as the preferred backcast year. This year meets the requirement of having 10 years difference between the backcast and the base year of the reviewed model.

4.4 Methodology to Build the Backcast

4.14 As the above requirements are met it was feasible to develop a backcast. However, determining the overall demand for travel in the backcast year was a challenge. The NTM takes the base and forecast demand for travel, in the form of trip ends, from the National Trip End Model (NTEM). However, the current NTEM version, NTEM7.2, has a 2011 base year and can't provide data for years before this. The demand data for year 2003 derived from the previous versions of NTEM were forecasts produced from a model base year of 1998.

4.15 A further complication in obtaining robust estimates of demand in 2003 is that trip rates per person have been falling. The fall in trip rates has been observed in NTS and incorporated in NTEM7.2. The phenomenon has also been independently observed by TRICS[21]. Declining trip rates were not sufficiently evident in the data that was available in 1998 and the constraints on the NTS sample size means that this trend would need to be sustained for many years before having a significant impact in the NTS observations to result in potential inclusion in the NTEM dataset.

4.16 The falling trips rates seen in NTS prompted much debate about possible changes to the nature or characteristics of people's travel behaviour that occurred over recent years and in 2014 this led to the Department taking a fresh look at its trip rate assumptions. In the subsequent analysis it was shown that trip rates had indeed been falling over the analysed period (from 1998 to 2010) but although people were making fewer trips, the largest reductions were to the shortest distance trips. These trips were mainly related to walking and cycling modes. These travel behaviour changes and particularly the new assumptions of reduced trip rates that were subsequently deployed in the Department's NTEM7 dataset, have made the selection of the most suitable levels of demand in the backcast year very difficult. As a result, an iterative process has been adopted. The methodology used in developing the backcast is based on a series of steps as shown in Figure 50.

4.17 The first step involves assembling all the model inputs for the backcast year of the sort that are more normally assembled for forecasting. These include changes to the network capacity, service levels, fuel costs and changes to public transport fares etc. Once all the above historic data are determined and checked they can then be considered as a final best representation of the year.

4.18 The second step involves determining the demand for the backcast year. However, to assess whether the demand is a good representation of the historic situation, it’s necessary to validate the backcast year traffic results with actual traffic data for 2003. If the results are not validated or poor then a revised demand should be tested. The following sections describe the iterative process and the data that were deployed.

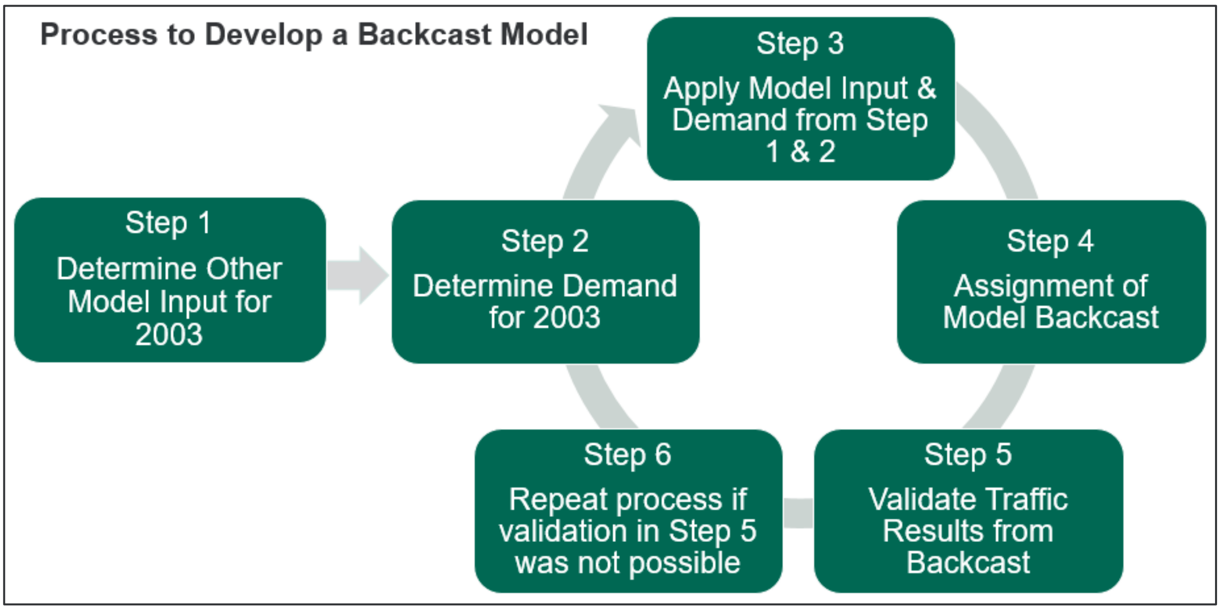

Figure 50 Process to Develop a Backcast Model

[21] TRICS is a large database of inbound and outbound transport surveys covering a variety of development types.

4.5 Model Input for Backcast Year

4.19 Assigning a new year in the model, different from the Base Year, requires a variety of changes and new model inputs that are different for each year. These are identified and described in a previous section of the report (Figure 49, section 4.3.2).

4.5.1 Cost files

4.20 The cost file includes information for the vehicle operating cost (VOC) per fuel type, value of time (VoT), fuel efficiencies and cost splits for each vehicle type based on fuel type and the GDP per capita for each year from 1998 to 2050. The cost (p/km) for 2003 and 2015 years is shown in Table 18. The fuel costs are calculated by the cost equation from TAG unit M3.2 (average speed assumption of 40kph):

$$FC = \frac{a}{V} + b + c * V + d * V^2, \; where: speed\ v = \frac{40km}{h}\ and\ a, b, c, d\ are\ costs\ factor$$

Table 18 Cost difference between 2003 and 2015

Vehicle Type user	2003 Costs (Backcast)	2015 Costs (Base Year)	Cost Difference of 2003 & 2015
HBW	7.19	7.23	1%
HBEB/NHBEB	6.12	6.03	-1%
HBEO/HBDO/NHBO	7.19	7.23	1%
LGV	6.68	7.19	8%
Rigid	20.22	23.99	19%
Artic	36.87	40.87	11%
PSV	26.59	31.05	17%

4.5.2 Network Capacity

4.21 The NTMv2R network represents the 2015 capacities. However, it has changed through years due to road schemes being built or policy proposals. Thus, it was required to amend the backcast scenario network to represent the 2003 capacities.

4.22 To achieve this, the Transport Statistics Great Britain database (TSGB)[22] was used. TSGB database includes the GB road network capacity through years in terms of road length based on region and road types. Based on TSGB, the total capacity change in the GB network is 1% less in 2003. Table 19 below shows the change in capacity between 2015 to 2003 in each region per road type.

[22] TSGB Database (published 12/2012 and updated 12/2019): https://www.gov.uk/government/collections/transport-statistics-great-britain

Table 19 Capacity change in length from 2015 to 2003 from TSGB data source

Region	Motorway	Rural Major	Urban Major	Rural Minor	Urban Minor	Total length
Northern	0%	-1%	-1%	0%	-2%	-1%
North West	-1%	0%	0%	-2%	0%	-1%
Yorks & Humber	-12%	-2%	2%	-1%	0%	-1%
East Midlands	-1%	-1%	0%	-1%	-1%	-1%
West Midlands	-12%	-1%	0%	0%	-3%	-2%
Eastern	1%	0%	1%	-2%	1%	-1%
London	0%	0%	0%	0%	-1%	-1%
South East	0%	0%	0%	-1%	0%	-1%
South West	0%	0%	-2%	-1%	-1%	-1%
Wales	0%	-1%	3%	-3%	-2%	-2%
Scotland	-15%	0%	-1%	-1%	3%	0%
Grand Total	**-5%**	**0%**	**0%**	**-1%**	**0%**	**-1%**

4.23 This table also describes how the capacity change was applied on the backcast model to get the 2003 capacity levels. It should be noted, however, that using this data underestimates the changes to capacity that occur from various transport schemes (road widening/dualling schemes).

4.5.3 Bus Fare Growth and Service Level

4.24 The bus fares and bus service levels are input in NTM as exogenous estimates provided by bus modelling tools developed by the Department. Therefore, there are available data that can be used to estimate the change in fares and service level between the base year 2015 and the backcast year 2003. The change is calculated in ratios and input in the model separately for four different categories of bus types and areas; “London buses”, “Metropolitan areas buses”, “Buses in all other areas” and “All Coaches”. Table 20 shows the ratios used for fares and service levels for 2003 compared to 2015.

Table 20 Bus fares and service level

Year	Bus fares				Bus service levels			
	London	Mets	'Shires'	Coach	London	Mets	'Shires'	Coach
2003	0.7087	0.8374	0.9091	0.9125	1.0176	1.1668	1.1447	1.0083
2015	1	1	1	1	1	1	1	1

4.5.4 Rail Fare Growth

4.25 The NTM input data related to rail travel is held constant from the base year, as modelled changes to rail patronage can’t be easily converted into changes to rail service levels or estimates of crowding. The Department has developed rail models specifically for these purposes. Hence, the only data required for the backcast is rail fares. The rail fares have changed over time and can be estimated from the ORR fares index and the GDP deflator series. The information for the ORR values and GDP deflator series are included in the published[23] databases by the Department.

4.26 The Rail Fare growth for the backcast year was calculated in two steps. The first step was to calculate the ratio of ORR fares index and GDP deflator separately for 2003 and 2015 (ORR fares/GDP Deflator series). The next step was to calculate the percentage difference of the above ratios that provides the rail fare change between 2003 (backcast year) and 2015 (Base year). The resulting fare change from 2015 to 2003 is shown in Table 21.

Table 21 ORR fares and GDP Deflator series

Year	ORR Fares	GDP Deflator series	ORR/GDP
2003	126.162	75.291	1.676
2015	217.198	95.453	2.275
Change from 2015 to 2003		-26.36%	

4.27 The limitation of having a constant rail input without crowding feedback could result in more rail trips and less traffic in 2003 or vice versa.

4.5.5 Bus, LGV and HGV Growth

4.28 The Bus, LGV and HGV growth between 2003 and 2015 has been imported in the model by using growth files. These files include only growth factors and not actual figures.

4.29 The Bus and LGV growth factors are available in historic growth files for 2003 to 2010 and for 2010 to 2015. The HGV growth factor is available in the GBFM file for 2004 to 2015 but not for 2003 to 2004. Thus, to include the growth for that single year, we have used the HGV growth factor given from the growth files. Thus, a new growth input file was created and was used, in combination with the existing GBFM file, to provide the final growth factors for Bus, LGV and HGV.

4.5.6 Speed Flow Curves

4.30 The Speed Flow curves used in the backcast are the same as those published with RTF18, except that the London curves were modified slightly to reverse the changes to capacity and speeds in London that occurred over the period to 2010. These changes were previously documented in the RTF15 forecasts paper and included decreases of 19%,13% and 6% for Central, Inner & Outer London respectively over the period 2003 to 2010. The speed flow curves are defined in terms of volume to capacity ratios (rather than hourly flows) so whilst use of the old curves resulted in different speeds or journey times, the changes to London road capacity still needed to be input separately. No estimates of further changes to speed flows occurring between 2010 and 2015 were made.

[23] Published information for ORR fares index (released 21/12/2018) and for GDP deflator series: http://dataportal.orr.gov.uk/displayreport/report/html/920430f4-6a8d-4bb8-9762-2bf89259e346 and https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/l8gg/qna

4.5.7 Changes to GDP and Value of Time

4.31 These data are available through the Department's Transport Appraisal Guidance within the Data Book (Tables A1.3.1, A.1.3.2, A1.3.5 and Annual Parameters section).

4.6 Demand for Backcast Year

4.6.1 National Trip End Model

4.32 The National Trip End Model (NTEM) is used to provide the demand levels for any specific year that is modelled in the NTM. NTEM is a trip generation model for England and Wales and it produces estimates of person travel by journey purpose for each zone in Great Britain[24]. The total number of trips from NTEM is not distinguished by mode, only by journey purpose and zone. The modal split is done by the Demand component of the NTM model where trips are allocated to each mode based on their generalised costs. The modal shares in the base year of 2015 are set during the calibration process to match 2015 NTS data.

4.33 The input of NTEM is either historic data or forecasts of the population, the number of dwellings, the household composition, employment data and probabilities of owning a car (as these derive from NATCOP). The output of NTEM is a demand (trip ends) file for a specified year providing the number of trip Productions (where they start) and Attractions (where they go) by a geographical area at the level of Middle Super Output Area (MSOA).

4.34 This NTEM output file is converted to an NTM input file that includes the demand aggregated into 1575 categories. These categories represent the 105 segments of NTEM for each of the 15 zones of NTM. The 105 NTEM segments are combinations of journey purpose, person type, income and household composition (number of adults and car availability) as described in Figure 4: Segmentation of Car Trips by Journey Purposes and Traveller Type.

4.35 Although the composition of area types within NTMv2R have slightly changed compared to the original NTMV2 model (due to population increases), the above trip segmentation and the format of NTEM output files has not changed. Thus, it is possible to use earlier or historic (NTMV2) demand estimates produced by previous NTEM versions.

4.6.2 National Trip End Model - Latest and Older Versions

4.36 NTEM is updated every few years to account for the latest population forecasts or other changes to travel behaviour as recorded in the National Travel Survey (NTS). The NTS is an official survey that is published every year and includes details of the travel choices that people make as well as the associated costs etc.

4.37 The latest NTEM version is NTEM7.2 with a Base year of 2011 and can provide the demand for any year between 2011 and 2051. This version of NTEM was based on NTS data for the period 2012 to 2014.

4.38 Two previous NTEM versions which were widely used in NTM analysis over the years are NTEM6.2 with Base year 2001 and NTEM5.4 with Base year 1998.

[24] Although the NTEM model geography includes Scotland, the model does not produce trip ends data for Scotland.

These historic NTEM versions were based on NTS data and population estimates at that time. Figure 51 shows the latest and old NTEM versions.

NTEM 7.2	NTEM 6.2	NTEM 5.4
• Base Year **2011**	• Base year **2001**	• Base Year **1998**
• Includes data from 2011 onwards	• Includes data from 2001 onwards	• Includes data from 1998 onwards
• **Latest NTEM version**		

Figure 51 Latest and Old NTEM versions

4.39 There is a significant difference in the number of trips estimated in the latest NTEM7.2 version compared to the older ones. NTEM7.2 has 23.4% fewer trip ends than the previous versions. The main reason for the difference between versions is the reductions to trip rates which were incorporated in NTEM7.

4.40 The reductions in trip rates were based on the analysis of evidence derived from the collection of data between 1998 to 2010 as published in the 2011 National Travel Survey (NTS). This showed that for most purposes there had been a reduction of trip rates occurring over the period and particularly between the old model base year of 2003 and 2010. Whilst trip rates reduction is observed for several of the Home-Based trip purposes there were also increases in holiday related purposes.

4.41 Based on the analysis of more contemporary traffic and NTS data available at the time of the NTEM7 publication, the observed trends in changing trip rates were continued beyond 2010 and linearly extrapolated from 2010 as far as 2016.

4.42 The numbers of trips in the NTMv2R 2015 base, and therefore its recalibration, were based on the best estimates of trip rates in 2015 as contained in NTEM7.2. The assumption about the continued decline of trips rates to 2015 has been confirmed by more recent NTS data. However, trip rates since 2015 have been showing increases.

4.43 Whilst it was not possible to produce estimates of trip ends for the year 2003 from NTEM7.2 it has been necessary to try to estimate the level of 2003 demand from NTEM versions that were developed nearer that time. These versions contain quite different assumptions not only about personal travel trip rates but also about the characteristics of those trips in terms of the distances travelled and the modes used.

4.44 Figure 52 shows the great variation in demand between the new and the old versions of NTEM. The demand for 2015 in NTEM 7.2 (new version) is 24 million trips lower from the 2015 demand in NTEM 6.2 (old version) and 25 million less from NTEM 5.4. The demand is shown in millions of trips occurring on an average day (week/7 days).

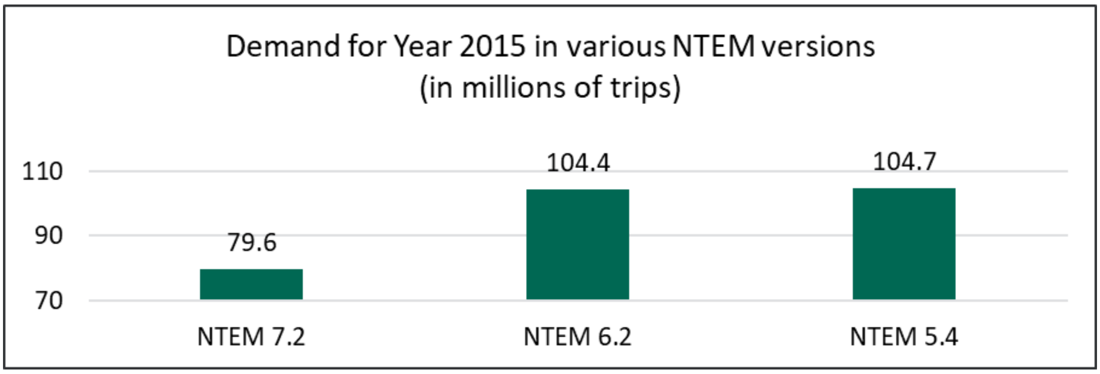

Figure 52 Average Daily Trip Ends from each NTEM version (year 2015)

4.7 Development of Backcast Scenarios 1, 2 & 3

4.45 As described in previous section, six backcast scenarios have been developed. This section is separated in two parts. The first part describes the input of demand for Scenario 1, 2 and 3 and the second part describes the validation of the model traffic output from the assigned scenarios.

4.7.1 Demand for 2003 Backcast Scenarios 1, 2 & 3

4.46 Given the differences between the latest and historic NTEM versions described in section 4.6.2, the backcast demand should ideally derive from the same NTEM version (NTEM7.2) that is used in the current NTM. This would provide trips with characteristics that are consistent with the base year calibration. However, the current NTEM version has a 2011 base year and can't provide data for earlier years.

4.47 Therefore, to estimate the 2003 demand we need to use the older NTEM versions NTEM6.2 and NTEM5.4. However, it is also clear that assigning the demand of NTEM6.2 and NTEM5.4 in the new model will not provide validated traffic. Further adjustments will need to be made on the demand levels to include the noted changes in the travel behaviour occurring over the backcast period. There was initially a choice of three available 2003 demand scenario files that were based on the older NTEM versions. The three demand files formed the initial three backcast scenarios; Scenario 1, 2 & 3 as summarised below:

- **Scenario 1:** Backcast Demand using the available 2003 demand from NTEM5.4;
- **Scenario 2:** Backcast Demand using the available 2003 demand from NTEM6.2;
- **Scenario 3**: Backcast Demand using the 2003 demand from NTEM6.2 and year 2003 "Spot Trip Rates" reflecting the reduction of trip rates observed between 1998 to 2010 in the NTS trip rate study.

4.48 The demand in Scenario 1 and Scenario 2 derives from NTEM5.4 and NTEM6.2 respectively. Scenario 3 is based on a demand file for 2003 that derives from NTEM6.2 but uses different trip rates (named “spot rates”). The "spot rates" for 2003 were originally used for creating a low trip rate scenario in the RTF15 forecasts and were estimated from the same analysis of 1998-2010 NTS data that was subsequently used to estimate the rates used in NTEM7. These "spot rates" are therefore broadly consistent with NTEM7 and considered the best available estimate of trip rates in 2003.

4.49 Figure 53 below shows the number of trip ends for each of the above backcast scenarios and for the 2003 Reference Case (from previous NTM version with a base year 2003 and trip ends from NTEM5.4).

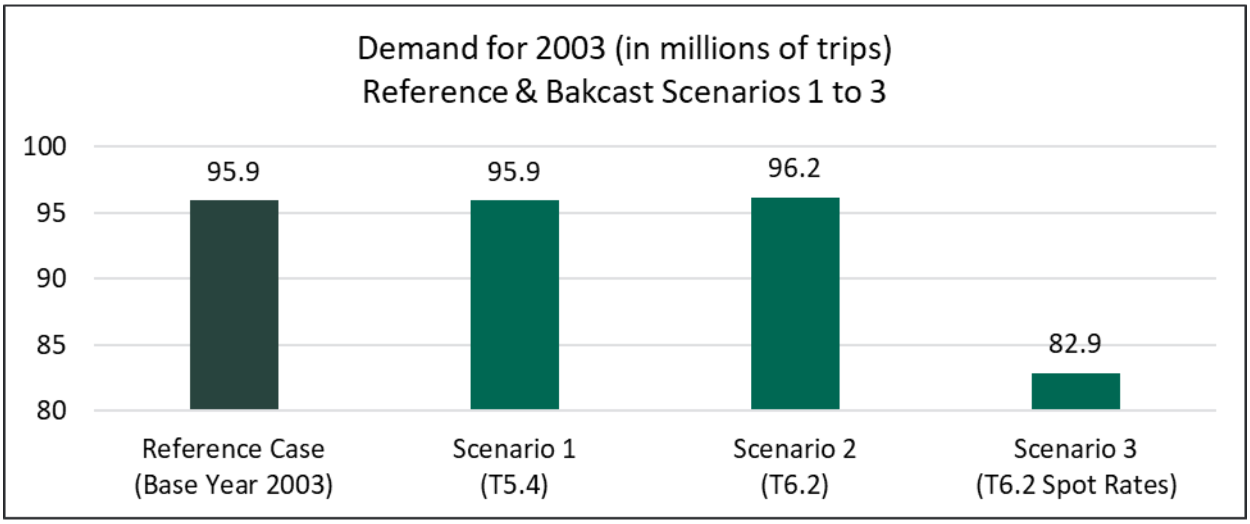

Figure 53 Average Daily Trip Ends - 2003 Backcast Scenarios 1, 2 & 3

4.7.2 Traffic Results Validation for 2003 Backcast Scenarios 1, 2 & 3

4.50 As described above, there are only three available demands and these were used initially to develop three backcast scenarios (Scenario1, Scenario 2 and Scenario 3). The three available demand files described in Section 4.6 and the various changes described in Section 4.5 were applied and assigned in the new NTMv2R model (step 3 & 4 from the backcast methodology) to form the first three backcast scenarios.

4.51 The overall car traffic results from the above three backcast scenarios were compared to the actual 2003 traffic data by using the traffic output from the previous NTM with a base year of 2003. Thus, the Reference case that is mentioned in this chapter refers to the old NTM with the 2003 base year. The results are shown in the figure below.

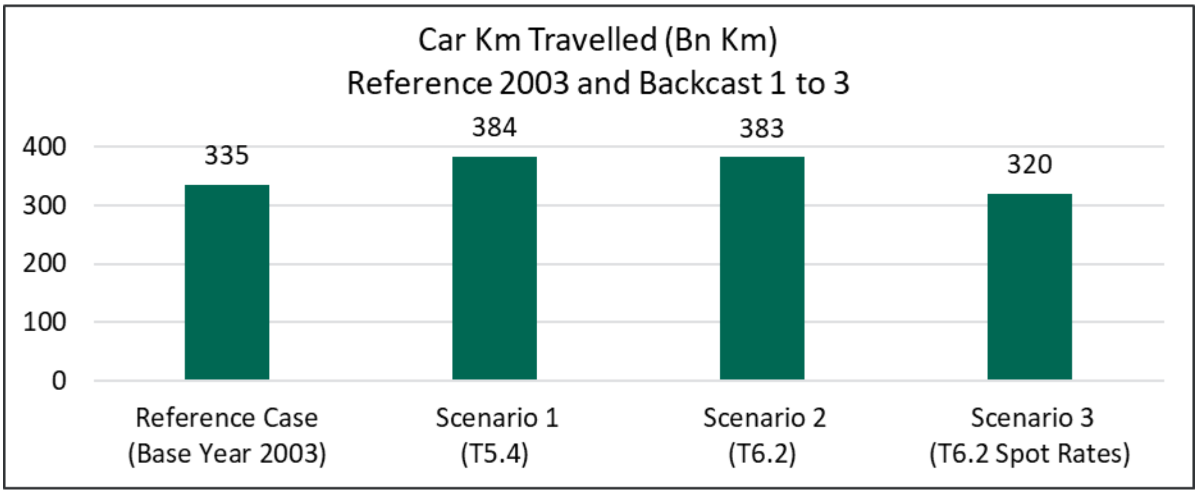

Figure 54 Car Distance Travelled - 2003 Backcast Scenarios 1, 2 & 3

Validation of Traffic results - Scenario 1 & 2

4.52 The traffic results from Scenario 1 and Scenario 2 show a significant deviation from the actual traffic data for 2003. This was expected as the levels of demand in these scenarios are much higher even than the ones in the latest NTM model with a 2015 Base year. Also, applying the same trip ends as used in the old model base (Scenario 1) has resulted in nearly 16% more traffic and this is due to the relative increase in the numbers of longer trips in the new model.

Validation of Traffic results - Scenario 3

4.53 The results from Scenario 3 are closer to the actual 2003 data, as this scenario includes the lower trip rates that were derived from the analysis of declining rates between 1998 and 2010. The 2003 traffic target is not achieved as the changes in travel behaviours that were incorporated into the new base model 2015, haven't all occurred in 2003. This has resulted in a steeper reduction in traffic than the actual.

4.54 Nevertheless, Scenario 3 is the best backcast scenario that can be developed from using the immediately available demand files. However, the estimated demand for 2003 could be improved to better represent the actual 2003 demand. Thus, further enhancements were applied on the demand files as described in the following sections. These enhancements led to the development of three further model backcast scenarios.

4.8 Development of Backcast Scenarios 4, 5 & 6

4.55 This section is again separated in two parts with the first describing the demand for Scenario 4, 5 and 6. The second then describes the validation of the traffic results from the assignment of the scenarios against the traffic output from the previous NTM version with 2003 base year (Reference case).

4.8.1 Demand for 2003 Backcast Scenarios 4, 5 & 6

4.56 As analysed in section 4.7, Scenario 3 is the best backcast that can be achieved from existing available demand files. However, it was noted that there was available data to improve the demand estimates for 2003. For this reason, three additional demand files were created and tested through three different scenarios.

- **Scenario 4:** Backcast Demand Estimation Using NTEM6.2 with the incorporated "Spot Rates" (to reflect the reduction of trip rates between 2003 to 2010) and actual population;
- **Scenario 5:** Backcast Demand Estimation by Trip Ends Change from NTEM6.2 to NTEM7.2 (by calculating a factor based on the difference in 2015 demand between NTEM7.2 for 2015 and NTEM6.2 for 2015 and applying the factor on the 2003 NTEM6.2 demand);
- **Scenario 6**: Backcast Demand Estimation by NTEM7.2 and extrapolated reduced rates from NTEM6.2 (by calculating a factor to represent the reduction of trip rates between 2003 and 2010 that was extrapolated for year 2015 and applying this factor on the NTEM7.2 demand for 2015).

4.57 Figure 55 shows the trip ends in the Reference scenario (2003), the current Base year scenario (2015) and the six backcast scenarios.

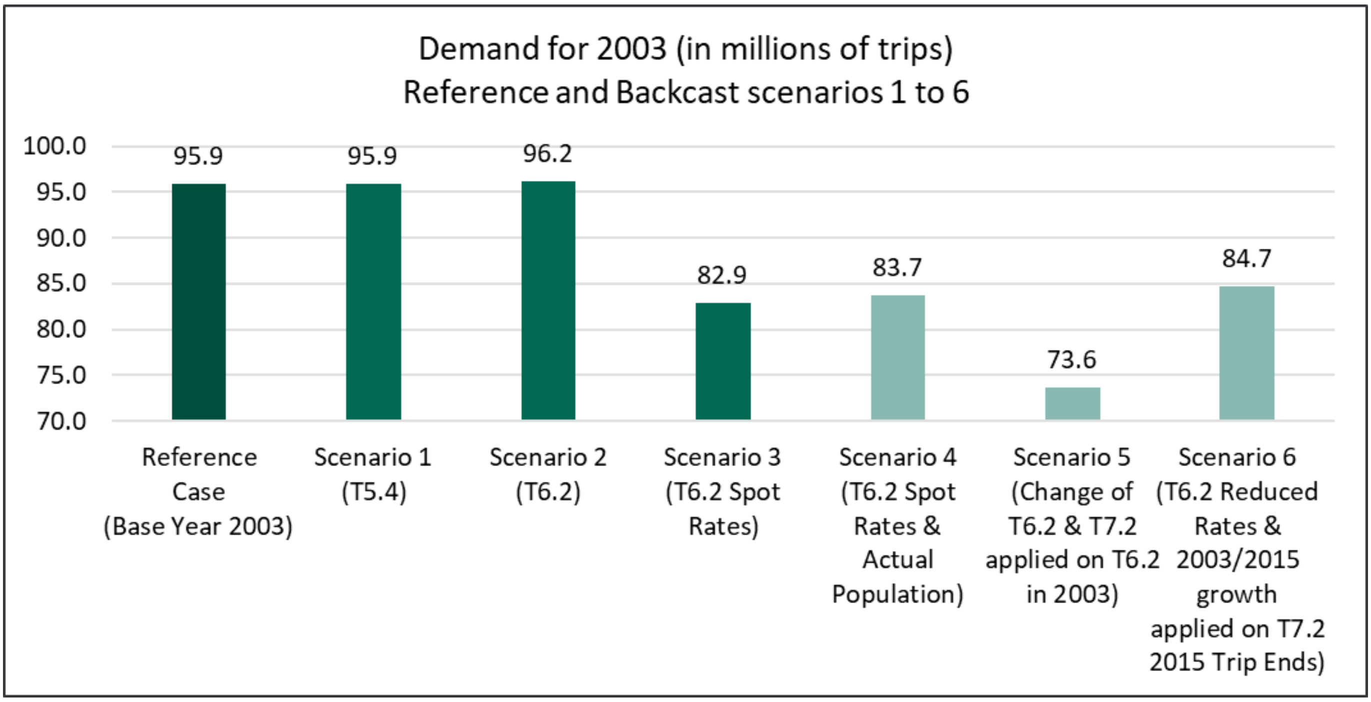

Figure 55 Trip Ends for Reference Case & Backcast Scenarios 1, 2, 3, 4, 5 & 6

4.58 The sections below describe how the 2003 demand for 2003 for scenarios 4 to 6 was estimated.

Backcast Demand Estimation - Scenario 4

4.59 Whilst the model performs well in Scenario 3, it was noted that the demand was estimated within NTEM6.2 based on population estimates rather than on actual population figures for 2003. Thus, it was considered appropriate to create a new demand file to include both the lower trip rates of Scenario 3 and the actual population figures for 2003. The new demand resulted in a slight increase to the numbers of trips and was used to develop a new backcast scenario (Scenario 4).

4.60 The Great Britain population that was used in NTEM6.2 for 2003 is given as 57381400 however the Actual GB population in 2003 was 57931700 (as published in the Population Estimates dataset in June 2019). The difference (0.96%) was applied as a factor on the demand file of Scenario 3 (NTEM6.2 and Spot Rates).

4.61 As shown in the NTM segments in Annex A (section A6), the demand file includes the trip ends aggregated in 1575 lines that represent the combination of the 15 model zones and the 105 model segments. The model segments are a combination of journey purpose, person type, income segment and household type (number of adults and car availability). Thus, the population factor was applied on the individual categories of trip ends. As a result, the estimated demand increased to 83.7 million trip ends per average day.

Backcast Demand Estimation - Scenario 5

4.62 The second method that was used to re-estimate the 2003 demand was based on the difference of trip ends for 2015 between the two NTEM versions of 6.2 and 7.2. This difference is a reduction of 23.45% in trip ends across all purposes in NTEM7.2. The change varied for each journey purpose and a specific change was applied to each purpose as shown in Table 22. These changes were applied on the NTEM6.2 trip ends file for year 2003 and the Scenario effectively assumes that the full impact of changing trip rates (between NTEM 6.2 and 7.2) had occurred by the year 2003. The resulting estimated demand in Scenario 5 is approximately 73.6 millions of average daily trip ends.

Table 22 Trip ends change between NTEM7.2 and NTEM6.2

Journey Purpose	Change in Demand in NTEM7.2 compared to NTEM6.2
HBW	-23.71%
HBEB	-6.07%
HBEd	-5.25%
HBPB	-19.89%
HBRec	-42.95%
HBHol	38.35%
NHBEB	-19.89%
NHBO	-18.83%

Backcast Demand Estimation - Scenario 6

4.63 The third approach to estimating the 2003 demand was to use the observed reductions in trip rates and apply them in a way that also reflected the trip making characteristics embodied in NTEM7.2. The Road Traffic Forecasts (RTF15) included a scenario that used an estimated demand for 2015 (as a forecast year) based on the reduction of trip rates between 2003 and 2010 (as derived from the regression analysis of NTS data) and a linear extrapolation of those trip rate trends from 2010 to 2015, all based on NTEM6.2.

4.64 Calculating the difference in trips between 2015 and 2003, from the above files, provided an estimate of the changing travel demand from 2003 to 2015 incorporating both the expected changes to the population and trip rates. These trip changes were applied to the demand in 2015, as given by NTEM7.2, to create a 2003 demand that incorporates the population changes, the trip rate reductions and the NTEM7.2 behaviour characteristics (trip length distributions). The estimated demand in Scenario 6 is approximately 84.7 millions of average daily trips.

4.8.2 Traffic Results Validation for 2003 Backcast Scenarios 4, 5 & 6

4.65 The traffic results from the above scenarios (4 to 6) and from the previous scenarios (1 to 3) are summarised in Figure 56. These results help to validate each scenario against actual traffic levels from the Reference Case (2003 traffic of old NTM model).

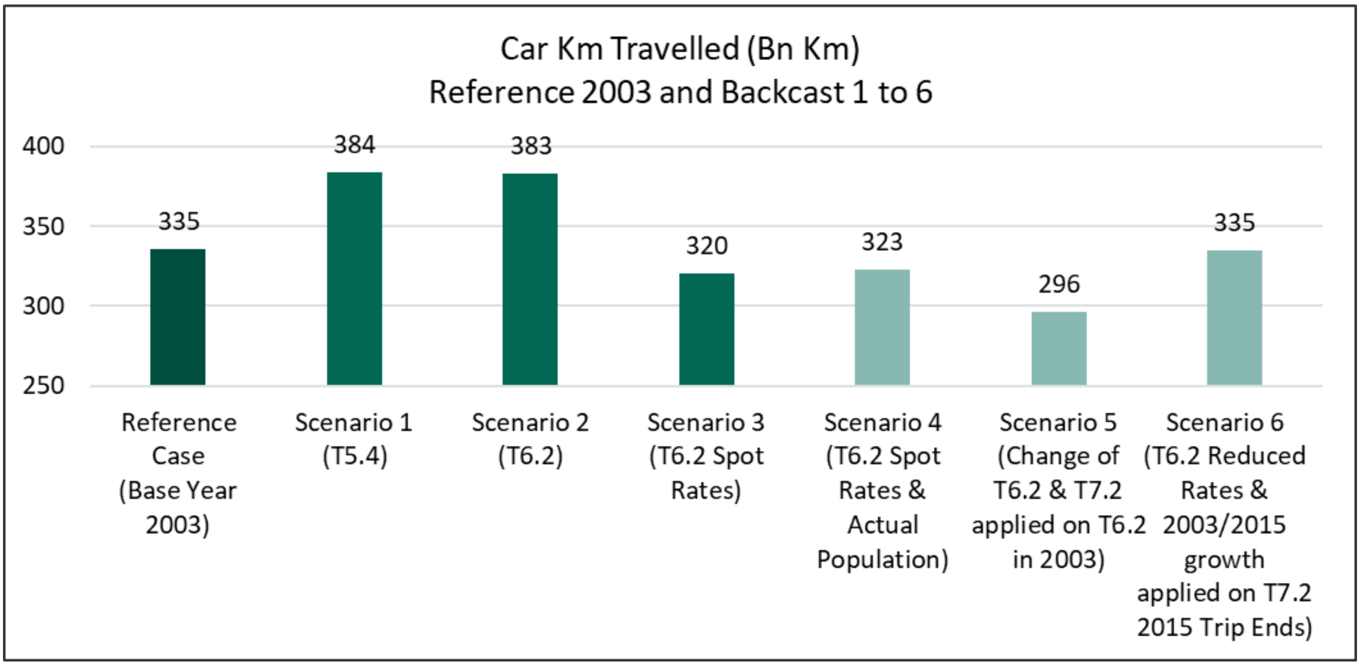

Figure 56 Car distance travelled for 2003 Backcast Scenarios 4, 5 & 6

Validation of Traffic Results - Scenario 4

4.66 The comparison of the above backcast scenario with the Reference Case showed that the traffic results from Scenario 4 have been improved and therefore the demand of Scenario 4 is a good representation of the 2003 actual demand. Although this scenario represents the best estimates of the trip rates and population in 2003, it is still based on NTEM6.2 and therefore does not include any changes in the travel characteristics that have occurred since the publication of NTEM6.2. These changes would result in a higher proportion of the longer distance trips and therefore more likely to use a car or train. To include these changes, we considered different methods of adjusting NTEM7 based demand files to better represent the year 2003.

Validation of Traffic Results - Scenario 5

4.67 The traffic results from Scenario 5 showed a significantly lower kilometerage of car distance travelled resulting from the lower demand in this scenario. Whilst the scenario has reduced the numbers of trips it has also assumed that the full impact of trip rate changes, seen in 2015, were applicable in 2003. This has overestimated the reduction in demand and as the scenario has also omitted the associated changes in trip lengths it has substantially underestimated the traffic volume in 2003. This might have been reduced if the reduction of trips was applied more to the shortest, rather than to all trips.

Validation of Traffic Results - Scenario 6

4.68 The traffic levels in Scenario 6 closely match the traffic results of the Reference Case. This result showed that the use of the NTS derived 2003 spot rates and the extrapolated trip rate data between 2010-2015 provides a good estimation of demand for travel in the backcast year.

4.9 Selection of Preferred Backcast

4.69 All the backcast scenarios were developed by using the same historic data for the input parameters such as fuel costs, network capacity, GDP and VoT change etc, however each scenario is using a different level of demand in terms of trip ends. The demand has a great impact on the model and this is shown in Figure 57 which represents the difference in distance travelled between each backcast scenario and the 2003 Reference case.

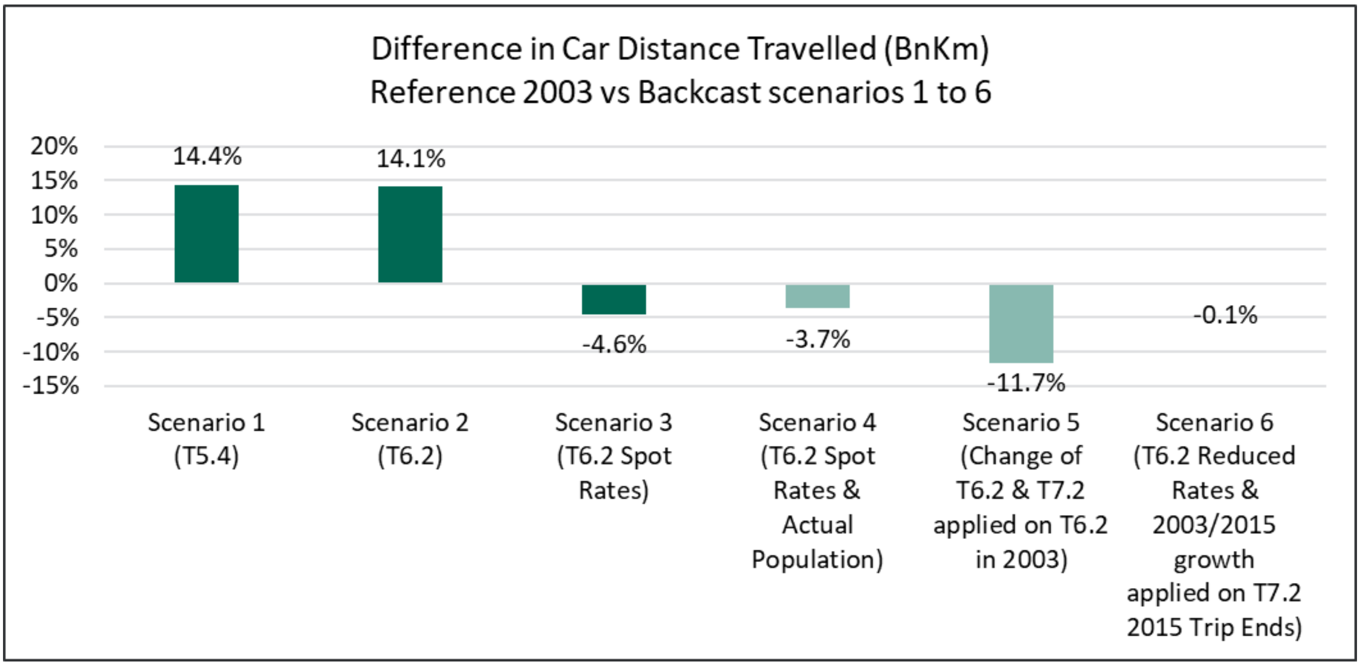

Figure 57 Difference in Car Distance Travelled - All 2003 Backcast Scenarios (1 to 6)

4.70 Although Scenario 6 seems to be the closest to the Reference case in terms of traffic levels, this scenario has not been taken as representing the final or best backcast scenario. This selection has also been based on the reliability and confidence of the data that was used to develop each of the six scenarios.

4.71 The demand in Scenario 1 and Scenario 2 does not represent the characteristics of the latest travel behaviour as represented in NTEM version 7, thus they are clearly not sufficient for backcasting the 2003 in the new model.

4.72 Scenario 3 is using the demand of 2003 that includes the reduction of trip rates (demand reduction) based on historic data from 1998-2010 derived from the NTS 2013 publication. Thus, it could be used as a good representation of a 2003 backcast scenario.

4.73 Scenario 4 represents the backcast year better than Scenario 3 as it incorporates not only the reduction of trip rates (as Scenario 3) but also the actual population estimates for 2003. Both Scenario 3 and Scenario 4 demonstrate a small difference in distance travelled from the Reference case.

4.74 Scenario 5 assumes that the difference in trip ends between the new and old NTEM version had occurred by 2003 and is the same for all the trip lengths. In NTEM7.2 the shorter trips are the ones affected more by the reduction of trip rates which itself is assumed to have continued beyond 2003 and up to 2016. Thus, the Scenario overestimates impacts of changes over the period and is not a good representative of a backcast scenario. This is clearly demonstrated by the difference in distance travelled of this scenario compared to the Reference case.

4.75 Scenario 6 is using the demand that incorporates the reduced trip rates from 2003 to 2010 which are based on historic NTS data which were then extrapolated from 2010 to 2015 assuming a constant trend of trip rate reduction occurred over the period. Hence, the data for 2010 to 2015 were not based on historic data. The resulting 2003 demand was then estimated by applying the absolute differences between the NTEM6.2 based year 2003 and 2015 with extrapolated trip rates files to the 2015 demand file from NTEM7.2. The difference from Scenario 6 and the Reference case is only -0.1% and significantly smaller than Scenario 3 and 4. This shows that the assumption that was applied in NTEM7.2 regarding the declining rates from 2010 to 2015, was correct. The above assumption is also validated from the previous NTS[25] report which shows that trip rates continue to decline from 2010 to 2015.

4.76 There is more reliability and confidence in using Scenario 4 as the preferred backcast scenario because it's based firmly on historic data without the assumptions that were required to generate Scenario 6. Based on the above observations, the most reliable backcast scenario that represents better the 2003 year and also the concept of the latest version of NTEM, is Scenario 4. The analysis that is described in the next sections is based on the comparison between the “Preferred Backcast” 2003 scenario (Scenario 4) and the Reference case 2003.

[25] NTS report 2016 (published in July 2017): https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/633077/national-travel-survey-2016.pdf

4.10 Comparison of Preferred Backcast 2003 and Reference case 2003

4.77 The following sections include the comparison between the backcast scenario for 2003 (Scenario 4) and the Reference Case 2003. The comparison is made for:

- overall car distance travelled,
- car distance travelled by journey purpose and separately by area type,
- car distance travelled by combination of journey purpose and area type,
- car distance travelled by road type,
- number of trips by mode,
- number of trips by mode and journey purpose,
- number of trips by mode and distance band.

4.10.1 Car Distance Travelled

4.78 The following section includes the comparison of the car distance travelled between the preferred backcast scenario and the Reference case (for 2003).

Overall Car Distance Travelled

4.79 Table 23 shows a small difference in distance travelled (-3.7%) between the backcast and the Reference case which indicates that the NTMv2R model can project traffic levels for 2003 validated by actual traffic data for the same year.

Table 23 Overall Car Distance Travelled in Reference Case 2003 and Preferred Backcast 2003

Scenario Name	Car Distance Travelled (BnKm)	Total Distance Travelled (BnKm)
Reference Case 2003	335	414
Backcast 2003	323	402
Difference Backcast 2003 vs Reference 2003	**-3.70%**	**-2.80%**

Car Distance Travelled by Journey Purpose

4.80 Figure 58 and Figure 59 show the car distance travelled by journey purpose and the difference on this distance between the backcast and the Reference case for the below journey purposes:

- home-based to work (HBW),
- home-based employer's business (HBEB),
- home-based education and home-based personal business (HBED-HBPB),
- home-based other and discretionary (HBDO),
- non-home-based employer's business (NHBEB),
- non-home-based (NHBO).

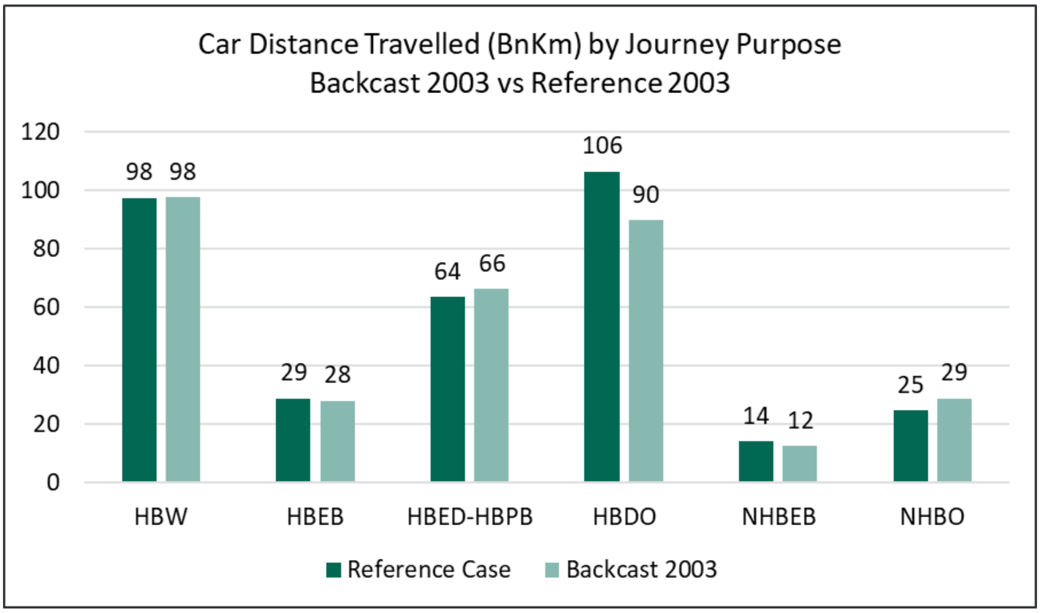

Figure 58 Car Distance Travelled - Preferred Backcast 2003 vs Reference Case 2003

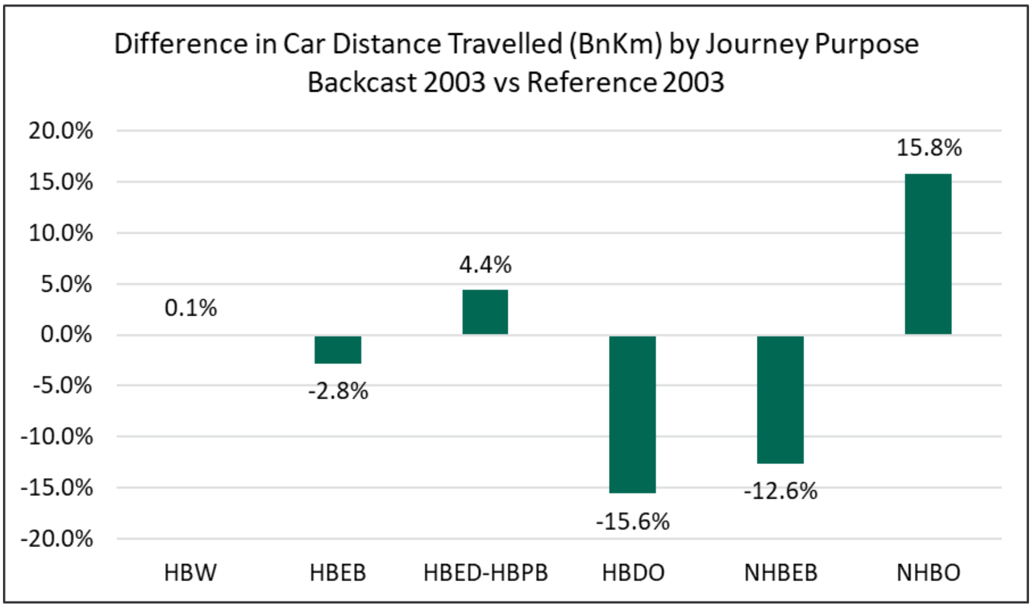

Figure 59 Difference in Car Distance Travelled - Preferred Backcast 2003 vs Reference Case 2003

4.81 The overall difference in car distance travelled between the backcast and 2003 reference case is -3.7% which might seem to imply that either there are slightly too few trips in the backcast scenario or that the model is assuming that the trips are generally shorter than they were in practice. However, this is not how the backcast is actually working. The characteristics of the trips in the NTEM7 base year involve fewer but more lengthy trips than in previous NTEM versions and projecting these changes to longer trips back to 2003 has resulted in the underestimation of traffic. Assuming that the numbers of trips are correct, then the trip lengths need to reduce over the period going back to 2003 to result in less of a change in traffic from 2015. This smaller reduction or impact is in keeping with the trend in behaviour that was observed over the period and, if captured, would have resulted in an improved fit of the backcast.

4.82 Looking at the different journey purposes the backcast model is performing well in comparison to the Reference case on the key journey purposes such as HBW, HBEB and HBED/PB with a difference smaller than 5% in these purposes.

4.83 The non-home-based trips (NHBEB and NHBO) and the discretionary and other trips (HBDO) however have more significant differences to the Reference case. The difference with the Non-Home-based trips may relate to the limited information available for the non-home-based trips, and revised assumptions about their derivation included in NTEM7.

4.84 Also, whilst the general trend of trip rates over the backcast period was a reduction, the trend for the longest trips types, those for holidays, was increasing. Thus, although there might be fewer holiday trips in 2003, the 15.6% difference or shortfall noted for the discretionary and leisure trips may indicate that the assumptions about this increasing trip rate or applying the full trip lengthening are too strong. Finally, these trip purposes are discretionary and are therefore the most responsive to changes in costs and journey times. Thus, any discrepancies between the backcast values selected for these data and the 2003 actuals will have a much greater impact on these purposes.

4.85 The 15.6% difference in the HBDO trips highlights the different characteristics of these trips between the old and the new NTEM version. The difference in the 2015 trip ends between NTEM7.2 (in the new model) and the older version NTEM6.2 is a 23% decrease across all trips ends. However, the difference HBDO trips between NTEM versions is more than 37%. This figure includes both a large reduction in leisure trips but also a large increase in holiday trips. These differences in combination with different characteristics in terms of the trip length distribution for short and long trips and the higher elasticities for discretionary purposes have combined to produce a large underestimation in the backcast.

Car Distance Travelled by Area Type

4.86 Figure 60 and Figure 61 show that the backcast model generally performs well within the areas with the highest number of trips (Rural, Urban and Conurbation) but not so well within London, which has small number of car trips compared to the total.

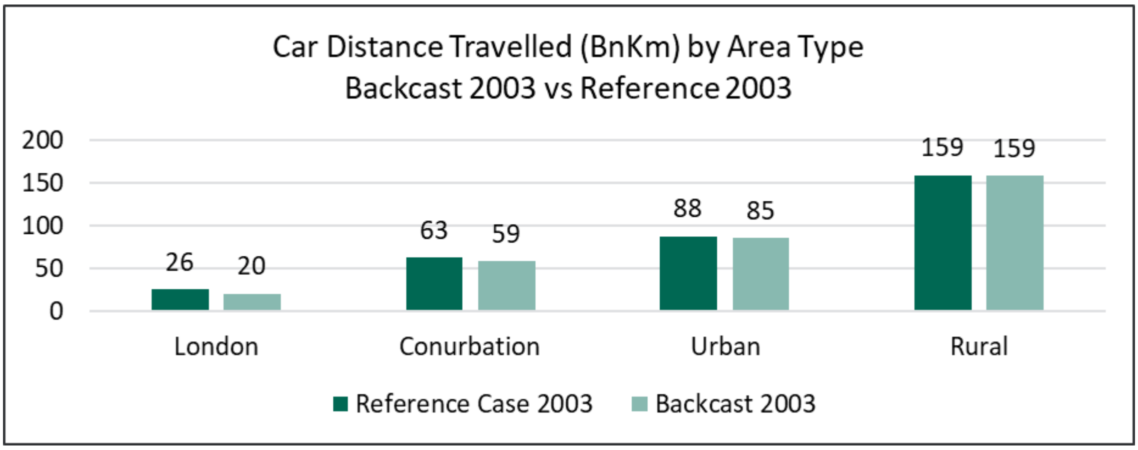

Figure 60 Car Distance Travelled by Area Type - Preferred Backcast 2003 vs Reference Case 2003

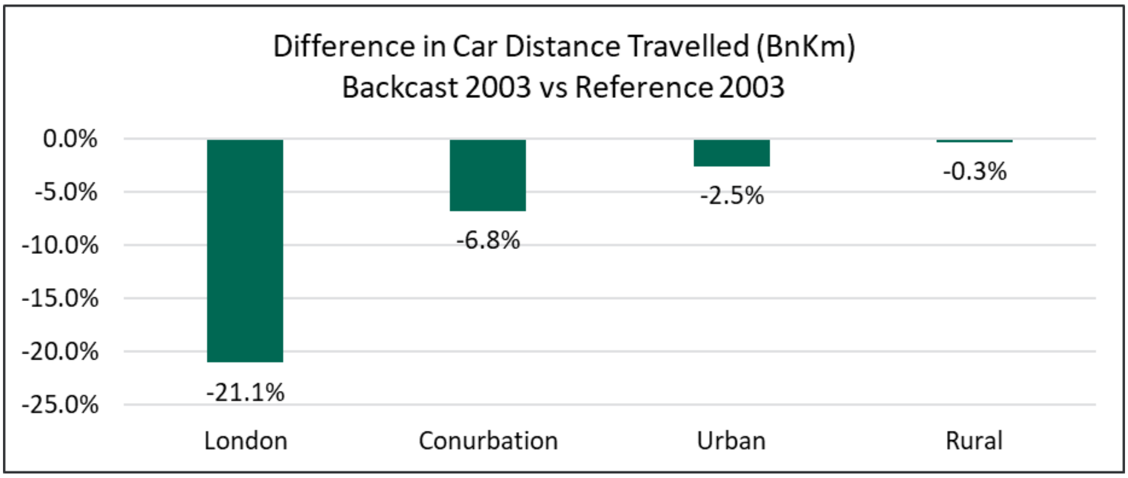

Figure 61 Difference in Car Distance Travelled by Area Type - Preferred Backcast 2003 vs Reference Case 2003

4.87 Several changes in travel behaviour have occurred over the last fifteen or twenty years, in areas with high density such as London, which we are trying to replicate over the period of this backcast. These travel behaviour changes are related to rapidly growing high density inner city areas such as London as mentioned above, Manchester, Cambridge, Oxford but maybe less relevant to the low-density areas of Outer London. However, because of the limited spatial detail available in the area-type definition in the model, the results in Figure 61may not be able to explore this distinction explicitly.

4.88 The general principles in transport suggest that people who own a car will likely use it for most of their trips, but London does not follow this pattern. People who live or work in London tend to use other modes even if they own a car and whilst this most recent type of behaviour has been built into the model base year, it is not easy to model the changes that have occurred over the last fifteen years. Using this more contemporary behaviour in 2003 has resulted in underestimating the 2003 traffic levels in the backcast.

4.89 An additional factor which could have contributed to the difference in London is the continued reduction in the road capacity that is available for cars. These changes are related to a continued trend in the allocation of road space to other modes such as bus and cycles and in the introduction of congestion charge in some areas. However, the changes to road capacity that were included in the backcast data related simply to road length and potential traffic lanes. This would result in an increase in capacity in 2003 and therefore more traffic.

Car Distance Travelled by Area Type and Journey Purpose

4.90 Figure 62 and Figure 63 show the absolute number and the difference in car distance travelled by area type and by journey purpose.

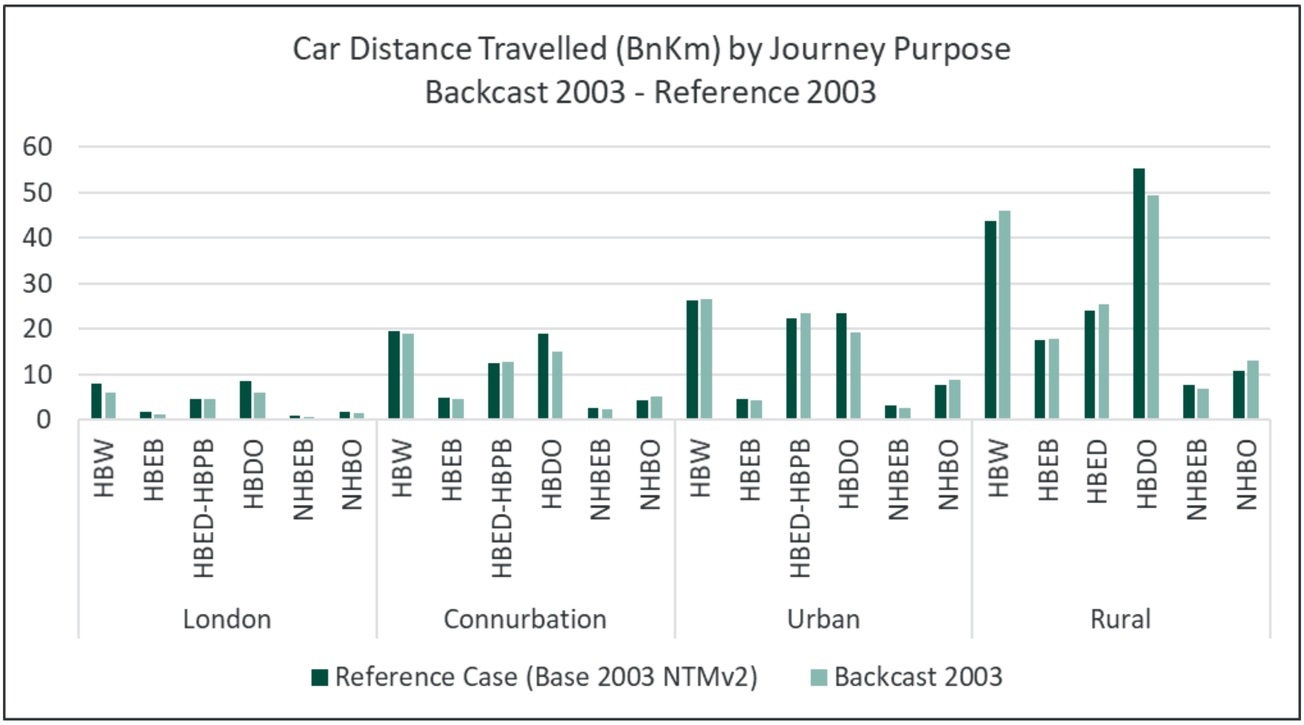

Figure 62 Car Distance Travelled by Area Type - Preferred Backcast 2003 vs Reference Case 2003

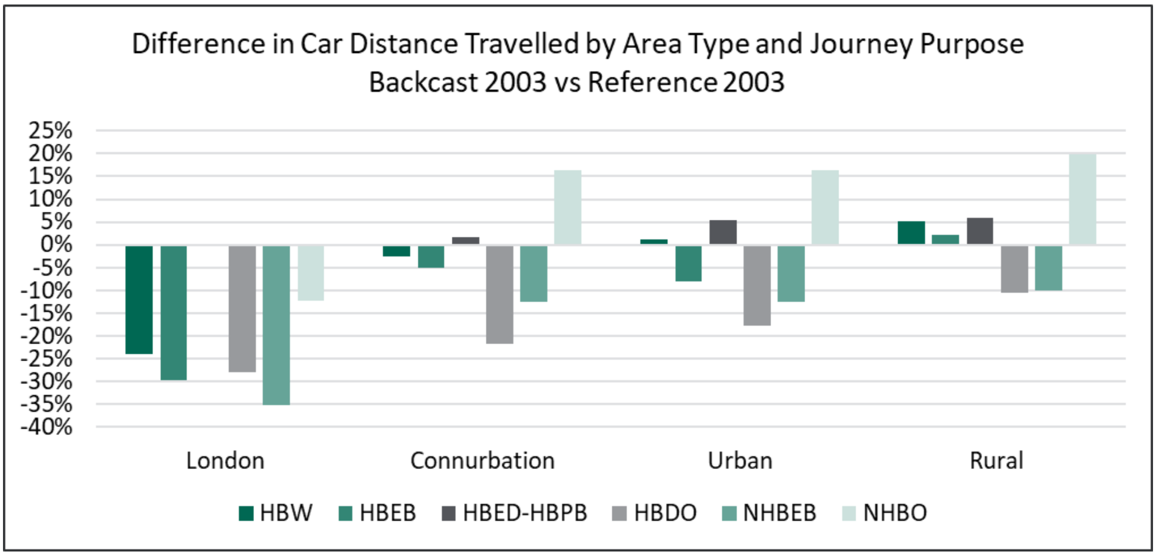

Figure 63 Difference in Car Distance Travelled by Area Type and Journey Purpose - Preferred Backcast 2003 vs Reference Case 2003

4.91 The HBW, HBEB and HBED/PB trips for all the areas are less than 5% different from the Reference case as shown in a previous figure (Figure 59). However, a detailed view on the journey purposes by area type shows that trips with these journey purposes are significantly lower in London. London trips that are made for any journey purpose are general lower in the backcast compared to the Reference case, showing again the different travel behaviour in London compared to previous years.

Car Distance Travelled by Road Type

4.92 Figure 64 and Figure 65 show the absolute number and the difference in car distance travelled by road type. The distance travelled by car for each road type is again broadly similar between the backcast and the Reference case with a largest difference being less than 5% for all road types. It is noted that the difference for minor roads (less than 0.5%) is much smaller than the difference in major roads.

4.93 This is an expected result as the data in the National Travel Survey (2012-2013) showed that major changes occurred in the travel behaviour between 2003 and 2015. The NTS data showed that a large reduction in the number of short trips by active modes and a shift to rail mode for the short and longer distance trips. These travel behaviour changes had to be incorporated in NTEM and then in the model and this is the main reason for re-calibrating the National Transport Model to a new base year (2015).

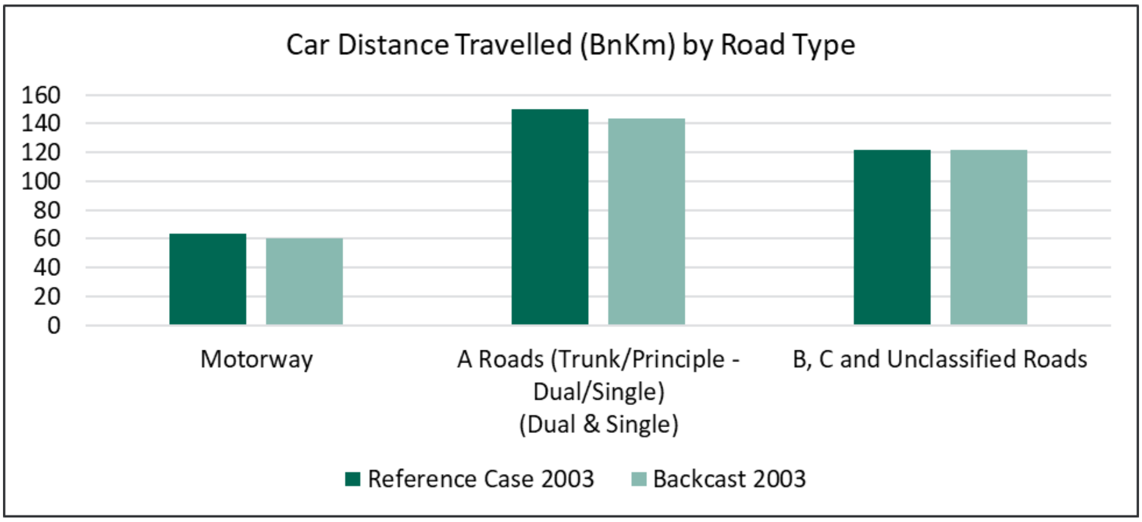

Figure 64 Car Distance Travelled by Road Type - Preferred Backcast 2003 vs Reference Case 2003

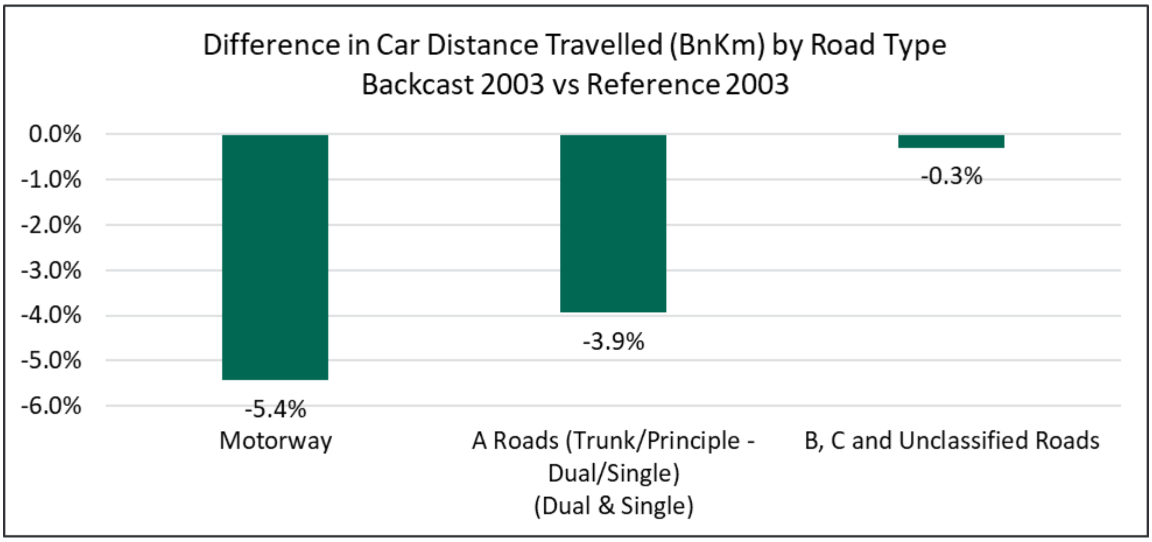

Figure 65 Difference in Car Distance Travelled by Road Type - Preferred Backcast 2003 vs Reference Case 2003

4.10.2 Mode choice

Trips by Mode choice

4.94 Table 24, Table 25 and Table 26 show the comparison between the Reference case (2003 Base year) and the preferred backcast scenario for 2003 by mode, journey purpose and distance band.

Table 24 Trips by Mode Choice

Run Name	Walk	Cycle	Car driv	Car pass	Bus	Rail	Total
Reference Case	27443948	1624694	38687248	20024959	6488697	1959354	96228900
Backcast_2003	-40.85%	-16.81%	-10.26%	-2.49%	29.34%	76.09%	-13.05%

Table 25 Trips by Mode Choice and by Journey Purpose

Mode	HBW	HBEB	HBEd	HBPB	HBRec	HBHol	NHBEB	NHBO	Total
1. Walk	-19.75%	-19.12%	-10.89%	-27.72%	-63.86%	-90.69%	-17.41%	-54.90%	-40.85%
2. Cycle	-17.94%	-29.91%	-4.44%	-31.90%	-34.68%	24.53%	35.42%	15.56%	-16.81%
3. Car driver	-15.51%	-19.56%	13.15%	-5.51%	-26.22%	25.38%	-17.55%	10.16%	-10.26%
4. Car passenger	-27.01%	-21.89%	34.77%	1.50%	-20.25%	-8.81%	-23.26%	27.19%	-2.49%
5. Bus	6.17%	100.59%	6.17%	49.49%	36.89%	-2.02%	64.09%	33.11%	29.34%
6. Rail	27.69%	136.51%	83.28%	96.60%	149.42%	243.33%	96.45%	109.85%	76.09%
All Modes	-13.44%	-11.76%	5.92%	-4.96%	-31.98%	13.11%	-12.72%	-10.14%	-13.05%

Table 26 Trips by Mode choice and by Distance Band

Mode	<10 miles	10-35 miles	35-100 miles	> 100 miles	Total
1. Walk	-40.85%	-54.70%	-	-	-40.85%
2. Cycle	-18.27%	56.51%	-	-	-16.81%
3. Car driver	-11.68%	-2.62%	-11.65%	-29.97%	-10.26%
4. Car passenger	-1.62%	-2.13%	-16.78%	-22.32%	-2.49%
5. Bus	28.58%	66.87%	-62.54%	-64.93%	29.34%
6. Rail	64.95%	65.70%	107.99%	243.71%	76.09%
All Modes	-16.01%	6.17%	-4.78%	0.04%	-13.05%

4.95 The above results show that the number of car trips remains similar between the backcast 2003 which is developed in the latest NTMv2R version and the Reference 2003 scenario developed in the old NTMv2 version. However, there is a significant difference on the number of trips made by active modes (walk and cycle) and by public transport modes (rail and bus).

4.96 Again, this is an expected result for the same reason that is described in the previous section. The data in the National Travel Survey (2012-2013) showed that the major changes occurred in the travel behaviour between 2003 and 2010 are related to a large reduction in the number of short trips by active modes and a shift to rail mode for the short and longer distance trips.

4.97 These travel behaviour changes had to be incorporated in a new NTEM version and then in NTM. These changes along with a range of other changes led the Department to re-calibrate the National Transport Model to a 2015 base year.

4.11 Backcast Conclusions

4.98 The results from the development of the 2003 backcast model have shown that the National Transport Model is able to provide projections for a year preceding the base year. The 2003 backcast has been compared to the 2003 Reference case scenario which is the base year of the earlier NTM version (NTMv2) and this is founded on the actual 2003 traffic count data. The comparison between the backcast 2003 and the Reference case 2003 is made for the same model outputs; total distance travelled, distance travelled by area type, by road type and by journey purpose. The analysis of the backcast results is deliberately consistent to the analysis that is conducted for the Road Traffic Forecast which is regularly published by the Department. The high-level analysis showed that the model is able to project the total traffic distance travelled for 2003 with a minor 3.7% difference compared to the actual 2003 traffic levels.

4.99 A deeper analysis of results included the distance travelled by area type, by road type and by journey type. The comparisons of the above three outputs showed again that the model can project similar values to the actual 2003 values. The backcast model performs well within the various area types (Rural, Urban and Conurbation) especially for the areas with the highest number of trips but not so well within London, which has small number of car trips compared to the total. Whilst the most recent type of travel behaviour observed for London has been built into the model base year, it is not easy to model the changes that have occurred over the last fifteen years. As a result, the model performs better for the other areas rather than for London.

4.100 The distance travelled by car for each road type is again broadly similar between the backcast and the Reference case with a largest difference being less than 5% for all road types. It is noted that the difference for minor roads (less than 0.5%) is much smaller than the difference in major roads. The backcast model is performing well in comparison to the Reference case on the key journey purposes such as HBW, HBEB and HBED/PB with a difference smaller than 5% in these purposes.

4.101 As mentioned in paragraph 4.2, the performance of a model backcast is an excellent method of evaluating a model's quality. The above results demonstrate the ability of the model to backcast traffic levels of a past year. This indicates the good quality of the National Transport Model.

5. Summary and Conclusions

5.1 Introduction

5.1 This chapter provides a summary of the model's Analytical Review covering:

- A brief summary of the scope of this work, the purpose of the model, how it is used in the Department and the overall conclusions of this work (in section 5.1);
- A summary of the methodology used to address the scope and the results from both the stress tests and the backcasting and the final conclusions (in section 5.2);

5.1.1 Scope of this work

5.2 One of the priorities of the Department's AMS is to open up its national models and to achieve this, in relation to NTMV2, a workstream was developed to promote a full understanding of the model’s behaviour. This Analytical Review represents a major component of that workstream and includes a model overview, the results of a series of model stress tests and a backcast.

5.3 The results from the stress tests provide insights of the model’s performance under moderate and major changes. The development of a backcast model provides an insight in the model’s robustness and it is considered as an excellent way of assessing the quality of a model (Gunn et al. 2006, Sammer et al. 2012).

5.4 The results of this work are intended to assure that the model is fit for the policy and forecasting work for which it is used, and its publication aims to both inform stakeholders and fulfil the AMS priority in relation to transparency of the NTM version 2 model.

5.1.2 Purpose and Use of NTM

5.5 The NTM is mainly used to produce the National Road Traffic Forecasts and to aid decision making through its use in strategic policy testing and analysis. The main model output is the road traffic volumes for various road types, area types, time periods and journey purposes. This is thus the main output used to assess the performance of the model during the stress tests and backcast.

5.6 To achieve the most reliable road traffic estimates the Department uses the best available data covering all the land-based modes of transport included in the model. This data includes a series of transport costs data, demand and travel behaviour data and input from other models as summarised below:

- Travel Demand from the latest version of the Department's National Trip End Model (NTEM7.2),
- Rail Journey Characteristics from the Rail Model (MOIRA),

- Bus traffic growth and changes to service levels as derived from the Department's Bus modelling tools,
- Goods vehicle traffic growth from the HGV and the LGV models,
- Detailed information of traveller types and their trip making behaviour from NTS data,
- Value of Time (VoT) and Vehicle Operating Costs (VoC) provided by TAG Databook of DfT,
- Long-distance bus trip costs from coach operator price data.

5.7 Including these data in the recalibrated NTMv2R model allowed the production of good estimates of base year road traffic demand and since then the model has been through a rigorous series of sensitivity tests allowing it to be used with confidence to produce the Road Traffic Forecast (RTF18) scenarios.

5.1.3 Overall Conclusions

5.8 The analysis performed on the stress tests and the backcast and presented in this report provides additional assurance regarding the model's performance and fitness for purpose.

5.9 The overall results from the stress tests indicate that the model performs well and provides justified model outputs under various tests. The overall results from the backcast work demonstrate the capability of the latest model version (NTMv2R) in projecting a backcast year. The combination of the above results indicates the good quality of the model.

5.10 These results indicate that the National Transport Model is a tool that can be trusted for the purpose of:

- Producing demand forecast scenarios in future years for the main road transport indicators such as traffic, congestion and vehicle emissions,
- Providing a tool that estimates the impact of a transport policy scenario or a change in forecasting assumption on the key indicators above.

5.11 With this piece of work, the Department is keen to set an example in being open about the capabilities of NTM and its potential shortcomings when applied in certain contexts. The focus is to make the articulation of model uncertainty more refined and to provide assurance that the newly recalibrated NTMv2R model is fully fit for the policy and forecasting type work that it is intended to be used for.

5.2 Summary of Methodology, Results and Conclusions

5.12 The below sections describe the methodology, the results and the conclusions from first the stress tests and then the backcast work in more detail.

5.2.1 Stress Tests Summary of Methodology, Results and Conclusions

5.13 The results from the stress tests showed that the model performs well under the various tests. These stress tests include Realism tests, a range of fuel cost tests with GDP changes, capacity reduction and increase tests and convergence tests.

5.14 The results from the Realism tests lie within the recommended range as described in TAG.

5.15 The fuel costs tests included sizeable increases in fuel costs and showed that the impacts on car travel in response to changes in GDP are larger when fuel costs are increased. This is a direct result of the increased fuel costs forming a larger part of the overall costs.

5.16 The capacity tests results, showed that the model performed well in response to the large changes in capacity but has clearly indicated that some care needs taking when modelling very large changes to road capacity in Urban areas as convergence problems may occur. In practice reductions of these magnitudes are not realistic, however they form a good test to assess the model’s reaction.

5.17 The convergence tests showed that the performance of six iterations of the demand and supply loop that is currently used in NTMv2R should be sufficient, for the purposes of producing most forecasts, and that further precision might only be required when analysing certain policy business cases.

5.18 The following paragraphs provide more details on the results of each of the tests.

Realism tests

5.19 The realism tests (Section 3.3) provide base year outturn car journey time, fuel cost and PT fare elasticities that lie within the recommended range as described in TAG and shown below. This provides some confidence in the model's performance and robustness.

5.20 The car journey time and fuel elasticities show that any increases will result in a decrease in car trips with significant increases in rail and bus trips. Similarly, the fare elasticities show that rail and bus trips are significantly affected by any change in fares but that the number of car trips doesn’t significantly change. This is due to the relatively small number of rail and bus trips compared to car trips.

Fuel costs tests

5.21 The fuel cost tests (Section 3.4.1) involved changing fuel cost by ±10% for years 2030 and 2050 and the results were used to calculate fuel cost elasticities in the forecast years.

5.22 The values show that the elasticities have declined quite markedly to 2030 (by 41%) and fall outside of the recommended range from TAG (-0.25 to -0.35) and whilst the elasticities continue to decline to the year 2050 (to 60%) this is at a much slower rate.

5.23 The phenomenon of declining price elasticities is not surprising and is regarded a feature of models founded on the principal of "generalised time". It is a result of the modelled GDP growth per capita increasing the value of travel time through time (i.e. in forecast years) and this results in monetary costs becoming a smaller component of the overall generalised time. The smaller the monetary cost element, the smaller the impact on price changes will be and thus the resulting price elasticity will be lower.

Fuel costs tests with GDP growth factor

5.24 The next set of tests (Section 3.4.2) repeated the above four scenarios (fuel cost ±10%), but using a higher GDP growth rate. The fuel elasticities for both 2030 and 2050 forecast years were again broadly symmetric for the changes in fuel cost and again lower in 2050 than in 2030. Comparing the scenarios with the lower GDP scenarios showed that whilst the fuel price elasticity has further declined (from 44% in 2030 and 63% in 2050), the additional decrease due to increased GDP was not as large as expected.

5.25 It is also interesting that the figures are not as symmetric as might have been expected and the differences involved in the ±10% change in fuel costs are having as much impact on the outturn elasticity than the impact of changing the GDP factor.

5.26 The High GDP test (Section 3.5) was performed because the earlier fuel cost test showed only minor impacts from varying GDP. The scenario was run with a GDP growth factor equal to 2.5 and this run was compared to the Reference (core) scenario (GDP growth factor 0.5).

5.27 The traffic results showed that the increasing GDP by a factor of 2.5 has made a difference of 0.4% in 2050 which, when compared to the 35% traffic growth forecast in the reference scenario in 2050, is trivial relative to the use of the model. It was noticeable however that increasing GDP in this way resulted in decreases in the home-based work (commuting), employer's business and non-home based other trips.

5.28 Investigating the effects of increasing GDP revealed a complex interaction between the different modes and although the overall scale of the GDP effect on travel remains small and increases slightly over time (from 0.15% to 0.2%), the impact on car driver trips declined from 0.84% in 2030 to 0.3% in 2050.

5.29 Looking at the changes by distance band showed that the biggest percentage impacts occur in the longest distances and although some of them are quite large the actual numbers of trips affected in these longer bands are quite small.

5.30 Additional tests were performed, investigating how the models' total disutility and component time and money costs change for each of the modes through time. Increasing the rate at which the VOT increases in the High GDP scenario has made a small change to the car fuel component of costs but made a much larger impact on the relatively larger monetary component of bus trips - which were then markedly reduced. This has resulted in a similarly large change to the disutility of bus trips and generated the switch to bus.

5.31 Further analysis with combined GDP and fuel cost changes were performed (Section 3.6) to confirm whether the decline in car fuel costs was responsible for the decline in both the outturn GDP and fuel cost elasticities. These tests included sizeable increases in fuel costs and showed that the impacts on car travel in response to changes in GDP are larger when fuel costs are increased. This is a direct result of the increased fuel costs forming a larger part of the overall costs.

Capacity tests

5.32 The Capacity tests (Section 3.7) involved significant changes in the network capacity and a set of six tests were performed in each of the 2030 and 2050 forecast years. The tests involved capacity increases and decreases of 50% for each of the urban, rural and then all road types. These large changes in capacity were designed to assess the model’s performance and its limits (essentially to “break” the model) and would never form a realistic scenario for any future application.

5.33 Whilst all the traffic and congestion impacts were larger in 2050, increasing the network capacity resulted in relatively small increases in traffic in both analysis years. In 2050 increasing the Urban road network by 50% resulted in only a 1.9% increase in car traffic focussed on local A and minor road types whilst the 50% increase in Rural capacity resulted in only a 1.1% increase in National traffic focussed on the Trunk A and minor road types.

5.34 Increasing all road types together resulted in a 2.2% increase in car traffic suggesting that there is little synergy across the networks and that it is constraints in certain locations that may be holding back growth.

5.35 The largest responses were seen in the higher value business and commute trips but again, these were not large and the greatest increase (of 4%) was in Employers business trips when all roads were increased.

5.36 In comparison to the 35% increase in car traffic seen in the 2050 Reference scenario, the traffic increase of a further 2.2% from such a large capacity increase is seen as relatively minor.

5.37 Reductions in congestion were however significant and this reduced by 40-50% in each of the scenarios in 2050 with slightly lower reductions in 2030. These reductions were enough to reduce congestion to less than model Base Year values.

5.38 Similarly, speeds increased for all road types and reversed the declines seen in the Reference scenarios. In 2050 increasing the capacity of all roads turned a 4.5% decline in speed from the 2015 Base year in the Reference case into a 3.3% increase, with the largest increase of 6.2% on Trunk A roads.

5.39 Most of the reduced capacity scenarios resulted in convergence problems suggesting that the model is very sensitive to such large changes. The problems focussed on Urban areas and particularly London where very large oscillations in trips were apparent between model iterations. The convergence problems were not a surprise as the model was tested using enormous reductions in capacity. This stress test was designed to thoroughly test the model resilience or break it and should not be considered a realistic scenario for any future application.

5.40 The only successful scenario analysed was the 2030 50% decrease in rural capacity and resulted in a fairly modest decrease in total car traffic of 6% overall.

5.41 Rural areas experienced a reduction of 8.4%. The reduction ranged from only 1.7% on the least congested minor road types increasing up to -12.4% and -12.6% on Motorways and Trunk respectively.

5.42 Motorways however experienced the largest increases in congestion (of 780%) and similarly the largest reduction in speed (of -43%). These impacts were far greater than those on the Rural Trunk and Principal A road networks where congestion only increased by 140% and speeds declined by about 15%.

5.43 Conurbations and other Urban area types behaved similarly to each other with traffic reductions of about 2.5%.

5.44 Surprisingly, the area type showing the largest traffic impact was London, where car traffic fell by 9.6%. This suggests that there are many medium or long-distance trips in London either coming from or going to the surrounding Rural areas which were being primarily impacted by the capacity reduction. These trips must have either changed mode or destination.

5.45 Overall, the model performed well in response to the large changes in capacity but has clearly indicated that some care needs taking when modelling very large changes to road capacity in Urban areas as convergence problems may occur. In practice reductions of these magnitudes are not going to happen, however they are considered a good way to test and assess the model's resilience.

Convergence tests

5.46 The Convergence tests (Section 3.8) involved two runs of the model each with a different number of iterations of the main demand-supply model loop. Run 1 had 6 iterations whilst run 2 had 10 and both were performed in 2030 and 2050. The model has been seen to be converged well in all the tests and, as expected, the second run replicated the results for the first over the course of the first 6 iterations.

5.47 In both analysis years the difference in number of trips between the last two iterations in Run 1 is significantly higher (around 10 times) that of the last two iterations of Run 2. However, the differences in the numbers of Car Drivers trips are small in all cases with Run 1 being less than 0.1% in both years and whilst the differences at the end of Run 2 are less than 0.01% for both years.

5.48 As with the earlier model version (NTMv2), it is considered that the performance of six iterations of the demand and supply loop should be sufficient, for the purposes of producing most forecasts, and that further precision might only be required when analysing certain policy business cases.

5.2.2 Backcast Summary of Methodology, Results and Conclusions

5.49 The section below provides a more detailed summary of the methodology, the results and conclusions from the backcast model development.

5.50 The development of the backcast model for year 2003 represents the second part of this workstream designed to help in evaluating the robustness of NTM. As described in the report (Section 4.2) the development of a backcast is considered an excellent way for evaluating the quality of a model.

Conclusions from Backcast

5.51 As discussed in paragraph 5.9, the results of the backcast scenario demonstrate the capability of the latest model version (NTMv2R) in projecting a backcast year. The analysis of results from the backcast scenario has been deliberately constructed to be as consistent as possible with the analysis performed for the 2018 Road Traffic Forecasts which were published by the Department in the spring of that year.

5.52 The high-level analysis showed that the model is able to project the total traffic distance travelled for 2003 with a minor 3.7% difference compared to the actual 2003 traffic levels.

5.53 A deeper analysis of results included the distance travelled by area type, by road type and by journey type. The comparisons of the above three outputs showed again that the model can project similar values to the actual 2003 values.

5.54 The backcast model performs well within the various area types (Rural, Urban and Conurbation) especially for the areas with the highest number of trips but not so well within London, which has small number of car trips compared to the total. Whilst the most recent type of travel behaviour observed for London has been built into the model base year, it is not easy to model the changes that have occurred over the last fifteen years. As a result, the model performs better for the other areas rather than for London. This significant difference in the travel behaviour of London, created the need to develop detailed models designed for London areas only. These models are developed and used by TfL.

5.55 The distance travelled by car for each road type is again broadly similar between the backcast and the Reference case with a largest difference being less than 5% for all road types. It is noted that the difference for minor roads (less than 0.5%) is much smaller than the difference in major roads.

5.56 The backcast model is performing well in comparison to the Reference case on the key journey purposes such as HBW, HBEB and HBED/PB with a difference smaller than 5% in these purposes.

5.57 The above results demonstrate the ability of the model to backcast traffic levels of a past year. The clear demonstration of the ability to backcast to 2003 provides further confidence in the model's forecasting ability and fitness-for-purpose.

5.58 The following paragraphs provide a summary of the methodology to develop the backcast for 2003 and the results from the assessment of the backcast compared to actual traffic data (the Reference case for 2003).

Methodology to Develop a Backcast

5.59 To develop a backcast model (Section 4.3) it is required to have an established model, historic data for both model input and validation of the backcast results and to be able to select a backcast year more than 10 years prior to the model base year. This is to ensure that modelled systematic changes are much larger than random variation or 'model noise'.

5.60 The selected backcast year is 2003 due to both the availability of data and the number of years between this and the Base year of the current NTM. This work represents the first successful attempt of developing an NTM backcast and it has been made possible by the availability of suitable data.

5.61 The main challenge of developing a backcast model was to determine the demand for the backcast year 2003 as the intervening backcast period (2003 to 2015) included major travel behaviour changes. As a result, an iterative process has been adopted. This process is based on a series of steps where several levels of demand for 2003 are tested (Section 4.4). inputted in the model and assessed for their validation whereby the traffic results are compared against the actual traffic levels.

5.62 A series of historic data (Section 4.5) was used to represent the backcast year of 2003 including such items as network capacity, fuel costs, GDP, VoT, rail fares and bus fares, traffic levels and the level of travel demand.

5.63 As a result of the complexity of defining the 2003 backcast demand, we developed six different backcast scenarios, each of them with a different level of 2003 travel demand (Section 4.6).

Selection of the Preferred Backcast

5.64 We have compared the results from the six scenarios to the 2003 actual data and identified the scenario that is the best representation of 2003 traffic levels. This, is Scenario 4 and it is referred to as the "Preferred Scenario" in this report (Section 4.7, Section 4.8 and Section 4.9).

5.65 This scenario was selected due to its capability to incorporate two main changes; the travel demand that derives from both the NTEM6.2 with the declining trip rates trend that was observed for years 1998 to 2010 in the National Travel

Survey (NTS in 2012-2013) and the actual population figures for 2003. The total car distance travelled compared to the actual distance travelled is only 3.7% less.

5.66 It should be noted however that whilst the preferred backcast scenario is Scenario 4, there is another scenario, Scenario 6, which has only -0.1% difference in the distance travelled from the actual 2003 traffic levels. Scenario 6 was not used as the preferred backcast scenario as the level of demand that was used for this scenario was based on a trip rate assumption. This assumption, which has since been validated by the NTS 2017 report, has meant that the results from Scenario 6 can also be used to strongly reinforce confidence in the performance and robustness of the model.

Results from Backcast exercise

5.67 A detailed analysis of the preferred backcast (Section 4.10) in relation to traffic levels, journey purposes, road types and area types showed similar results to the overall figure of 3.7% mentioned above. These results confirm the capability of the latest model version (NTMv2R) in projecting a backcast year and they are also taken as a strong indicator of the quality of the model. These results are summarised below.

5.68 The backcast model is performing well in comparison to the Reference case (actual 2003 data) for the key journey purposes such as commuting and business trips (HBW and HBEB) and education and personal trips (HBED/PB). The difference of distance travelled for these journey purposes in the backcast is less than 5% compared to the Reference case. The non-home-based trips (NHBEB and NHBO) and the discretionary and other trips (HBDO) however have more significant differences to the Reference case. The difference with the Non-home-based trips is related to the limited information available for the non-home-based trips, and new assumptions about their derivation.

5.69 The backcast model generally performs well within the areas with the highest number of trips (Rural, Urban and Conurbation) but not so well within London, which has small number of car trips compared to the total. The car distance travelled in rural, urban and conurbation areas is less than 7% different compared to the Reference case and 21% in London.

5.70 The changes in travel behaviour that occurred over the backcast period (2003 to 2015) are greater in the denser urban areas and particularly apparent in the densest urban area of all, London. Compared to other areas London has a unique travel behaviour and it is perhaps not surprising that it is this area that shows the most significant difference from the Reference case.

5.71 The general transport principles suggest that people who own a car will likely use it for most of their trips however people who live or work in London often tend to use other modes even if they own a car. Whilst this recent type of behaviour has been built into the model base year, it is not possible to model the changes that have occurred over the last fifteen years. Using this more contemporary behaviour in 2003 has resulted in underestimating the 2003 traffic levels.

5.72 The car distance travelled by road types (Motorways, A roads, B roads, C roads and Unclassified roads) are again broadly similar between the backcast and the Reference case with a largest difference being less than 5%. It is noted that the difference for minor roads is much smaller (less than 1%) than the difference in major roads.

5.73 This is an expected result as the data in the National Travel Survey (2012-2013) showed that major changes occurred in the travel behaviour between 2003 and 2015. The NTS data showed that a large reduction in the number of short trips by active modes and a shift to rail mode for the short and longer distance trips. These travel behaviour changes had to be incorporated in a new NTEM version and then in NTM. These changes along with a range of other changes led the Department in re-calibrating the National Transport Model to a new base year (2015).

5.74 The results from comparing the trips by mode showed that the number of car trips remains similar between the backcast 2003 which is developed in the latest NTMv2R version and the Reference 2003 scenario developed in the old NTMv2 version. However, there is a significant difference on the number of trips made by active modes (walk and cycle) and by public transport modes (rail and bus).

5.75 Again, this is an expected result as the data in the NTS showed major changes occurred in the travel behaviour related to a large reduction in the number of short trips by active modes and a shift to rail mode for the short and longer distance trips.

5.2.3 Final Conclusions

5.76 We have completed this workstream aiming to fulfil our Appraisal and Modelling Strategy objective in opening up the National Transport Model to allow to our stakeholders a better understanding of the model. To achieve the above objective, we have exposed our model under various tests, we developed an innovative backcast methodology and we are open about the model's performance to the wider public.

5.77 The analysis of the results from this workstream showed that the model is performing well under various stress tests and it is capable for backcasting (for year 2003). The model's performance provides reassurance for the robustness and the quality of the National Transport Model and its fitness for purpose. With the publication of this work we are aiming to promote within our stakeholders a full and widespread understanding of both the model's methodologies and its behaviour.

Annex A: Tables & Figures

A.1 Description of NTM zones

Zone Number	Zone Description
1	Central London
2	Inner London
3	Outer London
4	N & E Central Conurbation
5	West Central Conurbation
6	N & E Conurbation Surrounds
7	West Conurbation Surrounds
8	N & E Urban Big
9	West Urban Big
10	South Urban Big
11	Not Defined
12	N & E Urban Large
13	West Urban Large
14	South Urban Large
15	Not Defined
16	Urban Medium
17	Smaller Urban & Rural

A.2 NTM Zones, Regions and Area Types

Region	Area type 1: Central London	Area type 2: Inner London	Area type 3: Outer London	Area type 4: Metropolitan	Area type 5: Outer Conurbation	Area type 6: Urban Big (pop>250k)	Area type 7: Urban Large (pop>100k)	Area type 8: Urban medium (pop<25k)	Area type 9&10: Small Urban & Rural
London	1	2	3	-	-	-	-	-	-
South East	-	-	-	-	-	10	14	16	17
East of England	-	-	-	-	-	10	14	16	17
South West	-	-	-	-	-	10	14	16	17
Wales	-	-	-	-	-	10	14	16	17
West Midlands	-	-	-	5	7	9	13	16	17
North West	-	-	-	5	7	9	13	16	17
East Midlands	-	-	-	4	6	8	12	16	17
Yorkshire and the Humber	-	-	-	4	6	8	12	16	17
North East	-	-	-	4	6	8	12	16	17
Scotland	-	-	-	4	6	8	12	16	17

A.3 NTM Area Type included in each of the 11 NTM Regions

<table>
<tr><th>Regions</th><th>Area type 1: Central London</th><th>Area type 2: Inner London</th><th>Area type 3: Outer London</th><th>Area type 4: Metropolitan</th><th>Area type 5: Outer Conurbation</th><th>Area type 6: Urban Big (pop>250k)</th><th>Area type 7: Urban Large (pop>100k)</th><th>Area type 8: Urban medium (pop<25k)</th><th>Area type 9&10: Small Urban & Rural</th></tr>
<tr><td>1. London</td><td>Included</td><td>Included</td><td>Included</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2. South East</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td rowspan="4">included - Plymouth, Swansea, Cardiff, Bristol, Bournemouth, Southampton, Portsmouth, Brighton, Reading, Southend</td><td rowspan="4">included - Norwich, Peterborough, Cambridge, Bedford, Milton Keynes, Ipswich, Colchester, Basildon, Oxford, Swindon, Slough, Luton, High Wycombe, Margate, Medway Towns, Crawley, Farnborough, Cheltenham, Gloucester, Newport, Torquay, Exeter</td><td rowspan="10">included</td><td rowspan="10">included</td></tr>
<tr><td>3. East of England</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>4. South West</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>5. Wales</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>6. West Midlands</td><td>-</td><td>-</td><td>-</td><td rowspan="2">included - Liverpool, Manchester, Birmingham</td><td rowspan="2"></td><td rowspan="2">included - Blackpool, Preston, Ellesmere Port, Stoke</td><td rowspan="2">included - Telford, Nuneaton, Warrington, Wigan, Blackburn, Burnley</td></tr>
<tr><td>7. North West</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>8. East Midlands</td><td>-</td><td>-</td><td>-</td><td rowspan="4">included - Sheffield, Leeds, Newcastle, Glasgow</td><td rowspan="4"></td><td rowspan="4">included - Leicester, Nottingham, Hull, Middlesbrough, Edinburgh</td><td rowspan="4">included - Aberdeen, Dundee, York, Grimsby, Lincoln, Mansfield, Chesterfield, Derby, Northampton</td></tr>
<tr><td>9.Yorkshire and the Humber</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>10.North East</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>11.Scotland</td><td>-</td><td>-</td><td>-</td></tr>
</table>

A.4 Distance Bands in NTM

Distance Band Name	Miles
1	<1 mile
2	1-2 miles
3	2-3 miles
4	3-5 miles
5	5-10 miles
6	10-15 miles
7	15-25 miles
8	25-35 miles
9	35-50 miles
10	50-100 miles
11	100-200 miles
12	200-300 miles
13	>300 miles

A.5 Journey purposes in NTM

Purpose	Name	Description	Work - NonWork
1	HBW	Home-Based Work (Commuting)	NW
2	HBEB	Employers Business	W
3	HBEd	Education	NW
4	HBPB	Personal Business / Shopping	NW
5	HBRec	Recreation / Visiting Friends	NW
6	HBHol	Holidays / Day Trips	NW
7	NHBEB	Non-Home-Based Employers Business	W
8	NHBO	Non-Home-Based Other	NW

A.6 NTM segmentations based on 105 combinations for Journey Purposes and Traveller type (Person & Household types)

Purpose	Person Type	SEG / Income	Household: 1 adult / 0 car (1)	Household: 1 adult / 1 car (2)	Household: 2+ adult / 0 car (3)	Household: 2+ adult / 1 car (4)	Household: 2+ adult / 2+ car (5)	All
HB Work (1)	Full time employed (2)	High	1	2	3	4	5	
		Medium	6	7	8	9	10	
		Low	11	12	13	14	15	
	Rest of population (2)	All	16	17	18	19	20	
HB EB (2)	Full time employed (2)	High	21	22	23	24	25	
		Medium	26	27	28	29	30	
		Low	31	32	33	34	35	
	Rest of population (2)	All	36	37	38	39	40	
HB Education (3)	Child (0-15) (1)	All	41	42	43	44	45	
	Full time employed (2)	All	46	47	48	49	50	
	Other (16-74) (3)	All	51	52	53	54	55	
	Pensioner (4)	All	56	57	58	59	60	
HB PB / Shopping (4)	Child (0-15) (1)	All	61	62	63	64	65	
	Full time employed (2)	All	66	67	68	69	70	
	Other (16-74) (3)	All	71	72	73	74	75	
	Pensioner (4)	All	76	77	78	79	80	
	Child (0-15) (1)	All	81	82	83	84	85	

HB Rec / Visiting friends (5)	Full time employed (2)	All	86	87	88	89	90	
	Other (16-74) (3)	All	91	92	93	94	95	
	Pensioner (4)	All	96	97	98	99	100	
HB Hols / Day trips (6)	All persons	All						101
NHB EB (7)	All persons	High						102
		Medium						103
		Low						104
NHBO (8)	All persons	All						105

A.7 Time Periods in NTM

Period No.	Day.	Time
1	Mon-Fri	00:00 - 06:00
2	Mon-Fri	06:00 - 07:00
3	Mon-Fri	07:00 - 08:00
4	Mon-Fri	08:00 - 09:00
5	Mon-Fri	09:00 - 10:00
6	Mon-Fri	10:00 - 16:00
7	Mon-Fri	16:00 - 17:00
8	Mon-Fri	17:00 - 18:00
9	Mon-Fri	18:00 - 19:00
10	Mon-Fri	19:00 - 22:00
11	Mon-Fri	22:00 - 24:00
12	Saturday	00:00 - 09:00
13	Saturday	09:00 - 14:00
14	Saturday	14:00 - 20:00
15	Saturday	20:00 - 24:00
16	Sunday	00:00 - 10:00
17	Sunday	10:00 - 15:00
18	Sunday	15:00 - 20:00
19	Sunday	20:00 - 24:00

Annex B: The Generalised Cost Formulation

As with the earlier NTMV2 model, the total travel disutility in the model is actually expressed in units of Generalised Time. The formulation is described by the equation:

$$\text{Generalised Time} = \text{Travel Time(min/km)} + \text{Travel Cost(£/km)/VoT(£/min)}$$

Where the value of time (VoT) varies for each journey purpose and mode.

This is basically the same as generalised costs except that in this case travel costs are converted to equivalent units of time by use of the values of time, rather than converting times components to monetary costs in the alternative.

Travel time is made up of mode-specific access and egress times, wait and interconnection times (for public transport), parking search times (for cars) as well as the actual in-vehicle journey times.

Many of these time components remain constant but the increasing congestion levels experienced by car travel mean that Travel Time per km is increasing through the forecast years for Car mode. However, as there are no crowding or congestion feedbacks for other modes in the model, travel time remains constant for all the other modes.

Full details of the components of travel time, and any special weights that might be applied to them (e.g waiting time for a bus is penalised in comparison to the ride time), are provided in the model development reports and the separate “NTMv2R Overview of Model Structure and Update to 2015” report which is being published alongside this report.

Annex C: Capacity Test Convergence

This Annex contains some analysis of the convergence characteristics of the failed 2030 50% Reduction in Urban capacity run.

The figure below shows the numbers of Car Driver trips from 12 runs expressed as the percentage change in trips from the first Iteration (Run-A). Over the course of the 12 runs the model is trying to converge, but it would need many more iterations to properly achieve this. Although the position with car driver miles looks encouraging, with iterations changing by around ± 3.5% (with a similar result for car passengers), rail distances were oscillating by almost ±20%, bus by ±10% whilst walk trips were the most stable.

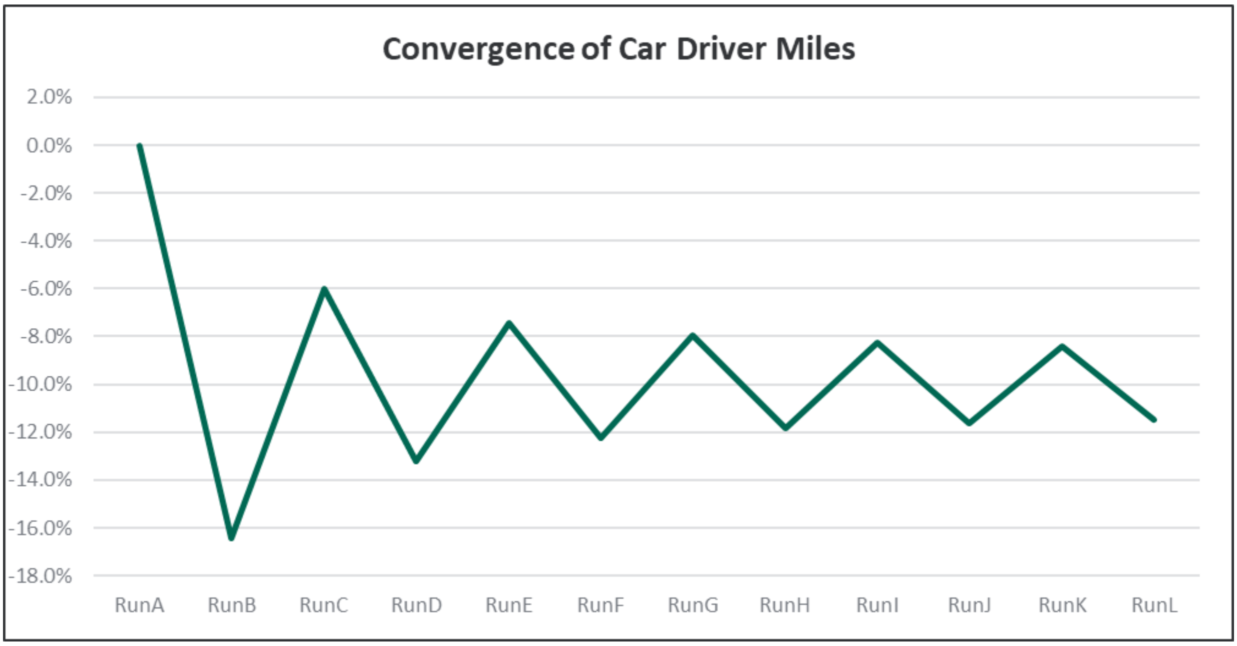

Figure C1 Car Driver Distance for 50% Urban Capacity Decrease - 2030

The greatest change amongst the different journey purposes is for mid distance holiday trips of between 15 and 30 miles, as shown in Table 27 below. The next most variable trips are mid-range employer's business trips but commute and the non-home-based purposes are also very similar. The smallest changes are associated with shorter distance trips, which use more of the less congested minor roads, and educational trips, for which opportunities to switch mode or destination are restricted and are therefore these trips are less elastic.

Table 27 Percent Change in Car Driver Traffic for Run-L versus Run-K

Distance Band	HBW	HBEB	HBEd	HBPB	HBRec	HBHol	NHBEB	NHBO	All
<1 mile	-0.8%	-0.6%	-0.9%	-0.7%	-0.6%	-0.2%	-0.8%	-0.6%	-0.7%
1-2 miles	-1.4%	-0.9%	-1.1%	-1.0%	-1.0%	-0.6%	-1.4%	-1.1%	-1.1%
2-3 miles	-1.4%	-1.0%	-0.8%	-0.9%	-0.9%	-0.9%	-1.5%	-1.2%	-1.0%
3-5 miles	-1.9%	-1.3%	-1.0%	-1.1%	-1.1%	-1.3%	-1.8%	-1.6%	-1.4%
5-10 miles	-2.7%	-2.6%	-1.5%	-1.9%	-2.2%	-2.2%	-3.1%	-2.9%	-2.4%
10-15 miles	-2.5%	-3.7%	-2.1%	-2.7%	-3.7%	-4.2%	-4.0%	-3.8%	-3.1%
15-25 miles	-4.0%	-6.1%	-2.4%	-3.4%	-4.8%	-10.5%	-5.7%	-4.8%	-4.6%
25-35 miles	-5.8%	-6.3%	-2.7%	-4.1%	-4.0%	-10.9%	-6.0%	-6.1%	-5.6%
35-50 miles	-5.2%	-4.4%	-2.7%	-3.3%	-2.6%	-5.2%	-5.5%	-5.1%	-4.3%
50-100 miles	-5.4%	-4.3%	-1.6%	-4.1%	-2.5%	-5.2%	-4.9%	-6.3%	-4.3%
100-200 miles	-6.3%	-4.1%	-1.4%	-2.0%	-0.8%	-4.6%	-5.3%	-4.6%	-3.3%
200-300 miles	-4.8%	-4.6%	-1.7%	-2.2%	-0.7%	-5.4%	-4.2%	-5.9%	-3.5%
>300 miles	-5.6%	-5.1%	-	-1.8%	-0.4%	-1.3%	-4.7%	-1.1%	-1.7%
All Distances	**-3.7%**	**-4.4%**	**-1.5%**	**-2.3%**	**-2.4%**	**-4.8%**	**-4.7%**	**-4.0%**	**-3.3%**

Table 28 below shows the difference in car driver traffic between runs L and K between origin and destination zones for the three London plus Rural area types. Although the national change is given as 3% across all origin and destination, there are much greater variations for trips between the three London area types (Central, Inner and Outer) and to and from Rural areas.

Trips from Rural areas to Central Inner & Outer London are changing by 49%, 47% and 19% respectively, whilst trips from Inner & Outer London to Rural areas are changing by 44% and 18%.

Table 28 Percent Change in Car Driver Traffic in zones for Run-l and Run-K

Origin / Destination	Central	Inner	Outer	Rural	All Destinations
Central	-41%	-53%	-72%	-78%	-64%
Inner	-56%	-44%	-50%	-44%	-48%
Outer	-72%	-46%	-23%	-18%	-24%
Rural	-49%	-47%	-19%	0%	-1%
All Origins	-50%	-47%	-26%	0%	-3%

The variation of the results has meant that, whilst the trips purposes were behaving in a broadly similar pattern to those for the 50% reduction in Rural capacity described in Section 3.7.2 of the review, no further insight can be drawn.

Annex D: Glossary

- AMS: Appraisal Modelling Strategy published in 2019 by DfT
- DfT: Department for Transport
- FORGE: Highway assignment component of NTM. (Fitting on Regional Growth with Elasticities)
- GBFM: Great Britain Freight Model
- GDP: Gross Domestic Product
- HBW: Home-based to Work trips (journey purpose)
- HBEB: Home-based Employer's Business trips (journey purpose)
- HBED/PB: Home-based Education & Personal Business trips (journey purpose)
- HBO: Home-Based other trips (journey purpose)
- NATCOP: National Car Ownership Program
- NHBEB: Non-home-based Employer's Business trips (journey purpose)
- NHBO: Non-home-based Other trips (journey purpose)
- NTEM: National Trip End Model
- NTM: National Transport Model
- NTMv2R: National Transport Model version 2 recalibrated model
- NTS: National Travel Survey
- Pass1: Multi Modal Demand Model component of NTM
- RTF18: The Road Traffic Forecast report published in 2018 by DfT
- TAG: Transport Appraisal Guidance
- VoT: Value of Time
- VoC: Vehicle Operating Costs
- TSGB: Transport Statistics Great Britain