Highways England

TRANS-PENNINE TUNNEL STRATEGIC STUDY PLUS

Transport Forecasting Report and Economic Appraisal Report

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JUNE 2020

CONFIDENTIAL

Highways England

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1 INTRODUCTION

1.1 BACKGROUND

1.1.1 The Highways England Delivery Plan 2015-2020 committed to examine Trans-Pennine routes, develop solutions that could improve connectivity between Manchester and Sheffield and address safety concerns in the area. Currently Manchester and Sheffield are the two worst connected cities in the North, with journeys taking over 75 minutes over a distance of 40 miles.

1.1.2 There have been a number of studies undertaken which have improved one or more of the following: the robustness of the traffic models underpinning the analytical assessment; the optimisation of the scheme package; and importantly, the analysis of the Level 3 benefits. The study timelines are described below.

1.1.3 A study was commissioned in 2015 to examine the possibilities of improving the highway links between these two areas. The study (known as the Trans-Pennine Tunnel Study (TPTS)) examined the feasibility of implementing a base tunnel connecting Manchester and Sheffield with no impact on the Peak District National Park. The finding of this work was that whilst an intervention of this nature would have a very strong strategic case, the economic case is weak. This is mainly due to the significant costs of such a length of tunnel.

1.1.4 In late 2016, further work was commissioned by Transport for the North (TfN) in partnership with DfT and Highways England (the Wider Transport Connectivity Assessment (WTCA)). This examined the case for additional highway interventions within the Greater Manchester and South Yorkshire areas to complement the tunnel and which could potentially unlock additional economic benefits. Whilst the package recommended by that study showed the potential for the economic case of a tunnel could be enhanced, this was only the case if the package included a shorter length of tunnel and if wider additional benefits were included beyond those that were conventionally considered at that time when coming to a view on value for money.

1.1.5 A summary of the conclusions to date, from the two studies indicates that – notwithstanding the strategic case for the investment – the economic case following the WebTAG guidance is currently weak, specifically:

- The Trans-Pennine tunnel (Option 8[1], 21km in length) is feasible in terms of construction, operation and maintenance however was deemed to offer poor value for money; and
- The WTCA work (with full tunnel Option 8) improved the economic case but only marginally and also provided low value for money.

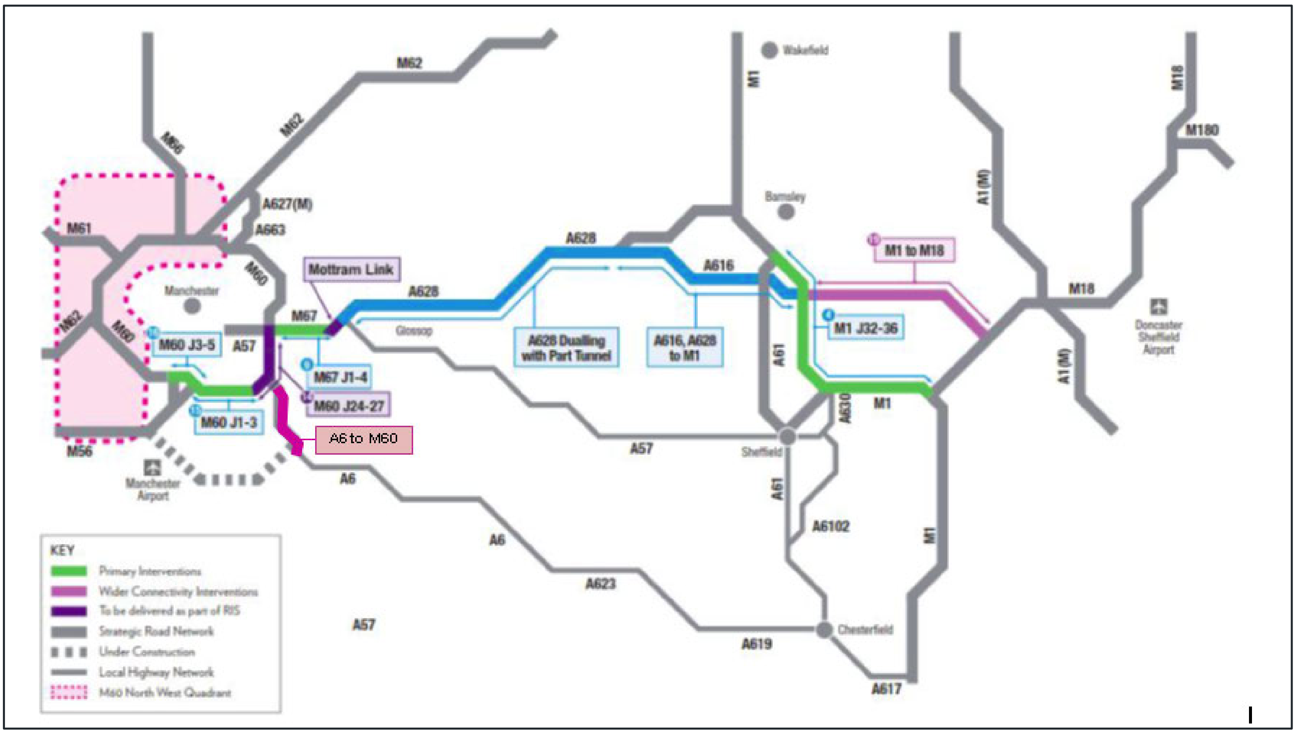
1.1.6 Further analysis that was subsequently developed as part of WTCA work looked at a case for a shorter tunnel (9km) with an optimised wider transport connectivity package proposal and surface access improvements to the A628. This analysis showed an improved value for money and could potentially enhance the value for money.

[1] As part of the TPTS study (July 2015 to Oct 2016), there were a range of options within a broad range of corridors. The preferred option for the Trans-Pennine Tunnel was known as 'Option 8'.

1.1.7 As stated in the Appraisal Specification Report (ASR), the objectives of the TPTS+ are therefore to take the identified package from the WTCA project and undertake additional wider economic modelling works to enhance both economic and strategic cases.

1.1.8 The package of interventions going forward will contain a shorter tunnel option and therefore there will be environmental issues to address due to interactions with the Peak District National Park. Consideration of environmental impacts is integral to the assessment of the potential value for money of any package of interventions. **Figure 1-1** below shows a schematic of the shorter tunnel with the optimised wider connectivity package (known as the **Test Package**).

Figure 1-1 Shorter Tunnel with the Test Package



1.1.9 The expected impacts of improved connectivity were proposed and an analytical modelling framework for monetising these were identified, as summarised in **Table 1-1** below.

Table 1-1 Proposed Modelling Framework

Impact	Approach to Monetising Impact
Level 1 Impacts	
Impact of road network operation	Traffic model to forecast impacts of solution (and to provide outputs to underpin the monetisation of other impacts)
Direct transport user benefits	DfT TUBA programme to monetise impacts of journey time savings using a WebTAG compliant segmentation
Safety impacts	COBALT programme to monetise accidents on the section of the highway network impacted by interventions
Construction impacts	Monetised impacts on journey time of existing road users during construction using TUBA or QUADRO programme

Impact	Approach to Monetising Impact
Level 2 Impacts	
Wider impacts	DfT WITA programme to monetise anticipated wider impacts: agglomeration, output change in imperfectly competitive market, and tax revenues arising from labour market impacts, based on fixed land-use
Reliability impact	Monetise impacts of improved reliability as a result of interventions
Resilience impacts	Not assessed as per discussed and agreed at TAG meeting
Level 3 Impacts	
Wider impacts	Dynamic land-use impacts assessed using evolving tools: ➢ Bespoke land-use modelling and economic appraisal ➢ Highways England Economy model
Distributional impacts	Optional at PCF Stage 0 and not part of scope
Sensitivity Tests	
Alternative growth impacts	Alternative growth profiles, potentially incorporating a 'Low' growth scenario and a 'Transformational' growth for the Northern Powerhouse region. ➢ Low Growth scenario: only TUBA is to be undertaken; ➢ Transformational growth scenario: both TUBA and Static wider impacts (WITA) are to be undertaken.

1.1.10 The assurance of the analytical framework used to date and the requirement to assess the wider economic impacts have robustly increased the analytical assurance requirements for the study. DfT and TfN has commissioned independent advice and review outside of the core study additional assurance.

1.1.11 The study was initially commissioned on the understanding that a suitable variant of the Highways England Trans-Pennine South Regional Transport Model (TPS RTM), referred to as vRTM, would be made available to the study team for the modelling and appraisal purpose. However, the vRTM was not made available within the specified study programme, consequently, the study team has therefore progressed with the TPS RTM with a number of adjustments to the base year and forecast year models (described in more detail in this document) prior to carrying out modelling and appraisal for the TPTS+ purpose.

1.2 TRANS-PENNINE SOUTH RTM

1.2.1 In July 2018, the revised Trans-Pennine South Regional Traffic Model (TPS RTM) Design Freeze 7 (DF7) was provided to WSP by the RTM maintenance consultant. The revision of the TPS RTM included the following:

- Update generalised cost parameters to WebTAG DataBook May 2018;
- Update car growth assumption to National Trip-End Model (NTEM) dataset 7.2;
- Update freight growth assumption using National Road Transport Forecast (NRTF) 1018 dataset; and
- Update fixed speed coding for urban and buffer areas using NRTF 2018 dataset.

1.2.2 High level review of the TPS RTM base year models has shown that the base year models are generally validated well in terms of flow and journey time validation for the roads within the vicinity of the TPTS study area as per Highways England guidance on the RTM validation criteria. A number of routes crossing the Pennines were not validated within the flow and journey time validation criteria, however deemed to have immaterial impacts for the purpose of assessing the TPTS+ study at this stage following discussion with DfT and Highways England. A more in-depth review of the Base year TPS RTM model is provided in **Section 2.3** of this document.

1.2.3 Following further review of the TPS RTM DF7 against the previous version (DF2), it was noticed that a number of TPS RTM coding were not accurately represented in the model and corrections have been made. Detail of the adjustments to the Base year TPS RTM is reported in the Technical Note '**1-551 TPTS+ WSP Improvements to DF7 Technical Note v2.0.pdf**'.

1.3 FUTURE YEARS ASSESSMENTS AND SCENARIOS

1.3.1 To develop a Benefit to Cost Ratio (BCR), the Department for Transport (DfT) requires an economic appraisal of a Do-Minimum (DM) transport supply against a Do-Something (DS) that follows WebTAG guidance. This includes testing the transport supply against a NTEM defined travel market scenario, referred to as NTEM Core scenario, where fixed land-use assumptions in both DM and DS transport supply has been adopted for the application of the forecast variable demand modelling and economic appraisal.

1.3.2 In addition to the NTEM Core scenario, a number of sensitivity tests have been discussed as below:

- A 'Low' growth scenario, representing impacts of the DfT alternative growth scenario with low trip rate assumptions on the TPTS+ study. The assumptions were based on the trend of declining road trips with an increase in rail trips over the last 15 years; and
- A 'Transformational' growth scenario as defined by TfN, representing impacts of additional land available in Greater Manchester and Sheffield City region on the TPTS+ study.

1.3.3 Summary of the modelling and appraisal outputs for the NTEM Core scenario is provided in Chapters 4 to 7 whereas the modelling and appraisal outputs produced for the Low Growth and Transformation Growth scenarios are provided in **Chapter 8** of this document.

1.3.4 Following BICC in September 2019, there was an instruction to the TPTS+ team to consider the affordability of the scheme. Further works have been therefore undertaken to break down the Optimised Package into individual schemes to allow three sub-packages to be configured that is based on the best performing schemes within the cost of each package. Detail of the individual scheme assessments, sub-package selection and modelling and economic appraisal of the sub-packages is provided in **Chapters 9** and **10** of this document.

1.3.5 As the individual schemes being refined in terms of affordability and configuration, the Opening Year and costs of the schemes have also been revised. **Chapter 11** provides an update to the benefits and thus BCRs for the Optimised Package with the revised costs and Opening Year.

1.3.6 Following requested by DfT in early 2020, two tolling sensitivity tests have been undertaken on the Optimised Package to provide an indication of impact on the operational and economic performance, and potential revenue of a tolled scenario for the Optimised Package. The methodology, assumptions and summaries of the tolling sensitivity tests are provided in **Chapter 12** of this document.

1.3.7 Following agreement with HE and DfT, the more accurate method that calculates Greenhouse gas emission using a "link-based" approach with traffic volume and speed were extracted from the modelling outputs as opposed to the TUBA method. The link-based approach calculates fuel consumption using traffic volume and speeds on individual links together with the emission data from the TAG DataBook that is in line with the TAG A3 guidance for the Do-Minimum and each of the sub-packages. The emission results were then input into the TAG "Environmental impacts worksheets" to quantify the net present values of CO2 emission over the lifecycle of the scheme. As a result, the economic appraisal for each of the sub-packages is required to be updated and thus reported in **Chapter 13** of this document. Within this Chapter, the incremental impacts of each sub-packages is also summarised as per agreed with HE and DfT.

1.4 REPORT STRUCTURE

1.4.1 The purpose of this report is to document the forecasting process, economic appraisal and results. This includes:

- **Chapter 2 RTM Model Summary:** provides an overview of the RTM modelling system, Base year reviews and adjustments made;
- **Chapter 3 Forecast Scenarios and Assumptions**: provides the methodology, assumptions and test packages for the purpose of the TPTS+;
- **Chapter 4 Optimised Package**: provides a summary of the tests carried out to inform the Optimised Package for the purpose of modelling and appraisal;
- **Chapter 5 Variable Demand Modelling:** provides an overview of parameters, convergence, PT inputs, matrix changes and impact on network performance;
- **Chapter 6 Urban Delay Function:** provides a summary of the modelling outputs with the fixed speed adjustment applied;
- **Chapter 7 Economic Appraisal:** provides a summary of the economic appraisal approach and results of the Optimised Package with the assumption of the Opening Year 2033;
- **Chapter 8 Alternative Growth Scenarios:** provides a summary of the modelling and appraisal outputs produced from the two alternative growth assumptions for the TPTS+;
- **Chapter 9 Individual Scheme assessment:** provides a summary of individual scheme assessments in terms of performance to determine the sub-packages;
- **Chapter 10 Package Analysis:** provide detailed summary of the analysis of the three sub-packages in terms of modelling and appraisal;
- **Chapter 11 Updated Scheme Opening Year:** provides a summary of the updated costs, benefits and BCRs for the Optimised Package to account for the revised Opening year and costs;
- **Chapter 12 Optimised Package with Tolling Sensitivity Tests:** provides a methodology, assumptions and summary of the impacts of tolling on the Optimised Package's performance in terms of traffic flows on the network and economic appraisal;
- **Chapter 13 Final Economic Appraisal:** summarises the final economic appraisal for each of the sub-packages together with the Optimised package with the greenhouse benefits from TAG method, and the incremental impacts of the sub-packages; and
- **Chapter 14 Summary and Conclusion:** summary and conclusions of the modelling and appraisal undertaken for the TPTS+.

1.5 RELATED DOCUMENTS

1.5.1 The following Technical Notes and Reports have been used in the development of the Traffic Forecasting and Economic Appraisal Report:

- Appraisal Specification Report (1-551 TPTS+ ASR 3.2);
- TPS RTM Local Model Validation Report DF7 (TPS Model Validation Report - V1.9 - 240317 - No Apps Clean);
- Improvement to DF7 Base year model (1-551 TPTS+ WSP Improvements to DF7 TN v2.0);
- Economic Appraisal Methodology and Assumption Technical Note (TfN SDC-RTM Economic Appraisal Methodology_v0.3), produced for the TfN SDC studies;
- Urban Delay Function Technical Note (TfN RTM Fixed Speed Network Update_Final), produced for the TfN SDC studies;
- Urban Delay Function Technical Note (1-551 TPTS+ Fixed Speed Adjustment for Urban Area v2.0), updated for the TPTS+ studies;
- Response to DfT's comments Technical Note (1-551 TPTS+ Responses to DfT Comments);
- Comparison of TPTS+ Static Agglomeration Benefits for WITA and the Economy Model (190405 TPTS+ static Agglom Comparison).

1.5.2 The technical notes are compiled together and provided in the Appendix A – Technical Notes.

2 RTM MODEL SUMMARY

2.1 OVERVIEW

2.1.1 The RTM modelling system is a multi-modal model that consists of a SATURN highways model, a fixed-cost Public Transport (PT) model and a Dynamic Integrated Assignment and Demand Modelling (DIADEM) Variable Demand Model. The demand model is carried out through a Highways England Integrated Demand Interface (HEIDI) front-end interface for the base year realism test and the forecast models.

2.1.2 This chapter provides a high-level summary of the modelling system that has been adopted for the modelling and appraisal of the TPTS+ studies.

2.2 MODELLING SYSTEM

2.2.1 The overview of the Demand modelling system is provided in **Table 2-1** and in the paragraphs below.

Table 2-1 RTM System Overview – Demand Segmentation

	Time Period	Modes	Vehicle Types	Trip Purposes
Demand Model	AM: 07:00 to 10:00 IP: 10:00 to 16:00 PM: 16:00 to 19:00 OP: 19:00 to 07:00	Highways vs Rail	Car	Commuting HBEB(1) NHBEB(2) HBO(3) NHBO(4)
		Highway	LGV HGV	LGV HGV
Assignment Model	Average hour for: AM: 07:00 to 10:00 IP: 10:00 to 16:00 PM: 16:00 to 19:00	Highway Only	Car	Employers' Business Commuting Other
			LGV	LGV
			HGV	HGV

Note: (1) Home-Based Employer's Business

(2) Non Home-Based Employer's Business

(3) Home-Based Other

(4) Non Home-Based Other

2.2.2 Model form:

- Incremental Production/Attraction (PA) for Home-Based trips;
- Incremental Origin/Destination (OD) for non Home-Based trips; and
- Fixed demand for LGV and HGV and special generator trips (i.e. ports, airports).

2.2.3 Model responses (in order of hierarchy):

- Macro time of day choice (transfer between different time periods of a day);
- Mode choice (transfer between car and PT); and
- Destination choice (choice between destinations).

2.2.4 Demand segments and Logit parameters adopted the WebTAG median values and are summarised in **Table 2-2** below.

Table 2-2 Demand Segments and Choice Parameters

Segment	Description	Type	Destination Choice		Mode Choice	Time Choice
			Highway	PT		
HBEB	Home-Based Business	VDM	-0.067	-0.036	0.45	1.0
HBW	Home-Based Commute	VDM	-0.065	-0.033	0.68	1.0
HBO	Home-Based Other	VDM	-0.090	-0.036	0.53	1.0
NHBEB	Non Home-Based Business	VDM	-0.081	-0.042	0.73	1.0
NHBO	Non Home-Based Other	VDM	-0.077	-0.033	0.81	1.0
EB	'Special generators' Business	Fixed	NA	NA	NA	NA
Commute	'Special generators' Commute	Fixed	NA	NA	NA	NA
Other	'Special generators' Other	Fixed	NA	NA	NA	NA
LGV	Light Goods Vehicles	Fixed	NA	NA	NA	NA
HGV	Heavy Goods Vehicles	Fixed	NA	NA	NA	NA

2.2.5 Demand data:

- PA demand data: proportion of Outbound and Return were derived from Mobile Phone Origin/Destination data (MPODD) at aggregate sectoral level for each Home-base purpose, then was applied to the calibrated base year assignment demand to produce 24-hour PA demand.
- Tour proportions: default values provided in DIADEM from the NTS data were 'Furnessed' to match the Outbound and Return proportions (by demand segments, sector movements and by time periods) that were derived from the MPODD data;
- Highway demand: derived from the validated base year highway TPS-RTM models for the base year and applied National Trip-End Model (NTEM) 7.2 growth assumptions for forecast year demands;
- Rail demand: derived from PLANET North (v5) and supplemented by MOIRA for long distance movements for the base year, subsequently applied NTEM 7.2 growth assumptions to produce forecast demand.

2.2.6 Cost Data:

- Highway Costs: extracted from SATURN highway base-minus assignments for the Pivot costs and extracted from forecast SATURN highway assignments for the forecast costs;
- Rail costs: rail travel time was extracted from National Rail networks and compressed to model zone systems for travel time; and rail fares were derived from MOIRA database, then adopted a distance-based fare function and applied growth in fares for the forecast years.

2.2.7 Demand model convergence criteria: adopted the WebTAG M2 guidance, as below:

- Convergence gap criterion for the whole model: 0.1%; and
- Convergence gap criterion for the study area: 0.2%

2.2.8 Cost Damping: two cost damping functions were adopted for the VDM process, as below:

- Varying Value of Time by distance: $VoT_d = VoT\left(\frac{\max(d,d_c)}{d_0}\right)^{nc}$; and
- Damping generalised cost by a function of distance: $GCost_d = GCost\left(\frac{\max(d,d_0)}{k}\right)^{-\alpha}$. Detail of the two cost damping functions are provided in WebTAG M2.

2.2.9 Model platform:

- Highway model: SATURN v11.4.16D
- Variable Demand Model: DIADEM 6.3.3
- PT costs/Demand: TEXT format; and
- HEIDI interface: HEIDI 5.3

2.3 LMVR SUMMARY

2.3.1 A review of the TPS-RTM Local Model Validation Report (LMVR) for the Base year model version DF7, focusing on the links crossing the Pennines, has shown that:

STRENGTHS

- Flows validation at mini-screenline levels are generally within acceptable criteria with majority are within 5% of the observed counts;
- Link flow validation are generally with the acceptable criteria (less than 5% difference between modelled flow and observed counts), particularly on the M60 surrounding Manchester, M62 between Manchester and Leeds, M1/M18 in Sheffield areas; and
- Journey time validation on the motorway networks such as M60, M62 between Manchester and Leeds, M18 and M1 are within the acceptable criteria (less than 15% difference between modelled and observed journey time).

LIMITATIONS

- An underestimate of total flows across the M62/A628, across all three modelled periods. This would potentially result in under-reporting of the TPTS+ impacts in terms of demand crossing the Pennines when the TPTS is built;
- An overestimate of total flows across the mini-screenline west of the M1 between Barnsley and Wakefield. However, the overestimate of demand for this mini-screenline seems to suggest being a result of excessive localised trips that access onto the M1 and therefore would not have significant impacts on the TPTS+;

- M67/A628/A616 Trans-Pennine routes: modelled speeds are faster than observed speeds for the westbound direction (more than 25% different, or 8-11 minutes faster), primarily due to the faster speed on A628 between Woodhead and Mottram in the model compared to observed data;
- Along the A628 Trans-Pennine routes whilst eastbound modelled flows are within the acceptable criterion, westbound traffic showing average 80% higher (300-400veh) compared to observed counts. Analysis of the flow validation on the A628 shows that the overestimate of the westbound traffic on A628 was on two sections: a) from M1 J37 Barnsley and b) near Mottram. A628 both directions near Woodhead (A6024) are however within the acceptable criterion. That suggests the overestimate of modelled flows on A628 are primarily associated with localised trips near Mottram and near M1 (as mentioned in the mini-screenline section) and therefore not likely to affect the demand crossing the Pennines
- A57 Snake Pass westbound: modelled speeds are slower than the observed speeds in the AM and PM peaks (between 15-20min slower). However, this links carries lower volumes of traffic (150-200veh) crossing the Pennines so its impact on the user benefits is likely to be relatively modest. In addition, the analysis from the Base year model shows that the majority of the modelled delays is at junction between Mottram Moor and Wooley lane, which will be offset in the forecast year with the Mottram bypass included.

2.3.2 Detail of the findings of the base year TPS RTM model validation is provided in the technical note '**1-551 TPTS+ Responses to DfT comments**'.

SUMMARY

2.3.3 Following reviews of the TPS RTM it is summarised that:

- Whilst the TPS RTM model shows weaknesses on number of links crossing the Pennines, the level of error in the model relating to modelled flow and journey time are primarily focused on Mottram areas and most significant flow difference are related to local traffic and not the through traffic that would potentially divert to the TPTS scheme;
- The RIS1 scheme, i.e. Mottram bypass, that is included in the forecast network would improve journey time along these sections prior to the TPTS interventions and therefore the level of errors in the base year model is less relevant as through traffic bypasses this section of the network to travel across the Pennines; and
- M62 between Manchester and Leeds carries significant amount of traffic and the impacts of the TPS would result in significant reduction of traffic on the motorways. The flow and journey time validation on the M62 are deemed acceptable and therefore would represent accurately the impacts of the TPTS on travel time savings.

2.3.4 With these above, it is considered that the base year model is deemed to be acceptable for the TPTS+ study at PCF Stage 0.

2.4 IMPROVEMENTS TO THE TPS RTM

2.4.1 As stated in the **Section 1.2** of this document, the TPS RTM DF7 models were provided to the TPTS+ study team in July 2018. Following reviews of the models, it was noticed that whilst number of changes had been made since the previous DF2 version, number of coding errors were still present in the DF7 version of the models.

2.4.2 From the works that was carried out on the Strategic Development Corridor (SDC) studies for the TfN using the same TPS RTM models, WSP identified eight locations where the coding errors occurred, as provided in **Figure 2-1** and **Table 2-3** below.

Figure 2-1 Location of Coding Errors

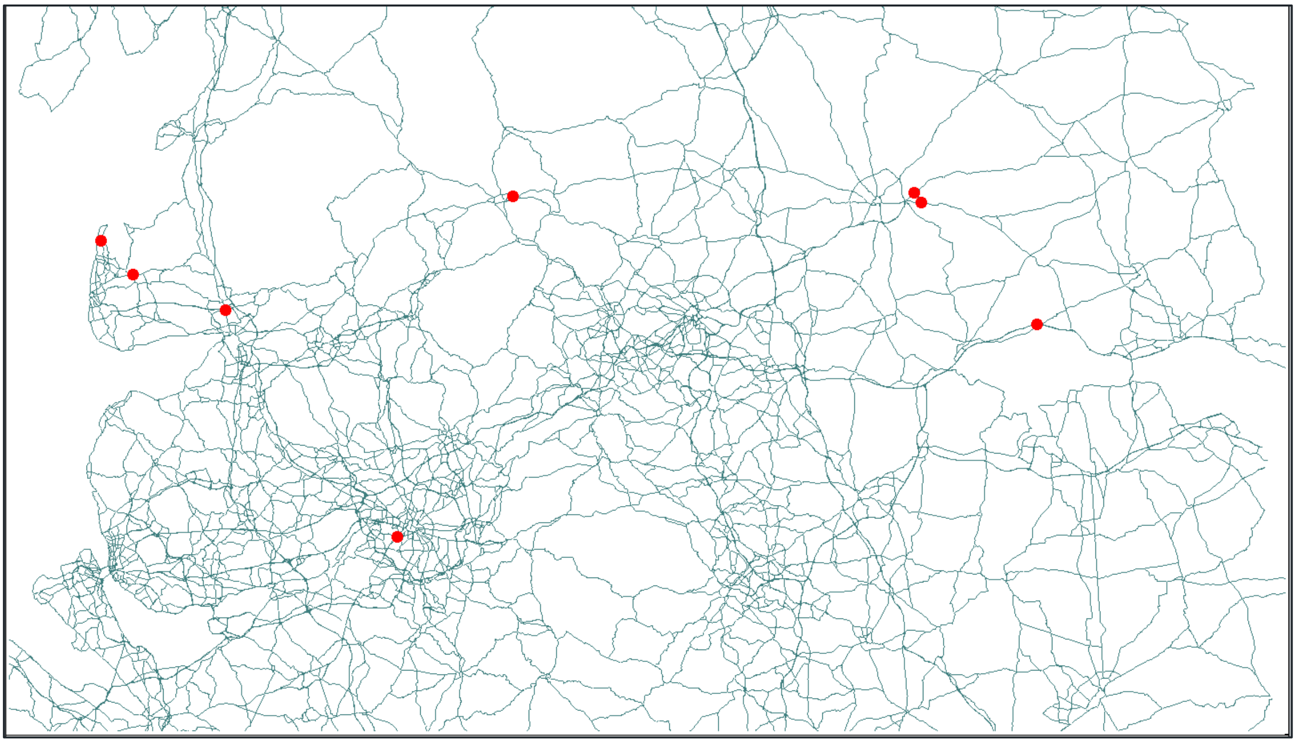


Table 2-3 Location and Coding Errors

No	Location	Node(s)	Description	Amendments made
1	A6 junction with B6241 north of Preston	82748	Incorrect U-turn coded, resulting traffic from M55 routeing to A6 and head back on to M55	Removed U-turn allocation from 82741
2	A585 Garstang New Road/Lodge Lane	88066	Incorrect turn allocation conflicting with signal phasing and staging causing significant delays	Amended arms 81418 and 82168 to allow for correct turn allocations
3	A585 junction with B5409 in Cleveleys	83215	Give-way coded on the mainline from node 82503	Removed Give-way marker
4	M62 eastbound mainline approach to J38	72723	Incorrect number of lanes coming from node 70282	Coded correct number of lane
5	A1079 junction with Long lane east of York	78375	Only Turn 1 coded, preventing traffic travelling on A1079 eastbound	Included other turn movements as per reality
6	A166 junction with Long lane east of York	78379	Only Turn 1 coded, prevent traffic travelling on A166 eastbound	Included other turn movements as per reality

No	Location	Node(s)	Description	Amendments made
7	A59 junction with A6131 outside Skipton	71746	Give-way coded on major arm from node 70737	Removed Give-way marker
8	A56 junction with A5081 outside Manchester	86677	Hamburger roundabout with right-turn missing from node 80965	Allow right turn

2.4.3 Detail of the corrections that have been made to the TPS RTM models and the result of the updated base year model is provided in the technical note '**1-551 TPTS+ WSP Improvements to DF7 Technical Note v2.0**'. A high-level summary of the outcomes of the adjustments made to the TPS RTM models in comparison with the TPS RTM DF7 version is provided below:

- Traffic on A1079/A166 east of York, A585 and M6 southbound in Preston show more plausible routeing compared to the DF7 model, thus resulted in improvements in flow validation in number of links surrounding the adjusted locations.
- Model assignment converged more quickly with reduced run time by 5-39%;
- Flow validation has improved slightly both in terms of flow an GEH criterion; and
- Journey time validation shows similar or slight improvements against the DF7.

2.4.4 Following discussion with Highways England, it was decided that the changes made to the TPS RTM models were to be included in the forecast models prior to the modelling and appraisal of the TPTS+ study.

3 FORECAST SCENARIOS AND ASSUMPTIONS

3.1 OVERVIEW

3.1.1 The ASR sets out a number of steps for the modelling and appraisal of the TPTS+ study. This chapter provides a more detailed summary of the methodology and assumptions that were agreed for modelling and appraisal of the TPTS+ study.

3.2 FORECAST PARAMETERS

MODEL PARAMETERS

3.2.1 The demand models developed for the TPTS+ study adopted the same parameters from the RTM model with detail of modelled periods, demand segmentation and parameters adopted for the demand models are provided in **Section 2.2.**

FORECAST YEARS

3.2.2 The TPTS+ adopts the RTM models forecast years to inform the appraisal:

- 2031: Opening Year; and
- 2041: Design Year

3.2.3 It is noted that the 2051 forecast year model was not available therefore the modelling and appraisal for the TPTS+ was based on 2031 and 2041.

UPDATED FORECAST DEMAND

3.2.4 As informed by the RTM maintenance consultant, the forecast demand has been updated in the version DF7, as below:

- Updated forecast car and PT growth assumption to the NTEM 7.2 dataset; and
- Updated forecast freight growth assumption to the National Road Transport Forecast (NRTF) 2018.

UPDATED GENERALISED COSTS

3.2.5 As part of the model update to DF7, the generalised costs for Values of Time (VoT) and Vehicle Operating Costs (VoC) for the assignments and demand model for the two forecast years 2031 and 2041 have been updated to reflect the latest WebTAG DataBook May 2018 values. A summary of the VoT and VoC for the forecast years is provide in **Table 5-1**.

3.2.6 In addition to the VoT and VoC values, tolls were also updated to reflect change in tolls between the base year and the forecast years that are in line with the WebTAG DataBook May 2018.

UPDATED FIXED SPEED LINKS

3.2.7 Fixed speed links in urban areas and buffer networks for the forecast years have been updated to reflect the NRTF 2018 speed depreciation in the future.

3.2.8 Fixed speed links coded in the base year 2015 models have been applied by relevant adjustment factors by road types to reflect speed decays in the forecast years using the NRTF 2018 dataset.

ANNUAL AVERAGE DAILY TRAFFIC DERIVATION

3.2.9 As reported in the LMVR, the highway models cover three modelled average periods (AM, IP, and PM) and are based on an average weekday in March 2015. To derive Annual Average Daily Traffic (AADT) flows, two sources of data, namely TRA0305[2] (five years period 2012-2016) and TRA0307[3] (2016 data) have been used to generate a set of factors to convert modelled flows to AADT flows, as illustrated in the equation below:

$$\mathrm{AADT24} = (3.000 \times \mathrm{AM} + 6.000 \times \mathrm{IP} + 3.000 \times \mathrm{PM}) \times 1.194 \times 1.032$$

3.2.10 Where:

- 3.000 – factor to convert AM average peak period to AM period;
- 6.000 – factor to convert average Inter-Peak period to Inter-Peak period;
- 3.000 – factor to convert PM average peak period to PM period;
- 1.032 – factor to convert March weekday traffic to annual average weekday traffic; and
- 1.194 – factor to convert annual weekday traffic to annual daily traffic.

3.3 UNCERTAINTY LOG

3.3.1 The updated uncertainty log was provided by the RTM maintenance consultant in July 2018. This includes number of Highways England Road Investment Strategy (RIS) and Local Authority (LA) highway interventions. Detail of the highway interventions are provided in **Appendix B – Uncertainty Log**.

3.3.2 For the land-use assumptions, it was agreed that for the Core forecast, the growth assumption derived from NTEM 7.2 dataset was used for the purpose of modelling and appraisal of the TPTS+ study without including explicit developments.

3.4 FORECAST NETWORKS

NETWORK CODING MANUAL

3.4.1 The RTM network coding manual (**RTM Network Coding Draft V08 Final**) has been adopted for the purpose of coding the Reference case and the test packages.

REFERENCE CASE (DO-MINIMUM)

3.4.2 The Reference Case networks represent the Do Minimum network on which the tested packages (representing the Do Something networks) will be built up on.

3.4.3 Building on a 2015 base year network, and incorporating recently completed schemes and schemes under construction, the list of the schemes that were included in the Reference Case network was provided by the TPS RTM maintenance team in 2018, which comprises of:

- Local Authority (LA) schemes;
- Highways England RIS1 schemes;

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722095/tra0305.ods
[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722097/tra0307.ods

3.4.4 Detail of the Highways England and LA highway interventions are provided in **Appendix B – Uncertainty Log**.

3.4.5 The reference case also included the corrections that were identified by WSP (described in **Section 2.4** of this document).

3.4.6 In addition, two Highways England's RIS schemes namely M60 J1-J5 and M60 J24-J27 were removed from the initial RTM forecast networks following advice made by Highways England in October 2018.

TEST PACKAGES

3.4.7 The test packages were built on top of the Reference Case, which include the following:

Package 1 - Trans-Pennine Improvements Only (TPTS Only)

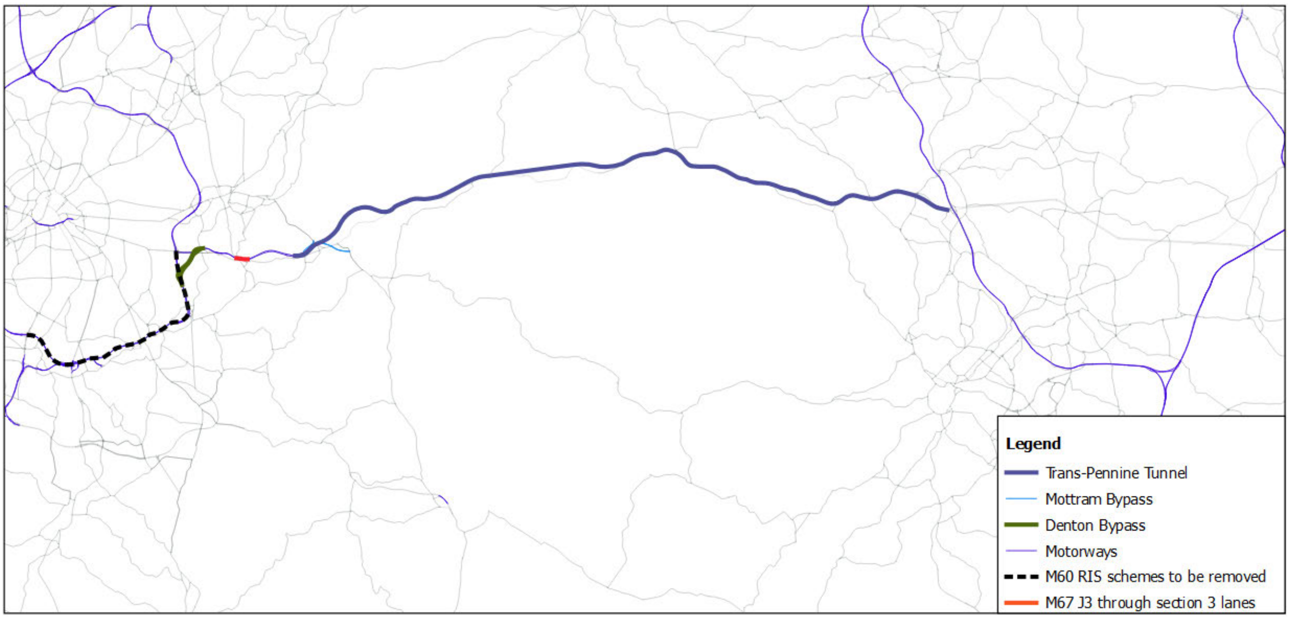
3.4.8 This package includes the following schemes on top of the reference case networks:

- Trans-Pennine improvements (This includes a shorter version of the Tunnel with A616 and A628 dualling providing a continuous dual carriageway standard route between M1 and M67);
- Denton bypass (to provide improved connectivity between M67 and M60); and
- M67 Junction 3 additional lane on the 'through junction' section.

3.4.9 Package 1 was tested primarily to verify the benefits that was done in the previous studies and also to provide a basis for analysing network performance of the other two packages for the purpose of informing the Optimised Package.

3.4.10 A schematic of the package is provided in **Figure 3-1** below.

Figure 3-1 Trans-Pennine Improvements Only



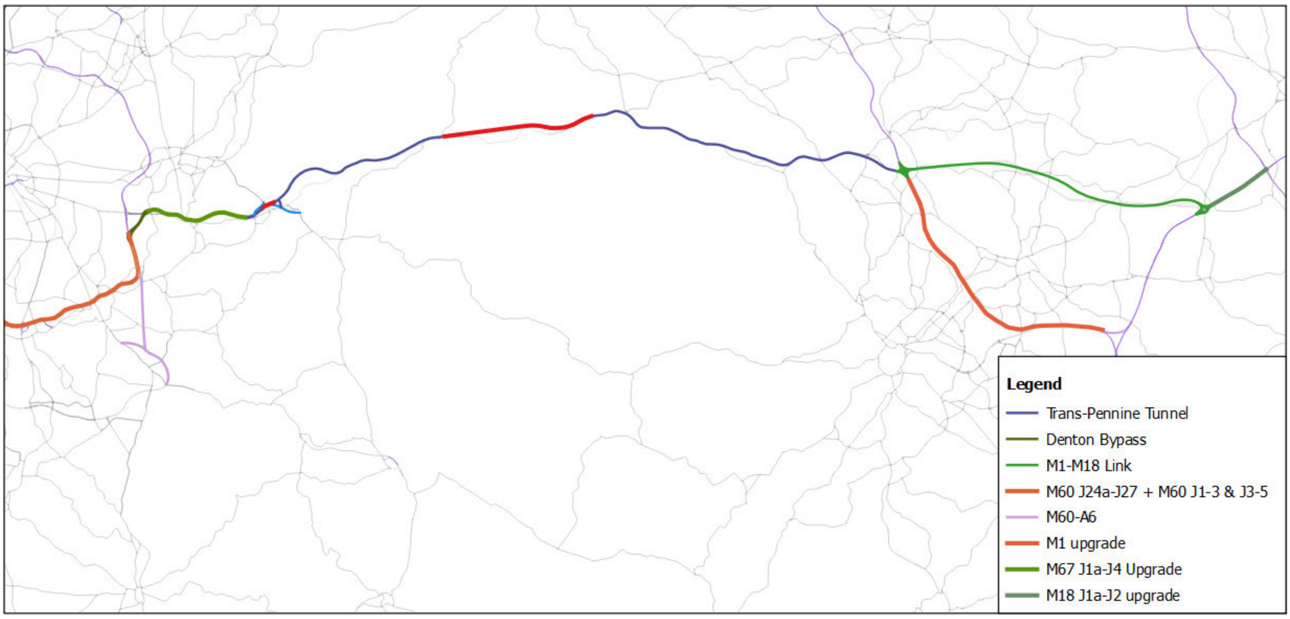
Package 2 – Full Package

3.4.11 This package includes all of the Wider Transport Connectivity (WTC) interventions on top of the Reference Case network, as below:

- Trans-Pennine improvements;
- Denton Bypass;
- M67 J1a- J4 additional capacity on both directions;
- M60 J24a-J27 capacity improvements;
- M60 J1-J3 and M60 J3-J5 upgrade;
- A6-M60 Link road;
- M1-M18 Link road;
- M1 J32-J36 capacity improvements; and
- M18 J1a-J2 capacity improvements.

3.4.12 A schematic of the Full Package is provided in **Figure 3-2** below.

Figure 3-2 Full Package (Test Package)



Package 3 – Optimised Package ('Optimised Package')

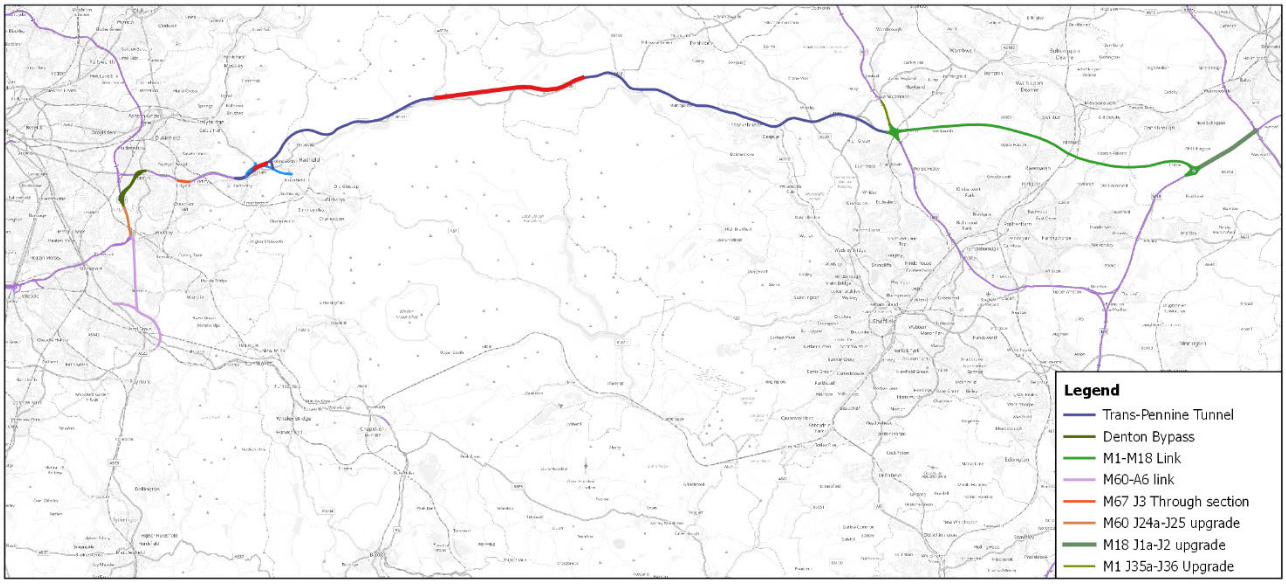
3.4.13 This package includes the Optimised interventions that were proposed for the modelling and appraisal of the final TPTS+ study, as below:

- Trans-Pennine improvements;
- Denton bypass;
- M67 J3 'through section' additional lane;
- M60 J24a-J25 capacity improvements;
- A6-M60 link road;
- M1-M18 link road;
- M18 J1a-J2 upgrade; and
- M1 J35a-J36 additional lane.

The Option Appraisal Report (OAR) sets out the transition from the Test Package to the Optimised Package.

3.4.14 A schematic of the Optimised Package is provided in **Figure 3-3** below.

Figure 3-3 Optimised Package



3.4.15 As agreed with DfT, a 'Fixed Demand' approach forecast assignments (i.e. no VDM was required) and subsequently TUBA assessments were undertaken to assess network performances and transport user benefits of the test packages in order to help inform the 'Optimised Package' for the purpose of modelling and appraisal of the TPTS+ study.

3.4.16 Detail of the Optioneering process to inform the 'Optimised Package' is provided in **Chapter 4** of this document.

OPTIMISED PACKAGE (DO-SOMETHING)

3.4.17 Upon completion of the assessment of the test packages using the 'Fixed Demand' approach, the Optimised Package was established by building from the 'Optimised Package' with additional refinements to junctions at M60 J24 to account for change in traffic volume as a result of the Denton bypass connecting M67 J1a to M60 J24a.

3.5 FORECAST DEMAND

3.5.1 As stated in the previous section, the forecast demand DF7 dataset 'core' growth scenario provided to WSP includes the following changes from the previous version:

- NTEM 7.2 dataset growth assumptions for car and PT; and
- Updated NRTF2018 growth assumptions for LGV and HGVs.

3.5.2 As agreed, the modelling and appraisal of the TPTS+ study has been developed using the core growth assumptions as provided.

3.5.3 In addition to the core growth scenario assumption, a number of alternative growth scenarios have been discussed, which includes Low growth and High growth (or transformational growth) scenarios.

A detailed discussion of the low and transformational growth scenarios is reported in **Chapter 8** of this document. The following paragraphs provide summary for the NTEM Core growth scenario only.

3.5.4 Summary of Base year 2015 and Reference demand for the Opening year 2031 and Design year 2041 are provided from **Table 3-1** to **Table 3-5** below.

Table 3-1 Demand Summary – Base Year 2015 (PCUs)

Purpose	AM Peak	Inter-Peak	PM Peak	12-hour
Car Business	323,830	345,909	343,179	4,076,481
Car Commute	2,379,779	912,452	2,238,292	19,328,925
Car Other	2,138,045	2,722,869	3,052,070	31,907,561
Car Total	**4,841,654**	**3,981,230**	**5,633,541**	**55,312,966**
LGV	607,023	556,666	589,780	6,930,405
HGV	325,583	336,565	237,279	3,707,974
Total	**5,774,260**	**4,874,461**	**6,460,600**	**65,951,346**

Table 3-2 Reference Demand – Opening Year 2031 (PCUs)

Purpose	AM Peak	Inter-Peak	PM Peak	12-hour
Car Business	364,042	386,080	383,696	4,559,693
Car Commute	2,551,883	976,268	2,398,893	20,709,936
Car Other	2,464,305	3,136,063	3,521,398	36,773,486
Car Total	**5,380,229**	**4,498,411**	**6,303,988**	**62,043,116**
LGV	754,227	691,868	732,575	8,611,614
HGV	329,623	340,936	240,060	3,754,664
Total	**6,464,080**	**5,531,214**	**7,276,623**	**74,409,394**

Table 3-3 Demand Growth (%) in Opening Year 2031

Purpose	AM Peak	Inter-Peak	PM Peak	12-hour
Car Business	12.4%	11.6%	11.8%	11.9%
Car Commute	7.2%	7.0%	7.2%	7.1%
Car Other	15.3%	15.2%	15.4%	15.3%
Car Total	**11.1%**	**13.0%**	**11.9%**	**12.2%**
LGV	24.3%	24.3%	24.2%	24.3%
HGV	1.2%	1.3%	1.2%	1.3%
Total	**11.9%**	**13.5%**	**12.6%**	**12.8%**

Table 3-4 Reference Demand – Design Year 2041 (PCUs)

Purpose	AM Peak	Inter-Peak	PM Peak	12-hour
Car Business	387,709	409,661	407,295	4,842,976
Car Commute	2,667,214	1,020,208	2,507,260	21,644,673
Car Other	2,636,343	3,356,139	3,769,576	39,354,593
Car Total	**5,691,266**	**4,786,009**	**6,684,131**	**65,842,242**
LGV	856,046	785,257	831,477	9,774,106
HGV	341,974	353,746	249,026	3,895,477
Total	**6,889,286**	**5,925,011**	**7,764,633**	**79,511,825**

Table 3-5 Demand Growth (%) in Design Year 2041

Purpose	AM Peak	Inter-Peak	PM Peak	12-hour
Car Business	19.7%	18.4%	18.7%	18.8%
Car Commute	12.1%	11.8%	12.0%	12.0%
Car Other	23.3%	23.3%	23.5%	23.3%
Car Total	**17.5%**	**20.2%**	**18.6%**	**19.0%**
LGV	41.0%	41.1%	41.0%	41.0%
HGV	5.0%	5.1%	5.0%	5.1%
Total	**19.3%**	**21.6%**	**20.2%**	**20.6%**

3.5.5 The overall growth in demand has been checked against NTEM Core target growth for cars for each of the forecast years and show a similar percentage growth for cars across the whole model.

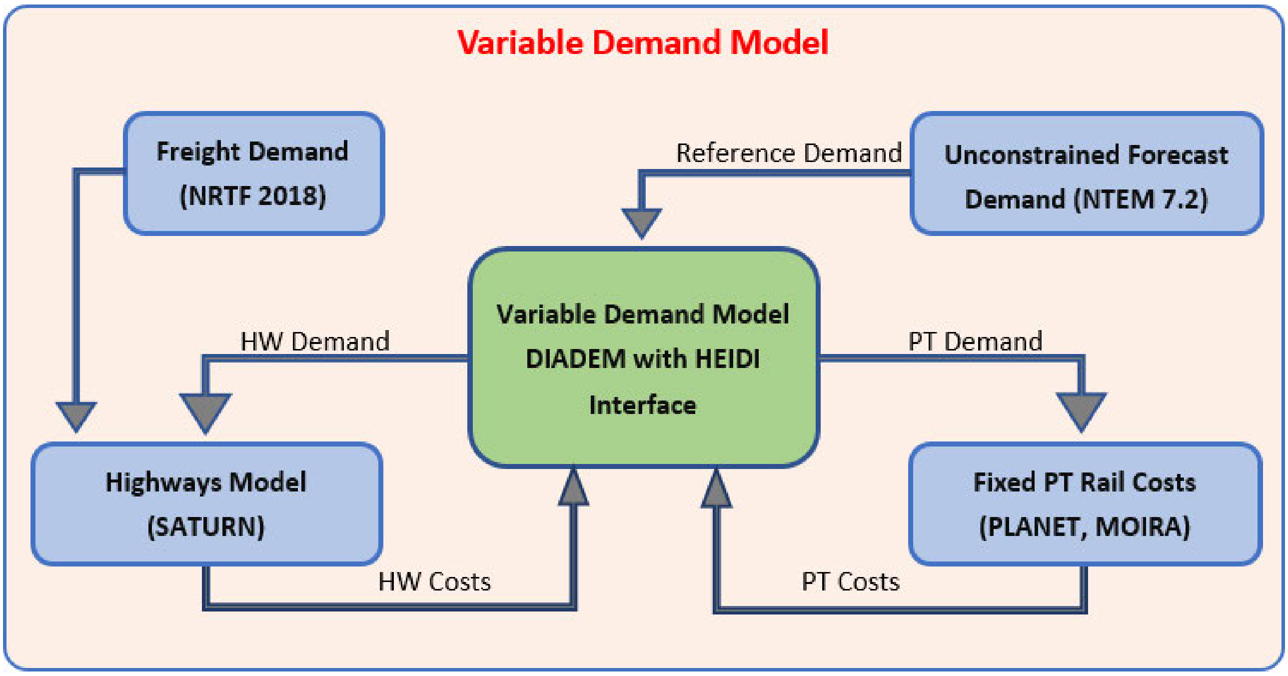
3.5.6 Similarly, LGV and HGV growth was also checked and shows overall consistency to the NRTF 2018 database.

3.6 VARIABLE DEMAND MODELLING

3.6.1 The Variable Demand Modelling (VDM) process is required to produce forecast demand for the Do-Minimum and the Do-Something (TPTS Improvements only and the Optimised Packages) for the TPTS+ study.

3.6.2 The VDM process was developed for the Highways England RTM model and consists of a SATURN highways model and the fixed PT Rail costs using the industry recognised DIADEM software with the RTM developed HEIDI front-end interface. The structure of the VDM has been therefore adopted for the modelling and appraisal of the TPTS+ study, as provided in **Figure 3-4** below.

Figure 3-4 RTM Variable Demand Model



3.6.3 Detail of demand segments and sensitivity parameters are provided in **Section 2.2** of this document. Within the VDM structure, a number of key elements are required and summarised in the following paragraphs.

3.6.4 It should be noted that the key elements summarised below are for the Core growth scenario only. For the Low Growth and Transformational growth scenarios, forecast demand for car, freight and rail are subject to change to reflect different growth scenarios.

CAR FORECAST DEMAND

3.6.5 Car demand for forecast years were provided by RTM consultant, which applied growth assumption from NTEM 7.2 dataset to the base year demand.

CAR HIGHWAY COSTS

3.6.6 Extracted from SATURN highway assignments.

FREIGHT FORECAST DEMAND

3.6.7 Freight demand for forecast years was provided by RTM consultant applying the latest NRTF 2018 growth assumptions to the base year freight demand.

PT RAIL DEMAND

3.6.8 PT Rail demand for forecast years were provided by RTM maintenance consultant, applying NTEM 7.2 growth assumptions to the base year rail demand.

PT RAIL COSTS

3.6.9 Rail costs (time and fares) was provided by RTM consultant, in which forecast rail travel time was updated from the base year rail travel time to account for future rail interventions, and forecast fares were derived by applying rail fare growth assumptions from PLANET with High-Speed 2 Rail included.

3.7 URBAN DELAY FUNCTION

3.7.1 As stated in the ASR, an urban delay function that was initially developed on behalf of Transport for the North (TfN) for the Strategic Development Corridor (SDC) studies has been further refined to account for flow reduction within urban areas. Detail of the urban delay function is provided in the two Technical Notes, the initial note that was developed for the TfN SDC (**TfN RTM Fixed Speed Network Update_Final**) and the refinement of the function for the purpose of the TPTS+ study (**1-551 TPTS+ Fixed Speed Adjustment for Urban Area v2.0**). The following paragraphs provide a high-level summary of the development of the urban delay function initially for the TfN and subsequently for the TPTS+ study.

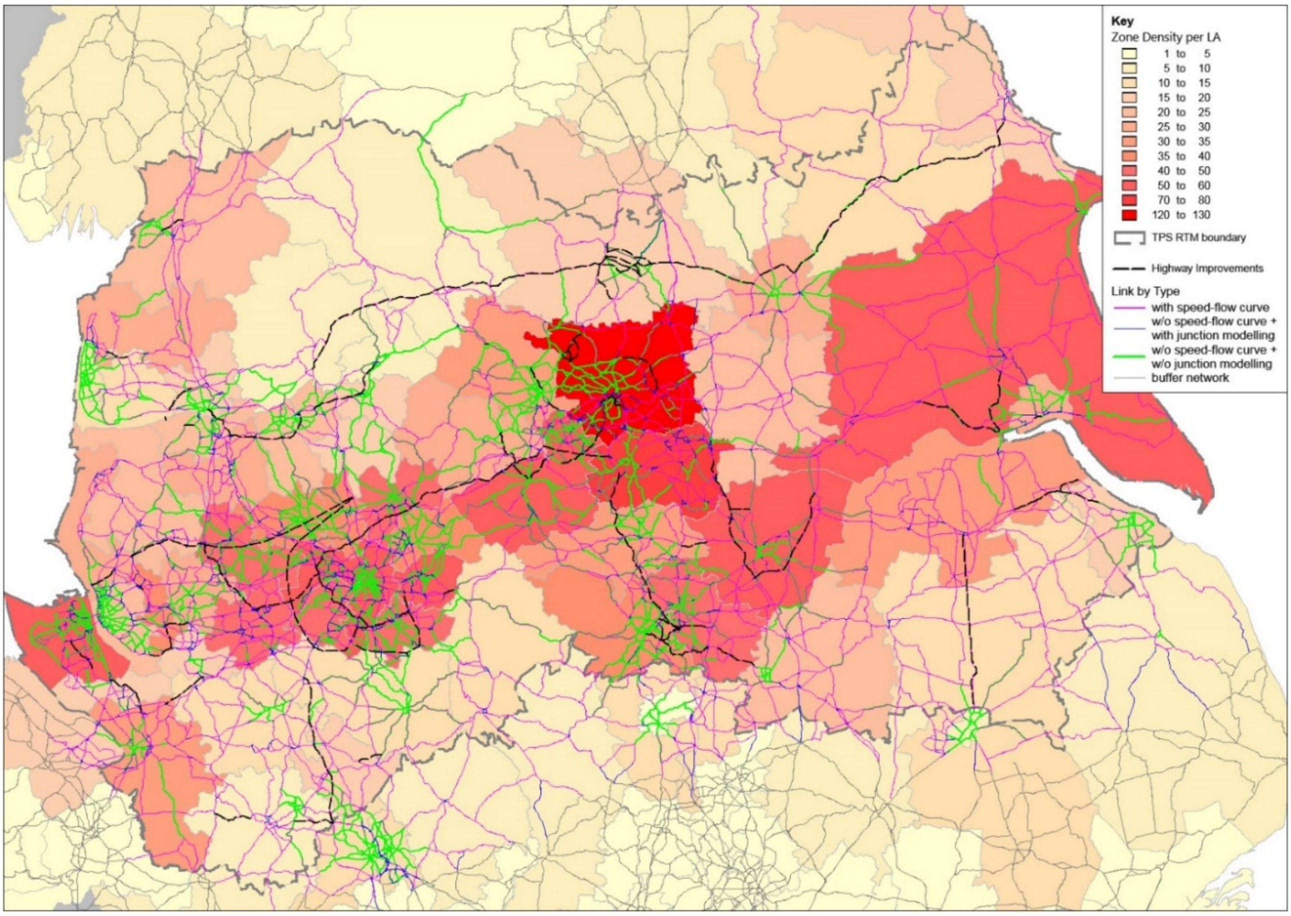
INITIAL DEVELOPMENT – TFN SDC STUDIES

3.7.2 The primary objective of the RTM was to focus on the Highways England Strategic Road Network (SRN) interventions with less of a focus on the urban areas. Detailed simulation coding was primarily focused on and adjacent to the Highways England SRN network, as a result change in delays in response to change in traffic volume was fully captured, thus more robust in modelling choice and subsequently to the appraisal of interventions on the SRN network.

3.7.3 In contrast to the SRN network, the urban areas were not the primary focus on the RTM model development. Urban areas were coded in a form of reduced simulation with an aggregate zone system and a ‘fixed speed’ with ‘Dummy’ type junction coding (i.e. unlimited link capacity, under representation of junction layout, number of lanes, number of approaches to junction, etc.). That means that localised levels of delay within urban areas were not able to represent change in delays as a result of change in traffic volume.

3.7.4 A high-level indication of the network coverage and limited coding within the TPS RTM model is provided in **Figure 3-5**.

Figure 3-5 TPS RTM Network/Zone System



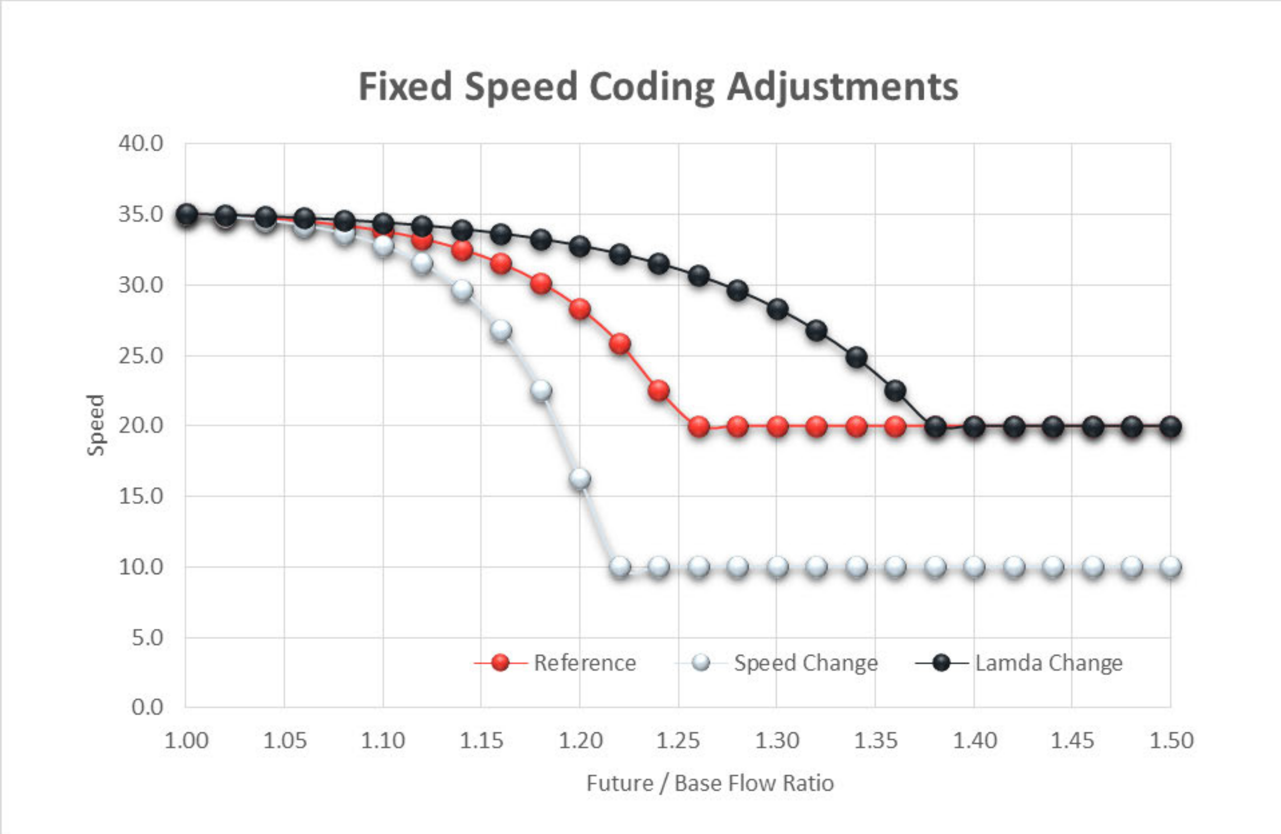
3.7.5 As a result of the reduced simulation within urban areas, any scheme interventions on the SRN network would not be accurately assessed due to not being able to fully capture the impacts of change in travel time/congestion within urban areas, and consequently would be likely to underestimate the benefits of scheme interventions.

3.7.6 The treatment of the fixed speed network coding within urban areas was initially discussed with TfN in 2017 during the SDC studies in which, TfN agreed the importance of the treatment of the fixed speed coding to the modelling and appraisal of the proposed interventions. As a result, TfN asked the SDC consultants for a solution that can be applied for the SDC studies.

3.7.7 In response to TfN, WSP proposed to develop a process that allows adjustment to the fixed speed networks at individual link levels in the forecast year models by pivoting from the base year flows, using a speed-decay function principle as currently implemented in the SATURN assignment.

3.7.8 A demonstration of the speed-decay function that has been applied to address the fixed speed coding for urban areas is provided in **Figure 3-6** below.

Figure 3-6 Speed-Decay Function



3.7.9 The speed-decay functions were calibrated using the M60 Smart-Motorway (M60SM) models with various change in demand tested to derive change in speed in response to demand increases. This was in order to produce a set of speed-flow curves to be applied for the urban areas of the RTM models.

3.7.10 A number of tests were subsequently carried out on the TPS RTM Base year models with the same demand changes to the M60SM tests to verify the fitness of the curves. The results of the tests on the TPS RTM models show similar reductions in speeds compared to the responses from the M60SM models.

3.7.11 Following discussions with TfN and a review of the process, it was agreed that the process was to be used for the purpose of modelling and appraisal for the SDC studies by applying the Urban Delay function to the post-VDM forecast assignments. The application of the Urban Delay function to the post-VDM forecast assignments was to ensure reduced risks of repetitive works whilst offering extra information where applicable.

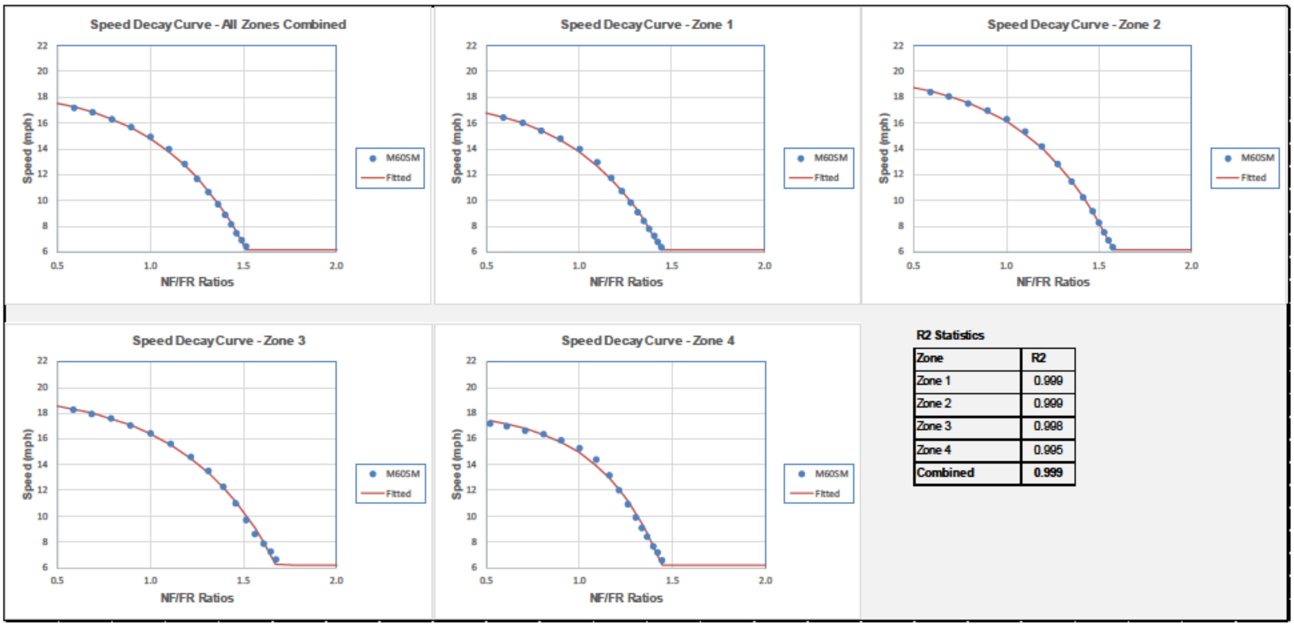
REFINEMENT FOR THE TPTS+ STUDIES

3.7.12 The initial development of the Urban Delay function on behalf of the TfN SDC studies only looked at the 'first half' of the curve, i.e. change in speed as a result of flow increase, as the objectives of the TfN was to assess the Transformational growth scenarios.

3.7.13 Following discussion and agreement with DfT and Highways England, the Urban Delay function has been refined to produce the 'second half' of the curve, i.e. accounting for change in speed as a result of flow reduction. The inclusion of the second half of the curve was deemed necessary for the purpose of the TPTS+ study since the modelling and appraisal of the TPTS+ interventions were based on the NTEM Core growth scenario assumptions and not Transformational growth scenarios as for the TfN SDC studies, where interventions along the SRN networks would result in a reduction in traffic within the urban areas.

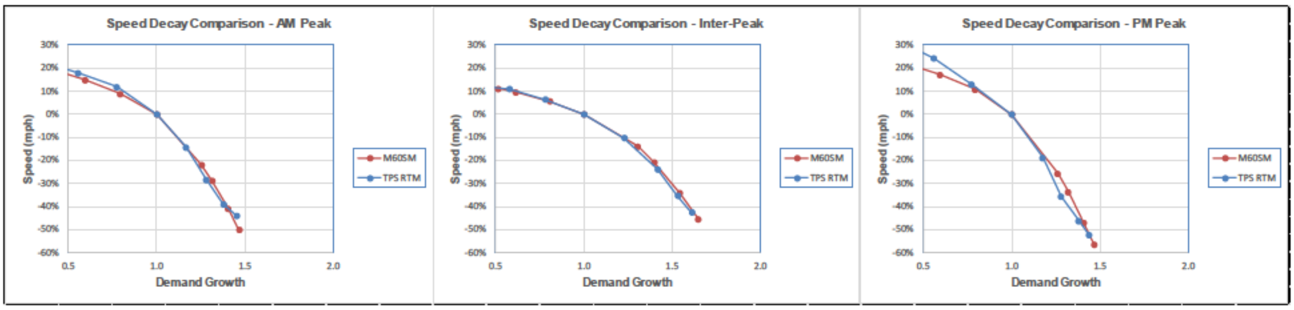
3.7.14 The outputs produced from the calibration of the speed change in response to flow changes that were undertaken using the M60SM model is provided in **Figure 3-7** below.

Figure 3-7 Calibration of Speed Decay Curve on M60SM Model



3.7.15 A similar exercise was then carried out on the TPS RTM base year model with a similar change in demand to verify the speed decays in the TPS RTM models by comparison to the M60SM. **Figure 3-8** below provides a summary of the comparison of the speed decay between the M60SM and the TPS RTM models.

Figure 3-8 Verification of Urban Delay Function on TPS RTM



3.7.16 As can be seen, the two models generally produce similar decay in travel speeds in responses to demand changes, except for the PM peak, where flow reduction results in a larger increase in speed in the TPS RTM models compared to the M60SM models. This is likely due to number of reasons, including the difference in the starting point of the two base year models, and the level of flow/journey time validation within the urban areas.

3.7.17 Similar to the TfN SDC studies, WSP proposed to apply the urban delay function to the post-VDM forecast assignments to ensure reduced risk of repetitive works whilst offering additional information where applicable.

3.8 ALTERNATIVE GROWTH SCENARIOS

3.8.1 In addition to the NTEM Core growth scenario, two alternative growth scenarios have been discussed for the modelling and appraisal of the TPTS+ study, as below:

LOW GROWTH SCENARIO

3.8.2 This scenario captures uncertainty around trends in both trip rates and license holding in young people, reflecting the changing preferences of people and assumes that these changes continue. In this future, people would travel less overall and find less need to own or have access to a car; and when they do travel, they would travel by rail rather than road[4].

3.8.3 The assumptions of the Low Growth scenario were based on the declining trend in road-based trip rates and increase in rail trip rates (road-based Commuting and Other trips have fallen by 18% and 15% respectively whilst trip by rail have increased by over 50% over the past 15 years).

TRANSFORMATIONAL GROWTH SCENARIOS

3.8.4 This scenario represents the TfN growth strategy which included assumptions for additional land availability in Greater Manchester and Sheffield City Region under a 'transformational' scenario in which areas at either ends of the tunnel are to be generated.

3.8.5 As part of the TfN transformational growth scenario, freight demand has been also produced to reflect change in freight demand under the transformational growth scenario.

3.8.6 A high-level summary of the modelling and appraisal of the Low Growth scenarios and the TfN transformational growth scenarios are provided in **Chapter 8** of this document.

3.9 SECTORING SYSTEM

3.9.1 To help analyse the impact of the packages, a sector system has been developed for the TPTS+ study. The sector system consists of 16 sectors which aggregate the traffic model zones into 16 distinct geographical areas, as shown in **Table 3-6** and illustrated in **Figure 3-9** below.

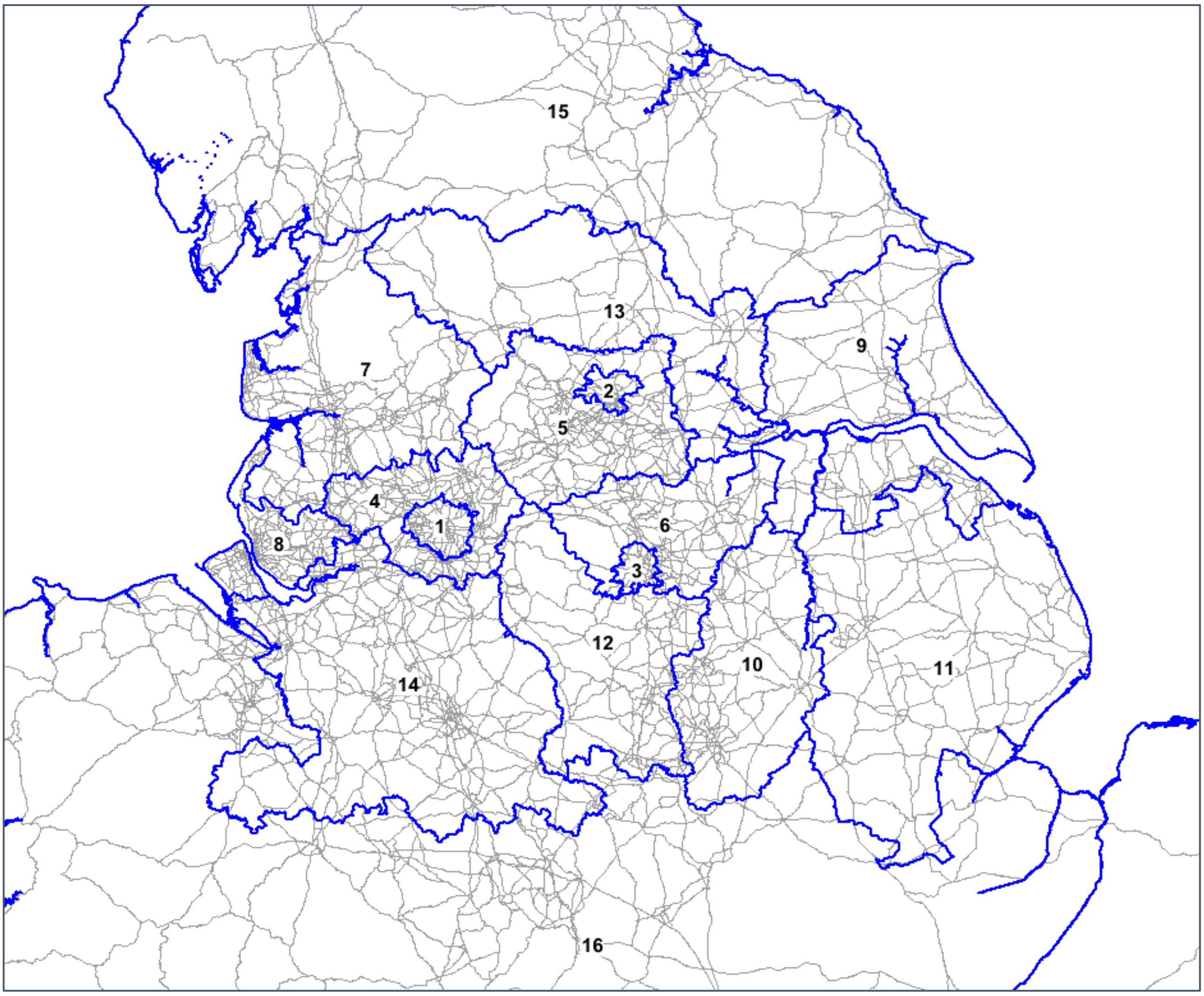
Table 3-6 TPTS+ Sector System

Sector Number	Description
1	Manchester urban area
2	Leeds urban area
3	Sheffield urban area
4	Manchester (outside M60 ring road)
5	West Yorkshire (outside Leeds)
6	South Yorkshire (outside Sheffield)
7	Lancashire

[4] Common Analytical Scenarios, DfT, October 2018

Sector Number	Description
8	Merseyside
9	Humberside
10	Nottinghamshire
11	Lincolnshire
12	Derbyshire
13	North Yorkshire
14	Cheshire, Shropshire, etc
15	North
16	South

Figure 3-9 TPTS+ Sector System



4 PACKAGE TESTING

4.1 OVERVIEW

4.1.1 This chapter provides a high-level summary of the tests that were carried out for the test packages to inform the Optimised Package.

4.1.2 As agreed, the tests undertaken to inform the Optimised Package were carried out using the 'Fixed demand' assignment approach with demand matrices produced from the post-VDM models for the Do-Minimum networks. It is also noted that for the purpose of informing the Optimised Package, the application of the Urban Delay function was not applied.

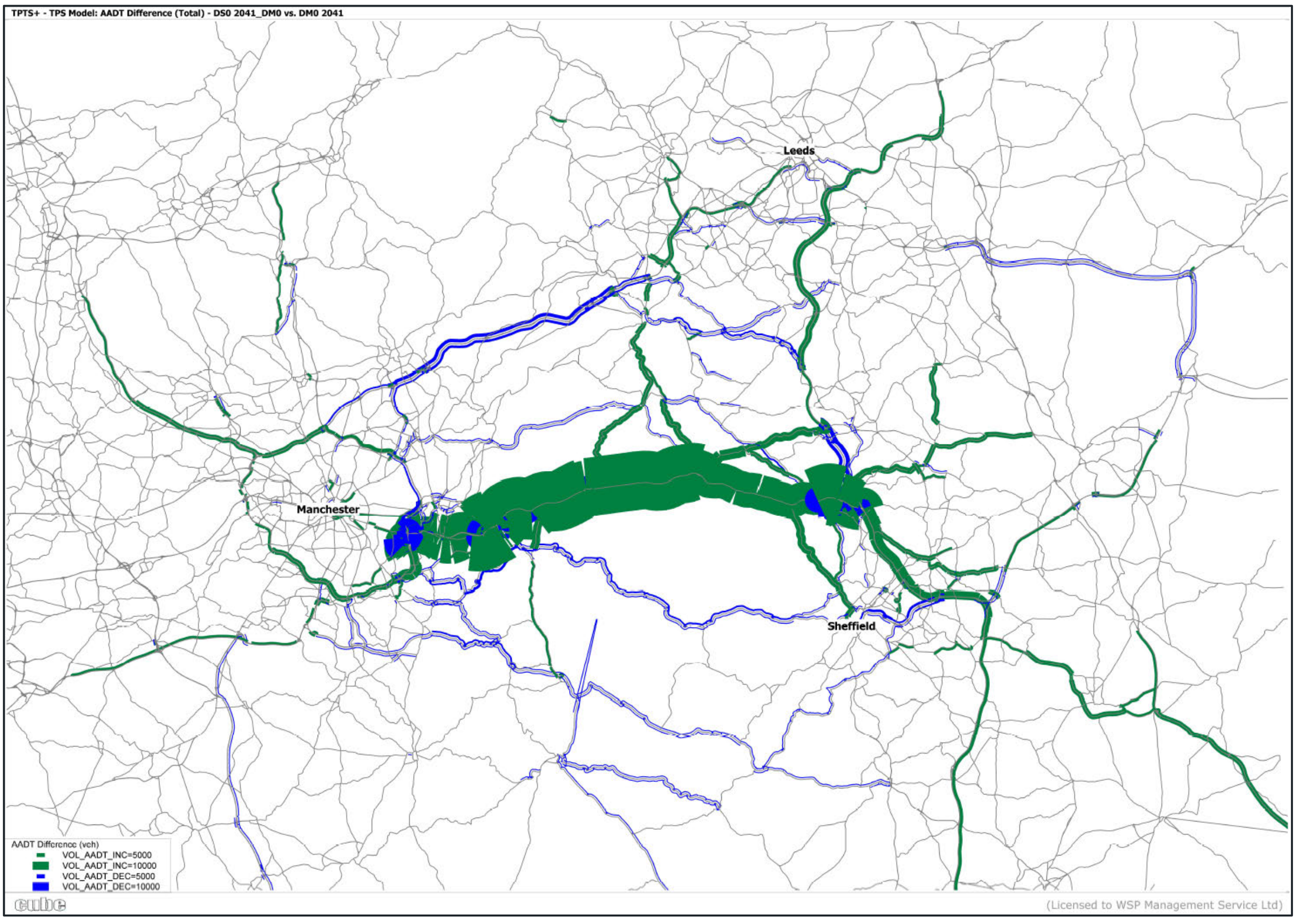
4.2 TEST RESULTS

4.2.1 The following sections provide a summary of the modelling outputs from the test packages to inform the Optimised Package, in terms of AADT flow difference and speed difference incrementally from Do-Minimum, TPTS Only, the Optimised Package and the Full Package; and TUBA user benefits of each package against the Do-Minimum.

NETWORK PLOT

4.2.2 **Figure 4-1** provides a high-level presentation of the flow difference on the network as a result of the TPTS Only in terms of AADT difference.

Figure 4-1 AADT Flow Difference - TPTS Only vs. Do-Minimum



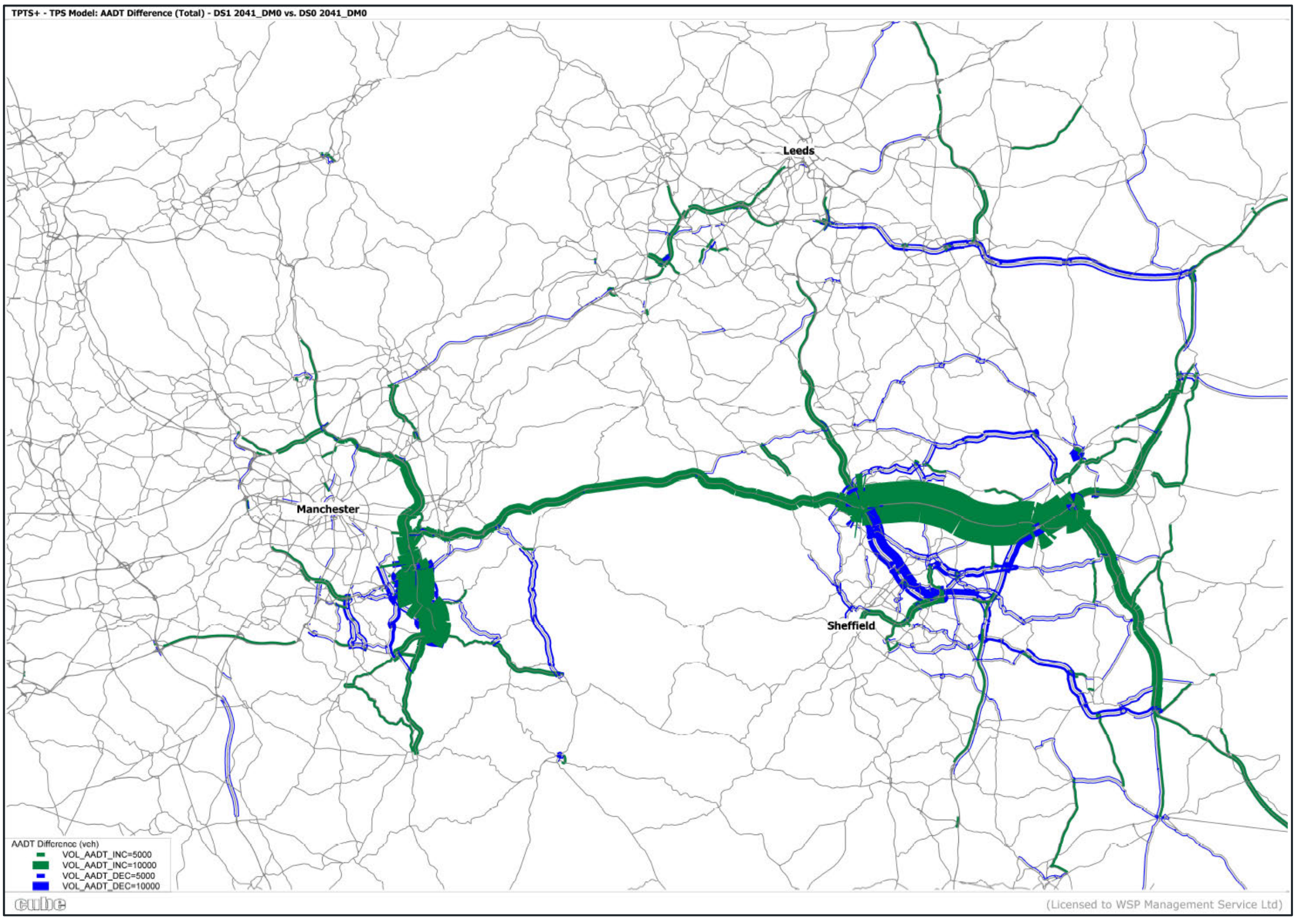
4.2.3 As can be seen, the TPTS Only interventions would result in significant flow changes in the vicinity of the interventions, with about 67,00 AADT 2-way flows forecast to travel on the TPT tunnel link (a net increase of 44,000 AADT 2-way crossing the Pennines compared to existing traffic volume on A628). The significant net increase in volume of the traffic is a result of:

- A 7,000 AADT reduction on M62 between Manchester and Leeds, and around 15,000 AADT reduction on number of links crossing the Pennines;
- Denton bypass and improvement on M67 J3 through the section would help relieve congestion at M60 J24 and on the M67, thus producing an increase of 55,000 AADT on the M67, contributing to the significant traffic volume on the TPT tunnel link.

4.2.4 The significant increase in flows on the M67 towards the TPT tunnel is anticipated as the Denton bypass coupled with the M67 J3 section improvement would alleviate significant delays on M60 J24 and M67, thus allowing more traffic to pass through the M60 and M67 towards the TPT tunnel.

4.2.5 **Figure 4-2** below provides an illustration of the impacts of the Optimised Package on the TPTS Only in terms of flow difference on the network.

Figure 4-2 AADT Flow Difference - Optimised Package vs. TPTS Only



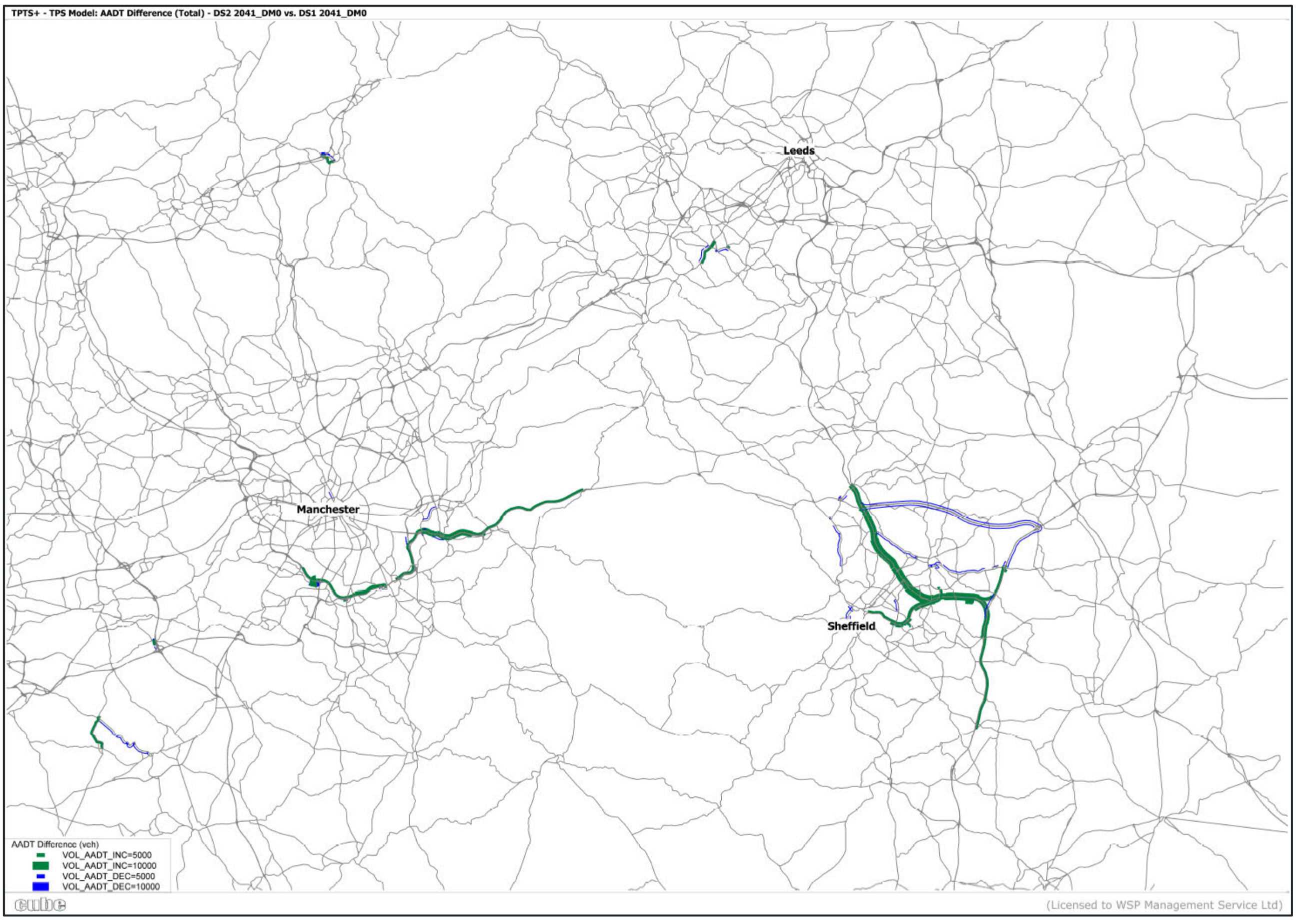
4.2.6 As can be seen, the Optimised Package would result in significant impacts in terms of flow difference on the network, in particular:

- The A6-M60 scheme coupled with M60 J24-J24a improvements would produce significant traffic rerouting on the road networks surrounding Stockport and M60 between J22 and J25 and also produce additional 7,000 AADT on the TPT tunnel compared to the TPTS improvements only;
- The M1-M18 link coupled with M18 J1-J1a capacity improvements would result in significant traffic rerouting on M1, M18 in Sheffield and Rotherham areas, creating an increase in traffic on the M18 east of junction 2 (5,000 AADT 2-way) and on the A1(M) south of M18 J2 (10,000 AADT 2-way).

4.2.7 Similar to the interventions on the western side of the TPT tunnel, the increase on M18 and A1(M) is anticipated as the improvements would help alleviate congestion on the M1 J32-J25, thus allowing more traffic travelling on the TPT tunnel to continue travelling on the network.

4.2.8 **Figure 4-3** below provides the impacts of the Full Package on the Optimised Package in terms of flow difference.

Figure 4-3 AADT Flow Difference - Full Package vs. Optimised Package



4.2.9 In contrast to the significant impacts by the interventions for the TPTS Only and the Optimised Package, the Full package only offers a marginal change in traffic volume from the Optimised Package. The main changes are as below:

- Slight increase in flows on M67 (2,000 AADT 2-way) as a result of capacity enhancement on M67 between J1 and J4 (from 3 lanes to 4 lanes);

- Modest increase in M1 between M1 J35a to M1 J31 (6,000 AADT 2-way) and slight reduction in traffic on M1-M18 link (2,000 AADT 2-way) as a result of the capacity improvements on M1 J32 to J36;
- Flow increase on M60 from M60 J1-J5 (2,000 AADT 2-way) toward the M67 as a result of capacity improvements on the M60 J1-3 and J3-J5.

4.2.10 It can be seen from the three figures that even with significant interventions made, the Full Package only offers marginal change in terms of traffic volume on the network. The early conclusion was that the Full Package would likely produce marginally larger benefits compared to the Optimised Package.

4.2.11 **Figure 4-4** to **Figure 4-6** provide a high-level summary of the impacts of each test package on the speed difference on the networks incrementally from Do-Minimum, TPTS Only, Optimised Package and Full Package. The speed difference plots were produced for the PM peak for the purpose of providing comparison.

Figure 4-4 Speed Difference – TPTS Only vs. Do-Minimum (PM Peak)

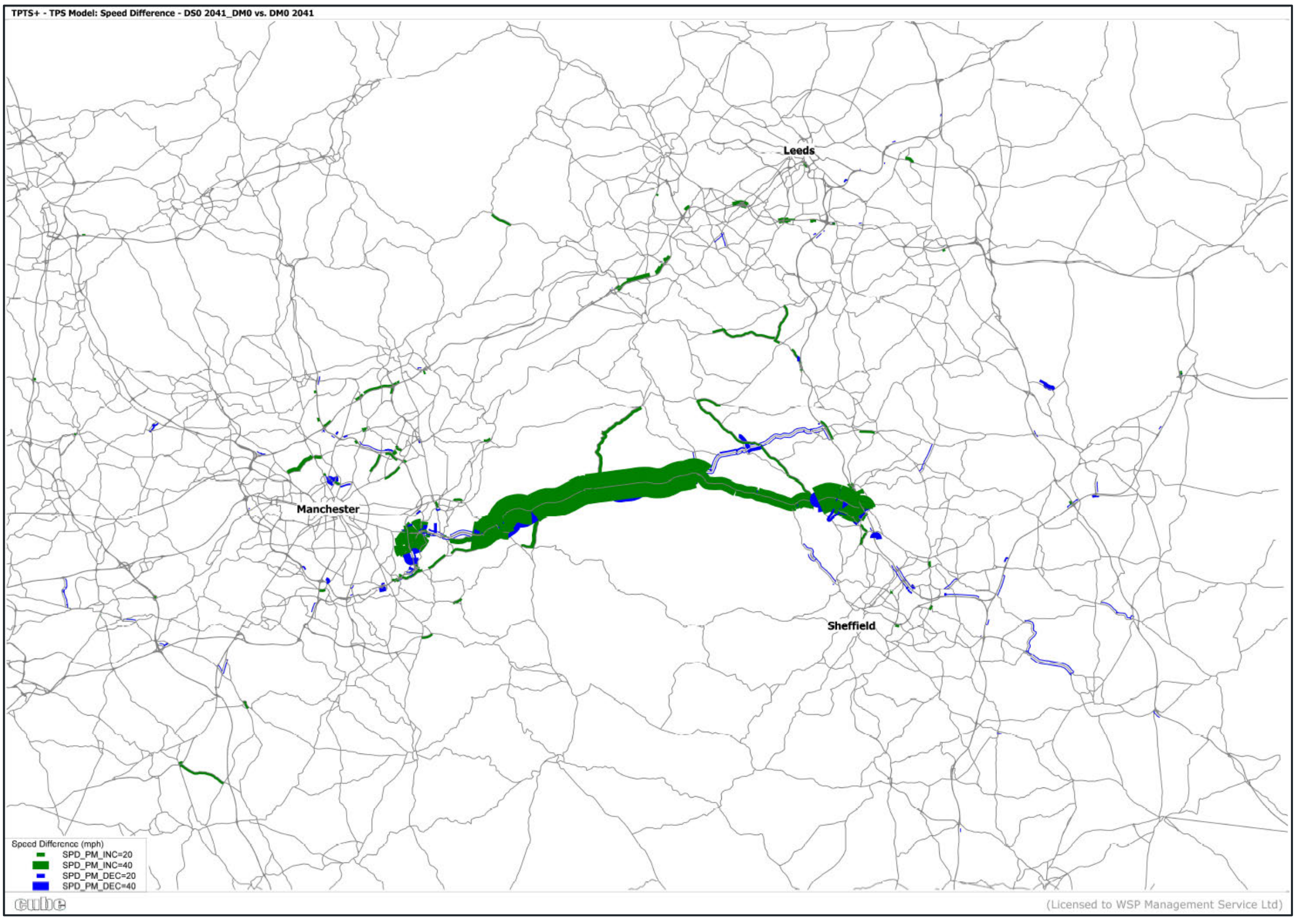
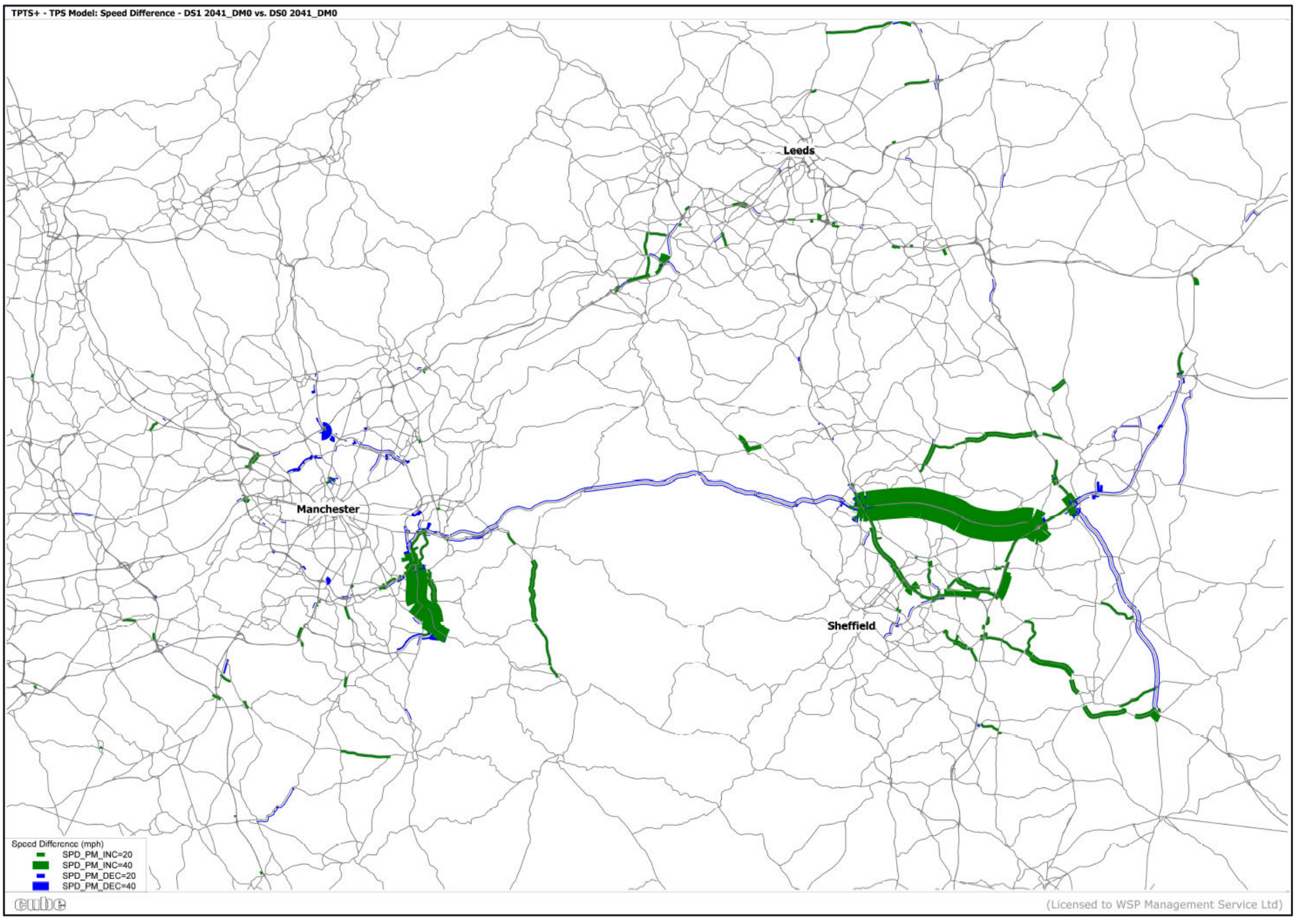


Figure 4-5 Speed Difference - Optimised Package vs. TPTS Only (PM Peak)



4.2.12 It can be seen from **Figure 4-4** and **Figure 4-5** that the TPTS Only and Optimised Package both provide significant improvement in travel speed along the scheme interventions:

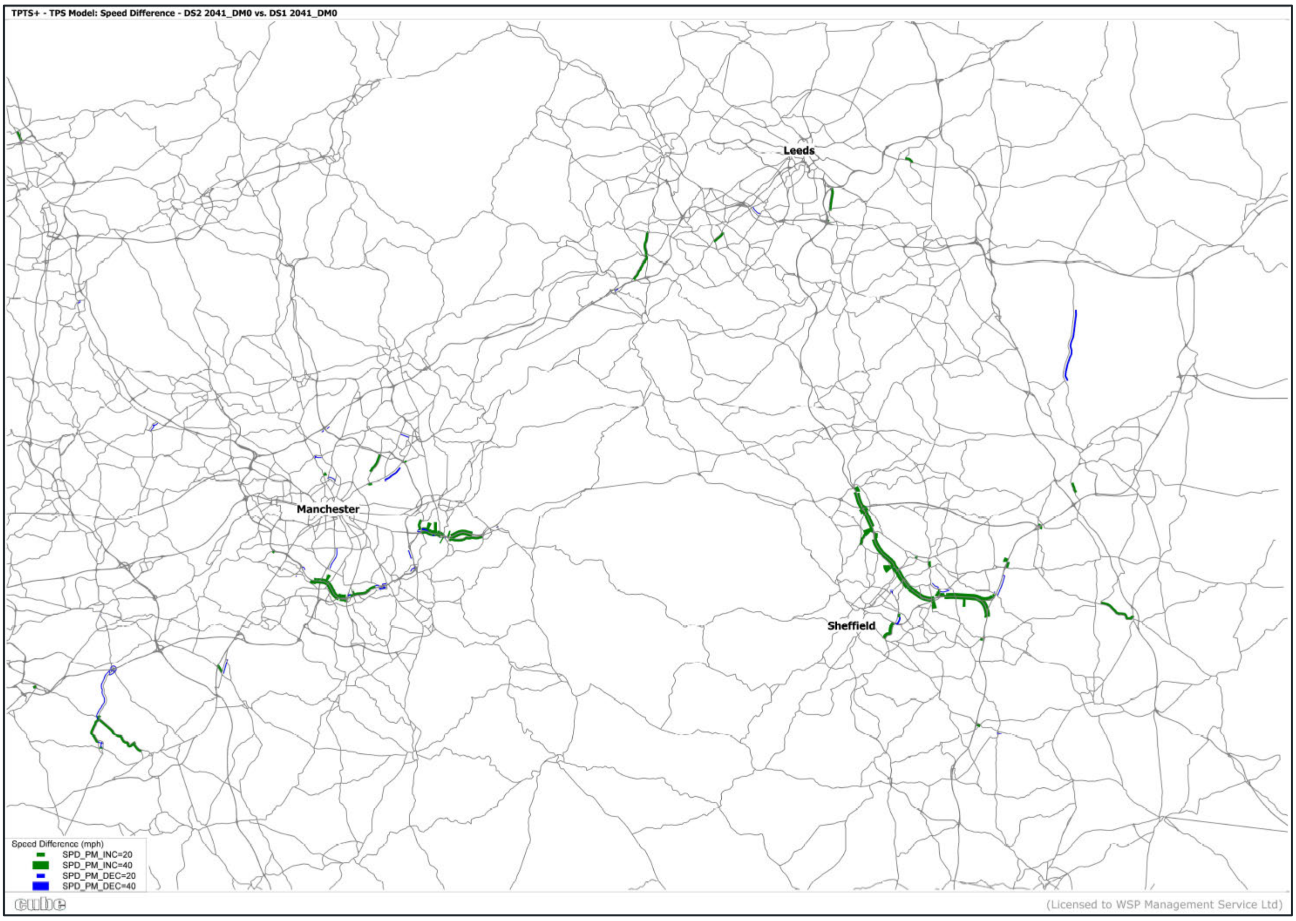
- Significant improvement in travel speed along the Pennines as a result of TPTS interventions;
- Improvements in travel speed on M60 J24-J24a as a result of the Denton bypass;

4.2.13 In addition to the TPTS Only package, the Optimised Package also offers:

- Further improvement on M60 J24a-J25 travel speed as a result of the M60 J24a-J25 capacity enhancements;
- Improvements in travel speed in Stockport areas due to A6-M60 schemes;
- On the eastern side, M1-M18 link would result in improvement in travel speed on the existing M1 J32-J35a and M18 J1-J2;

4.2.14 It is noted that the Optimised Package would however result in a reduction of travel speed for the TPT tunnel and A1(M) south of M18 compared to the TPTS Only. This is expected due to the increase in traffic volume on these two links as a result of the increase on the M1-M18 link in the Optimised Package from the TPTS Only.

Figure 4-6 Speed Difference - Full Package vs. Optimised Package (PM Peak)



4.2.15 It can be seen that additional interventions in the Full Package only offer marginal improvements in travel speed on the M60 and M67 on the Manchester side, and on the M1 J32-J25 in the Sheffield area. These results reinforce the conclusion that the Full Package would be not likely to produce significantly larger benefits than the Optimised Package.

USER BENEFITS

4.2.16 As part of informing the Optimised Package, a TUBA assessment was carried out for the three test packages (TPTS Only, Optimised Package, and the Full Package) against the Do-Minimum.

4.2.17 **Table 4-1** below provides a summary of the TUBA user-benefits for the three test packages.

Table 4-1 TUBA Summary - Test Packages (£000s)

Package	TPTS Only	Optimised Package	Full Package
Consumer User (Commute)	282,666	808,966	869,771
Consumer User (Other)	392,800	963,257	1,046,413
Business User and Provider	1,616,573	3,818,502	4,154,606
Private sector provider / other business Impacts	-1,779	-5,480	-5,718
Indirect Tax Revenue	148,513	161,305	170,762

Package	TPTS Only	Optimised Package	Full Package
Greenhouse Gas	-89,737	-64,426	-77,127
Total	**2,349,035**	**5,682,124**	**6,158,707**

4.2.18 It can be seen from **Table 4-1** that the Optimised Package would produce significantly larger benefits compared to the TPTS Only, by about £3.4bn. On the contrary, the Full Package only produces marginally larger benefits compared to the Optimised Package, about £0.4bn higher.

4.2.19 It should be noted that the TUBA assessment on the three test packages was based on the 'Fixed demand' assignment approach and therefore would potentially overestimate the user benefits of the interventions. The application of the VDM would be likely to reduce the benefits of the interventions, particularly for the Optimised Package and the Full Package since the fixed demand assignments and appraisals were based on the post-VDM demand matrices produced for the Do-Minimum.

4.2.20 The outputs from the TUBA benefits assessment verifies the conclusion that the Full Package would only offer marginally larger benefits compared to the Optimised Package.

4.3 SUMMARY

4.3.1 The test packages, namely the TPTS Only, the Optimised Package and the Full Package were used for the purpose of informing the Optimised Package that was then used for the modelling and appraisal of the TPTS+ study.

4.3.2 As agreed with DfT and Highways England, the fixed demand approach was used for both modelling and appraisal of the test packages to help inform the Optimised Package.

4.3.3 The modelling and appraisal outputs from the test packages show that whilst the Optimised Package would offer a significant change in traffic volume, traffic rerouting on the network, and a significant increase in user benefits compared to the TPTS Only, the Full Package only offers a marginal change in traffic volume and marginal increase in user benefits compared to the Optimised Package.

4.3.4 Following discussion with DfT and Highways England, it was agreed that the Optimised Package was to be taken forward for as the 'Optimised Package' for the modelling and appraisal of the TPTS+ study.

4.3.5 Prior to carrying out the VDM for the Optimised Package, an adjustment (i.e. revision of signal timing on signalised roundabouts) was made at the M60 J24 to account for a change in traffic as a result of the Denton Bypass.

5 VARIABLE DEMAND MODELLING

5.1 OVERVIEW

5.1.1 As stated in the ASR, the Variable Demand modelling is required for the purpose of the modelling and appraisal of the TPTS+ study. The structure of the VDM process and input parameters required for the VDM is provided in **Sections 2.2** and **3.6** of this document. This chapter provides a summary of the additional inputs, modelling outputs and result analyses from the VDM models, as outlined below:

- Forecast Generalised Cost parameters for Highways and VDM models;
- VDM and highways assignment convergence statistics; and
- Impacts on VDM on matrix totals and network flows.

5.1.2 This chapter provides a summary of the VDM modelling outputs for Do-Minimum, TPTS Only and the Optimised Package and the impacts of VDM on the Do-minimum models, in terms of demand changes at matrix total and at sectoral level, and change in trip-length distributions etc.

5.1.3 The following sections describe each of the elements in more detail.

5.2 GENERALISED COSTS

5.2.1 As stated in **Section 3.2**, the generalised costs for Value of Time (VoT) and Vehicle Operating costs (VoC) were obtained from the TAG DataBook May 2018 values for both 2031 and 2041, as provided by the TPS RTM maintenance consultant. **Table 5-1** below provides summary of the VoT and VoC parameters for the forecast VDM model and for the SATURN highway assignments.

Table 5-1 Generalised Cost Parameters

User Class	Highway Assignments						Variable Demand Model		
	AM Peak		Inter-Peak		PM Peak		Highways		PT
	PPM	PPK	PPM	PPK	PPM	PPK	VoT	VoC	VoT
Opening Year 2031									
Business	36.65	11.24	37.56	11.24	37.18	11.24	2234.7	11.24	3208.0
Commute	24.58	5.44	24.98	5.44	24.66	5.44	1484.8	5.44	1302.0
Other	16.96	5.44	18.06	5.44	17.76	5.44	1064.3	5.44	594.0
LGV	25.91	13.58	25.91	13.58	25.91	13.58	NA	NA	NA
HGV	60.49	54.08	60.49	54.08	60.49	54.08	NA	NA	NA
Design Year 2041									
Business	44.39	10.72	45.49	10.72	45.03	10.72	2706.5	10.72	3886.0
Commute	29.77	5.27	30.25	5.27	29.87	5.27	1798.3	5.27	1577.0
Other	20.54	5.27	21.88	5.27	21.51	5.27	1289.0	5.27	720.0
LGV	31.81	13.16	31.38	13.16	31.38	13.16	NA	NA	NA
HGV	73.26	55.94	73.26	55.94	73.26	55.94	NA	NA	NA

Note: PPM – Pence Per Minute

PPK – Pence Per Kilometre

5.3 MODEL CONVERGENCE

5.3.1 The VDM convergence statistics for the Opening Year 2031 and Design Year 2041 Do-Minimum, the TPTS Only and the Optimised Package models are shown in **Table 5-2** below.

Table 5-2 VDM Convergence Statistics

Scenario	Iteration	Full Model Gap (%)	Subset-Area Gap (%)
Do-Min 2031	9	0.05%	0.21%
TPTS Only 2031	8	0.05%	0.22%
Optimised Packages 2031	10	0.05%	0.22%
Do-Min 2041	8	0.08%	0.34%
TPTS Only 2041	8	0.07%	0.31%
Optimised Packages 2041	6	0.09%	0.36%

5.3.2 It should be noted that the 'subset-area' gap criteria were not met for all the VDM model runs, particularly for the 2041 VDM forecast models, where the convergence gap for the sub-area was in excess of 0.30%. In order to address this, the VDM outputs in which the best convergence gaps were achieved on both 'full model' and 'sub-area' were selected as the final outputs for the modelling and appraisal purpose.

5.3.3 To ensure the modelling outputs from the best 'gap' VDM loops are still be able to produce robust economic appraisal for the TPTS+ study, TUBA analyses were carried out for the loop 10 of the VDM models and compared with the TUBA outputs from the best gaps demand to evaluate the TUBA benefits. The analysis shows that the difference in terms of TUBA benefits between the 'best gap' and the loop 10 VDM loop are about 4% of the 'best gap' TUBA benefits over 60-year appraisal period (as shown in **Table 5-3** below).

Table 5-3 Impacts of Non-Converged VDM on TUBA Benefits (£000s)

VDM Loop	Best Gap	Loop 10	%Difference
Consumer User (Commute)	531,941	516,695	-3%
Consumer User (Other)	619,692	506,112	-18%
Business User and Provider	3,014,825	2,973,863	-1%
Private sector provider (Toll revenues)	-4,395	-3,449	-22%
Indirect Tax Revenue	381,819	392,567	3%
Greenhouse Gas	-227,459	-237,171	4%
Total	**4,316,423**	**4,148,617**	-4%

5.3.4 It was discussed with TAG and agreed that the change in TUBA benefits are small and therefore the 'best gap' VDM loop model outputs were deemed acceptable for the purpose of the modelling and appraisal of the TPTS+ study at this stage.

5.3.5 The Post-VDM highway assignment convergence statistics for the Opening Year 2031 and Design Year 2041 Do-Minimum and Do-Something models are shown in **Table 5-4** below.

Table 5-4 Highway Assignment Convergence Statistics (Post-VDM)

Period	Scenario	Loops	Delta	% Flow	% Gap
Opening Year 2031					
AM Peak	Do-Minimum	41	0.0110	97.8	0.0100
	TPTS Only	55	0.0103	97.7	0.0120
	Optimised Package	53	0.0113	98.3	0.0110
Inter-Peak	Do-Minimum	62	0.0063	99.1	0.0067
	TPTS Only	64	0.0059	98.8	0.0160
	Optimised Package	57	0.0050	99.0	0.0049
PM Peak	Do-Minimum	94	0.0117	97.9	0.0160
	TPTS Only	84	0.0105	97.9	0.0140
	Optimised Package	78	0.0103	98.5	0.0130
Design Year 2041					
AM Peak	Do-Minimum	64	0.0131	98.7	0.0079
	TPTS Only	37	0.0126	97.7	0.0120
	Optimised Package	53	0.0143	98.7	0.0094
Inter-Peak	Do-Minimum	91	0.0069	98.6	0.0079
	TPTS Only	104	0.0063	99.2	0.0063
	Optimised Package	83	0.0072	99.0	0.0075
PM Peak	Do-Minimum	120	0.0123	97.1	0.0180
	TPTS Only	89	0.0144	97.9	0.0240
	Optimised Package	95	0.0147	97.5	0.0100

5.3.6 The table shows that the SATURN assignments converged for all of the modelled periods in the 2031 and 2041 Do-Minimum and Do-Something models, with exception of the PM Peak Do-Minimum 2041 model. Analysis shows that whilst the model did not converge to the targeted %flow criterion, it did however converge to the targeted %gap criterion and the %flow was close to the targeted value of 97.5% and therefore considered acceptable for the appraisal purpose given the current stage of the project.

5.4 IMPACT OF VARIABLE DEMAND MODEL

5.4.1 This section provides a summary of the impacts of the VDM on to the forecast models, in terms of changes in demand totals and traffic flow differences on the networks for the Do-Minimum forecast models.

DEMAND SUMMARY

5.4.2 **Table 5-5** to **Table 5-7** show the impacts of VDM on change in demand by hierarchy (mode choice, time choice and destination choice) in response to change in travel costs for the Do-Minimum, TPTS Only and the Optimised Package 2041 respectively.

5.4.3 It should be noted that the reference demand refers to either 'Fixed demand' or pre-VDM matrix totals and are provided in earlier in **Section 3.5** of this document.

5.4.4 It is also noted that special trip generators (e.g. airport/seaport trips) and freight (LGV and HGV) are assumed not to be subject to VDM impacts and therefore not reported here.

Table 5-5 Impact of VDM on Demand Changes – Do-Minimum 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Reference Demand								
AM Peak	1,266,425	7,115,329	7,967,726	**16,349,481**	147,552	748,961	215,273	**1,111,786**
Inter-Peak	2,322,985	6,913,195	20,066,673	**29,302,852**	103,255	98,972	352,932	**555,159**
PM Peak	1,283,365	7,200,327	11,199,745	**19,683,437**	137,878	775,738	235,340	**1,148,956**
Off-Peak	1,042,930	4,438,938	10,333,761	**15,815,629**	62,131	213,881	117,939	**393,950**
Total	**5,915,705**	**25,667,788**	**49,567,906**	**81,151,399**	**450,816**	**1,837,552**	**921,484**	**3,209,851**
Post-VDM demand								
AM Peak	1,255,744	7,071,401	7,958,372	**16,285,517**	155,315	808,883	232,739	**1,196,938**
Inter-Peak	2,309,851	6,880,404	20,038,639	**29,228,895**	108,826	106,890	382,061	**597,777**
PM Peak	1,271,592	7,152,423	11,172,966	**19,596,981**	145,308	837,803	255,151	**1,238,262**
Off-Peak	1,056,520	4,429,909	10,364,233	**15,850,663**	66,033	230,993	127,876	**424,901**
Total	**5,893,707**	**25,534,137**	**49,534,211**	**80,962,056**	**475,482**	**1,984,568**	**997,828**	**3,457,878**
Change								
AM Peak	-10,682	-43,928	-9,354	**-63,964**	7,763	59,922	17,466	**85,152**
Inter-Peak	-13,133	-32,790	-28,034	**-73,958**	5,570	7,918	29,129	**42,618**
PM Peak	-11,773	-47,904	-26,779	**-86,456**	7,430	62,064	19,811	**89,306**
Off-Peak	13,591	-9,029	30,473	**35,034**	3,902	17,112	9,937	**30,951**
Total	**-21,997**	**-133,651**	**-33,695**	**-189,343**	**24,666**	**147,017**	**76,344**	**248,027**
%Change								
AM Peak	-0.8%	-0.6%	-0.1%	**-0.4%**	5.3%	8.0%	8.1%	**7.7%**
Inter-Peak	-0.6%	-0.5%	-0.1%	**-0.3%**	5.4%	8.0%	8.3%	**7.7%**
PM Peak	-0.9%	-0.7%	-0.2%	**-0.4%**	5.4%	8.0%	8.4%	**7.8%**
Off-Peak	1.3%	-0.2%	0.3%	**0.2%**	6.3%	8.0%	8.4%	**7.9%**
Total	**-0.4%**	**-0.5%**	**-0.1%**	**-0.2%**	**5.5%**	**8.0%**	**8.3%**	**7.7%**

Table 5-6 Impact of VDM on Demand Changes - TPTS Only 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Reference Demand								
AM Peak	1,266,425	7,115,329	7,967,726	**16,349,481**	147,552	748,961	215,273	**1,111,786**
Inter-Peak	2,322,985	6,913,195	20,066,673	**29,302,852**	103,255	98,972	352,932	**555,159**
PM Peak	1,283,365	7,200,327	11,199,745	**19,683,437**	137,878	775,738	235,340	**1,148,956**
Off-Peak	1,042,930	4,438,938	10,333,761	**15,815,629**	62,131	213,881	117,939	**393,950**
Total	**5,915,705**	**25,667,788**	**49,567,906**	**81,151,399**	**450,816**	**1,837,552**	**921,484**	**3,209,851**
Post-VDM demand								
AM Peak	1,255,863	7,071,637	7,958,561	**16,286,062**	155,190	808,775	232,704	**1,196,670**
Inter-Peak	2,309,864	6,880,406	20,038,478	**29,228,749**	108,736	106,876	382,007	**597,618**
PM Peak	1,271,559	7,152,605	11,173,872	**19,598,036**	145,193	837,691	255,116	**1,238,000**
Off-Peak	1,056,765	4,429,730	10,363,386	**15,849,880**	65,978	230,962	127,857	**424,797**
Total	**5,894,051**	**25,534,378**	**49,534,298**	**80,962,727**	**475,098**	**1,984,304**	**997,684**	**3,457,085**
Change								
AM Peak	-10,562	-43,692	-9,165	**-63,419**	7,638	59,814	17,431	**84,884**
Inter-Peak	-13,120	-32,788	-28,195	**-74,104**	5,480	7,904	29,074	**42,459**
PM Peak	-11,806	-47,722	-25,873	**-85,401**	7,315	61,953	19,776	**89,044**
Off-Peak	13,835	-9,209	29,625	**34,252**	3,847	17,081	9,918	**30,847**
Total	**-21,654**	**-133,411**	**-33,608**	**-188,672**	**24,282**	**146,752**	**76,200**	**247,234**
%Change								
AM Peak	-0.8%	-0.6%	-0.1%	**-0.4%**	5.2%	8.0%	8.1%	**7.6%**
Inter-Peak	-0.6%	-0.5%	-0.1%	**-0.3%**	5.3%	8.0%	8.2%	**7.6%**
PM Peak	-0.9%	-0.7%	-0.2%	**-0.4%**	5.3%	8.0%	8.4%	**7.7%**
Off-Peak	1.3%	-0.2%	0.3%	**0.2%**	6.2%	8.0%	8.4%	**7.8%**
Total	**-0.4%**	**-0.5%**	**-0.1%**	**-0.2%**	**5.4%**	**8.0%**	**8.3%**	**7.7%**

Table 5-7 Impact of VDM on Demand Changes - Optimised Package 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Reference Demand								
AM Peak	1,266,425	7,115,329	7,967,726	**16,349,481**	147,552	748,961	215,273	**1,111,786**
Inter-Peak	2,322,985	6,913,195	20,066,673	**29,302,852**	103,255	98,972	352,932	**555,159**
PM Peak	1,283,365	7,200,327	11,199,745	**19,683,437**	137,878	775,738	235,340	**1,148,956**
Off-Peak	1,042,930	4,438,938	10,333,761	**15,815,629**	62,131	213,881	117,939	**393,950**
Total	**5,915,705**	**25,667,788**	**49,567,906**	**81,151,399**	**450,816**	**1,837,552**	**921,484**	**3,209,851**
Post-VDM demand								
AM Peak	1,256,297	7,072,013	7,959,302	**16,287,612**	155,114	808,731	232,683	**1,196,529**
Inter-Peak	2,309,793	6,880,032	20,037,318	**29,227,143**	108,681	106,870	381,973	**597,524**
PM Peak	1,271,711	7,152,965	11,174,691	**19,599,367**	145,123	837,645	255,095	**1,237,863**
Off-Peak	1,056,459	4,429,467	10,363,037	**15,848,963**	65,944	230,949	127,846	**424,740**
Total	**5,894,261**	**25,534,476**	**49,534,348**	**80,963,085**	**474,863**	**1,984,195**	**997,598**	**3,456,656**
Change								
AM Peak	-10,128	-43,316	-8,425	**-61,869**	7,562	59,770	17,410	**84,743**
Inter-Peak	-13,191	-33,163	-29,356	**-75,710**	5,426	7,898	29,041	**42,365**
PM Peak	-11,654	-47,362	-25,054	**-84,070**	7,245	61,907	19,755	**88,907**
Off-Peak	13,529	-9,471	29,276	**33,335**	3,814	17,068	9,907	**30,790**
Total	**-21,444**	**-133,312**	**-33,558**	**-188,314**	**24,047**	**146,643**	**76,114**	**246,805**
%Change								
AM Peak	-0.8%	-0.6%	-0.1%	**-0.4%**	5.1%	8.0%	8.1%	**7.6%**
Inter-Peak	-0.6%	-0.5%	-0.1%	**-0.3%**	5.3%	8.0%	8.2%	**7.6%**
PM Peak	-0.9%	-0.7%	-0.2%	**-0.4%**	5.3%	8.0%	8.4%	**7.7%**
Off-Peak	1.3%	-0.2%	0.3%	**0.2%**	6.1%	8.0%	8.4%	**7.8%**
Total	**-0.4%**	**-0.5%**	**-0.1%**	**-0.2%**	**5.3%**	**8.0%**	**8.3%**	**7.7%**

5.4.5 As stated in **Section 2.2** of this document, the TPS RTM model is an incremental PA model which pivots from the base year costs with the following choice response hierarchies:

- Macro time of day choice: travel choice between different time period of a day;
- Mode choice: choice between car and public transport; and
- Destination choice: choice between different destinations.

5.4.6 The results from the **Table 5-5** to **Table 5-7** demonstrate that:

- Mode choice responses resulted in transferring trips from car to rail across all the purposes and time periods. This is a result of larger increase in car travel costs compared to the increase in PT costs in the forecast years.
- Time choice responses resulted in transferring car trips from peak to off-peak periods. This is a result of larger increase in travel costs during the peak hours compared to cost change during the off-peak period. It is also noted that the reduction in the car trips in the AM and PM peak are larger than that in the inter-peak (0.4% reduction in the AM and PM compared to 0.3% reduction in the

inter-peak). It is deemed plausible given the larger increase in travel costs in the AM and PM peak compared to the inter-peak.

5.4.7 Incremental impact of VDM on change in demand between the Do-Minimum, TPTS Only and the Optimised Package is provided in **Table 5-8** below.

Table 5-8 Incremental Impact of VDM on Demand Changes - 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Do-Minimum VDM								
AM Peak	1,255,744	7,071,401	7,958,372	**16,285,517**	155,315	808,883	232,739	**1,196,938**
Inter-Peak	2,309,851	6,880,404	20,038,639	**29,228,895**	108,826	106,890	382,061	**597,777**
PM Peak	1,271,592	7,152,423	11,172,966	**19,596,981**	145,308	837,803	255,151	**1,238,262**
Off-Peak	1,056,520	4,429,909	10,364,233	**15,850,663**	66,033	230,993	127,876	**424,901**
Total	**5,893,707**	**25,534,137**	**49,534,211**	**80,962,056**	**475,482**	**1,984,568**	**997,828**	**3,457,878**
TPTS Only VDM								
AM Peak	1,255,863	7,071,637	7,958,561	**16,286,062**	155,190	808,775	232,704	**1,196,670**
Inter-Peak	2,309,864	6,880,406	20,038,478	**29,228,749**	108,736	106,876	382,007	**597,618**
PM Peak	1,271,559	7,152,605	11,173,872	**19,598,036**	145,193	837,691	255,116	**1,238,000**
Off-Peak	1,056,765	4,429,730	10,363,386	**15,849,880**	65,978	230,962	127,857	**424,797**
Total	**5,894,051**	**25,534,378**	**49,534,298**	**80,962,727**	**475,098**	**1,984,304**	**997,684**	**3,457,085**
Optimised Package VDM								
AM Peak	1,256,297	7,072,013	7,959,302	**16,287,612**	155,114	808,731	232,683	**1,196,529**
Inter-Peak	2,309,793	6,880,032	20,037,318	**29,227,143**	108,681	106,870	381,973	**597,524**
PM Peak	1,271,711	7,152,965	11,174,691	**19,599,367**	145,123	837,645	255,095	**1,237,863**
Off-Peak	1,056,459	4,429,467	10,363,037	**15,848,963**	65,944	230,949	127,846	**424,740**
Total	**5,894,261**	**25,534,476**	**49,534,348**	**80,963,085**	**474,863**	**1,984,195**	**997,598**	**3,456,656**
TPTS Only vs. Do-Minimum VDM								
AM Peak	120	236	189	**545**	-125	-108	-35	**-268**
Inter-Peak	13	2	-161	**-146**	-90	-14	-55	**-159**
PM Peak	-33	182	906	**1,055**	-115	-112	-35	**-262**
Off-Peak	245	-180	-847	**-783**	-55	-31	-19	**-104**
Total	**344**	**241**	**87**	**671**	**-384**	**-265**	**-144**	**-793**
Optimised Package vs. TPTS Only								
AM Peak	434	376	740	**1,550**	-76	-44	-21	**-141**
Inter-Peak	-71	-375	-1,161	**-1,606**	-55	-6	-33	**-94**
PM Peak	152	360	819	**1,332**	-70	-46	-21	**-137**
Off-Peak	-306	-263	-349	**-917**	-34	-13	-11	**-57**
Total	**210**	**99**	**50**	**358**	**-235**	**-108**	**-86**	**-429**

5.4.8 It can be seen from **Table 5-8** that:

- Mode choice response would result in trips that transferred to the Rail in the Do-Minimum has now switched back to cars due to reduction in car travel costs in the Do-Something compared to the Do-Minimum;
- Time choice responses would result in transferring trips from the inter-peak and off-peak back to the AM and PM periods due to reduction in cost change during the peak periods in the Do-Something compared to the Do-Minimum (i.e. increase in demand in the AM and PM peak and

reduction in Inter-peak and off-peak periods in the Do-Something compared to the Do-Minimum); and

- The Optimised Package would result in a stronger response in demand compared to the TPTS Only due to additional improvements to the network capacity (i.e. WTC schemes).

5.4.9 The impacts of VDM on the demand changes are considered plausible.

EFFECTS OF FITTING-ON FACTORS

5.4.10 It should be noted that prior to the SATURN assignments, a set of adjustment factors, namely 'Fitting-On' factors have been applied to the output OD demand produced from VDM to create a post-VDM matrix to be assigned onto the highway network.

5.4.11 The 'Fitting-On' factors are essentially adjustment factors at individual OD cell levels, by time periods and by user classes that have been calculated during the development of the RTM base year demand model to address the issue with the inconsistency between the PA and OD format.

5.4.12 The application of the 'Fitting-On' factors has resulted in a reduction of matrix totals in the post-VDM demand matrices that have been used for SATURN assignments compared to the OD demand outputs from the VDM.

5.4.13 An example of the effects of the 'Fitting-On' factors is shown in **Table 5-9** below where incremental change between Do-Minimum, TPTS improvement only, and the Optimised Package from the OD matrices for SATURN assignments are produced to compare against **Table 5-8** (demand totals produced directly from the VDM process).

Table 5-9 Effects of 'Fitting-On' Factor - 2041

Period	Car				Change			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Period	**Do-Minimum VDM**							
AM Peak	1,087,760	7,613,034	7,390,589	**16,091,383**				
Inter-Peak	2,291,211	5,798,975	18,777,903	**26,868,089**				
PM Peak	1,140,469	7,166,550	10,551,612	**18,858,632**				
Off-Peak	1,134,335	4,028,112	10,254,768	**15,417,215**				
Total	**5,653,775**	**24,606,671**	**46,974,872**	**77,235,318**				
TPTS Only and Change from Do-Minimum								
AM Peak	1,087,071	7,612,447	7,390,229	**16,089,748**	-689	-587	-359	**-1,635**
Inter-Peak	2,290,642	5,799,120	18,778,584	**26,868,345**	-569	145	680	**256**
PM Peak	1,139,687	7,166,697	10,551,791	**18,858,174**	-782	146	178	**-458**
Off-Peak	1,135,614	4,028,322	10,254,571	**15,418,507**	1,278	211	-197	**1,292**
Total	**5,653,014**	**24,606,586**	**46,975,175**	**77,234,774**	**-761**	**-85**	**302**	**-544**
Optimised Package and Change from TPTS Only								
AM Peak	1,087,419	7,612,684	7,390,534	**16,090,636**	348	236	304	**888**
Inter-Peak	2,290,560	5,799,011	18,778,221	**26,867,793**	-82	-108	-362	**-552**
PM Peak	1,139,439	7,166,484	10,551,758	**18,857,681**	-248	-213	-32	**-493**
Off-Peak	1,135,454	4,028,281	10,254,241	**15,417,976**	-160	-41	-330	**-531**
Total	**5,652,872**	**24,606,460**	**46,974,754**	**77,234,086**	**-142**	**-126**	**-421**	**-688**

5.4.14 It can be seen that the application of the 'Fitting-On' factor results in:

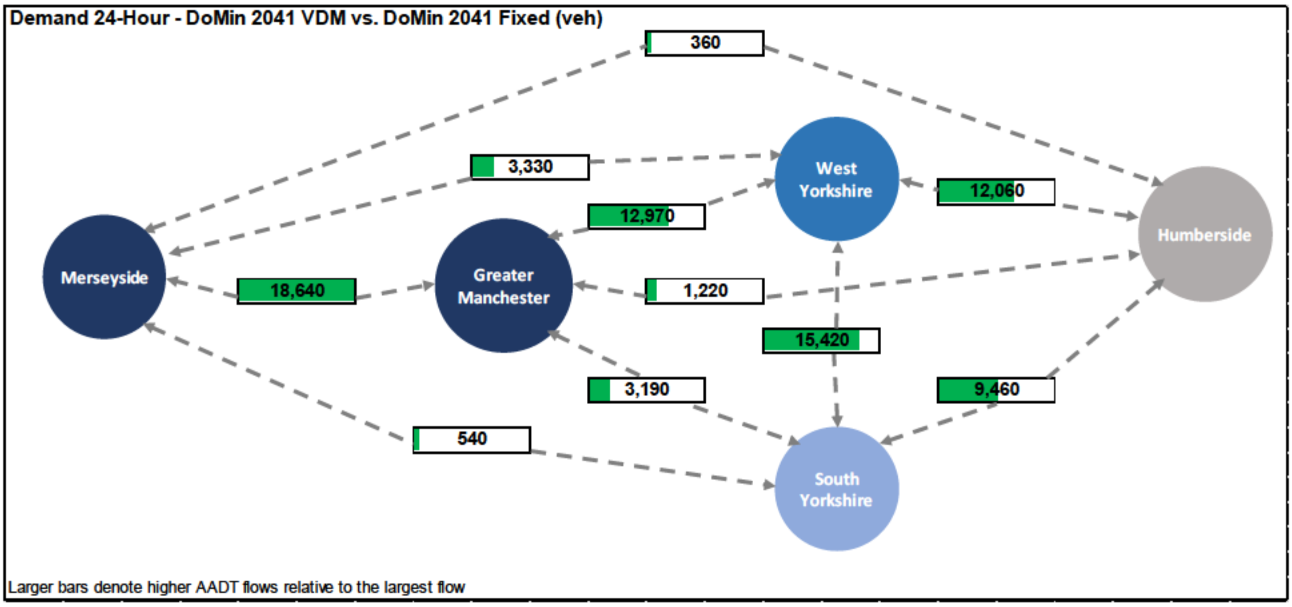
- Reduction in the demand totals in the AM and PM peak periods as opposed to the increase in demand output from the VDM process in the 'TPTS only' package compared to Do-Minimum;
- Reduction in the demand totals in the PM peak period as opposed to increase in demand output from the VDM process in the Optimised Package from the 'TPTS Only' package.

5.4.15 Following discussions with Highways England, it was agreed that the overall change in demand was negligible and therefore would not be an issue for the modelling and appraisal of the TPTS+ study.

DESTINATION CHOICE RESPONSE

5.4.16 Impacts of the destination choice response on demand changes in the Do-Minimum from the Fixed demand, and change in demand in 'TPTS Only' and 'Optimised' packages from the Do-Minimum are illustrated in **Figure 5-1** to **Figure 5-3** below.

Figure 5-1 Impact of Destination Choice on VDM Demand Change - 2041



5.4.17 It can be seen from **Figure 5-1** that the destination choice response mechanism in the VDM would result in a significant shift in distribution of demand on the network, particularly an increase in demand across the major conurbation areas such as between Manchester, Leeds, Humberside, West Yorkshire and South Yorkshire. This is anticipated as a number of RIS1 schemes that were included in the forecast years along M1, M62 etc. would offer journey time improvements along these corridors, thus encouraging more traffic to travel between those areas.

5.4.18 **Figure 5-2** and **Figure 5-3** show the impacts of the TPTS Only and Optimised Package on change in distribution of demand from the Do-Minimum in terms of AADT flows.

Figure 5-2 Impact of Destination Choice on TPTS Only Demand Change - 2041

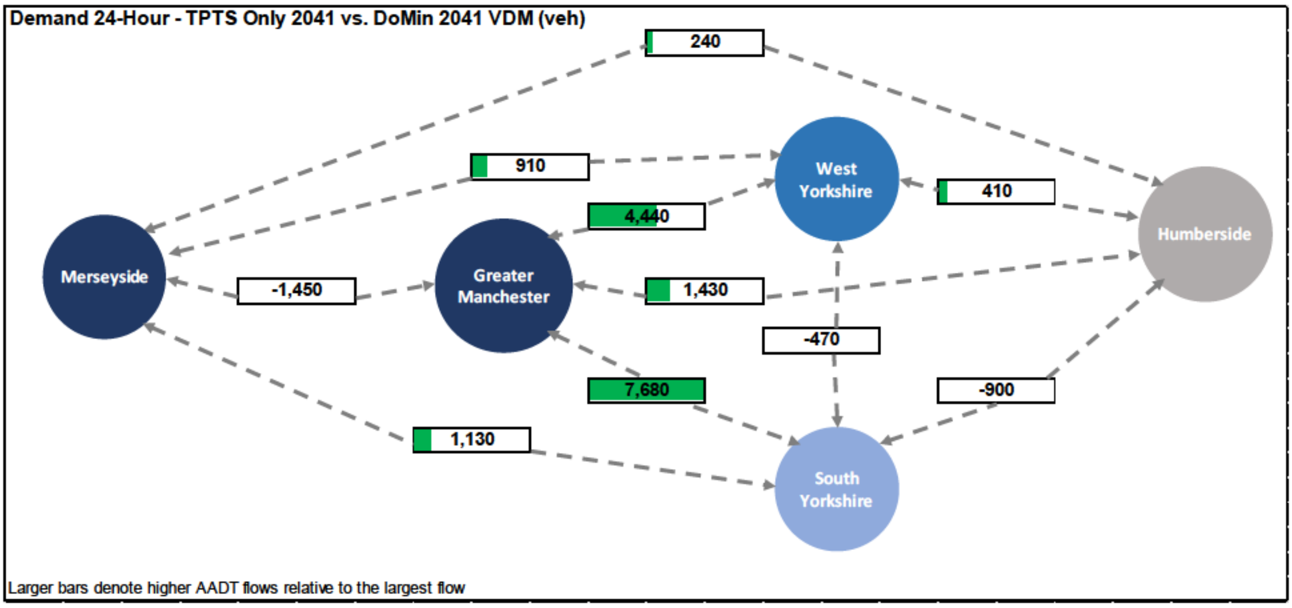
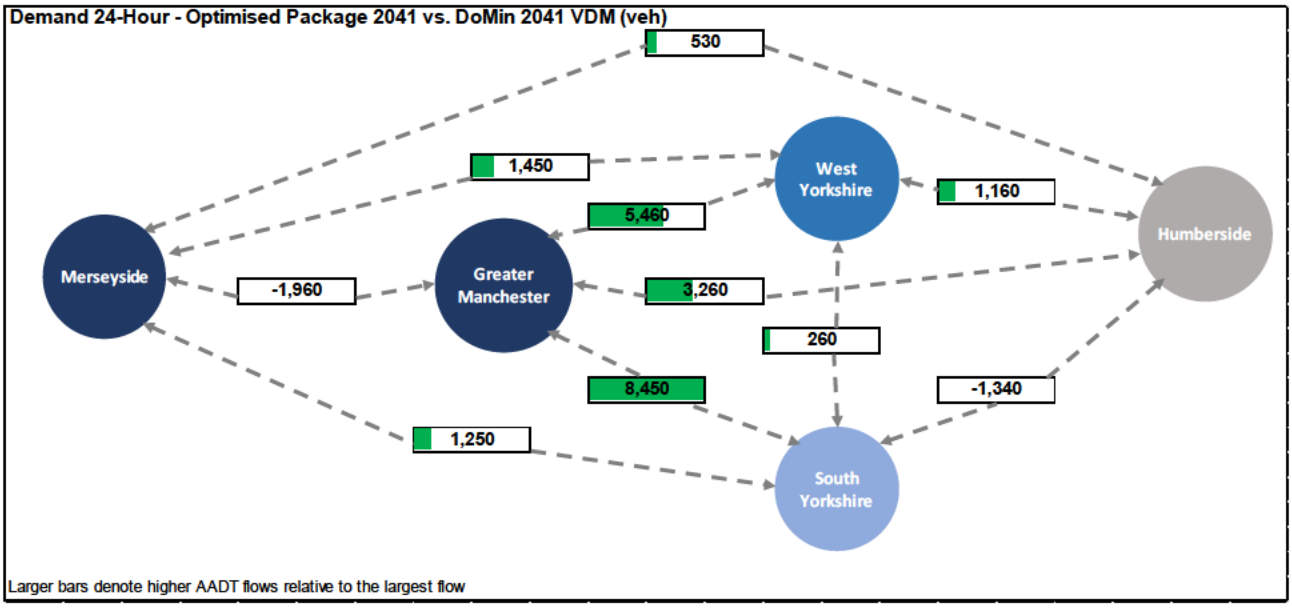


Figure 5-3 Impact Destination Choice on Optimised Package Demand Change - 2041

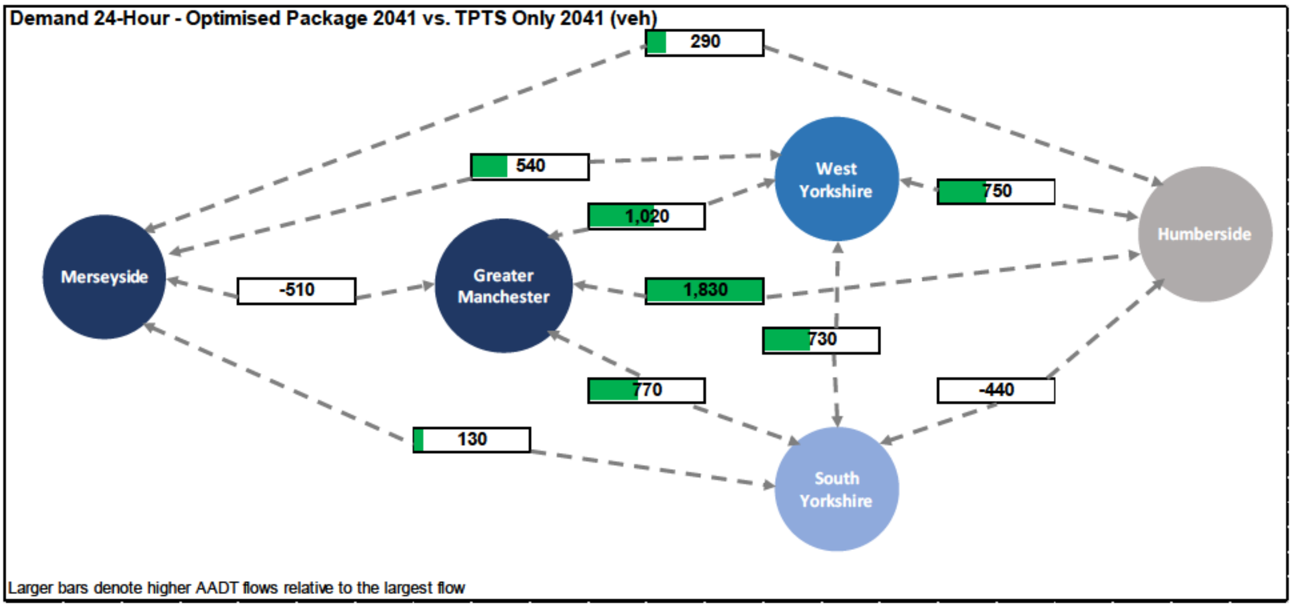


5.4.19 It can be seen that the improvement on the Pennines route would result in additional trip making between Manchester and West Yorkshire/South Yorkshire. The TPTS Only package also create additional trip making between Manchester and Humberside.

5.4.20 Trip making between Liverpool and Manchester however shows reduction, offset by an increase in trips from Liverpool to West and South Yorkshire as a result of the TPTS improvements.

5.4.21 With the Optimised Package in place, the effects of the destination choice mechanism were forecast to be stronger due to additional improvements to the network. As a result, more trip making between Manchester, West Yorkshire, South Yorkshire and Humberside is forecast in the Optimised Package compared to the 'TPTS Only' package, as provided in **Figure 5-4**.

Figure 5-4 Change in Demand: Optimised Package vs. TPTS Only - 2041



5.4.22 The impacts of destination choice on demand change from the Fixed demand to the Do-Minimum and the test packages is considered plausible.

TRIP-LENGTH DISTRIBUTION

5.4.23 The impact of VDM on Trip-Length Distribution (TLD) for each of the Do-Minimum, TPTS Only and the Optimised Package at 12-hour average is provided in **Figure 5-5** to **Figure 5-7** below. It is noted that freight (LGV and HGV) is not subject to VDM therefore the TLD plots are only reported for the three car user classes: Business, Commute, and Other.

Figure 5-5 Impact of VDM on TLD - Business

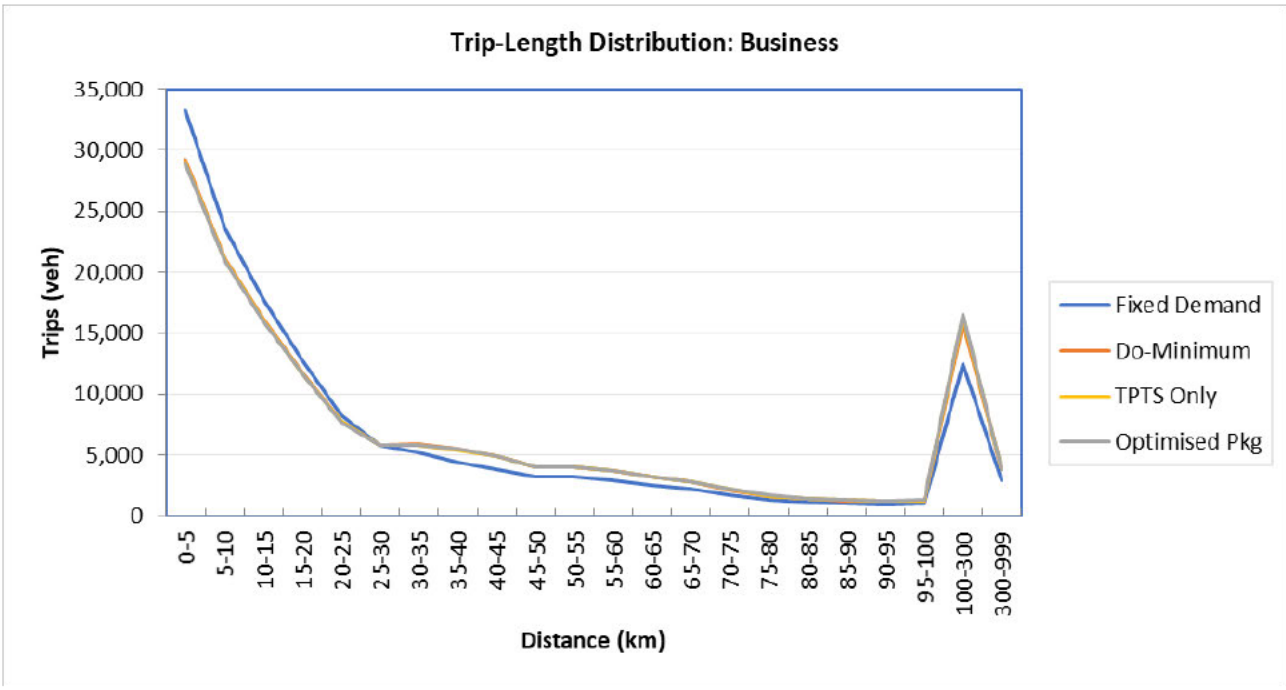


Figure 5-6 Impact of VDM on TLD - Commute

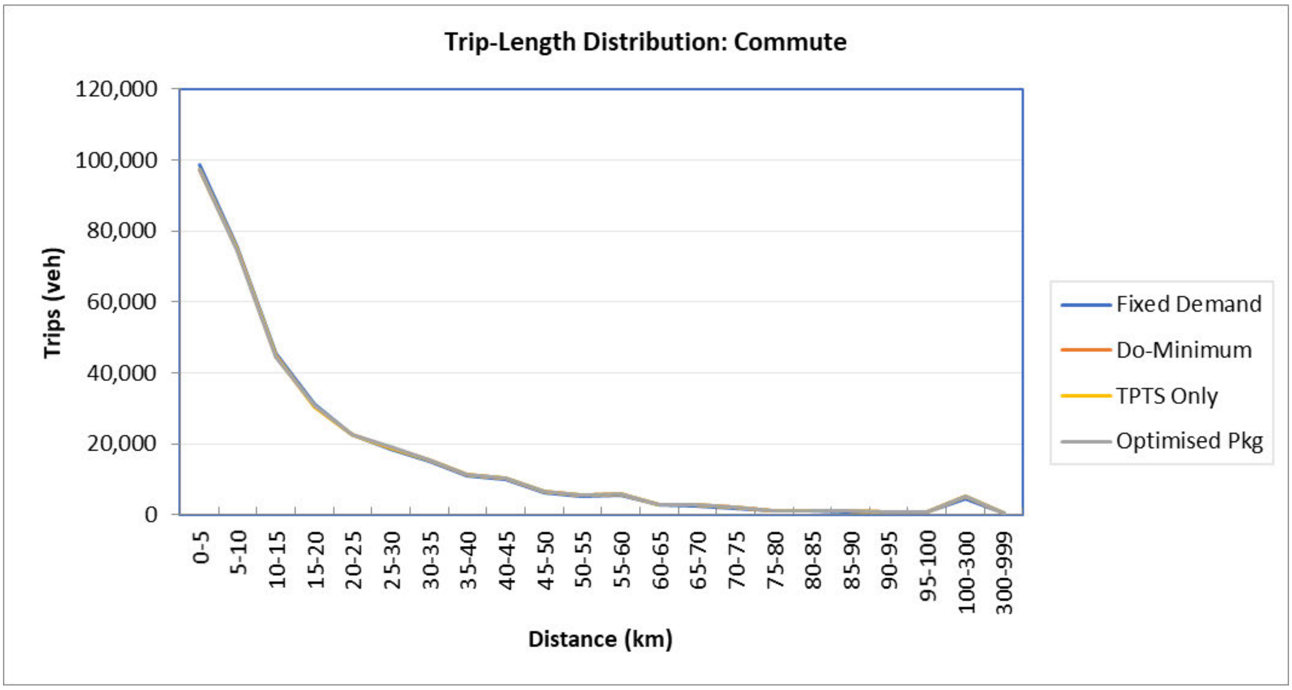
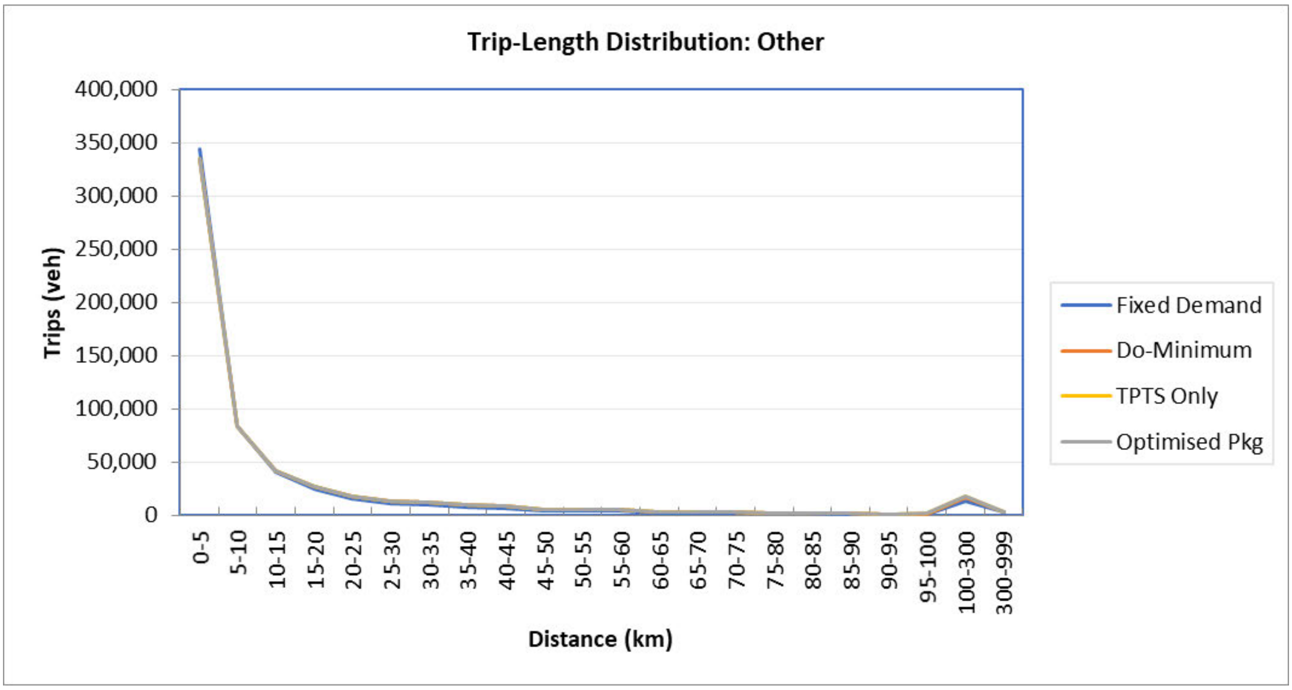


Figure 5-7 Impact of VDM on TLD – Other



5.4.24 It can be seen that the VDM would result in reduction in short distance trips and an increase in long distance trips, more noticeably for business trips. For Commuting and Other, however, the impact of VDM on TLD is minimal with small increase in long distance trips for Other purpose.

5.4.25 The significant increase in long distance business trips would help explain the significant proportion of benefits associated with business trips compared against commute and other as summarised in the next chapter.

5.4.26 Detail of average trip length at the 12-hour average for the Fixed demand, Do-Minimum, TPTS Only and the Optimised Package are provided in **Table 5-10** below, for each of the three purposes: Business, Commuting, and Other.

Table 5-10 Mean Trip Length Summary (km) – 2041

Period	Scenario	Fixed Demand	Do-Minimum	TPTS Only	Optimised Package
AM Peak	Business	41.3	48.2	48.7	49.0
	Commuting	18.4	18.9	18.9	19.0
	Other	16.5	19.5	19.6	19.7
Inter-Peak	Business	38.5	46.1	46.6	47.0
	Commuting	20.0	20.7	20.7	20.8
	Other	13.6	16.0	16.1	16.2
PM Peak	Business	43.7	51.2	51.6	52.0
	Commuting	18.9	19.4	19.5	19.5
	Other	15.0	17.5	17.6	17.8
12-Hour Average	Business	40.4	47.8	48.3	48.7
	Commuting	18.9	19.5	19.6	19.6
	Other	14.4	17.0	17.1	17.2

TRAFFIC VOLUME ON THE NETWORKS

5.4.27 The impact of the VDM on the traffic flows on the Do-Minimum 2041 networks are provided in **Figure 5-8** below where significant increase in traffic volume is shown on the forecast networks, for example:

- 12,000 AADT increase on M62 between Manchester and Leeds;
- 19,000 AADT increase on M1 between Sheffield and Leeds;
- Around 10,000 AADT increase on number of routes crossing the Pennines (A628, A57 etc.); and
- Increase in traffic volume on SRN networks outside the Pennines (M60, M61 and M6 etc.)

5.4.28 The increase in traffic volume on the road networks are explained by the effects of the destination choice within the VDM process where highway interventions in the forecast years would alleviate significant congestions on the network, and as a result in trips that originally travel entirely within a catchment area would now travel further on the network. The increase in the traffic volume on the network verifies the change in trip-length distribution plots that were shown in previous section.

Figure 5-8 Impacts of VDM on Network Flows – DM 2041 (AADT)

5.5 VDM SUMMARY

5.5.1 **Chapter 5** shows the impact that VDM has had on the Do-Minimum, the TPTS Only and the Optimised Package.

5.5.2 In summary, the impact of the VDM on the demand changes are plausible in terms of mode choice, time choice and destination choice in response to change in travel costs between the base year and the forecast years.

5.5.3 It should be noted that the effects of the 'Fitting-On' factors result in slightly counter-intuitive outputs in terms of demand totals compared to the demand output from the VDM process. The change resulted from the 'Fitting-On' factor application however was deemed negligible and therefore considered not affecting the overall outcomes of the modelling and appraisal of the TPTS+ study.

6 URBAN DELAY FUNCTION

6.1 OVERVIEW

6.1.1 As discussed in **Section 3.7** of this document, the Urban Delay Function (UDF) was applied to the post-VDM Do-Minimum and Do-Something forecast assignments to reduce risk of repetitive works whilst offering extra information on the impacts of the Urban Delay function to the flow, speed and consequently the scheme benefits.

6.1.2 This section provides the impacts of the urban delay function on the traffic flows, speed and scheme benefits and the modelling outputs from the post-UDF application.

6.2 MODEL CONVERGENCE

6.2.1 The Post-VDM with UDF highway assignment convergence statistics for the Opening year 2031 and Design year 2041 reference case and SOP models are shown in **Table 6-1** below. This shows that the SATURN assignments converged for all the modelled periods in 2031 forecast models. For the 2041 models, whilst the AM time periods in 2041 converged for both the Do-Minimum and Do-Something models, the Do-Minimum did not converge in the Inter-peak period, and the TPTS Only package did not converge for the Interpeak and PM period to the acceptable %flow criterion.

Table 6-1 Highway Assignment Convergence Statistics (Post-VDM)

Period	Scenario	Loops	Delta	% Flow	% Gap
Opening Year 2031					
AM Peak	Do-Minimum	46	0.0109	98.0	0.0120
	TPTS Only	46	0.0135	98.0	0.0120
	Optimised Package	42	0.0084	97.8	0.0088
Inter-Peak	Do-Minimum	63	0.0050	98.5	0.0053
	TPT Only	61	0.0052	99.1	0.0046
	Optimised Package	60	0.0052	98.8	0.0051
PM Peak	Do-Minimum	66	0.0213	97.7	0.0210
	TPTS Only	65	0.0108	98.0	0.0110
	Optimised Package	68	0.0119	97.9	0.0150
Design Year 2041					
AM Peak	Do-Minimum	43	0.0121	98.0	0.0110
	TPTS Only	53	0.0143	98.2	0.0098
	Optimised Package	50	0.0120	97.6	0.0099
Inter-Peak	Do-Minimum	120	0.0096	97.7	0.0200
	TPTS Only	120	0.0060	98.5	0.0130
	Optimised Package	84	0.0076	98.8	0.0087
PM Peak	Do-Minimum	66	0.0134	97.6	0.0190
	TPTS Only	120	0.0156	97.3	0.0150
	Optimised Package	111	0.0126	98.5	0.0079

6.2.2 Analysis shows that whilst the model did not converge to the targeted %flow criterion, it did however converge to the targeted %gap criterion and the %flow was close to the targeted value of 97.5% and therefore this is considered acceptable for the appraisal purpose given the current stage of the project.

6.3 IMPACT OF THE URBAN DELAY FUNCTION

6.3.1 This section provides a summary of the impact of the Urban Delay Function on the forecast models, in terms of flow and speed difference.

NETWORK PLOTS

6.3.2 **Figure 6-1** and **Figure 6-2** below show the impact of the UDF application to the Do-Minimum 2041 models in terms of flow and speed difference.

Figure 6-1 Flow Difference - 'With' and 'Without' Urban Delay Function (AADT)

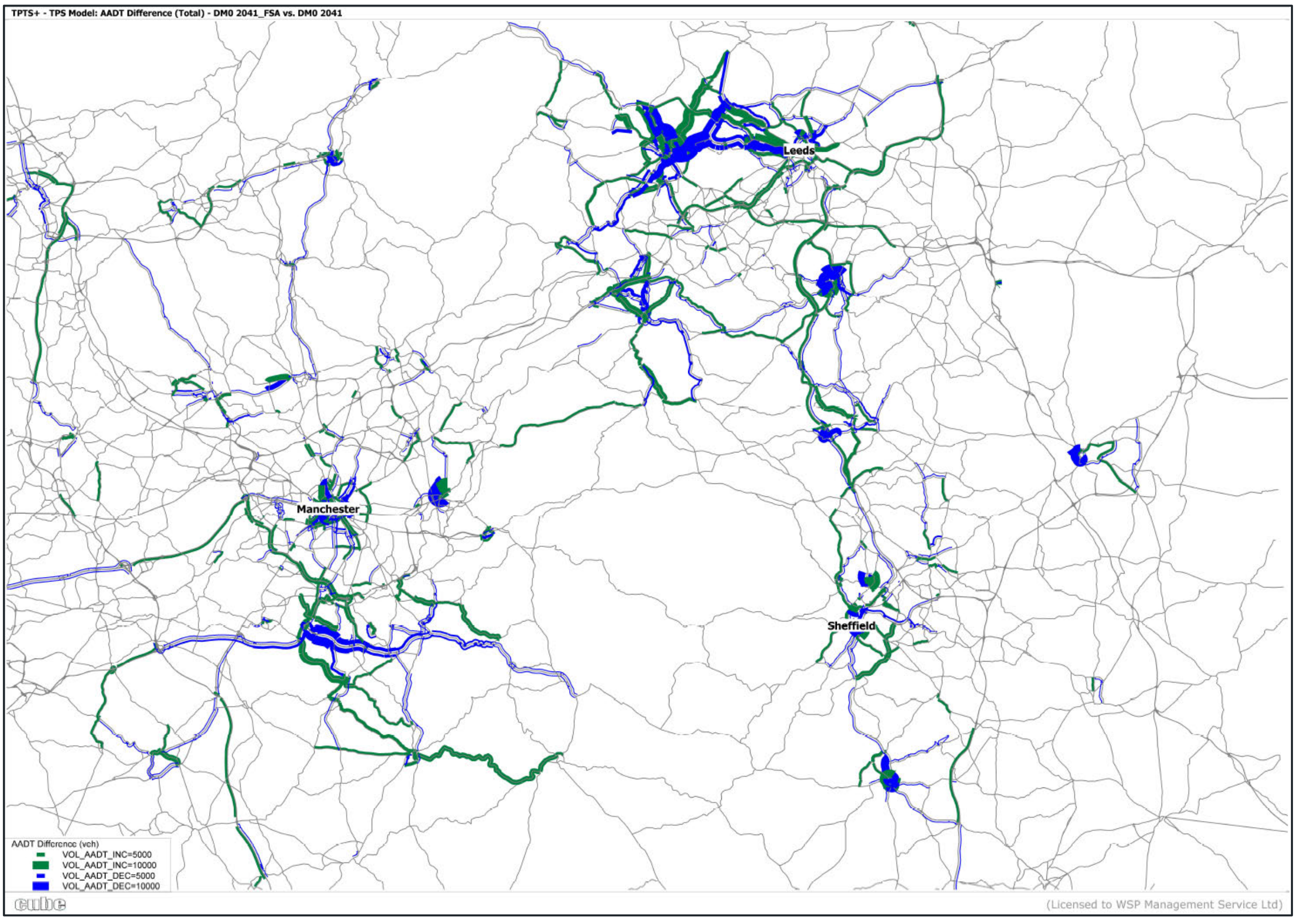
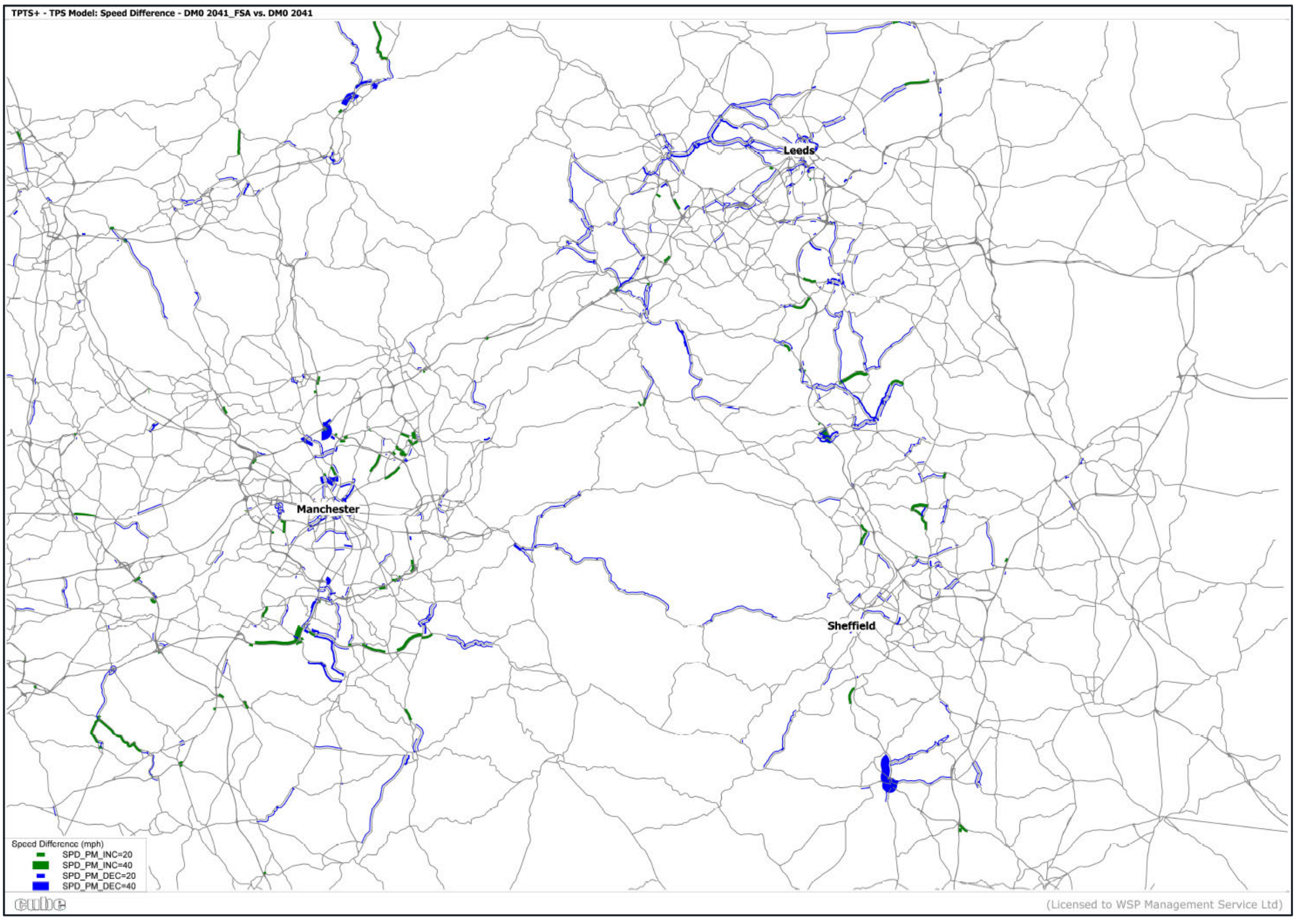


Figure 6-2 Speed Difference – 'With' vs. 'Without' Urban Delay Function (PM Peak 2041)



6.3.3 It can be seen from **Figure 6-1** and **Figure 6-2** that the UDF application would result in changes in flow and speed in the urban areas such as Manchester, Leeds, and Sheffield urban areas where the fixed speed adjustment was applied, whilst showing minimal impacts on flow and speed for rural areas where UDF was not applied, for example, on the routes crossing the Pennines.

6.3.4 The impact of the UDF application can be seen clearly on the speed difference plot where increase in traffic volume in the forecast models with respect to the base year flow would result in reduction in travel speed within the urban areas. The reduction of speed in urban areas would consequently result in reduction in traffic volume in the post-UDF model compared to the VDM outputs.

6.3.5 The application of the UDF were implemented to both Do-Minimum and the test packages it is therefore expected that the change in flow between the respective test package and the Do-Minimum are similar for the 'with' and 'without' the UDF application.

6.3.6 **Figure 6-3** and **Figure 6-4** provide an example of the network difference plots between the TPTS Only and Do-minimum for the 'with' and 'without' the UDF application.

Figure 6-3 Flow Difference - w/o UDF Application

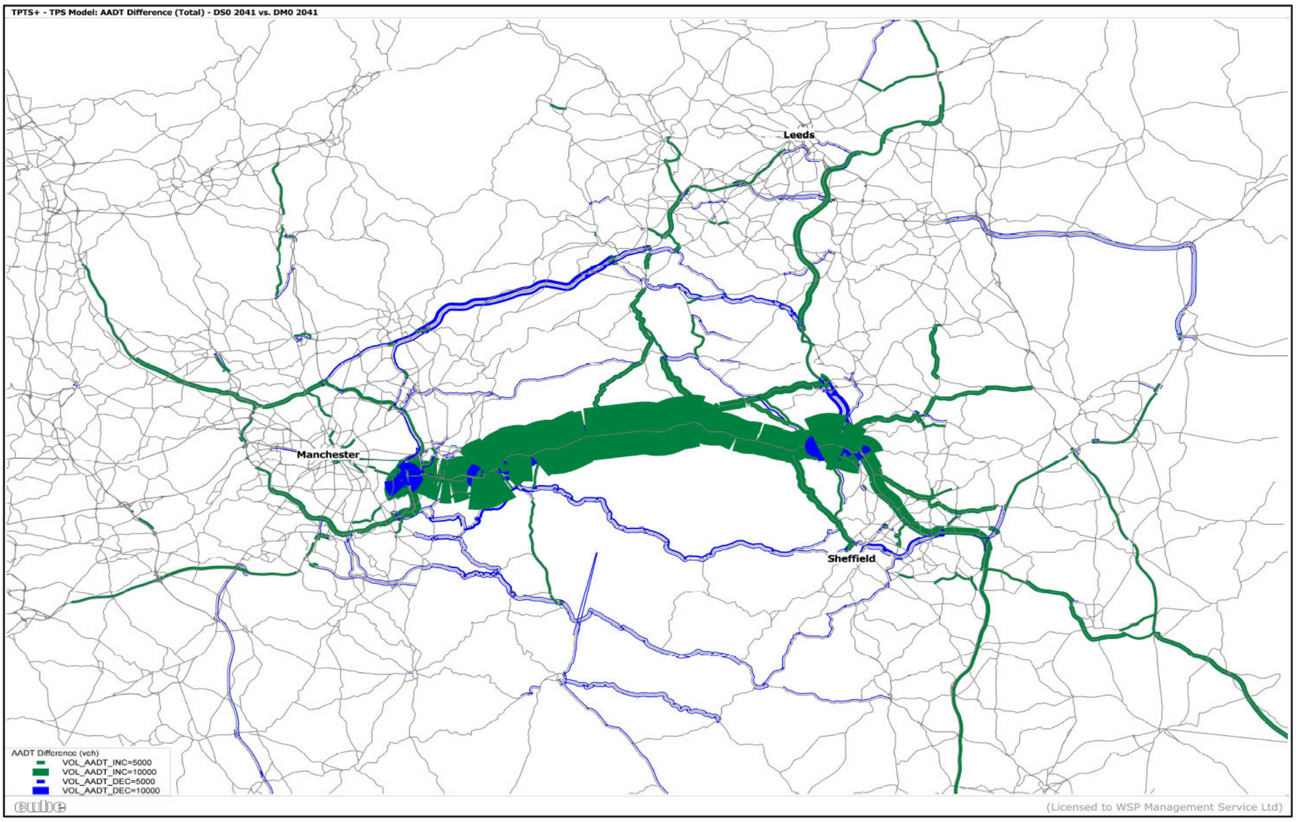
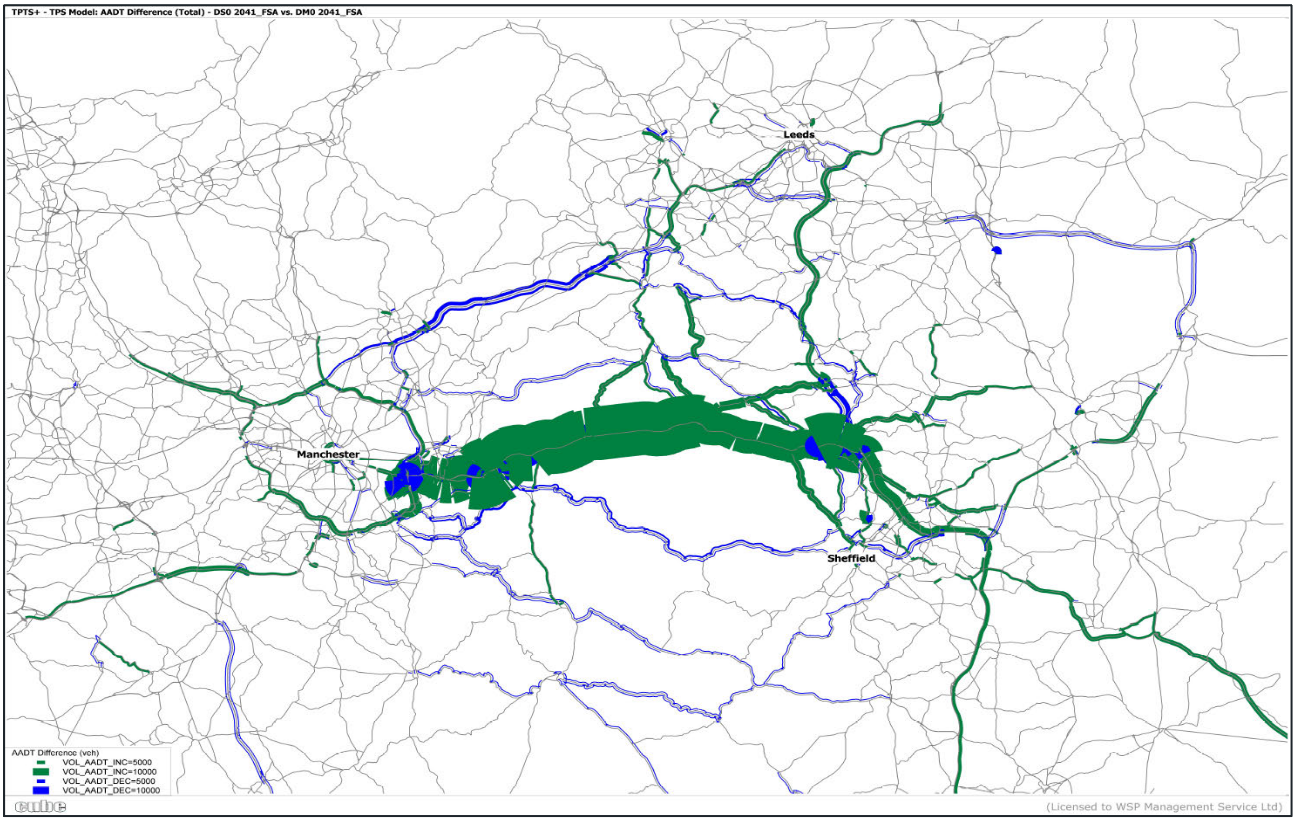


Figure 6-4 Flow Difference - with UDF Application



6.3.7 It can be seen the difference in terms of flows are similar between the 'with' and 'without' the UDF application. It is concluded that the application of the UDF, whilst addressing the issues with the fixed speed coding in urban areas, does not change the overall difference between Do-Minimum and Do-Something. Similar finding was found on the flow difference between the Optimised Package and Do-Minimum for the 'with' and 'without' UDF application.

TUBA USER BENEFITS

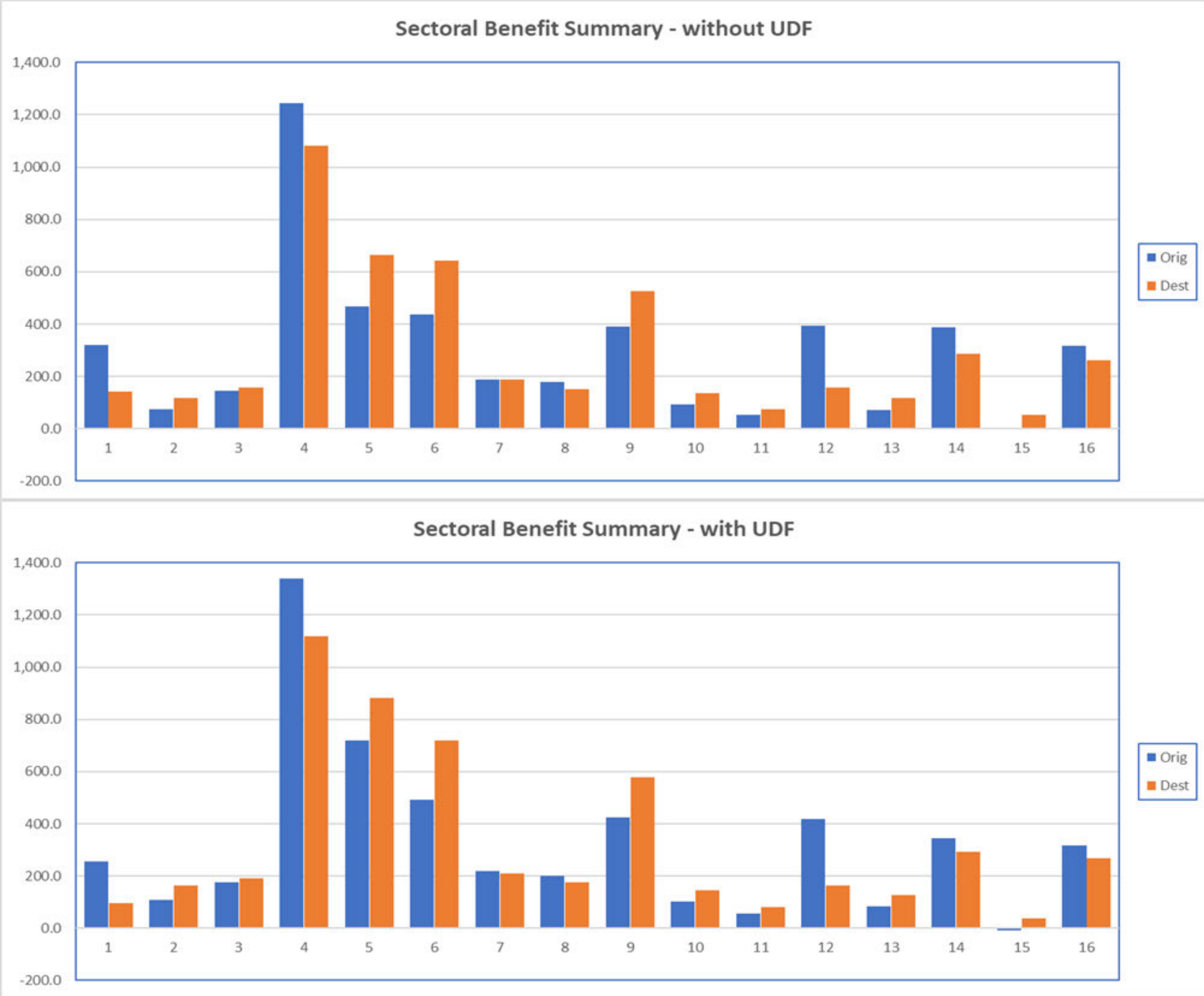
6.3.8 A high-level summary of the change in benefits with UDF included is provided in **Table 6-2**. As can be seen, the impact of the UDF application would result in an increase in the total TUBA user benefits by 16% and 11% for the TPTS Only and the Optimised Package respectively. This is largely anticipated as the reduction in flow and speed in urban areas would result in more traffic travelling on the SRN road network and consequently would benefit more from the capacity improvements of the TPTS+ interventions.

Table 6-2 Impact of UDF on TUBA User Benefits

Package	TPTS only			Optimised Package		
	VDM	with UDF	%Diff	VDM	with UDF	%Diff
Consumer User (Commute)	202,740	218,666	8%	531,941	608,806	14%
Consumer User (Other)	231,400	348,259	51%	619,692	755,689	22%
Business User and Provider	1,475,607	1,649,827	12%	3,014,825	3,273,272	9%
Private sector provider (Toll revenues)	-3,196	-3,306	3%	-4,395	-4,437	1%
Indirect Tax Revenue	189,840	187,105	-1%	381,819	372,293	-2%
Greenhouse Gas	-109,021	-98,816	-9%	-227,459	-195,078	-14%
Total	**1,987,370**	**2,301,735**	**16%**	**4,316,423**	**4,810,544**	**11%**

6.3.9 Detailed sector benefits produced from the VDM and the VDM + UDF TUBA assessment is provided in **Figure 6-5** below for the Optimised Package.

Figure 6-5 Impact of UDF on TUBA Sector Benefit - Optimised Package



6.3.10 It can be seen that the UDF would generally result in an increase in TUBA benefits across the sectors with exception of the Manchester urban areas (sector 1) where the TUBA benefits reduce by 21% and 34% for Origin and destination totals respectively.

6.3.11 The reduction in benefits for Manchester urban areas are expected as the reduction in speed in the urban areas would attract traffic on the M60 motorways toward the M67 to the TPT tunnel, particularly in the Optimised Package, where A6-M60 scheme would result in traffic increase on the M60 system (as can be seen in **Figure 6-6**).The increase of traffic volume on the M60 (without any improvements) would have an adverse effect (i.e. increase in congestion along the M60, local traffic taking longer to access the M60 thus resulting in dis-benefits for Manchester urban areas).

6.4 POST-UDF MODEL OUTPUTS

6.4.1 This section provides a summary of the Post-UDF model outputs. It should be noted that the modelling and appraisal of the TPTS Only was carried out primarily for the purpose of comparison against the previous studies and therefore this section only reports the modelling outputs of the Optimised Package with the UDF applied.

ASSIGNMENT STATISTICS

6.4.2 Assignment statistics from the Post-UDF modelling outputs are provided in **Table 6-3** below, providing a comparison of over-capacity queues, total travel time, distance and average network speeds between Do-Minimum and the Optimised Package.

Table 6-3 Assignment Statistics - 2041

Summary	Do-Minimum 2041			Optimised Package 2041			Difference		
	AM Peak	Inter-Peak	PM Peak	AM Peak	Inter-Peak	PM Peak	AM Peak	Inter-Peak	PM Peak
Matrix Total Summary									
Business	385,156	404,452	402,575	385,136	404,256	402,270	-20	-196	-304
Commuting	2,650,111	1,008,969	2,494,167	2,650,139	1,008,9 7	2,494,446	27	-52	279
Other	2,634,678	3,349,695	3,758,417	2,634,819	3,349,552	3,758,792	141	-143	374
LGV	856,046	785,257	831,477	856,046	785,257	831,477	0	0	0
HGV	341,974	353,746	249,026	341,974	353,746	249,026	0	0	0
Total	**6,867,965**	**5,902,119**	**7,735,661**	**6,868,113**	**5,901,728**	**7,736,010**	**148**	**-391**	**349**
Network Statistics									
Over-capacity queues (veh.hrs)									
Car	33,444	12,552	42,175	32,703	11,636	41,787	-741	-917	-388
LGV	4,715	1,755	4,963	4,576	1,649	4,797	-140	-106	-167
HGV	7,045	3,027	4,395	6,594	2,638	4,105	-451	-389	-290
Total travel time (veh.hrs)									
Car	1,254,584	765,845	1,378,634	1,255,943	766,977	1,380,414	1,359	1,133	1,780
LGV	195,799	151,961	185,890	195,509	151,704	185,551	-290	-257	-339
HGV	255,889	241,826	184,143	255,153	241,063	183,537	-736	-763	-606
Total travel distance (veh.kms)									
Car	92,582,956	57,933,794	99,959,855	92,851,003	58,205,996	100,254,267	268,048	272,202	294,412
LGV	14,520,503	12,005,198	13,738,349	14,521,459	12,007,201	13,738,470	957	2,003	121
HGV	19,197,754	19,723,248	13,814,626	19,191,219	19,719,303	13,812,815	-6,535	-3,944	-1,811
Average speed (kph)									
Car	73.8	75.6	72.5	73.9	75.9	72.6	0.1	0.3	0.1
LGV	74.2	79.0	73.9	74.3	79.1	74.0	0.1	0.1	0.1
HGV	75.0	81.6	75.0	75.2	81.8	75.3	0.2	0.2	0.3

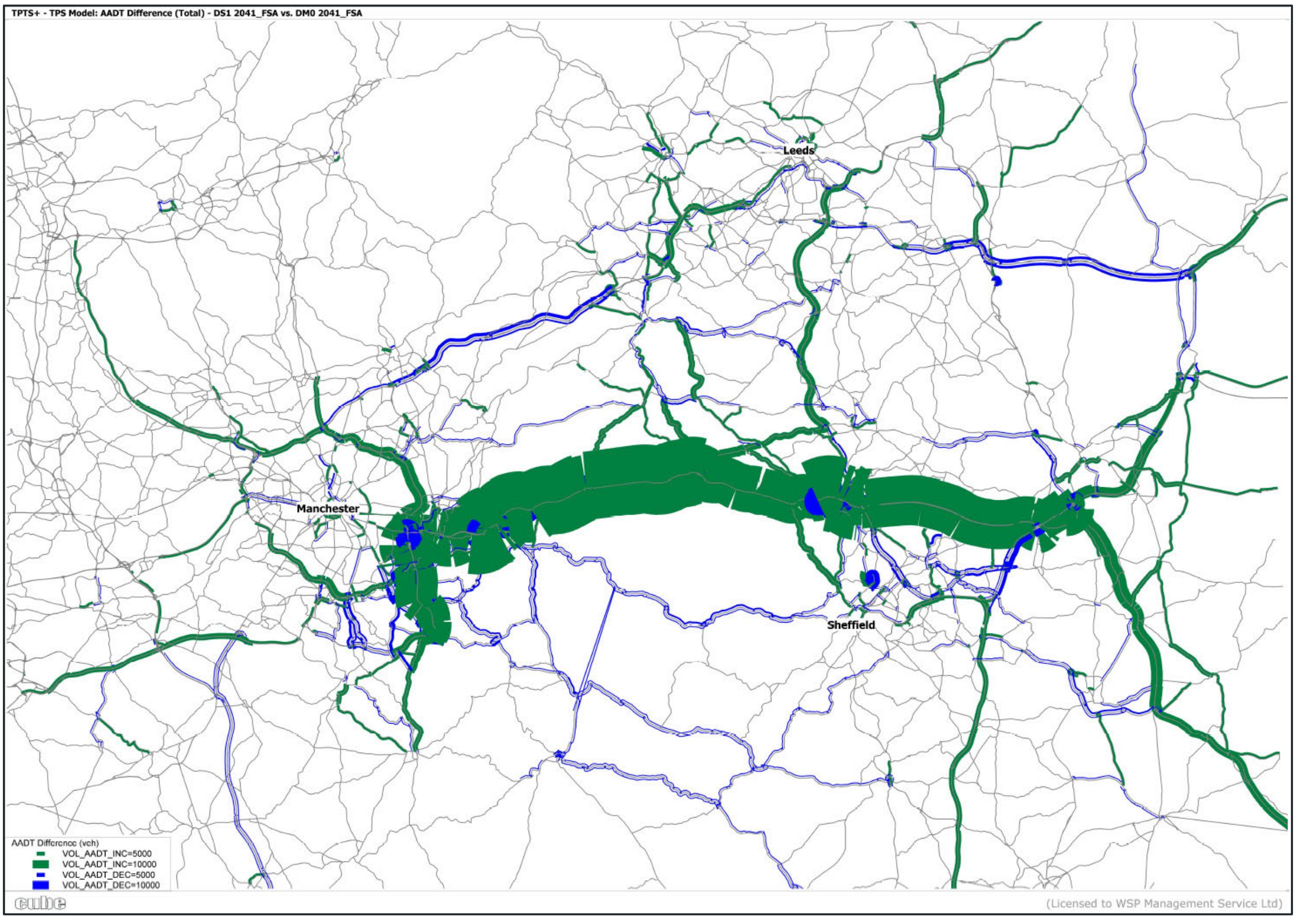
6.4.3 As can be seen, the Trans-Pennine Tunnel and interventions on A6-M60 and M1-M18 link would result in congestion relief across the Pennines, thus result in a reduction in over-capacity queues on the network and consequently improve overall travel speed on the network, particularly on areas where improvements are in place.

6.4.4 It is noted that the total travel time and distance increases in the Optimised Package compared to the Do-minimum. This is expected, particularly for cars where the impact of VDM would produce an increase in long distance business and Other trips crossing the Pennines (as seen in Figures below), thus resulting in an overall increase in travel time and distance for cars on the network.

TRAFFIC VOLUME IMPACTS

6.4.5 **Figure 6-6** below illustrates differences in terms of flows between the Optimised Package and the Do-Minimum in 2041.

Figure 6-6 Flow Difference - Optimised Package vs. Do-Minimum 2041 (Total)



6.4.6 As can be seen, the Optimised Package would result in a significant increase in flows for traffic crossing the Pennines. Similar impacts can be seen in the Fixed demand assignments. A high-level summary of the change in traffic flow in the Optimised Package compared to the Do-Minimum is highlighted below:

- Between 79,000 and 81,000 2-way AADT is forecast to travel on the Trans-Pennine tunnel in the Optimised Package. This is a result of a net increase of 67,000 2-way AADT flows on M67 toward the tunnel, 23,000 2-way AADT reduction from existing A628, a reduction of 6,000 2-way AADT on M62 between Manchester to Leeds and about 6,000 on other routes crossing the Pennines.
- The introduction of the A6-M60 in Manchester would result in significant traffic rerouting in Stockport areas, shifting traffic away from local road networks on to the M60 motorways.
- M1-M18 link is forecast to carry 56,000 2-way AADT between M1 J35a and M18 J1a, resulting in a reduction of traffic on the existing M1 and M18 (between 4,000 and 6,000 2-way AADT), on M62 between A1 and M18 (reduction of 6,000 2-way AADT); however, would create an increase in traffic on M18 east of M18 J2 (between 5,000 and 10,000 2-way AADT) and on A1(M) from M18 toward south (about 13,000 2-way AADT)

6.4.7 To understand in more detail the traffic changes on the network as a result of the Optimised Package, flow difference plots by each of the main trip purposes (Business, Commute, Other and Freight (LGV + HGV)) are provided in **Figure 6-7** to **Figure 6-10** below.

Figure 6-7 Flow Difference - Optimised Package vs. Do-Minimum 2041 (Business)

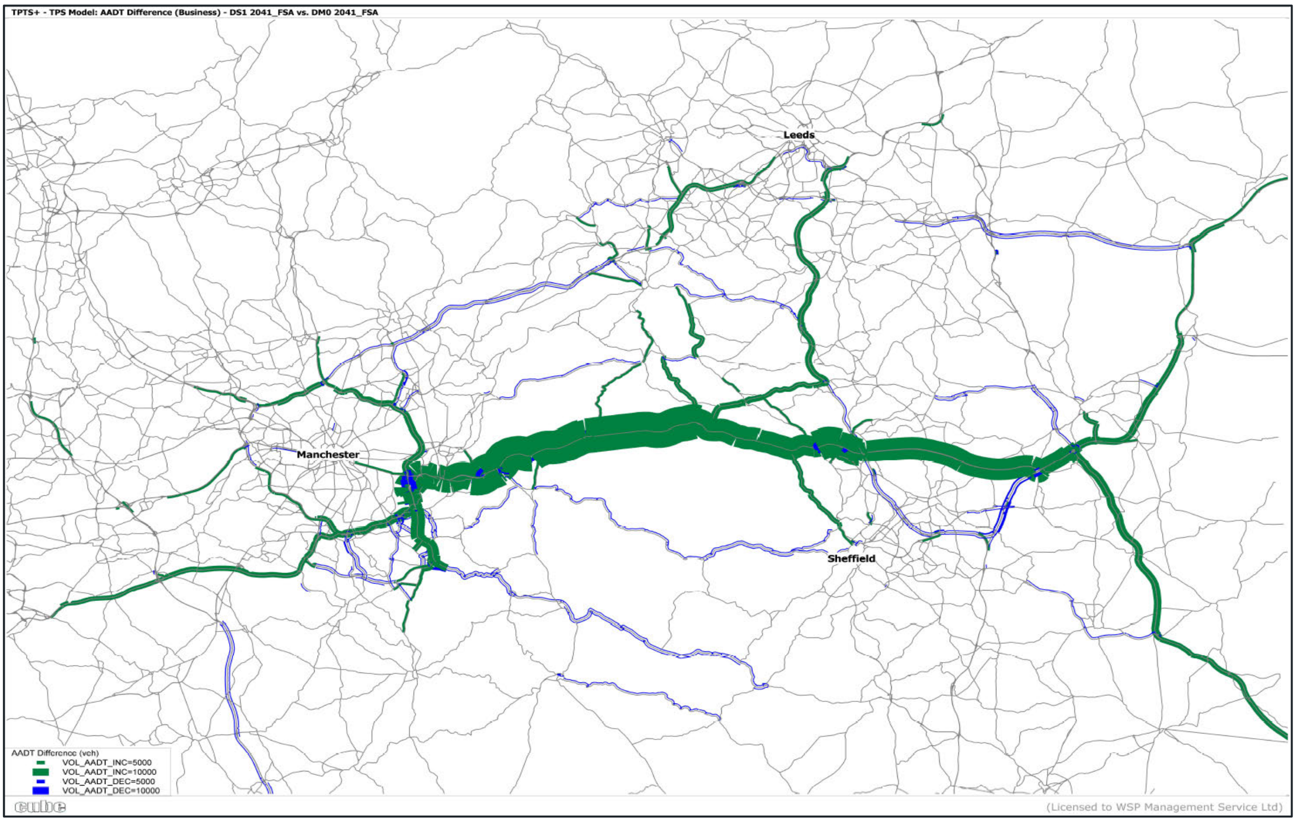


Figure 6-8 Flow Difference - Optimised Package vs. Do-Minimum 2041 (Commute)

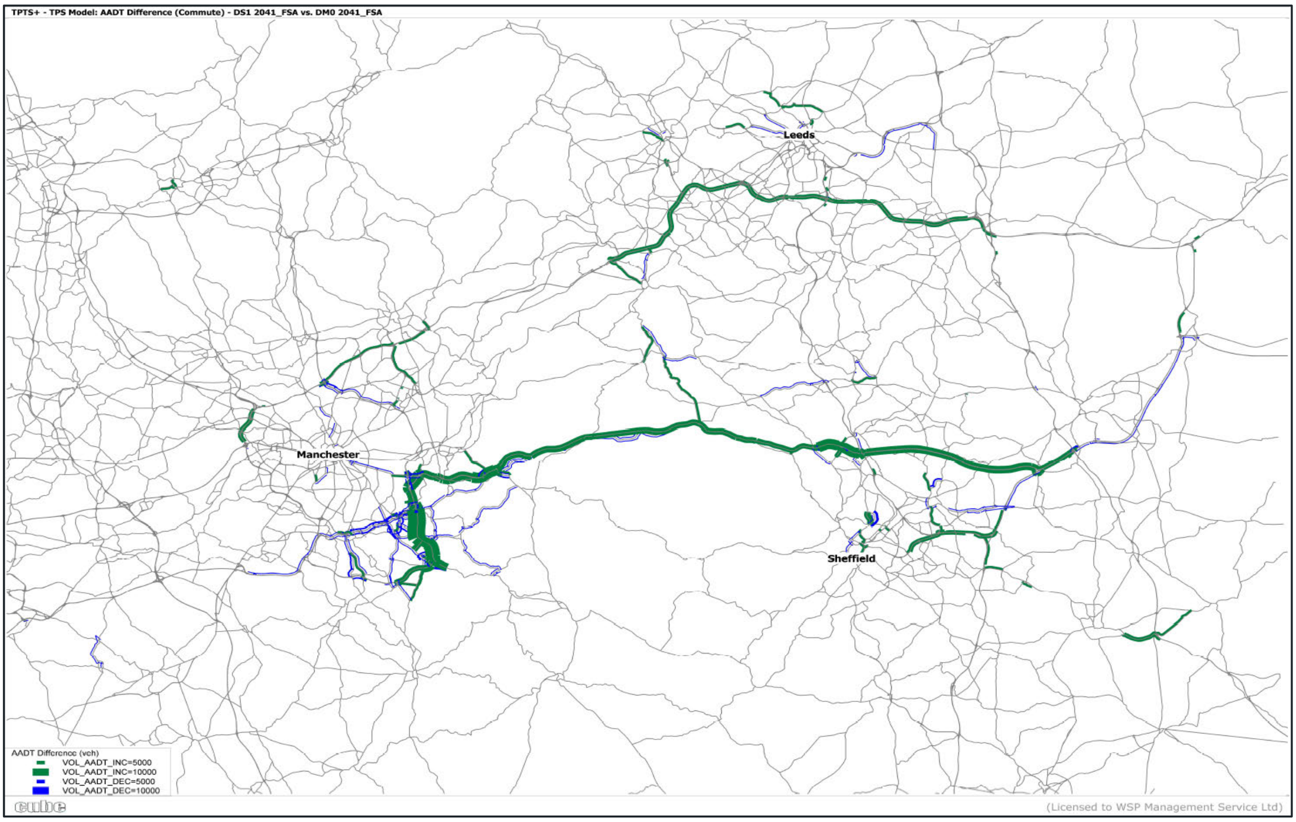


Figure 6-9 Flow Difference - Optimised Package vs. Do-Minimum 2041 (Other)

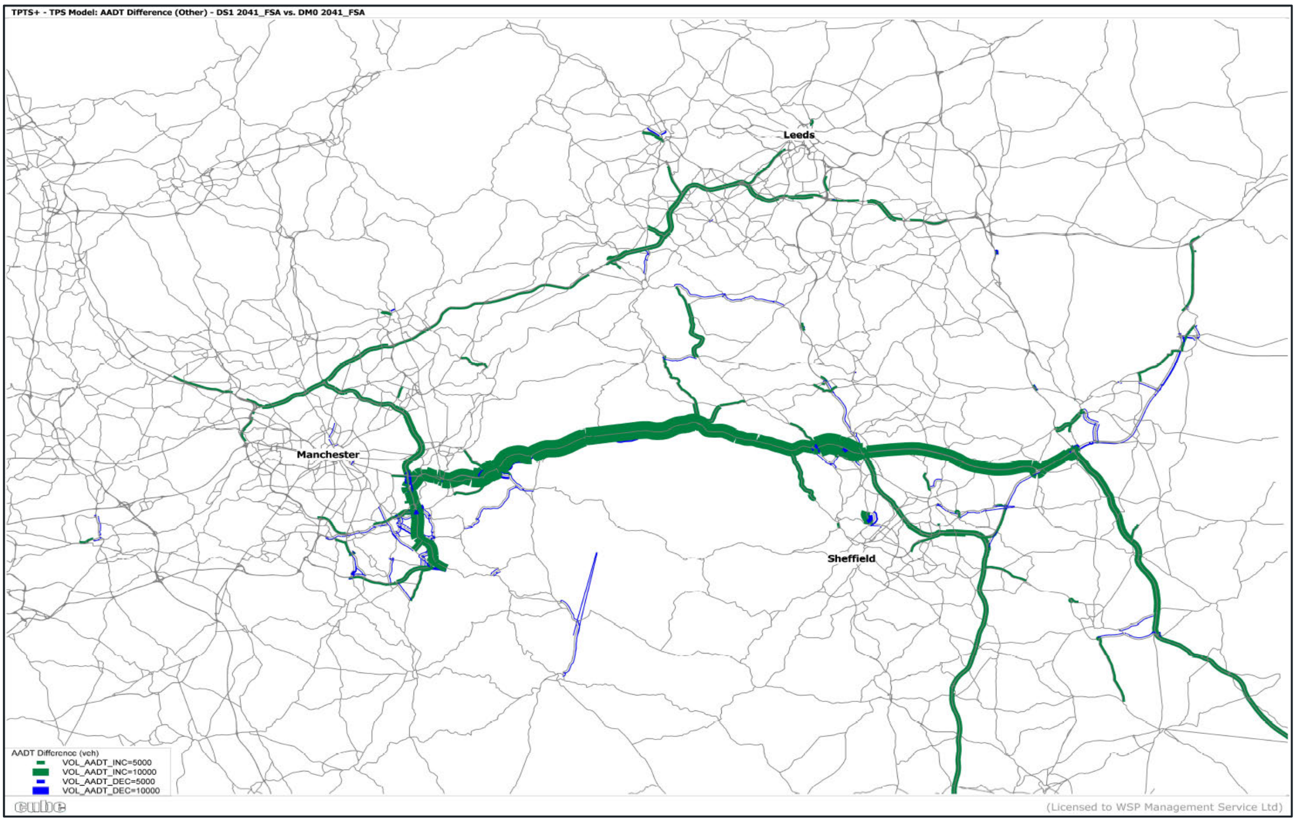
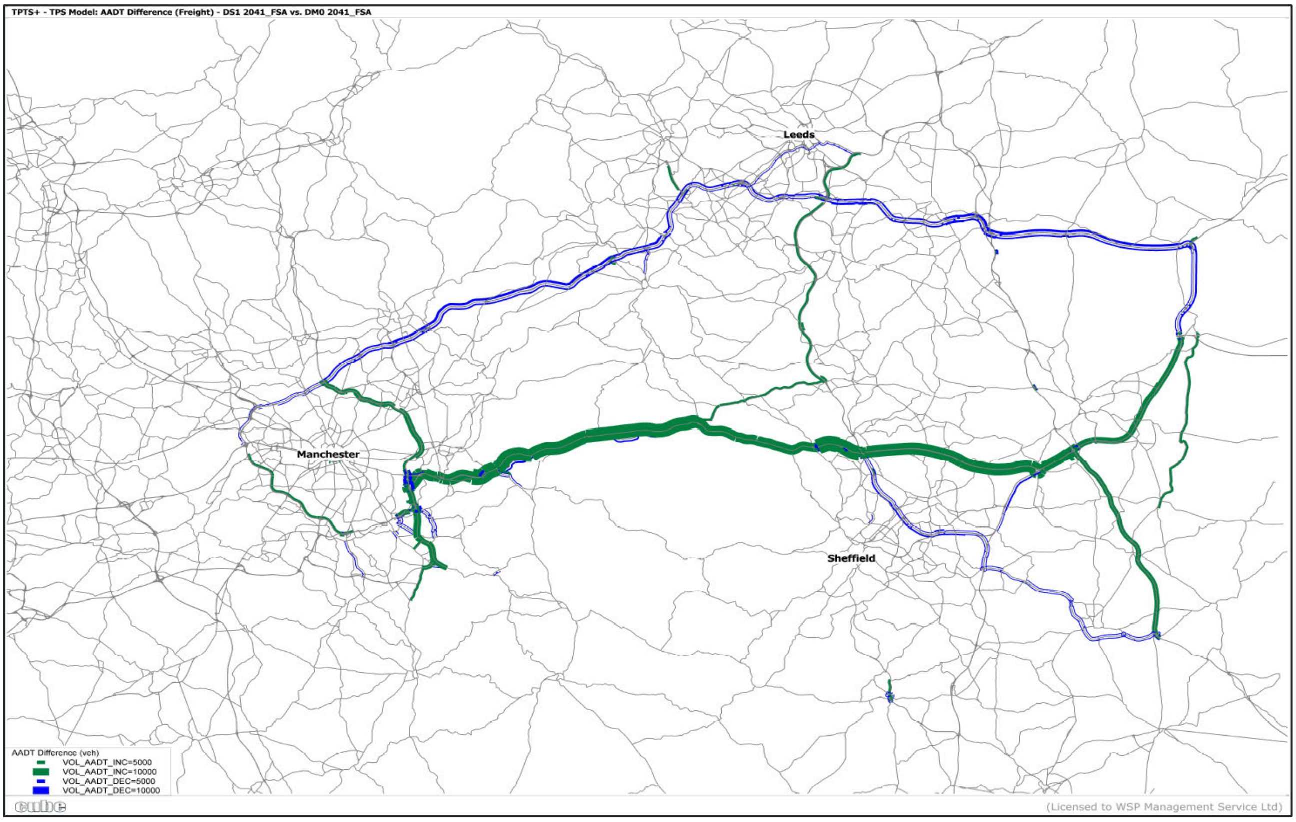


Figure 6-10 Flow Difference - Optimised Package vs. Do-Minimum 2041 (Freight)



6.4.8 As can be seen, the impact of the tunnel on the Commuting trips is local, i.e. primarily between the Manchester and Sheffield conurbation areas. This is anticipated as the majority of Commuting trips are associated with short distances (the average commuting journey in England is about 30minutes).

6.4.9 In contrast with the Commuting trips, Business trips and Other trips are more associated with long distance travel and are therefore expected to have a stronger impact from the interventions. As can be seen, the TPTS interventions are forecast to encourage longer distance travel for business trips and Other trips.

6.4.10 Freight, on the other hand is only subject to route choice (within the RTM) and therefore only shows primarily rerouting between M62 and the TPTS interventions.

6.4.11 Analysis of traffic composition on the Trans-Pennine tunnel link shows that 54% of traffic travelling in the TPT tunnel are associated with Business trips, 6% is Commuting, 24% for Other purposes and Freight (LGV and HGV) accounts for 16% of the total traffic in the tunnel as can be seen in **Table 6-4** below.

Table 6-4 Traffic Composition on Trans-Pennine Tunnel – 2041

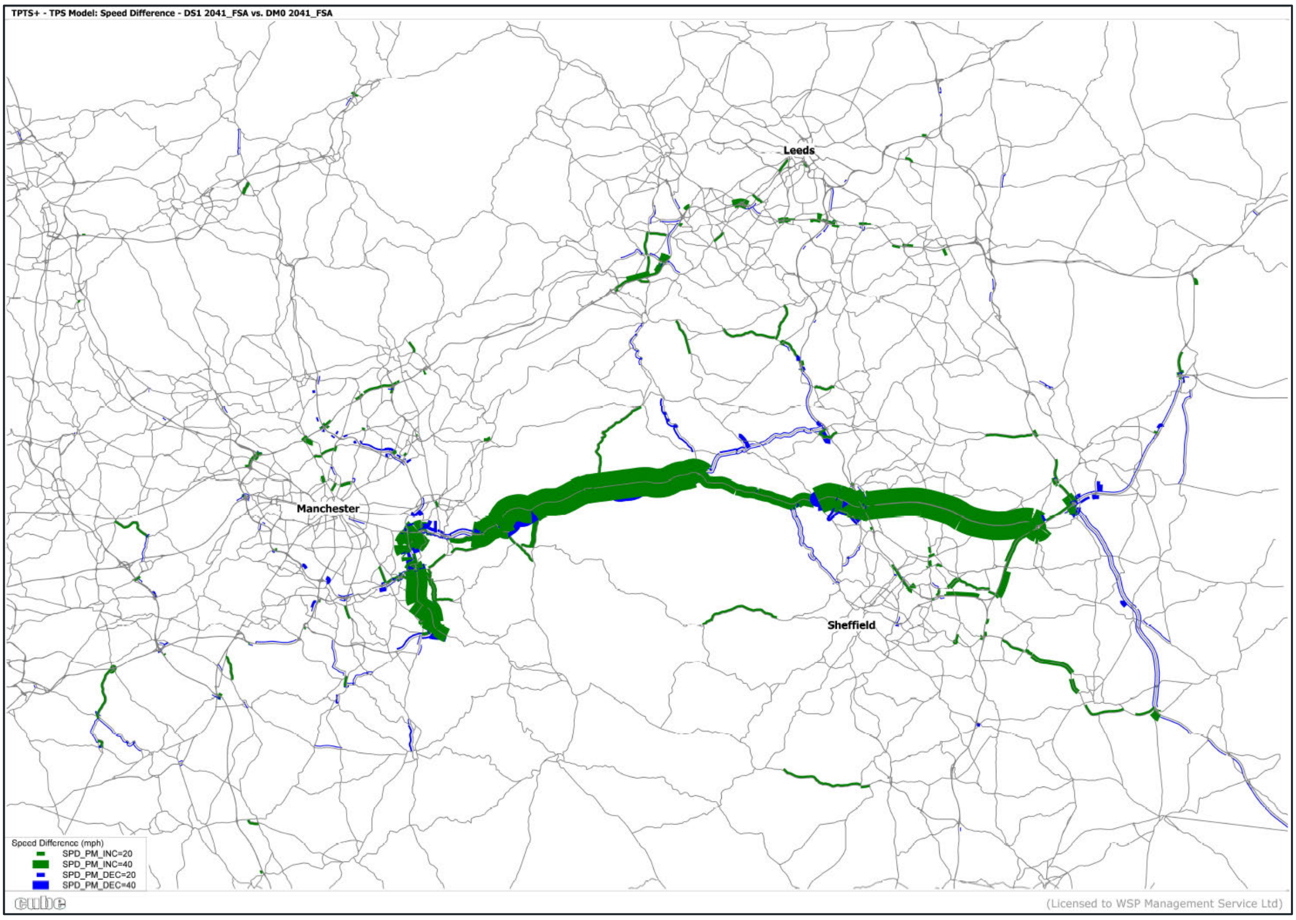
Purpose	Eastbound		Westbound		Total	
	Volume	Proportion	Volume	Proportion	Volume	Proportion
Car - Business	23,000	54%	19,800	54%	42,800	54%
car - Commute	2,300	5%	2,100	6%	4,400	6%
Car - Other	10,500	25%	8,900	24%	19,400	24%
Freight	6,800	16%	5,900	16%	12,700	16%
Total	**42,600**	**100%**	**36,700**	**100%**	**79,300**	**100%**

6.4.12 The significant proportion of business trips travelling via the TPTS interventions would explain the significant proportion of benefits associated to business trips.

TRAVEL TIME IMPACTS

6.4.13 **Figure 6-11** provides a summary of the impacts of the Optimised Package over the Do-Minimum in terms of travel speed difference for the 2041 PM peak. Similar difference can be seen for the AM and Inter-Peak periods.

Figure 6-11 Speed Difference - Optimised Package vs. Do-Minimum 2041 (PM Peak)



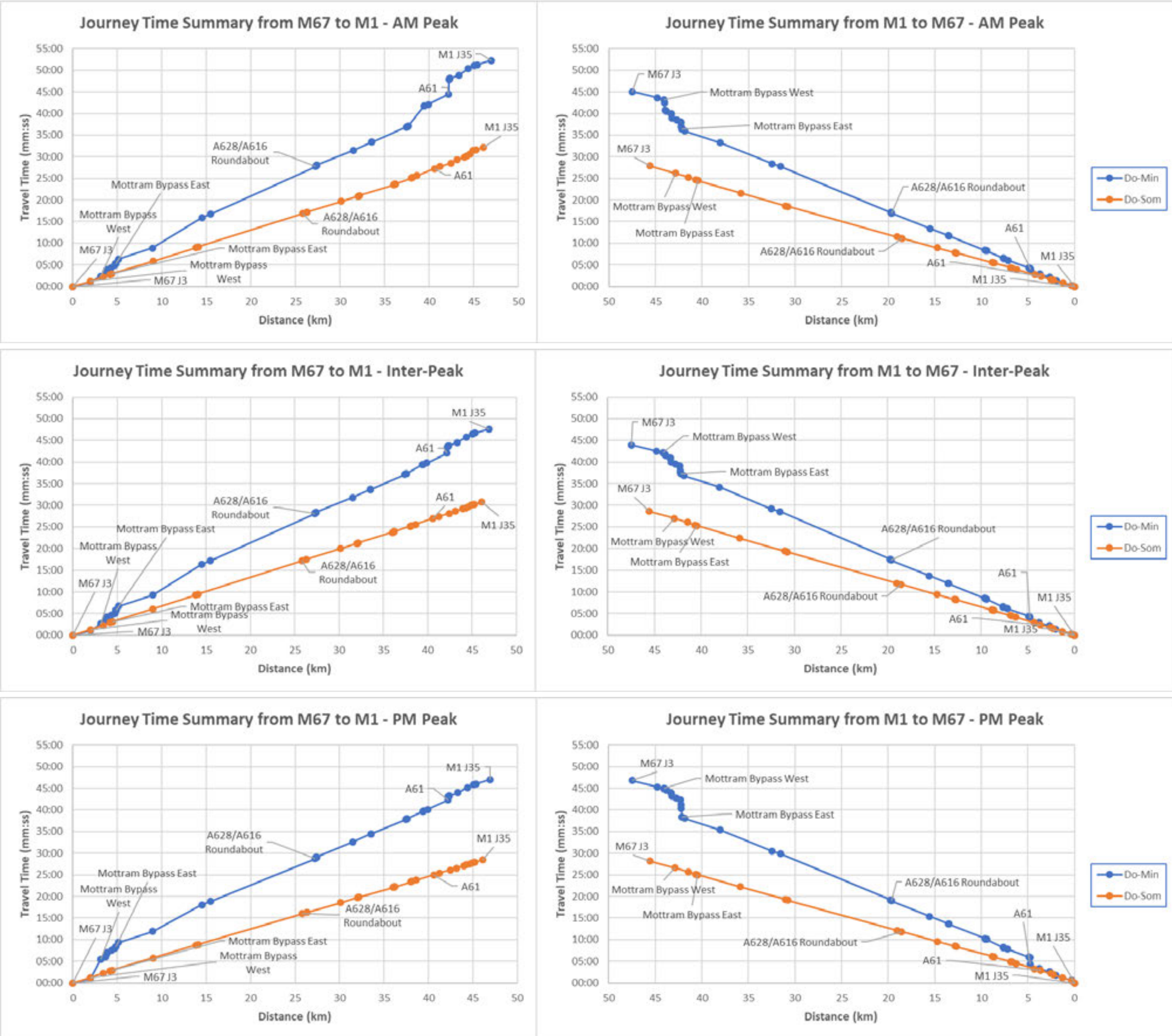
6.4.14 As can be seen, the Optimised Package would result in improvements in travel speeds for traffic crossing the Pennines. A high-level summary of the change in speed in the Optimised Package compared to the Do-Minimum is highlighted below:

- Significant increase in speed on A628/A616 as a result of the Trans-Pennine tunnel and dualling of A628 and A616;
- Significant time savings on M18 in Sheffield/Rotherham as a result of the M1-M18 link; and
- Improvement in travel speed on M60 and local roads in Manchester area as a result of the M60-A6 link road.

6.4.15 It is however noted that there is a reduction in travel speed on the M60 and A1(M) as a result of increases in traffic on M60 toward the tunnel and on A1(M).

6.4.16 Analysis of the travel time on the A628/A616 between the M67 and M1 J35 shows that significant improvement in travel speed with the tunnel in place, with average 20mph increase in travel speed, or 15-20 minutes time savings, across the three modelled periods. **Figure 6-12** below provides the Travel time by distance between the Do-Minimum and the Optimised Package across for the three modelled periods AM peak, Inter-Peak and PM peak.

Figure 6-12 Travel Time Plot between M67 and M1



6.5 SUMMARY

6.5.1 The Urban Delay Function was designed and deployed to better reflect realistic traffic speeds in congested urban areas that were subject to fixed speed coding in the RTM. This better reflection of urban speed-flow relationships has led to an 11-16% increase in TUBA benefits for the TPTS interventions, with the Optimised Package producing smaller increases in benefits due to a larger increase in traffic on the SRN networks (M60, A1) as a result of the interventions.

6.5.2 Analysis of flow and travel time impacts of the interventions show that traffic travelling between Manchester and Sheffield on the A628/A616 would benefit from speed and travel time improvements. The average speed increases by about 20mph, leading to reductions in journey time of between 15-20minutes.

6.5.3 Business users make up a significant proportion of trips travelling though the Trans-Pennine tunnel, which explains the significant business user benefits produced by TUBA.

7 ECONOMIC APPRAISAL

7.1 OVERVIEW

7.1.1 This chapter provides a summary of the Economic Appraisal that has been carried out for the TPTS+ study. This includes the methodology and assumptions of the intervention costs and on the calculation of:

- Level 1 benefits: TUBA, accident benefits, and delays during construction;
- Level 2 benefits: static clustering wider impact benefits, and reliability benefits; and
- Level 3 benefits: dynamic clustering wider impacts and switching value

7.1.2 As agreed with DfT and Highways England, the modelling and appraisal of the TPTS Only (Trans-Pennine improvements only) was used for the purpose of comparison against the previous studies only, the benefit figures reported in this chapter therefore refer to the appraisal outputs of the Optimised Package that are produced for the NTEM Core growth assumption and with application of the Urban Delay function.

7.1.3 It is noted that in the following **Chapters 7** to **8**, the appraisal results are calculated for the scheme Opening year of 2033. The updated appraisal results with the scheme Opening year 2041 for the Optimised Package is reported in **Chapter 11** of this document.

7.2 SCHEME COSTS

7.2.1 The latest Highway interventions costs for the TPTS Only and the Optimised Package were provided by Highways England in May 2019, with outturn costs of **£9.00bn** and **£11.88bn** respectively in 2016 price base, as provided in **Table 7-1** below. It should be noted that the outturn cost summary provided in this Table was for the scheme Opening year of 2033. The updated outturn costs to reflect the latest assessment with the scheme Opening year of 2041 is reported in **Chapter 11**.

Table 7-1 Outturn Cost Summary (2016 price base, £m)

Scheme	M67, M60 to A57	M60 J24 to 25	M18 J1a to 2	M1 J35a to 36	A6 to M60	M1 to M18	A628 + Tunnel	A616 dualling to M1	Denton Bypass	Total
Base estimate	43.00	21.50	30.60	16.00	443.80	878.50	3,013.80	342.40	348.30	**5,137.90**
Risk	8.40	4.30	6.20	3.20	69.70	159.40	747.40	81.60	70.30	**1,150.50**
Uncertainty Allowance	0.20	0.00	0.00	0.00	5.10	14.00	99.60	3.10	0.30	**122.30**
Sub-total	51.60	25.70	36.70	19.20	518.70	1,051.90	3,860.80	427.10	418.90	**6,410.60**
Inflation Adjustment	23.30	15.10	22.70	11.50	237.80	680.60	2,963.20	243.20	209.60	**4,407.00**
Portfolio Risk	8.90	5.30	6.70	4.10	75.50	170.20	661.80	68.70	61.40	**1,062.60**
Adjustment sub-total	32.10	20.40	29.40	15.70	313.20	850.80	3,625.00	311.90	271.00	**5,469.50**
Estimated Outturn Costs										
TPTS Only	**83.80**						**7,485.80**	**739.00**	**689.90**	**8,998.50**
Optimised Package	**83.80**	**46.10**	**66.10**	**34.80**	**832.00**	**1,902.70**	**7,485.80**	**739.00**	**689.90**	**11,880.20**

7.2.2 It should be noted that the outturn cost estimates provided in **Table 7-1** are to be used to inform what Highways England would have to pay in real monetary terms and therefore only used for the Financial Case. The scheme cost estimates have been produced by Highways England's Commercial Services Division with regard to Highways England's Cost Estimation Manual. For the

Economic Case, Present Values of Costs (PVC) are to be calculated for calculation of Benefits to Costs Ratios (BCR).

7.2.3 To calculate the PVC for the Economic Case, the following adjustments were made to the outturn costs supplied by Highways England Commercial:

- Removal of all VAT elements;
- Removal of all Historic costs; and
- Deflation of costs to 2010 prices using the DfT GDP deflator.

7.2.4 Outputs produced from Highways England's Commercial Services template (i.e. Economy Outputs) were then converted to 2010 market prices and values by applying:

- Discounting to convert prices to 2010 values; and
- Conversion to market prices using the factor of 1.19 to account for the country average taxation.

7.2.5 **Table 7-2** below provides a summary of the Capital Expenditure (CAPEX) PVC of the TPTS Only and the Optimised Package with the total values of **£3.25bn** and **£4.40bn** respectively in 2010 market prices and values.

Table 7-2 CAPEX PVC Summary (£000s, 2010 Prices and Values)

Scheme	M67, M60 to A57	M60 J24 to 25	M18 J1a to 2	M1 J35a to 36	A6 to M60	M1 to M18	A628 + Tunnel	A616 dualling to M1	Denton Bypass	Total
Preparation	4,532	3,361	3,120	2,281	30,531	55,128	260,261	32,315	24,561	**416,089**
Supervision	1,307	1,380	1,918	1,090	4,205	6,213	34,792	4,052	4,169	**59,125**
Construction	34,566	17,464	25,636	12,856	305,737	614,143	2,272,477	244,571	268,689	**3,796,139**
Land	882	27	63	53	35,311	33,626	29,284	23,314	8,077	**130,637**
Total CAPEX PVC (converted to market prices and values)										
TPTS Only	41,286						2,596,815	304,252	305,495	**3,247,848**
Optimised Pacakge	41,286	22,232	30,738	16,279	375,784	709,110	2,596,815	304,252	305,495	**4,401,990**

7.2.6 It is noted that the CAPEX PVC reported in **Table 7-2** above was calculated from the 'Most Likely' costs from the Highways England Commercial. In addition to the Most Likely costs, Highways Benchmarks also provides a 'Minimum' and a 'Maximum' cost with P2.5 and P97.5 Quantified Risks respectively to help understand the uncertainty of the cost impacts. A summary of the CAPEX PVC with P2.5 and P97.5 is provided in **Table 7-3** below.

Table 7-3 CAPEX PVC P2.5 and P97.5 Summary (£000s, 2010 Prices and Values)

Scheme	M67, M60 to A57	M60 J24 to 25	M18 J1a to 2	M1 J35a to 36	A6 to M60	M1 to M18	A628 + Tunnel	A616 dualling to M1	Denton Bypass	Total
Preparation	2,085	1,632	1,633	1,250	15,511	27,644	145,883	18,071	14,180	**227,888**
Supervision	429	742	881	599	1,624	2,592	13,455	1,468	1,781	**23,571**
Construction	16,089	9,516	15,380	7,982	155,812	260,287	1,156,882	114,967	115,303	**1,852,219**
Land	420	0	22	1	19,640	18,765	12,341	13,040	4,742	**68,971**
Total CAPEX PVC P2.5 (converted to market prices and values)										
TPTS Only	19,023						1,328,562	147,545	136,006	**1,631,136**
Optimised Pacakge	19,023	11,891	17,915	9,832	192,586	309,288	1,328,562	147,545	136,006	**2,172,648**
Scheme	**M67, M60 to A57**	**M60 J24 to 25**	**M18 J1a to 2**	**M1 J35a to 36**	**A6 to M60**	**M1 to M18**	**A628 + Tunnel**	**A616 dualling to M1**	**Denton Bypass**	**Total**
Preparation	8,005	5,638	5,118	3,655	49,723	84,891	423,171	49,709	37,226	**667,137**
Supervision	2,901	2,514	3,338	2,001	10,394	13,371	80,177	8,825	8,146	**131,668**
Construction	72,224	30,945	40,915	21,394	675,691	1,134,752	4,184,080	506,301	482,717	**7,149,020**
Land	1,690	51	109	95	66,505	66,723	56,633	43,765	22,206	**257,776**
Total CAPEX PVC P97.5 (converted to market prices and values)										
TPTS Only	84,821						4,744,060	608,600	550,295	**5,987,777**
Optimised Pacakge	84,821	39,148	49,481	27,145	802,313	1,299,738	4,744,060	608,600	550,295	**8,205,600**

7.2.7 In addition to the CAPEX, Operating Expenditure (OPEX) was also produced to provide estimates of costs associated with maintenance/operations of the interventions. Specific operating cost estimates have not been produced for this study. Rather operating cost estimates developed as part of the previous WTCA study have been adapted for this work. The costs were provided by the Highways team for the 60-year appraisal periods post scheme opening year, discounted to 2010 prices, and subsequently converted to market prices and values for the PVC calculations. The costs provided by Benchmark Estimating already applied the GDP deflator to 2010 prices. It was then discounted to 2010 values using the WebTAG discounting method (i.e. 3.5% pa). **Table 7-4** below provides a summary of the OPEX PVC for the TPTS Only and the Optimised Package with the total values of **£0.38bn** and **£0.47bn** respectively in 2010 market prices and values.

Table 7-4 OPEX PVC Summary (£000s at 2010 prices and values)

Scheme	M67, M60 to A57	M60 J24 to 25	M60 J1a to 2	M1 J35a to 36	A6 to M60	M1 to M18	A628 + Tunnel	A616 dualling to M1	Denton Bypass	Total
OPEX 2010 Cost	7,692	5,117	1,806	1,806	76,696	190,284	1,055,666	113,203	5,117	**1,457,387**
Single Year cost 2010	128	85	30	30	1,278	3,171	17,594	1,887	85	**24,288**
Discounted to 2010	2,306	1,500	530	530	22,992	53,446	278,709	33,196	1,534	**394,743**
Total OPEX PVC (converted to market prices and values)										
TPTS Only	2,744						331,664	39,503	1,825	**375,737**
Optimised Pacakge	2,744	1,785	631	631	27,360	63,601	331,664	39,503	1,825	**469,744**

7.2.8 The total PVC for the TPTS Only and the Optimised Package is summed from the two Tables above with the total values of **£3.62bn** and **£4.87bn** respectively in 2010 market prices and values.

7.3 APPRAISAL PARAMETERS

PARAMETERS

7.3.1 For the economic appraisal, TUBA and WITA require the benefits to be calculated for all the periods for the whole year with predefined user classes/purpose as provided in **Table 7-5** below.

Table 7-5 Economic Appraisal Parameters

Time Slice	Vehicle Type	Trip Purpose
1. Weekday AM Peak: 07:00 to 10:00 2. Weekday Inter-Peak: 10:00 to 16:00 3. Weekday PM Peak: 16:00 to 19:00 4. Weekday Off-Peak: 19:00 to 07:00 5. Weekend + Bank Holiday (24 hours)	Car	1. Employers' Business 2. Commuting 3. Other
	LGV(1)	4. LGV Non-Freight 5. LGV Freight
	HGV(1)	6. HGV (OGV1) 7. HGV (OGV2)
	Rail Passenger(2)	8. Employers' Business 9. Commuting 10. Other

Note: (1) - LGV and HGV only used for TUBA benefit calculation

(2) – Rail is only required for calculation of WITA benefits.

7.3.2 User classes were converted to TUBA/WITA predefined user classes/purposes as provided in **Table 7-6**.

Table 7-6 Conversion to TUBA/WITA User Class

Vehicle Type	Assignment User Class	TUBA/WITA User Class	Conversion Factor
Car	Employers' Business	Employer Business	1.00
	Commuting	Commuting	1.00
	Other	Other	1.00
LGV	LGV (Freight + Non-Freight)(1)	LGV Non-Freight	0.12
		LGV Freight	0.88
HGV	HGV (OGV1 + OGV2)(2)	OGV1	0.40
		OGV2	0.60
Rail Passenger	Employer Business	Employer Business	1.00
	Commuting	Commuting	1.00
	Other	Other	1.00

Note: (1) – Non-freight/Freight proportional split is based on WebTAG DataBook values

(2) – OGV1/OGV2 proportional split is derived from National Transport Model (NTM) 2015 database during development of the RTM models

NON-MODELLED PERIODS AND ANNUALISATION OF BENEFITS

7.3.3 TUBA requires benefits to be calculated for all relevant periods for the whole year. As the TPS RTM models were developed for an average weekday in March 2015 with three distinct average peak periods of AM peak, Inter-Peak and PM peak, it was necessary to apply annualisation factors to convert the benefits that accrued for each average hour to the annual values.

7.3.4 For non-modelled periods, it was not appropriate to expand the modelled hours' benefits to cover the non-modelled hours. Doing so may potentially overestimate the benefits/dis-benefits for the non-modelled hours due to the following:

- Significantly lower volume during the non-modelled hours (i.e. night-time) compared to the modelled hours (i.e. peak hours), thus travel cost difference between Do-Minimum and Do-Something is significantly less than that during the peak hours; and
- There is no explicit model to represent accurately the travel costs during the non-modelled hours.

7.3.5 TUBA guidance suggests that a conservative approach should be used to identify benefits/dis-benefits for non-modelled hours so that it would represent as close as possible the change in travel costs between Do-Minimum and Do-Something compared to changes between the Do-Minimum and Do-Something in the modelled hours. As such it was only appropriate to calculate benefits for hours in which traffic levels were similar to those in the modelled hours.

7.3.6 The derivation of the benefits for the non-modelled periods was discussed during the TfN SDC studies and agreed a consistent approach to be adopted. For the purpose of the TPTS+ studies, it was recommended that the same approach was to be adopted for the appraisal of the TPTS Only and the Optimised Package, as below:

- For pre-peak shoulders: costs and demand were derived from the AM and PM peak models by applying adjustments to both AM and PM peak demand and costs; and
- For weekend and bank holiday: cost and demand were taken from the Inter-Peak model, with number of hours claimed, determined from the road traffic statistics TRA0307 (Motor vehicle traffic distribution by time of day and day of the week on all roads, Great Britain).

7.3.7 **Table 7-7** summarises the annualisation factors applied to each modelled period's benefits to calculate TUBA benefits.

Table 7-7 Annualisation Factors for TUBA Benefit Calculation

Period	Modelled Hour	Annualisation Factor
Weekday AM Peak (07:00 – 10:00)	Average AM Peak Model	783
Weekday Inter-Peak (10:00 – 16:00)	Average Inter-Peak Model	1,566
Weekday PM Peak (16:00 – 19:00)	Average PM Peak Model	783
Weekday Off-Peak (05:00 – 07:00 + 19:00-20:00)	Derived from AM and PM Peak Models	783
Weekend (daytime)	Average Inter-Peak Model	688

7.3.8 In contrast to TUBA, whereby benefits are calculated directly from the number of trips associated with travel cost changes from the interventions, WITA requires a full 24-hour average travel costs across all travel modes to produce accurately the overall travel costs prior to the calculation of wider impacts. Therefore, in addition to the time slices provided in **Table 7-7** above, two extra time slices were included so that a full 24-hour average cost can be calculated for the purpose of WITA calculation, as provided in **Table 7-8** below.

Table 7-8 Additional Annualisation for WITA Calculation

Period	Modelled Hour Used	Annualisation Factor
Weekday Off-Peak (remaining)	Average Off-Peak Model	2,350
Weekend (remaining)	Average Off-Peak Model	590

7.3.9 The annualisation factors were used for both Highways and PT in the calculation of WITA benefits.

DEMAND PURPOSE SPLIT FOR NON-MODELLED HOURS

7.3.10 According to WebTAG DataBook, trip purpose splits vary by time period with a noticeably lower proportion of Commuting and Business trips and a higher proportion of 'Other' trips travelling during the weekend compared to the weekday split. To allow as close as possible the calculation of benefits for each purpose during the non-modelled hours, the 'donor' model's demand (i.e. inter-peak model) was adjusted to account for the difference in purpose split between the non-modelled hours from the inter-peak purpose split.

7.3.11 **Table 7-9** provides a summary of the purpose split by time period as extracted from WebTAG DataBook and the adjustment factors required used for each purpose of the non-modelled periods from the inter-peak demand. This yielded the same traffic volume but with adjustments that reflected the relative impact of different values of time.

Table 7-9 Adjustment Factors for Non-Modelled Hours' Demand

Purpose	WebTAG DataBook's Purpose Split (%)		Adjustment Factor
	Non-Modelled Period	Inter-Peak demand	
Weekday Off-Peak period			
Car - Business	3.47	16.47	0.78193
Car - Commuting	7.89	11.81	3.26491
Car - Other	88.64	71.72	0.67728
Rail – Business	1.85	15.76	1.12412
Rail – Commuting	2.79	5.49	7.02561
Rail – Other	95.36	78.75	0.55532
Weekend + Bank holiday			
Car - Business	12.88	16.47	0.21089
Car - Commuting	38.54	11.81	0.66820
Car - Other	48.58	71.72	1.23581
Rail – Business	17.72	15.76	0.11733
Rail – Commuting	38.55	5.49	0.50854

Purpose	WebTAG DataBook's Purpose Split (%)		Adjustment Factor
	Non-Modelled Period	Inter-Peak demand	
Rail – Other	43.73	78.75	1.21090

7.3.12 For further details on the appraisal methodology used in the appraisal of the TPTS please review the attached methodology '**TfN RTM Economic Appraisal Methodology_v0.3**' which was developed for the purpose of the TfN SDC studies.

7.4 USER BENEFITS

7.4.1 Transport user benefits calculated for the TPTS+ studies used the DfT recognised TUBA software, which adopts May 2018 WebTAG DataBook parameters.

7.4.2 The TUBA benefits produced from the Optimised Package is provided in **Table 7-10** below. It should be noted that this section only reports the detailed benefits for the Optimised Package with the scheme Opening year 2033. The summary of TUBA benefits for the TPTS Only is provided in **Section 6.3** of this document.

Table 7-10 TUBA Benefit Summary – Optimised Package (£000s)

Purpose	Time Savings	User Charges	VOC	Total
Commuting	641,950	-149	-32,996	608,806
Other	995,696	-349	-239,659	755,689
Business (Car)	2,270,285	672	80,511	2,351,467
Business (Freight)	831,223	2,516	88,066	921,804
Operator Revenues				-4,437
Greenhouse Gas				-195,078
Indirect Tax Revenues				372,293
Total	**4,739,154**	**2,690**	**-104,078**	**4,810,544**

7.4.3 Business users account for 68% of all the Transport Economic Efficiency (TEE) benefits (49% for Car and 19% for Freight). Commuters represent 13% of TEE benefits and other users represent 16% of benefits. The large proportion of benefits associated with business trips are supported by the modelling outputs, where the Optimised Package would result in a significant increase in business trips crossing the Pennines to travel south.

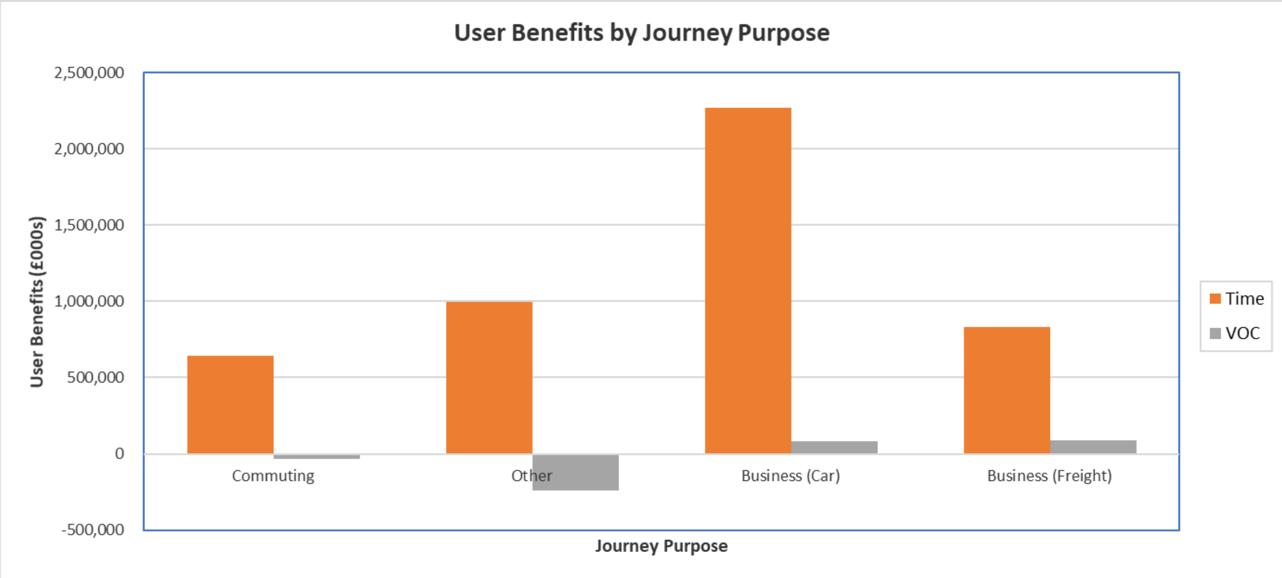
7.4.4 Analysis of the Vehicle Operating Cost (VOC) user benefits show that fuel VOCs are positive for Business (car and freight) journey purposes, and negative for Commuting and Other journey purposes.

7.4.5 Non-fuel VOC, however, whilst showing negative benefits for Commute and Other, shows positive benefits for Car Business and Freight. This is again anticipated as Commute and Other are assumed not to perceive the non-fuel elements of cost such as tyres, maintenance and depreciation, therefore the negative benefits are the product of increase in number of trips in the Do-Something against the Do-Minimum even with improvements in travel speed. Business trips, however, are assumed to perceive non-fuel elements of cost, the benefits are calculated using the 'rule of half' and therefore produce benefits due to the improvement in travel speed across the network.

7.4.6 It is noted that the negative VOC benefits produced by the interventions are outweighed by the positive Indirect Tax Revenues.

7.4.7 **Figure 7-1** shows the distribution of time saving benefits and vehicle operating costs by journey purpose. This shows that the largest level of benefits is generated by business trips, which is as expected given that the proposed TPTS+ improvements allow a large increase in business trips not only between the Manchester and Sheffield areas but also long-distance trips that would benefit from the TPTS+ interventions for faster travel time.

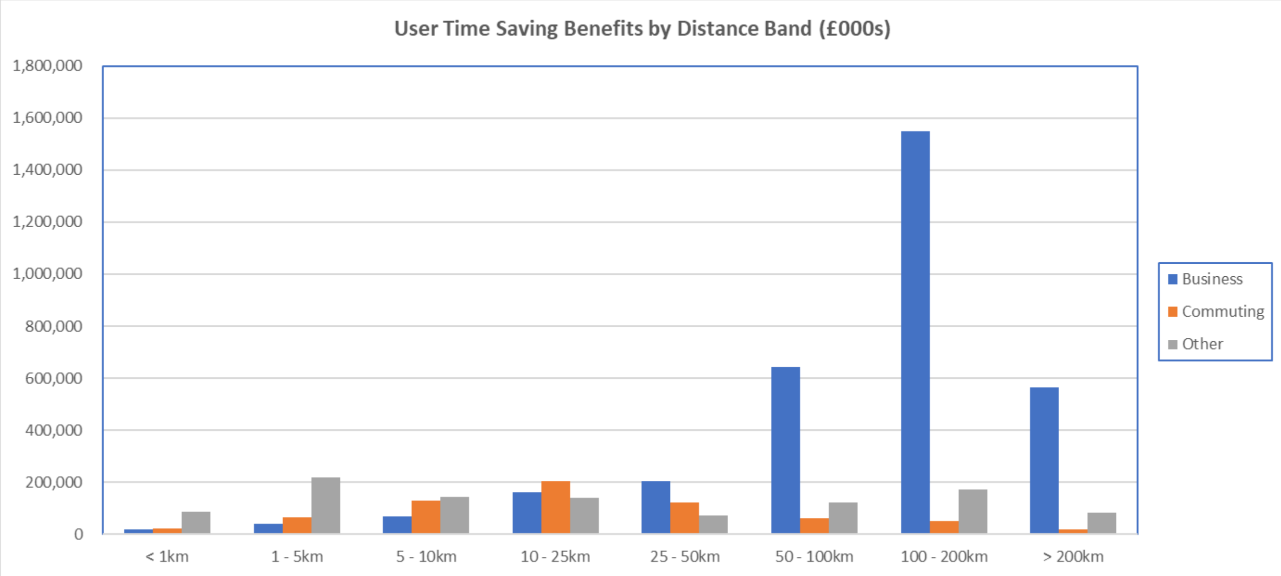
Figure 7-1 TUBA Benefits by Journey Purpose



SPATIAL DISTRIBUTION OF TUBA BENEFITS

7.4.8 **Figure 7-2** below shows TUBA benefits by travel distance. As expected and consistent with the Select Link Analysis (SLA) of traffic travelling on A628 (reported in **1-551 TPTS+ Responses to DfT comments**), the majority of the benefits are associated with long distance business trips. This is consistent with the increase in business trips using the Tunnel and long-distance trips that would use the tunnel for faster travel times to travel from Manchester/Liverpool to Sheffield/Leeds and the south. The significant business benefits in the 100-200km range are mainly car business, which is a product of time savings on the M62 and the Tunnel/M1-M18 link for traffic from Manchester to Sheffield/Rotherham/Doncaster/Hull and on the A1 to the south (as shown in **Figure 6-7**).

Figure 7-2 TUBA Benefits by Travel Distance



7.4.9 **Figure 7-3** and **Figure 7-4** below show the distribution of benefits at Local Authority District (LAD) level, separately for origin and destination. As can be seen, the majority of benefits are within the vicinity of the tunnel, such as Manchester, Sheffield, Leeds where the scheme would offer largest travel time improvements.

7.4.10 Areas such as North Lincolnshire and Doncaster to the east also benefit from the tunnel, primarily due to the M1-M18 links that provides shorter distance and faster travel times between the M1 J35 and M18 Junction 2.

7.4.11 It is noted that there are some minor TUBA dis-benefits located in Scarborough, Carlisle, Derby and Wrexham. With exception of the dis-benefits in Scarborough (about -£43m), the dis-benefits for the other areas are negligible (about -£4m in total) in values and would not affect the overall result of the appraisal.

7.4.12 Further analysis of the dis-benefits in Scarborough shows that 80% of the dis-benefits are associated with intra-district travel. Analysis of the flow difference of the road network within this area shows negligible change in AADT (less than 100 vehicles per day), however speed difference plots show significant reduction at one junction in East Ayton in the Do-Something in the PM peak.

7.4.13 The significant reduction in speed in the PM peak was suggested a ‘noise’ in the model at this junction. However, the overall impact of this is deemed negligible to the overall benefits of the TPTS+ interventions and therefore ignored in the appraisal outputs that this stage.

Figure 7-3 TUBA Benefits by LAD – Origin

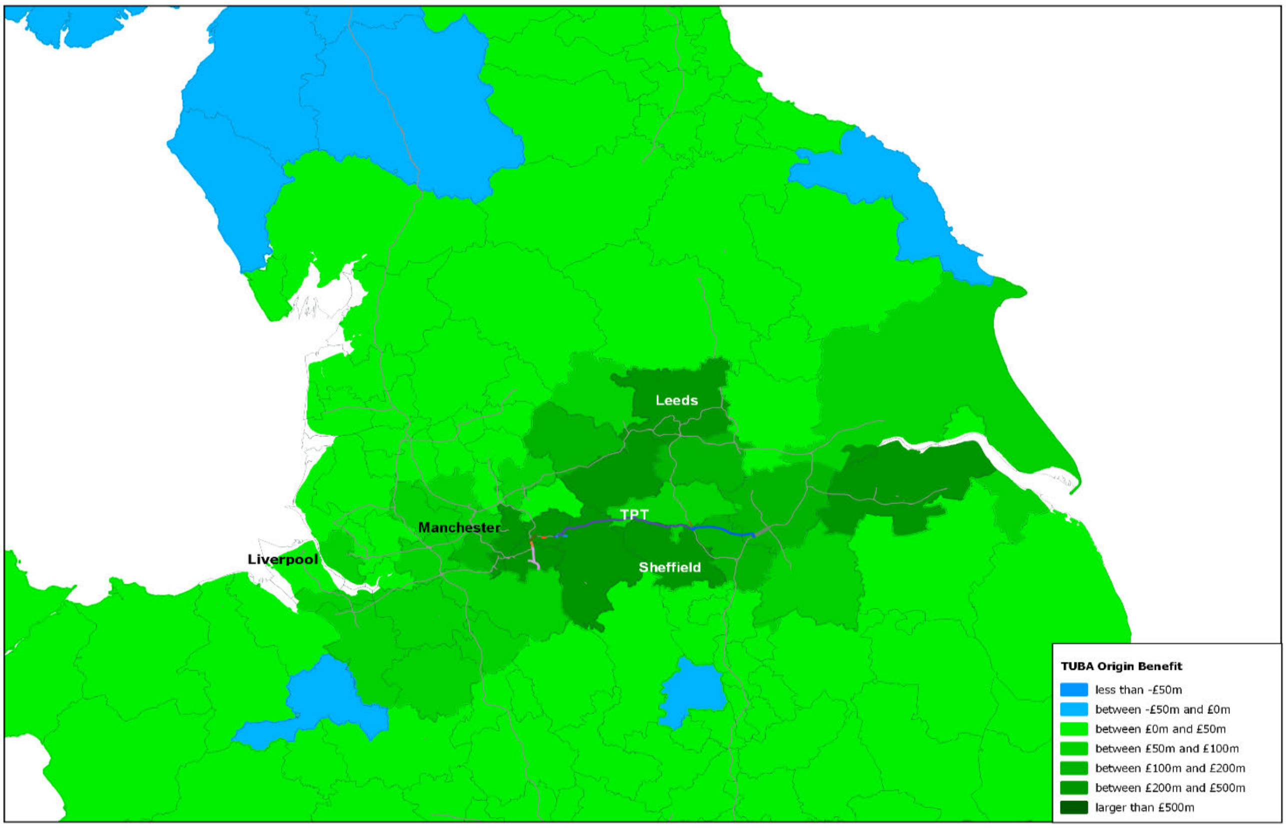
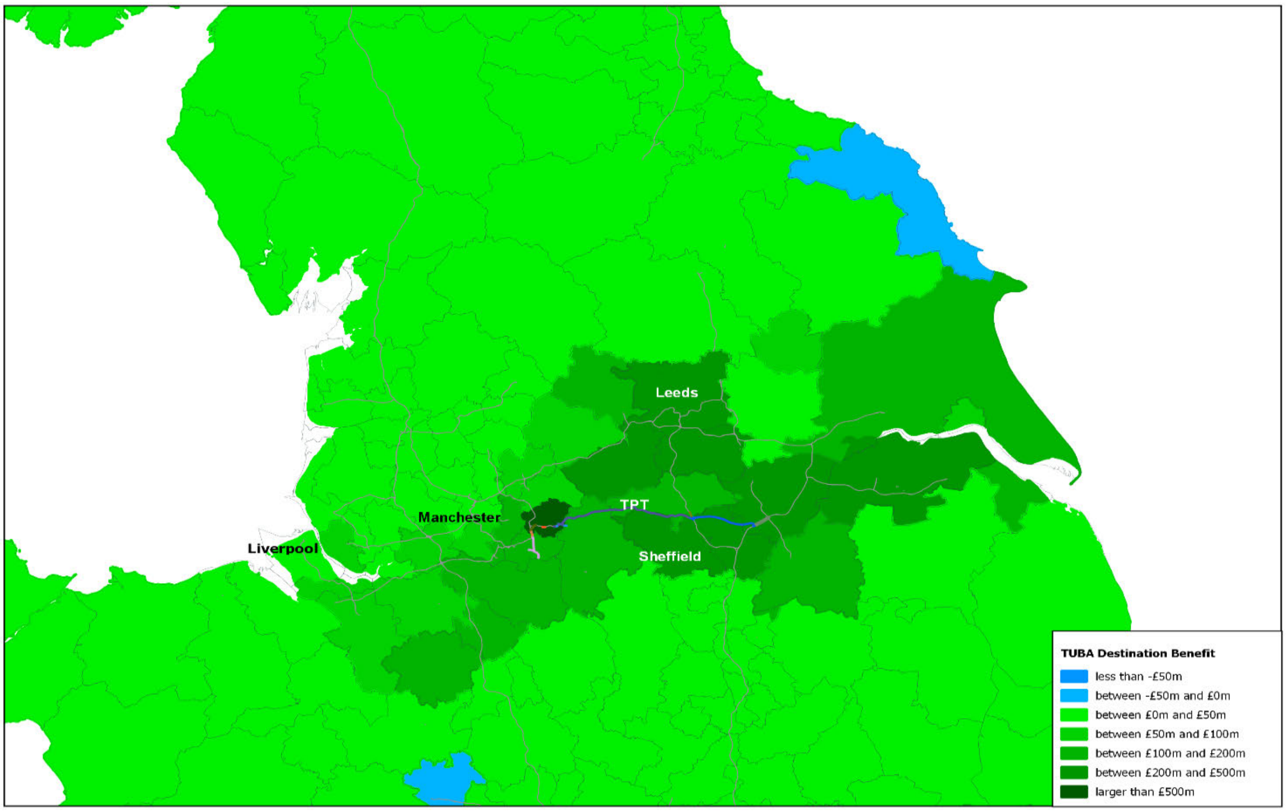


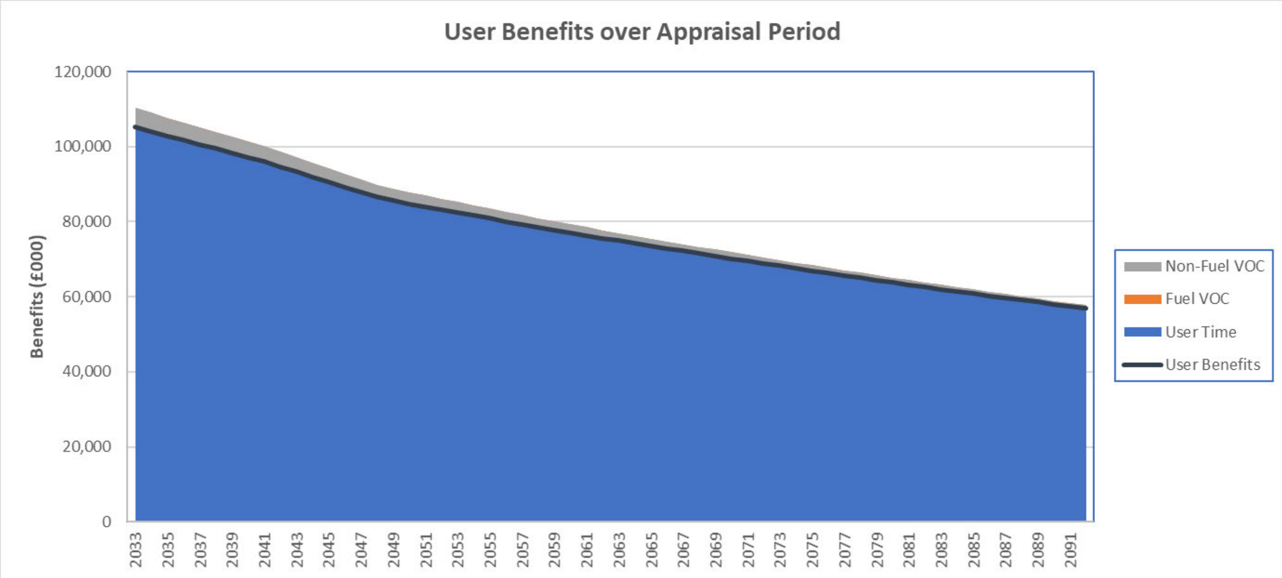
Figure 7-4 TUBA Benefits by LAD – Destination



TEMPORAL DISTRIBUTION OF TUBA BENEFITS

7.4.14 **Figure 7-5** shows the distribution of benefits across the appraisal period. This shows that the highest annual level of benefits is in 2033 and then decline over the appraisal period.

Figure 7-5 TUBA Benefits over Appraisal Period



7.4.15 The decline in TUBA benefits in 2041 from the Opening year 2033 suggests that:

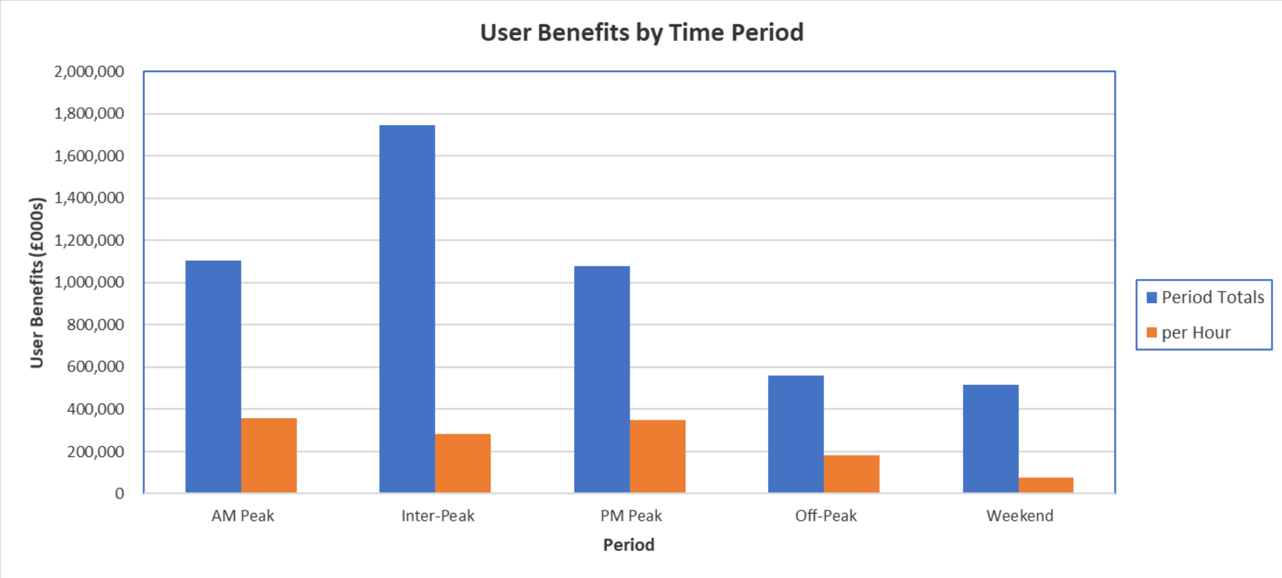
- The TPTS+ interventions, whilst producing significant time savings on the routes crossing the Pennines, would result in increased in traffic on the M60, M67 and M1 toward the schemes, resulting in increased congestion on the existing road network;
- The impact of VDM on change in demand on the existing road network (M60, M1), adds more congestion on to M60 and M1.

7.4.16 The modelled years of 2031 and 2041 result in traffic growth of only eight years from the Opening of the scheme, with no further growth modelled beyond 2041. Traffic growth would expect to continue beyond 2041 and this would result in network performance changes across the network. This could include growth in traffic on the scheme until it reaches capacity, potentially unlocking further benefits. It could also include traffic growth on the wider network in both the Do Minimum and Do Something scenarios. The distribution of this growth could potentially create disbenefits where the scheme leads to increased traffic on the wider network. The benefit profile could therefore be different if future growth is considered beyond 2041.

7.4.17 The scope of this stage of the study means that the point at which growth would be curtailed cannot be estimated and additional impacts beyond 2041 cannot be attributed to the scheme. It is not possible to predict whether the net effect of the growth would result in a positive or negative impact on the scheme economics. However, this uncertainty is inherent in standard traffic modelling and appraisal and in considered acceptable for this stage of the study

7.4.18 **Figure 7-6** provides a summary of the distribution of benefits by time periods. This shows that the greatest period benefits are across the interpeak period which is as expected given the length of the Inter-Peak period. The greatest per hour benefits are generated in the AM and PM peak hours which is to be expected as they have the highest trip demand. The inter-peak, however, does not show significantly less benefits than the peaks, reflecting the congested nature of sections of the route throughout the day.

Figure 7-6 TUBA Benefits by Time Periods



7.5 ACCIDENT BENEFITS

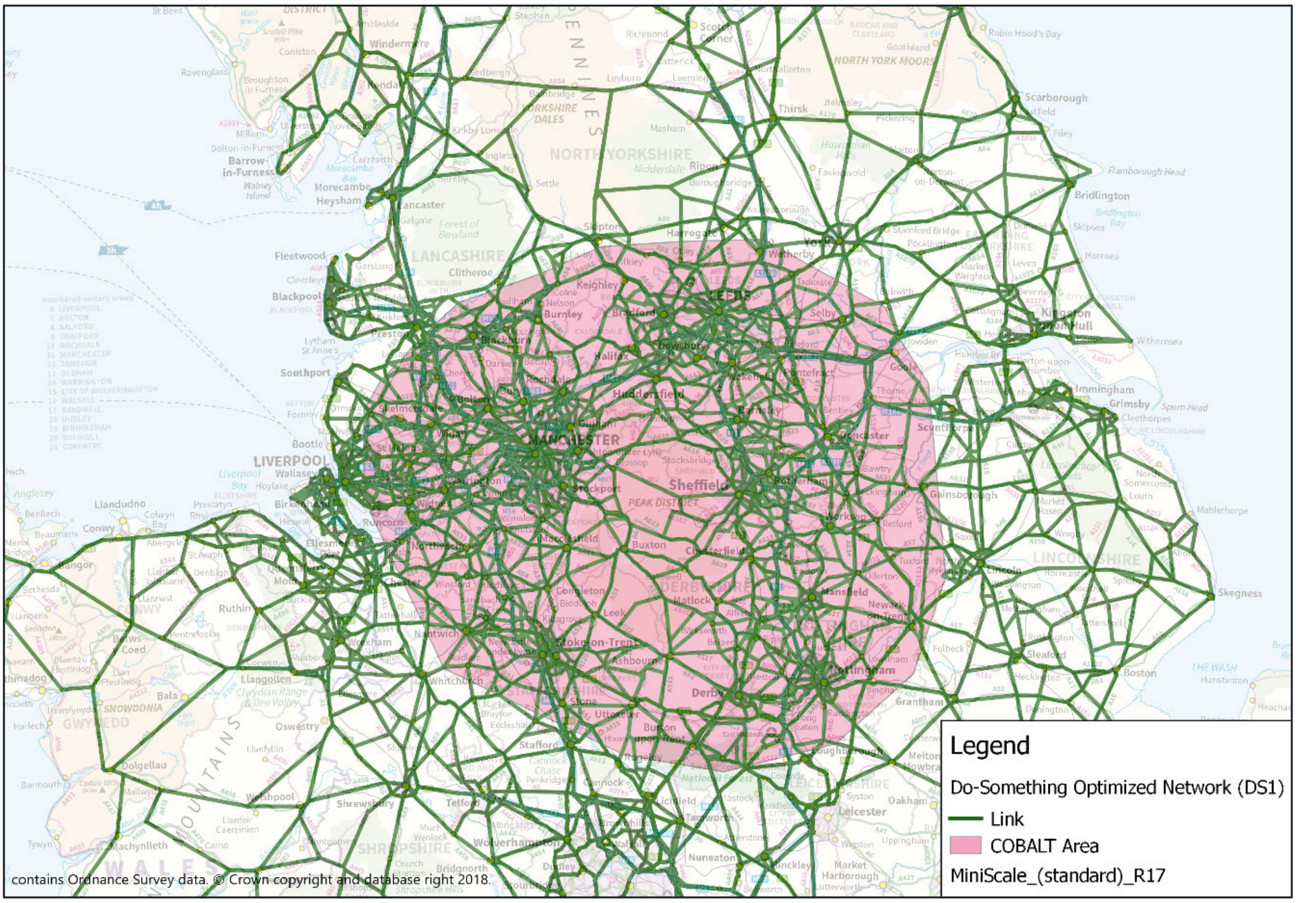
7.5.1 As stated in the ASR, impacts of the TPTS+ interventions on accident benefits is required for the Level 1 benefits. This section provides a summary of the methodology and assumptions for the estimates of accident benefits for the TPTS Only and the Optimised Package.

7.5.2 The assessment of accident benefits for the TPTS+ study was carried out using the DfT recognised COBALT software, using May 2018 WebTAG DataBook parameters.

ASSUMPTIONS

7.5.3 COBALT analysis was undertaken for all the modelled links within a defined cordon, as illustrated in **Figure 7-7** below.

Figure 7-7 COBALT Analysis Area



7.5.4 The cordon area for the COBALT analysis was based on the initial indication of the flow difference between Do-Minimum and Do-Something produced from the Fixed demand assignments where significant change in flow occurs as a result of TPTS+ interventions. Links outside the cordon were excluded from the COBALT analysis.

7.5.5 Within the cordon boundary, the modelled links were assigned appropriate COBA link type, as summarised in **Table 7-11** below.

Table 7-11 COBA Link Type

No	COBA Link Type
1	2 Lanes Motorways
2	3 Lanes Motorways
3	4+ Lanes Motorways
4	Single Carriageway designed to modern standard
5	Single Carriageway designed to modern standard with Hard shoulder
9	Single Carriageway not designed to modern standard
10	Dual Carriageway with 2 lanes each direction, designed to modern standard
11	Dual Carriageway with 2 lanes each direction, designed to modern standard, with hard shoulder
13	Dual Carriageway with 3 lanes each direction, designed to modern standard

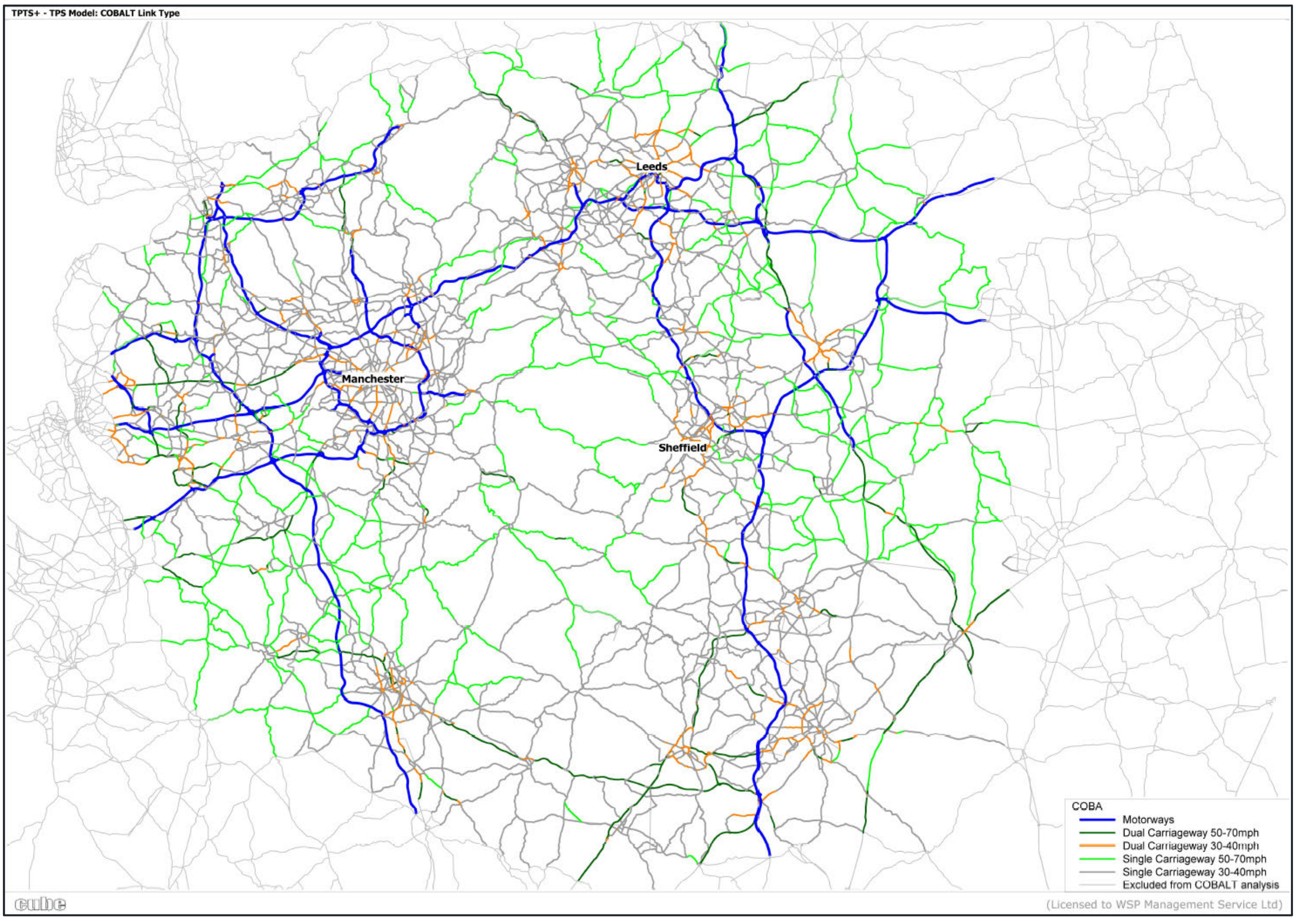
No	COBA Link Type
14	Dual Carriageway with 3 lanes each direction, designed to modern standard, with hard shoulder

7.5.6 The allocation of modelled links to pre-defined COBA link type was carried out using a GIS-based mapping process to ensure all modelled links were assigned an appropriate COBA type. Within each COBA link type, a speed limit was initially assigned using the speed-flow curve information from the traffic model and subsequently refined using Google maps Street view.

7.5.7 Within the COBALT network, the distance was obtained from the respective TPS RTM highway Do-Minimum and Do-Something models, and the AADT flows were produced for each of the Base year 2015, Opening year 2031 and the Design year 2041 for the Do-Minimum and each of the Do-Something respectively.

7.5.8 **Figure 7-8** presents the COBALT network coded for the TPTS+ study.

Figure 7-8 COBALT Network



7.5.9 The following parameters/assumptions were adopted for the calculation of accident benefits:

- Base year: 2015
- Opening year: 2031
- Design year: 2041
- Method: link-junction combined
- Accident rates: DfT default accident rates
- Appraisal period: 60 years

7.5.10 For each of the Do-Something scenarios, the following assumptions were made on the COBALT link types:

- Trans-Pennine Tunnel: Dual carriageway, 2 lanes each direction, with hard-shoulder, 50-70mph;
- M1-M18 Link: 2 lane motorways, 50-70mph; and
- A6-M60 Link: dual carriageway, 2 lanes each direction, with hard-shoulder, 50-70mph.

7.5.11 COBALT runs were carried out for the TPTS Only and the Optimised Package and results from the COBALT analysis is provided in the section below.

RESULTS

7.5.12 **Table 7-12** below provides a summary of the accident benefits for the TPTS Only and the Optimised Package over the 60-year appraisal period.

Table 7-12 COBALT Results (60 Years Appraisal)

Element	TPTS Only			Optimised Package		
Economic Summary (£000s)						
without-Scheme Accident Costs	26,622,468			26,622,466		
with-Scheme Accident Costs	26,516,250			26,488,464		
Accident Benefits	**106,218**			**134,002**		
Accident Summary						
without-Scheme Accidents	676,358			676,358		
with-Scheme Accidents	674,103			673,348		
Accidents saved	**2,255**			**3,011**		
Casualty Summary	Fatal	Serious	Slight	Fatal	Serious	Slight
without-Scheme Casualties	7,353	83,455	846,696	7,353	83,455	846,696
with-Scheme Casualties	7,324	83,035	843,979	7,331	82,891	843,441
Casualties saved	**29**	**420**	**2,718**	**22**	**564**	**3,256**

7.5.13 Over the 60 years appraisal period, about 676 thousand accidents are forecasted to occur within the cordoned COBALT network with the total prevention costs of £26.6bn in 2010 prices and values, which equates to about 11 thousand accidents to occur every year with the costs of prevention of about £640m per year in 2010 prices and values. This compares to 178 thousand accidents[5] and £15bn cost of accident preventions[6] in 2010 prices.

[5] RAS10003: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/743318/ras10003.ods
[6] RAS60003: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/743271/ras60002.ods

7.5.14 The 'TPTS Only' and the 'Optimised Package' are forecast to produce 2,255 and 3,011 accidents savings respectively over 60 years appraisal period, with the overall respective benefits of **£106.2m** and **£134.0m** for the TPTS Only and Optimised Package.

7.6 DELAYS DURING CONSTRUCTION

7.6.1 As stated in ASR, impacts to road users during the construction of the interventions were required to for the Level 1 benefits. This section provides a summary of the methodology and assumptions for the estimates of delays to road users during construction of TPTS+ interventions.

7.6.2 To produce estimates of delays to road users during construction, the following tasks were undertaken:

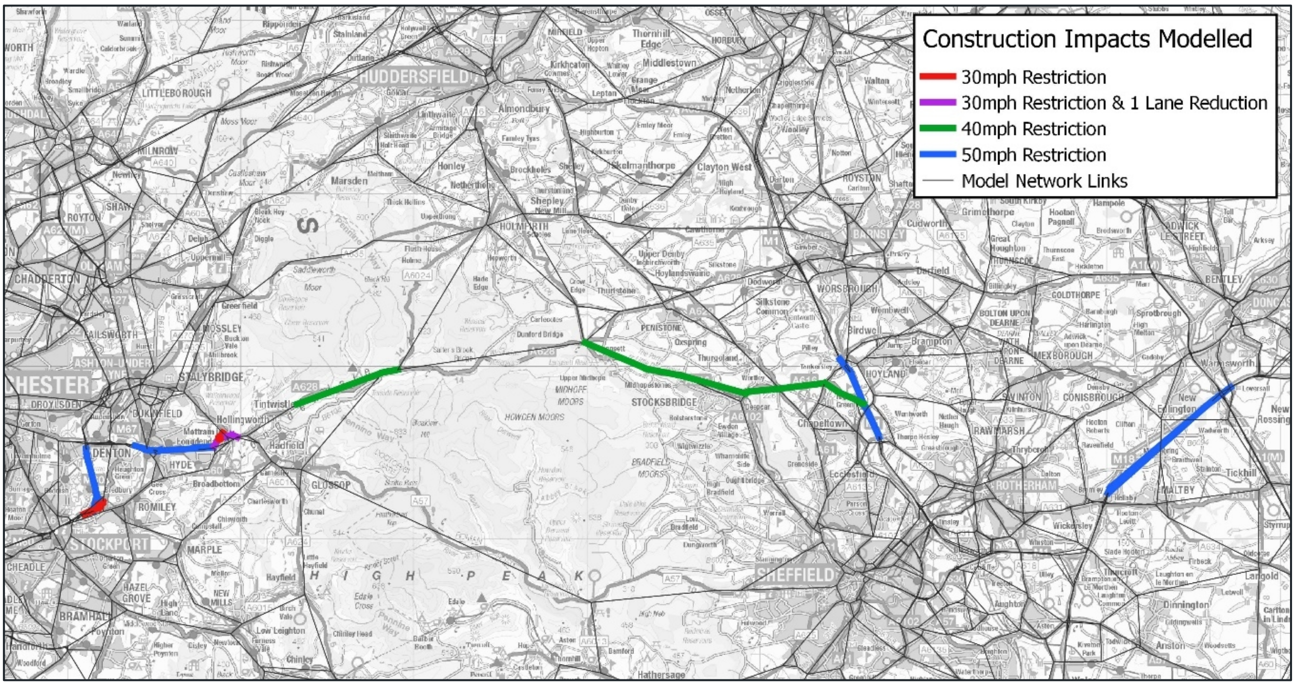
- Apply coding to the Do-Minimum 2031 networks to represent disruption to traffic during construction (detail provided in the subsequent section);
- Assign the Do-minimum 2031 matrices to the amended networks to create model assignments that represent disruption to traffic as a result of roadworks; and
- Run TUBA between the roadworks' assignments against the Do-Minimum models for a single year appraisal to produce the impacts of road works to road users.

7.6.3 TUBA software, which adopts May 2018 WebTAG DataBook was used for the purpose of assessing delays during constructions of the TPTS+ study.

ASSUMPTIONS

7.6.4 To represent the impacts of construction on the network, a reduction to free-flow speeds as coded in the Do-Minimum network have been applied at sections where speed restriction and narrow lane traffic management would be in place during construction. Locations where speed and lane restriction were applied is illustrated in **Figure 7-9**.

Figure 7-9 Restrictions during Construction



7.6.5 Please note that the assumptions were based on the current drawings for the Optimised Package that were provided by the Highways team, as below.

- Free-flow speed reduction to 30mph at M60 J25;
- Free-flow speed reduction to 50mph on M60 J24-J25 (both directions);
- Free-flow speed reduction to 50mph though M67 J3 (both directions);
- Free-flow speed reduction to 50mph on M67 J3-J4 (both directions);
- Free-flow speed reduction to 30mpj on Mottram Link, number of lanes reduced to 1 (both directions);
- Free-flow speed reduction to 30mph from Mottram Link road to Roe Cross road (both directions);
- Free-flow speed reduction to 40mph on A628 where online works are planned (both directions);
- Free-flow speed reduction to 40mph on A616 from A628 to M1 (both directions);
- Free-flow speed reduction to 50mph on M1 J35-J36 (both directions); and
- Free-flow speed reduction to 50mph on M18 J1-J2 (both directions).

7.6.6 It is assumed that the construction of the tie-ins between the TPTS+ interventions and the exiting network would take place over a 2-year period. The 2-year construction period is based on the assumption that most of the interventions are off-line, as such the 2-years takes into account the tie-in to the existing network. A TUBA run was therefore carried out for a single year 2031 for the Do-Minimum and Do-Minimum + roadworks and subsequently multiplied by 2 to produce estimate of delays for the 2-years construction periods. The outputs from the TUBA appraisal to produce delays during construction of the TPTS+ interventions are provided in the section below.

RESULTS

7.6.7 The initial delay costs to road users during roadworks that was produced from a single year TUBA assessment is -£10.31m (include time saving, VoC, and indirect tax revenues).

7.6.8 Analysis of TUBA benefit at a sectoral level however shows that whilst the anticipated impacts of roadworks would be generally negative and limited to Manchester and Sheffield areas where roadworks would take place, the sectoral benefits produced from TUBA shows number of counter-intuitive results (i.e. positive benefits) in number of sectors outside the influence areas of the roadworks, which was likely attributed to model noise.

7.6.9 A masking process was therefore carried out to remove the counter-intuitive values from TUBA, such as intra-sector of Liverpool, Hull, Lincolnshire, south and north of England. The revised TUBA benefits with the masking process applied resulted in -£14.09m dis-benefits to road users during 1-year construction period. A summary of TUBA sector benefits with masking process applied is provided in **Table 7-13** below.

Table 7-13 Revised TUBA Benefits with Masking Applied (£000s)

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Orig
1	-0.22	-0.01	-0.02	0.06	0.00	-0.03	0.02	0.01	-0.03	-0.02	-0.01	-0.03	0.00	-0.12	-0.01	-0.06	**-0.46**
2	0.02	0.01	-0.04	-0.04	0.02	-0.07	0.00	-0.02	0.01	-0.03	0.00	-0.04	0.01	-0.03	0.00	-0.21	**-0.41**
3	-0.02	-0.05	0.02	-0.06	-0.16	-0.44	-0.02	-0.02	-0.16	0.01	0.00	-0.01	-0.03	-0.02	-0.05	0.00	**-1.02**
4	-0.06	-0.02	-0.04	0.98	-0.03	-0.09	-0.01	0.09	-0.10	-0.04	-0.02	-0.04	-0.01	-0.24	-0.01	-0.10	**0.26**
5	0.01	-0.02	-0.16	-0.13	-0.49	-0.32	-0.02	-0.04	-0.01	-0.13	0.00	-0.11	-0.01	-0.09	-0.01	-0.63	**-2.14**
6	-0.05	-0.08	-0.32	-0.19	-0.30	-1.74	-0.09	-0.07	-0.10	-0.09	-0.01	-0.19	-0.05	-0.13	-0.06	-0.27	**-3.74**
7	0.01	0.00	-0.02	-0.14	0.00	-0.04		0.00	0.00	-0.02	0.00	-0.02	0.00	-0.10	0.00	-0.10	**-0.41**
8	0.01	-0.01	-0.02	-0.01	-0.03	-0.04	-0.08		-0.02	-0.01	0.00	-0.01	-0.01	-0.07	0.00	-0.04	**-0.33**
9	-0.04	-0.02	-0.16	-0.17	-0.07	-0.20	-0.02	-0.03		-0.01	0.14	-0.08	0.00	-0.11	0.01	-0.18	**-0.94**
10	-0.05	-0.04	0.04	-0.07	-0.12	-0.06	-0.02	-0.01	-0.03	0.00	0.00	0.02	-0.02	-0.01	-0.06	-0.01	**-0.44**
11	-0.01	-0.01	0.01	-0.03	-0.03	-0.01	-0.01	0.00	-0.02	-0.01		0.00	-0.01	0.00	-0.02		**-0.15**
12	0.01	-0.04	0.02	0.26	-0.09	-0.13	0.00	0.00	-0.08	0.02	-0.01	-0.08	-0.04	-0.02	-0.09	0.00	**-0.26**
13	0.00	0.00	-0.03	-0.06	-0.03	-0.05	-0.01	-0.02	0.02	-0.02	0.00	-0.04		-0.04	-0.01	-0.16	**-0.45**
14	-0.02	-0.02	-0.01	-0.08	-0.02	-0.05	-0.05	-0.07	-0.06	-0.01	0.00	-0.03	-0.01	-0.29	-0.02	-0.07	**-0.82**
15	0.00	-0.01	-0.03	-0.06	-0.04	-0.07	-0.01	-0.01	-0.08	-0.05	0.00	-0.08	-0.03	-0.05		-0.41	**-0.94**
16	-0.07	-0.18	0.04	-0.21	-0.49	-0.12	-0.09	-0.04	-0.16	0.00		0.01	-0.11	-0.07	-0.35		**-1.83**
Dest	**-0.47**	**-0.49**	**-0.73**	**0.07**	**-1.86**	**-3.47**	**-0.41**	**-0.25**	**-0.83**	**-0.41**	**0.08**	**-0.71**	**-0.32**	**-1.39**	**-0.67**	**-2.24**	**-14.09**

7.6.10 The revised TUBA results were then multiplied by 2 to reflect delays to road users during 2-year construction period, providing the total delays costs during construction of **-£28.18m**.

7.7 WIDER IMPACT BENEFITS – STATIC CLUSTERING

7.7.1 Wider impacts – static clustering refers to the impacts that assumes fixed land-use (connectivity impacts) or do not require land-use change to be explicitly quantified. The wider impacts static clustering includes the following:

- Agglomeration impacts (fixed land-use);
- Output in imperfectly competitive market (10% of TUBA business user benefit); and
- Labour supply impacts.

7.7.2 Level 2 static Wider Economic Benefits (WEBs) was assessed from model outputs using agglomeration and decay parameters as described in WebTAG unit A2.1. This approach to assessing Static WEBS used WSP's WITA emulation tool which has previously been approved for use on the Trans-Pennine Tunnel Study Stage 0 by Highways England and DfT. The output change and tax revenues arising from labour market impacts were calculated using the same WITA emulation tool and produced zero, as there was no change in employment data under the static clustering assumption.

7.7.3 It is expected that the TPTS+ interventions would generate strong wider impacts due to improved connectivity linking businesses, particularly for areas in the vicinity of the TPTS+ interventions (between Manchester and Sheffield).

7.7.4 Due to the absence of active travel and bus costs in the model the WITA agglomeration impacts output from WITA initially adopted a reduction by 35% (i.e. adjustment factor of 0.65). The adjustment factor of 0.65 was obtained from the incremental analysis for with and without the missing modes that was carried out on the M60 Smart Motorway (M60SM) study.

7.7.5 Following discussion with Highways England on the comparison of the Level 2 impacts between the Economy model and WITA (as detailed in the TN '**190405 TPTS+ static Agglom Comparison'**[7]), it was agreed that the WITA level 2 agglomeration impact would reduce by 20% to account for missing modes. The value of 20% was considered more appropriate for this study as:

- An analysis undertaken by David Simmonds[8] that evaluated the impact of removing non-car modes on the TPTS+ study shows that the agglomeration impact would increase by 25% compared to without removing non-car mode generalised costs; and
- The value 35% was derived from the analysis of the M60 improvements only, over 4 years old and might have used out-of-date assumptions.

7.7.6 Following discussion at a TAG meeting in April 2019 attended by representatives from HE, DfT and TfN, it was agreed that a 20% reduction to the level 2 WITA agglomeration benefits was to be adopted for the TPTS+ study.

7.7.7 **Table 7-14** below provides summary of WITA level 2 benefits, with and without 20% adjustment factors.

Table 7-14 WITA Benefits (£000s)

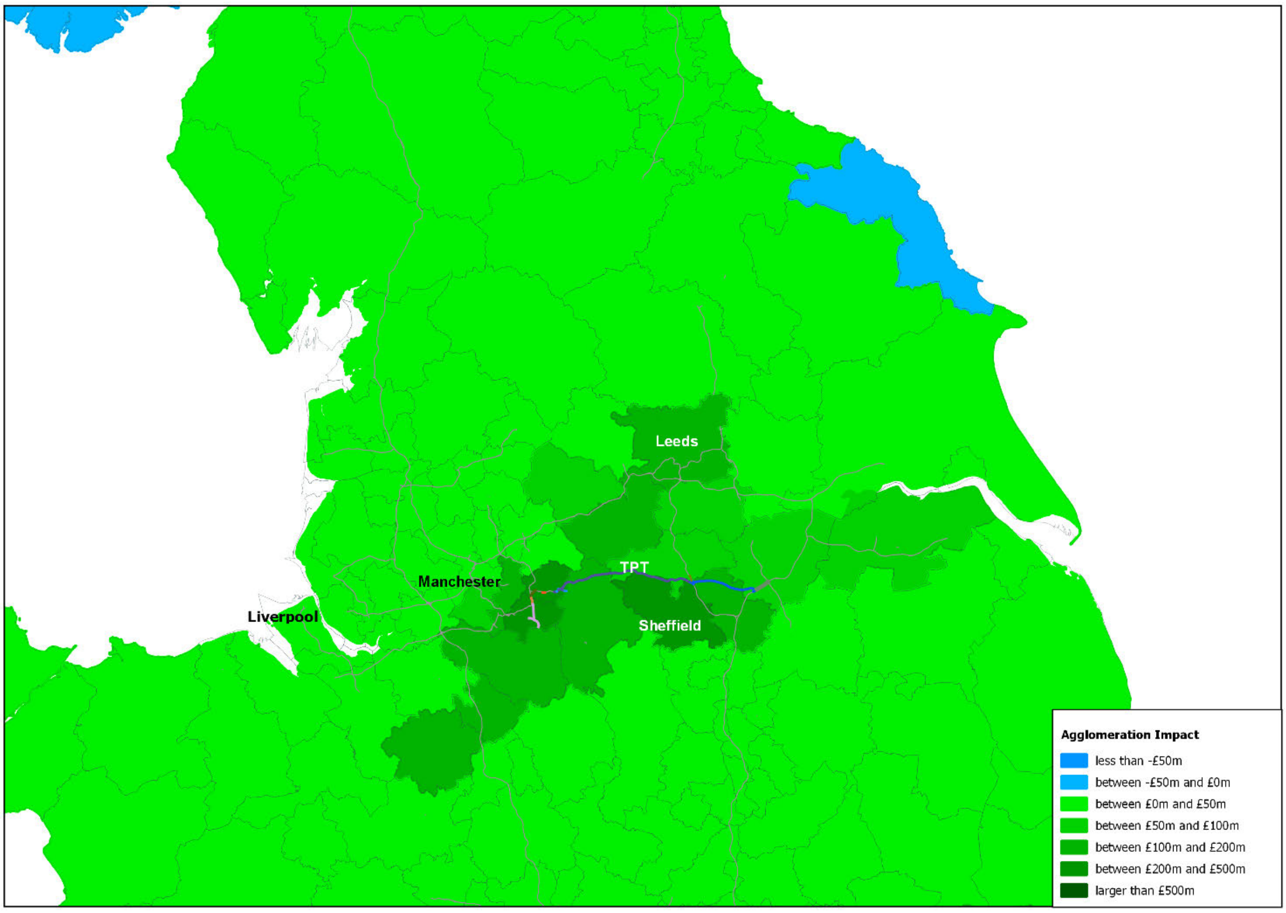
Package	TPTS only		Optimised Package	
	WITA	Adjusted	WITA	Adjusted
Agglomeration impacts	2,174,003	1,739,202	3,853,884	3,083,107
Change in imperfectly competitive market	129,559	129,559	235,147	235,147
Labour supply impacts	8,382	8,382	20,024	20,024
Move to more/less productive jobs	0	0	0	0
Total	**2,311,944**	**1,877,144**	**4,109,055**	**3,338,278**

7.7.8 It is noted that the 20% adjustment factors to account for missing modes are only applied for the agglomeration impacts as Change in imperfectly competitive market applies 10% of TUBA business user benefits, and the calculation of 'Labour supply impacts' is not affected by the missing modes.

7.7.9 **Figure 7-10** shows the geographical distribution of agglomeration benefits, at LAD level.

[7] http://share/share/llisapi.dll?func=ll&objaction=overview&objid=72042958
[8] Annex A - Switching value tests for assessing agglomeration impacts under different mode assumptions - Appendix to the Report in the location above.

Figure 7-10 Agglomeration Impacts by LADs



7.7.10 It can be seen that the majority of the agglomeration benefits are concentrated around the TPTS+ improvements, for example Manchester, Sheffield and Leeds areas. This is anticipated given the improvement in travel time produced from the tunnel and the wider schemes M6-M60 and M1-M18 would result in bringing three major conurbation areas closer together, thus producing strong wider agglomeration impacts.

7.7.11 WITA static clustering will be added in on top of the level 1 BCR to form the adjusted BCR for the TPTS+ study.

7.8 RELIABILITY IMPACTS

INTRODUCTION

7.8.1 Reliability refers to variation in journey times that individuals are unable to predict. Such variation could come from recurring congestion at the same period each day or from non-recurring events such as incidents.

7.8.2 According to WebTAG A1.3, three different methods can be used to estimate reliability impacts for motorway and dual carriageways (MyRIAD), urban areas (change in standard variation of travel time), or for rural areas (change in 'stress' method).

7.8.3 WebTAG A1.3 states that, for journeys predominantly on single carriageways outside urban areas, it is not currently possible to estimate monetised reliability benefits. Instead, the assessment of changes in reliability should be based on changes in “stress”, the ratio of the annual average daily traffic (AADT) flows to the Congestion Reference Flow (CRF). Reliability of road journey is believed to decline as flows approach capacity. Thus “stress”, is, with some limitation, considered to be a reasonable proxy for reliability.

7.8.4 The “stress” approach is based on the change in “stress” within the range 75% to 125% as a result of the interventions, combined with numbers of vehicles affected. Stress is the ratio of counted or measured AADT flows to the congestion reference flows. Where a proposal provides a new route, the approach takes account of improvements in reliability for those remaining on the old route as well as those transferring to the new. Proposals that provide modest improvements for large volumes of traffic may be more highly rated than those providing large improvements for small volumes.

7.8.5 To take account of possible “bottleneck” effects, where the effect of one link or junction operating close to capacity affects the reliability of an extended length of road, the method focuses on those key links/junctions rather than the whole length of roads.

7.8.6 WebTAG A1.3 states that it is not appropriate to present the numeric results of the calculations, instead the result should be used to assist in reaching an appropriate textual score, using the following guidelines:

- Values in excess of 3 million will usually assessed as “Large” (“Beneficial” if the value is positive, “Adverse” if the value is negative);
- Values between 1 and 3 million will usually be assessed as “Moderate”;
- Values between 200 thousand and 1 million will usually be assessed as “Slight”; and
- Values less than 200 thousand will usually be assessed as “Neutral”

RELIABILITY IMPACTS FOR THE TPTS+ STUDY

7.8.7 There have been several discussions with the team working on the A66 on the methodology to undertake reliability impacts that could be adopted for the TPTS+ study however the conclusion was that their work is not sufficiently advanced to support what is needed in the timescales for the purpose of the study. It was therefore discussed at a project board meeting that similar exercise as per the previous TPTS work was to be adopted for this study to derive quantitative monetised benefits for the reliability impacts of this study.

7.8.8 Analysis of the models show that with the TPTS+ packages introduced, a number of key routes (i.e. M62, A628, M60, M1 and A1(M)) would have significant impacts in terms of flow and delay changes. It was therefore decided that the key routes and the tunnel were to be used for the purpose of assessing the reliability impacts using the “stress” method.

7.8.9 The AADT and Congestion Reference Flow for each of the key routes were calculated from the Do-Minimum and Do-Something 2041 model outputs for the purpose of producing the analysis. **Table 7-15** and **Table 7-16** below provide summary of the overall assessment and assessment score for the TPTS only and Optimised Package respectively.

Table 7-15 Reliability Impacts - TPTS Only

Element	Old Route (i)					New Route (ii)		
	M62	A628	M1	M60	A1(M)	TPTS	M1-M18	A6-M60
Without scheme stress (a)	87	65	82	66	63	77	77	77
With scheme stress (b)	86	50	87	67	64	58	0	0
Difference in stress (c=a-b, restricting a and b to the range 75% - 125%)	2	15	-5	-1	0	18	77	77
With scheme AADT (d)	155,502	60,432	157,399	136,516	63,093	69,187	0	0
Overall impact (e=c*d)	259,272	898,849	-774,782	-119,042	-19,469	1,273,634	0	0
Overall assessment:e = e(i) + e(ii)	**1,518,462**							
Assessment Score	**Moderate beneficial**							

Table 7-16 Reliability Impacts – Optimised Package

Element	Old Route (i)					New Route (ii)		
	M62	A628	M1	M60	A1(M)	TPTS	M1-M18	A6-M60
Without scheme stress (a)	87	65	82	66	63	77	77	77
With scheme stress (b)	85	63	78	72	76	69	55	55
Difference in stress (c=a-b, restricting a and b to the range 75% - 125%)	2	2	3	-5	-13	8	21	21
With scheme AADT (d)	157,347	73,304	144,663	144,644	76,051	79,541	56,661	48,537
Overall impact (e=c*d)	388,255	133,070	482,838	-727,948	-971,762	597,394	1,199,153	1,040,007
Overall assessment:e = e(i) + e(ii)	**2,141,007**							
Assessment Score	**Moderate beneficial**							

Note: a(ii) is calculated using weighted average of 'without Scheme AADT' and 'without Scheme Stress'

7.8.10 As can be seen, both the TPTS Only and the Optimised Package would produce 'Moderate beneficial' reliability impacts as a result of interventions. The Optimised Package, whilst producing larger overall assessment, has also larger adverse impacts on existing routes such as M60 and A1(M) due to additional traffic flows on these two routes.

7.8.11 According to the document **Value for Money Assessment: Advice Note for Local Transport Decision Makers**[9], paragraph 3.7, Reliability benefits using the 'stress' approach can be estimated by applying uplifts of 10% of the time savings benefits produced from TUBA to reflect 'Moderate beneficial' impacts. The reliability benefits for the TPTS+ packages were therefore derived by applying 10% of the TUBA time savings benefits, as shown in **Table 7-17** below.

Table 7-17 Reliability Benefits (£000s)

Package	TPTS only		Optimised Package	
	VDM	with UDF	VDM	with UDF
TUBA Time Saving benefits	1,976,368	2,271,776	4,297,581	4,739,154
Reliability Benefits (10%)	**197,637**	**227,178**	**429,758**	**473,915**

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267296/vfm-advice-local-decision-makers.pdf

7.8.12 Similar to static clustering WITA benefits, reliability benefits will be used to inform the adjusted BCR for the TPTS+ study.

7.9 APPRAISAL SUMMARY

7.9.1 The summary of costs, benefits and BCR for the 'TPTS Only' and the 'Optimised Package' under the NTEM Core scenario is provided in **Table 7-18** below.

Table 7-18 Appraisal Summary – NTEM Core (Opening Year 2033)

Appraisal Summary	TPTS Only	Optimised Package
Present Value of Cost (£m)		
CAPEX	3,247.85	4,401.99
OPEX	375.74	469.74
Total PVC	3,623.58	4,871.73
Level 1 PVB (£m)		
User Benefits	2,213.45	4,633.33
Indirect Tax Revenue	187.11	372.29
Greenhouse Gas	-98.82	-195.08
Accident	106.22	134.00
Construction	-28.18	-28.18
Total	**2,379.77**	**4,916.37**
Initial BCR	0.66	1.01
Level 2 PVB (£m)		
Reliability	227.18	473.92
Wider Impacts - Static Clustering	1,877.14	3,338.28
Total	4,484.09	8,728.56
Adjusted BCR	**1.24**	**1.79**

7.9.2 Level 3 benefits are not included in this report, however a Technical Note on the Highways England Economy Model can be found on the Highways England knowledge management system (SHARE) here: http://share/share/llisapi.dll?func=ll&objaction=overview&objid=70785859.

7.9.3 As can be seen, the Optimised Package offers Low to Medium Value for Money (VfM) whereas the 'TPTS Only' only offers Poor to Low Value for Money. It should be noted that this is based on the Benefit Cost Ration only, i.e. not considering key uncertainties.

7.10 IMPACTS NOT ASSESSED

7.10.1 There are two key impacts that have not been assessed as part of this study, i.e. Resilience benefits and savings associated with future road maintenance.

RESILIENCE

7.10.2 The A628 across the Pennines is a single carriageway road that is subject to a number of closures through the year, relating to adverse weather conditions, both high-wind and snow. The closure of the A628 is often in combination with the closure of the A57 Snake Pass, that provides an alternative for some trips between the two city regions. In such circumstances, the only reasonable alternative for the bulk of the traffic using the A628 is to use the M62, involving a journey almost 40 miles longer than the A628 route (between the M1 and M60).

7.10.3 As the Tunnel will traverse the highest section of the Pennines, it is likely that the new route, with a tunnel and a dual carriageway standard, will not require such a closure. This would lead to significant annual economic benefits that have not been quantified nor used in the above assessment.

FUTURE MAINTENANCE COST AND DELAY

7.10.4 As reported above, in line with Transport Business Case guidance, whole life costs have been included in the cost-benefit assessment. These include the cost of day-to-day operational maintenance of the road as well as planned future renewals such as re-surfacing or carriageway pavement re-construction.

7.10.5 Whilst these costs have been estimated and included for each new intervention, it is important to note that these costs will directly, and indirectly result in cost savings or benefits during future maintenance, that would not materialise in the absence of the interventions. These potential savings are briefly discussed below.

POTENTIAL COST SAVINGS AND DELAY BENEFITS

7.10.6 The new roads will not need re-surfacing or require pavement re-construction for many years, but the existing roads will need regular pavement maintenance in the absence of the new schemes. With the new schemes there would therefore be a direct (albeit, small) cost saving for a reduced level of maintenance of the existing road.

7.10.7 The existing road across the Pennines is of single carriageway standard. As such, whenever significant maintenance is required, single lane (shuttle-working) operation with temporary traffic lights would need to be implemented. These maintenance periods will add significant delay to traffic throughout the duration of the works along the entire route. The road network in the area is such that reasonable diversion routes are not available and so the bulk of the traffic will be subject to the roadworks delay, with others subject to lengthy diversion routes.

7.10.8 With the TPT scheme being a dual carriageway, it would be possible to undertake maintenance with a single lane closed in each direction and a single lane available to traffic in each direction. With the protection from the weather and installed lighting within the tunnel, the maintenance along the tunnel section could be restricted to over-night periods when traffic is light. So, there would be fewer periods of maintenance and those periods would result in much shorter delays to traffic due to two-lanes being available at all times and traffic not being held at temporary traffic signals.

7.10.9 Traditionally, a QUADRO assessment would be undertaken to quantify maintenance related traffic delays, which over a 60-year assessment period could be very significant. However, this is not within scope of the current study and programme constraints also preclude such an analysis being undertaken. Nevertheless, the potential savings in traffic delay during maintenance should be considered as part of the value for money statement

8 ALTERNATIVE GROWTH SCENARIOS

8.1 OVERVIEW

8.1.1 This chapter provides a summary of the alternative growth scenarios that have been agreed for the modelling and appraisal purpose of the TPTS+ study: DfT Low Growth scenario[10] and TfN Transformational growth scenarios.

8.1.2 The modelling tests (using VDM) on the alternative growth scenarios were undertaken on Do-minimum and the Optimised Package only. A TUBA assessment was subsequently carried out on the VDM, for 'without' and 'with' UDF application to understand the impacts of the UDF on the alternative growth scenarios.

8.2 LOW GROWTH SCENARIO

INTRODUCTION

8.2.1 As stated in **Section 3.8**, a Low Growth scenario refers to change in travel behaviour, with assumptions based on a declining trend in road-based trips and increase in rail-based trips over the last 15 years.

8.2.2 For this test, the DfT scenario 6, 'Extrapolated trip rates' scenario reference demand (Car, Rail, and freight) was provided to the TPTS+ team by an RTM maintenance consultant in December 2018. A HEIDI/VDM process was subsequently carried out, followed by the application of the Urban Delay function to produce the forecast models for the Do-Minimum and the Optimised Package for 2031 and 2041 forecast years.

8.2.3 TUBA runs for 'without' and 'with' UDF were carried out to produce direct transport user benefits for the Optimised Package.

8.2.4 The following sections provide a summary of the modelling and appraisal outputs from the Low Growth scenario for the TPTS+ study.

MODELLING OUTPUTS

8.2.5 This section summarises the modelling outputs produced for the Low Growth scenario for the TPTS+ study. As stated in the previous section, the modelling for the Low Growth scenario was undertaken for the Do-Minimum and the Optimised Package only.

8.2.6 **Table 8-1** provides the summary of the Reference demand produced from the Low Growth scenario in comparison against NTEM Core scenario, in terms of road and rail demand totals.

[10] Road Traffic Forecast 2018, scenario 6

Table 8-1 Low Growth Demand Summary - 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
NTEM Core Demand								
AM Peak	1,266,425	7,115,329	7,967,726	**16,349,481**	147,552	748,961	215,273	**1,111,786**
Inter-Peak	2,322,985	6,913,195	20,066,673	**29,302,852**	103,255	98,972	352,932	**555,159**
PM Peak	1,283,365	7,200,327	11,199,745	**19,683,437**	137,878	775,738	235,340	**1,148,956**
Off-Peak	1,042,930	4,438,938	10,333,761	**15,815,629**	62,131	213,881	117,939	**393,950**
Total	**5,915,705**	**25,667,788**	**49,567,906**	**81,151,399**	**450,816**	**1,837,552**	**921,484**	**3,209,851**
Low Growth Scenario								
AM Peak	1,168,194	5,183,042	6,425,490	**12,776,726**	141,507	538,405	183,720	**863,632**
Inter-Peak	2,084,536	5,035,889	16,256,374	**23,376,799**	98,698	71,148	301,319	**471,165**
PM Peak	1,186,051	5,245,054	9,049,329	**15,480,435**	131,899	557,654	201,164	**890,717**
Off-Peak	967,137	3,233,539	8,370,362	**12,571,038**	58,225	153,752	102,165	**314,142**
Total	**5,405,917**	**18,697,525**	**40,101,556**	**64,204,998**	**430,329**	**1,320,958**	**788,368**	**2,539,655**
Change from NTEM Core								
AM Peak	-98,232	-1,932,287	-1,542,236	**-3,572,754**	-6,045	-210,557	-31,553	**-248,154**
Inter-Peak	-238,449	-1,877,305	-3,810,299	**-5,926,053**	-4,557	-27,824	-51,613	**-83,994**
PM Peak	-97,314	-1,955,272	-2,150,416	**-4,203,002**	-5,979	-218,084	-34,176	**-258,239**
Off-Peak	-75,793	-1,205,399	-1,963,399	**-3,244,591**	-3,906	-60,129	-15,774	**-79,808**
Total	**-509,787**	**-6,970,264**	**-9,466,350**	**-16,946,401**	**-20,487**	**-516,594**	**-133,116**	**-670,196**
%Change from NTEM Core								
AM Peak	-7.8%	-27.2%	-19.4%	**-21.9%**	-4.1%	-28.1%	-14.7%	**-22.3%**
Inter-Peak	-10.3%	-27.2%	-19.0%	**-20.2%**	-4.4%	-28.1%	-14.6%	**-15.1%**
PM Peak	-7.6%	-27.2%	-19.2%	**-21.4%**	-4.3%	-28.1%	-14.5%	**-22.5%**
Off-Peak	-7.3%	-27.2%	-19.0%	**-20.5%**	-6.3%	-28.1%	-13.4%	**-20.3%**
Total	**-8.6%**	**-27.2%**	**-19.1%**	**-20.9%**	**-4.5%**	**-28.1%**	**-14.4%**	**-20.9%**

8.2.7 It can be seen from **Table 8-1** that the Low Growth scenario shows a reduction in demand in both road and rail-based trip totals with largest reduction in Commuting trips, followed by Other trips in both road and rail. This is in line with the assumptions set out in the 'low trip rates' growth scenario in which Commuting trips have seen a larger decline in Commuting trips compared to the Other trips.

8.2.8 The impact of VDM on matrix totals show similar compared to the NTEM Core scenario, with an overall reduction in road-based trips and an increase in rail-based trips in the Do-Minimum post-VDM from the Reference demand. The reduction of road-based trips is primarily attributed to the reduction in the peak hours as a result of a larger increase in travel costs during the peak hours compared to off-peak periods.

8.2.9 **Table 8-2** provides a summary of the impacts of the VDM on the Optimised Package in comparison to the Do-Minimum demand matrices for the forecast year 2041.

Table 8-2 Change in Demand Totals – 2041

Period	Car				Rail			
	Business	Commute	Other	Total	Business	Commute	Other	Total
Do-Minimum - Post-VDM								
AM Peak	1,162,921	5,157,511	6,424,868	**12,745,301**	148,187	580,111	199,160	**927,458**
Inter-Peak	2,069,613	5,008,604	16,218,603	**23,296,820**	103,467	76,659	327,042	**507,168**
PM Peak	1,180,161	5,217,887	9,049,887	**15,447,936**	138,287	600,852	218,737	**957,875**
Off-Peak	974,357	3,220,499	8,378,382	**12,573,238**	61,530	165,662	111,276	**338,469**
Total	**5,387,052**	**18,604,501**	**40,071,742**	**64,063,295**	**451,471**	**1,423,284**	**856,215**	**2,730,970**
Optimised Package - Post-VDM								
AM Peak	1,162,996	5,157,619	6,424,529	**12,745,145**	148,001	579,968	199,096	**927,065**
Inter-Peak	2,070,173	5,008,937	16,219,619	**23,298,729**	103,333	76,640	326,941	**506,914**
PM Peak	1,180,024	5,217,780	9,049,758	**15,447,563**	138,115	600,703	218,671	**957,489**
Off-Peak	974,371	3,220,484	8,377,980	**12,572,834**	61,449	165,621	111,241	**338,312**
Total	**5,387,564**	**18,604,820**	**40,071,886**	**64,064,271**	**450,899**	**1,422,933**	**855,948**	**2,729,780**
Change								
AM Peak	75	108	-339	**-156**	-186	-143	-64	**-393**
Inter-Peak	560	333	1,016	**1,908**	-134	-19	-101	**-254**
PM Peak	-137	-107	-129	**-373**	-172	-148	-66	**-386**
Off-Peak	14	-15	-403	**-404**	-81	-41	-35	**-157**
Total	**512**	**319**	**145**	**976**	**-572**	**-351**	**-267**	**-1,190**

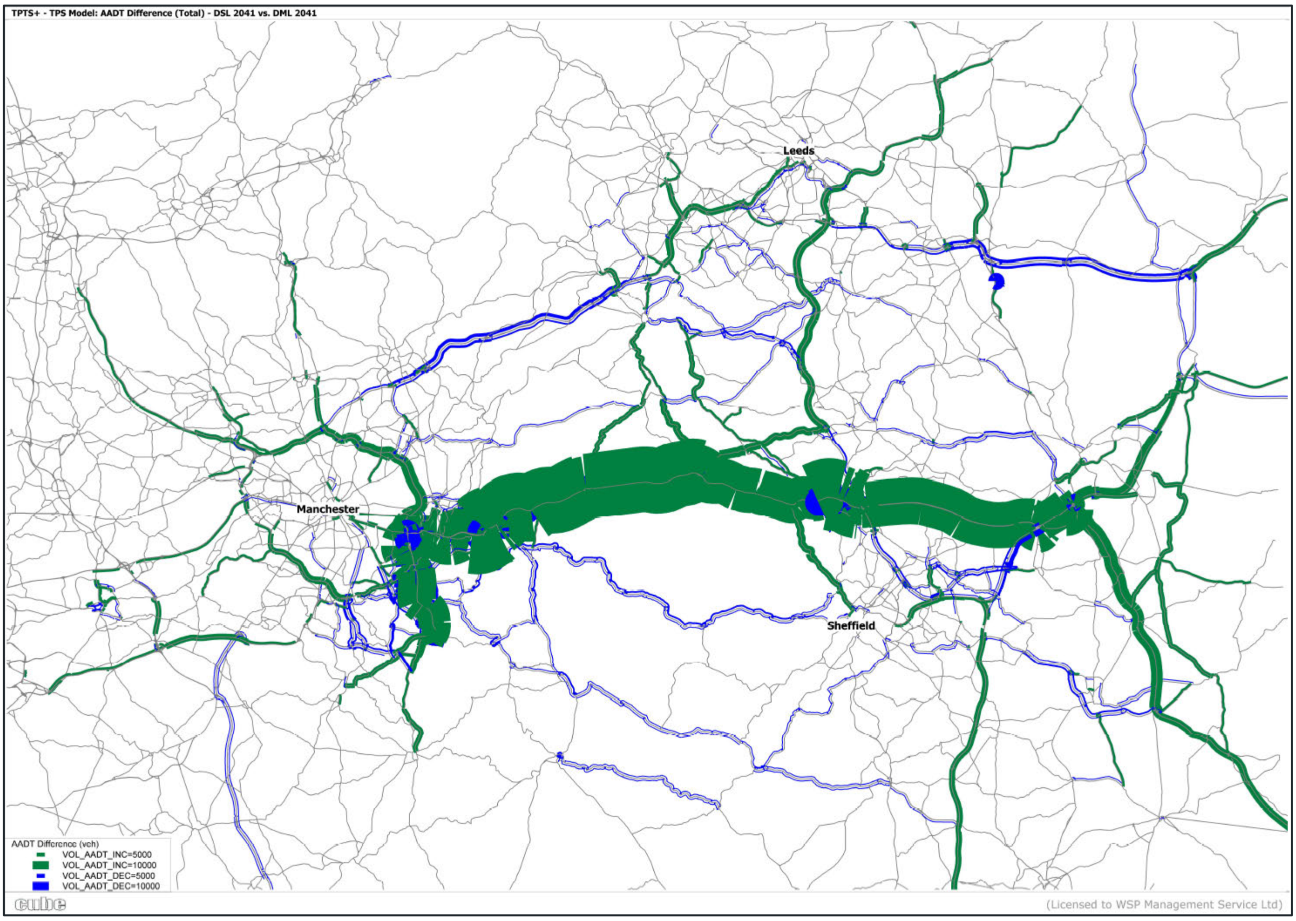
8.2.10 It can be seen that the introduction of the Optimised Package would result in overall increases in car demand and a reduction in rail demand from the Do-Minimum due to additional capacity being added to the Optimised Package.

8.2.11 It is however noted that whilst showing an overall increase in car demand in the Optimised Package from the Do-Minimum, the AM peak and PM peak show a reduction in car demand from the Do-Minimum, which seems counter-intuitive as one would expect increase in trips across the three peak periods.

8.2.12 Further analysis suggests that this was the impacts of the macro-time choice responses, which transfers car from the AM and PM peak to the inter-peak periods due to much smaller change in the travel costs in the inter-peak compared to the AM and PM peak under the Low Growth scenario demand.

8.2.13 The impacts of the Optimised Package on the network in terms of flow difference under the Low Growth scenario are provided in **Figure 8-1** below.

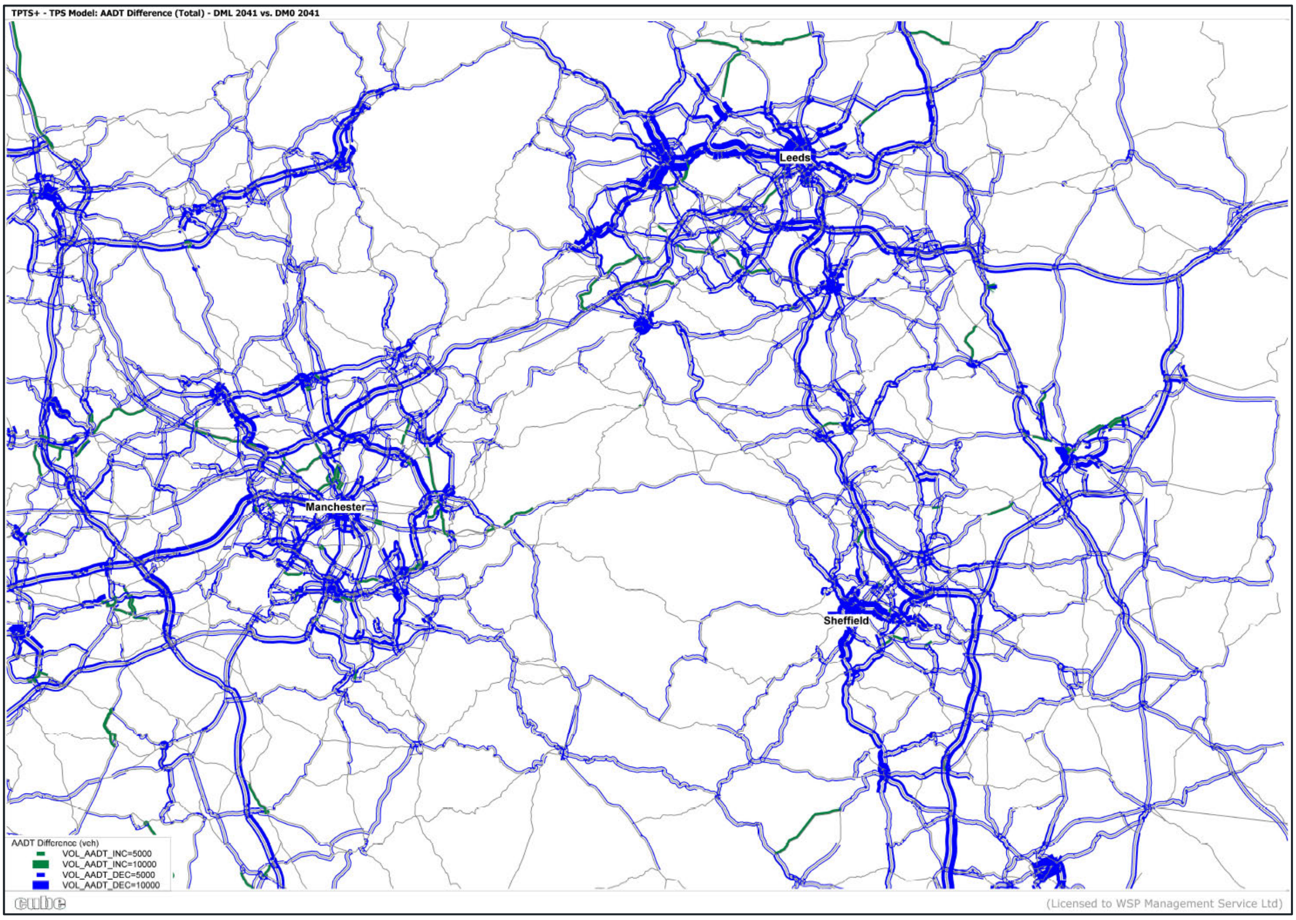
Figure 8-1 Flow Difference between DS and DM - Low Growth Scenario 2041



8.2.14 Similar to the change in demand in the NTEM Core scenario, the Low Growth scenario VDM also produces significant increases in traffic volume on the Trans-Pennine Tunnel, drawing traffic from the M60 and extending to M1-M18 link and to the A1(M) toward the south. Similar reduction is forecast on M62 and existing roads crossing the Pennines as have been seen in the NTEM Core scenario.

8.2.15 With reduction of car demand in the Low Growth scenario compared to the NTEM Core scenario, it is expected that the Low Growth scenario would see reduction in traffic volume on the network compared against the NTEM Core scenario, as can be seen in **Figure 8-2** below.

Figure 8-2 Flow Difference between NTEM Core and Low Growth – 2041



APPRAISAL OUTPUTS

8.2.16 **Table 8-3** below provides a summary of the TUBA benefits produced for both 'with' UDF and 'without' UDF for the Low Growth scenario. the figures were put side by side with the benefits produced for the NTEM Core scenario for the comparison purpose.

Table 8-3 TUBA Benefit Summary - Low Growth Scenario (£000s)

Package	Optimised Package - Core Scenario			Optimised Package - Low Growth		
	VDM	with UDF	%Diff	VDM	with UDF	%Diff
Consumer User (Commute)	531,941	608,806	14%	496,052	537,681	8%
Consumer User (Other)	619,692	755,689	22%	527,214	582,223	10%
Business User and Provider	3,014,825	3,273,272	9%	3,182,083	3,309,134	4%
Private sector provider (Toll revenues)	-4,395	-4,437	1%	-4,014	-4,458	11%
Indirect Tax Revenue	381,819	372,293	-2%	320,820	317,411	-1%
Greenhouse Gas	-227,459	-195,078	-14%	-104,410	-56,423	-46%
Total	**4,316,423**	**4,810,544**	**11%**	**4,417,744**	**4,685,568**	**6%**

8.2.17 It can be seen the Low Growth scenario would produce similar TUBA benefits compared to the NTEM Core growth scenario, with marginally smaller values (£120m).

8.2.18 It is noted that without the application of the UDF, TUBA for the Low Growth scenario shows slightly higher benefits compared to the NTEM Core. The application of the UDF only increases TUBA benefits by 6% for the Low Growth scenario as opposed to 11% in the NTEM Core scenario.

8.2.19 Detailed analysis of the Low Growth scenario shows that whilst car demand in the Low Growth scenario are lower than the NTEM Core scenario (about 21% at 12-hour level), freight demand (LGV and HGV) show higher totals than the NTEM Core scenario, by 18% and 15% for LGV and HGV respectively in 2041, as provided in **Table 8-4** below.

Table 8-4 Demand Summary 2041 - Low Growth vs. NTEM Core

Purpose	Highway Demand				%Change			
	AM Peak	Inter-Peak	PM Peak	12-hour	AM Peak	Inter-Peak	PM Peak	12-hour
NTEM Core								
Business	385,136	404,256	402,270	**4,787,757**				
Commute	2,650,139	1,008,917	2,494,446	**21,487,256**				
Other	2,634,819	3,349,552	3,758,792	**39,278,142**				
Car	**5,670,093**	**4,762,725**	**6,655,508**	**65,553,155**				
LGV	856,046	785,257	831,477	**9,774,106**				
HGV	341,974	353,746	249,026	**3,895,477**				
Total	**6,868,113**	**5,901,728**	**7,736,010**	**79,222,738**				
Low Growth Scenario and %Change from NTEM Core								
Business	357,361	362,427	372,668	**4,364,649**	-7%	-10%	-7%	**-9%**
Commute	1,932,667	734,773	1,820,539	**15,668,257**	-27%	-27%	-27%	**-27%**
Other	2,130,764	2,711,092	3,044,052	**31,790,997**	-19%	-19%	-19%	**-19%**
Car	**4,420,791**	**3,808,292**	**5,237,259**	**51,823,904**	**-22%**	**-20%**	**-21%**	**-21%**
LGV	1,012,724	928,562	984,049	**11,561,689**	18%	18%	18%	**18%**
HGV	394,694	408,304	287,453	**4,496,265**	15%	15%	15%	**15%**
Total	**5,828,209**	**5,145,158**	**6,508,761**	**67,881,857**	**-15%**	**-13%**	**-16%**	**-14%**

8.2.20 The reduction in car demand of 21% in the Low Growth scenario against the NTEM Core scenario at 12-hour level are as expected and in line with the 'Low trip rates' scenario as defined by the DfT. The increase in freight demand of 18% and 15% for LGV and HGV respectively however are not expected as the 'Extrapolated trip rates' from the RTF2018 only show marginal difference growth between the Core and the 'Extrapolated trip rates' scenario. This suggests that the growth in freight demand in the Low Growth scenario was not properly applied.

8.2.21 Analysis of flow difference in terms of freight demand (i.e. LGV + HGV) also show increase in freight volume across the network in the Low growth scenario against the NTEM Core, as illustrated in **Figure 8-3** below.

Figure 8-3 Flow Difference (Freight) between NTEM Core and Low Growth – 2041

8.2.22 As a result, TUBA benefits associated with freight demand produced for the Low Growth scenario show higher than that from the NTEM Core scenario, resulting in overall larger benefits in the Low growth scenario compared to the NTEM Core. The comparison of the TUBA benefits between the Low Growth and NTEM Core without the UDF is provided in **Table 8-5** below.

Table 8-5 TUBA Benefits without UDF - Low Growth vs. NTEM Core

Purpose	Low Growth				NTEM Core				Difference from NTEM Core			
	Time	Charges	VOC	Total	Time	Charges	VOC	Total	Time	Charges	VOC	Total
Commuting	510,608	-15	-14,541	496,052	562,735	-103	-30,691	531,941	-52,126	87	16,150	-35,889
Other	709,673	-196	-182,263	527,214	866,845	-284	-246,868	619,692	-157,172	88	64,605	-92,479
Business (Car)	2,107,353	944	60,082	2,168,378	2,124,037	941	68,172	2,193,151	-16,685	3	-8,090	-24,773
Business (Freight)	949,739	4,182	59,784	1,013,704	743,964	2,116	75,594	821,674	205,775	2,066	-15,811	192,030
Operators				-4,014				-4,395	0	0	0	381
Greenhouse Gas				-104,410				-227,459	0	0	0	123,049
Indirect Tax				320,820				381,819	0	0	0	-60,999
Total	**4,277,373**	**4,914**	**-76,939**	**4,417,744**	**4,297,581**	**2,670**	**-133,793**	**4,316,423**	**-20,208**	**2,244**	**56,854**	**101,321**

8.2.23 Having discussed with Highways England and the TPS RTM consultant, it was revealed that whilst the freight demand for the NTEM Core scenario was developed using the RTF2018 database, the freight demand for the Low Growth scenario was derived from the older version of the RTF (i.e. RTF2015) and therefore resulted in higher freight demand totals in the Low Growth scenario than should have been. High level analysis of the appraisal outputs suggests that the TUBA benefits for the Low Growth scenario could have been £200m lower than the NTEM Core if the corrected freight demand had been applied. This is at, a high-level, based on the assumption that similar growth in freight between the NTEM Core and the Low Growth scenario as per RTF database would produce similar benefits for freight.

8.2.24 It is however noted with the Fixed Speed adjustment applied, TUBA benefits produced for the Low Growth scenario is lower than the NTEM Core, of about £125m over the appraisal period, as summarised in **Table 8-6** below.

Table 8-6 TUBA Benefits with UDF - Low Growth vs. NTEM Core

Purpose	Low Growth				NTEM Core				Difference from NTEM Core			
	Time	Charges	VOC	Total	Time	Charges	VOC	Total	Time	Charges	VOC	Total
Commuting	552,076	-70	-14,326	537,681	641,950	-149	-32,996	608,806	-89,874	79	18,670	-71,125
Other	762,695	-252	-180,220	582,223	995,696	-349	-239,659	755,689	-233,001	96	59,439	-173,466
Business (Car)	2,193,705	448	64,868	2,259,021	2,270,285	672	80,511	2,351,467	-76,580	-224	-15,643	-92,447
Business (Freight)	981,444	5,208	63,462	1,050,113	831,223	2,516	88,066	921,804	150,221	2,693	-24,604	128,309
Operators				-4,458				-4,437				-21
Greenhouse Gas				-56,423				-195,078				138,655
Indirect Tax				317,411				372,293				-54,882
Total	**4,489,920**	**5,334**	**-66,216**	**4,685,568**	**4,739,154**	**2,690**	**-104,078**	**4,810,544**	**-249,234**	**2,644**	**37,862**	**-124,976**

8.2.25 As agreed in the TAG meeting, the corrected Low Growth scenario was not to be re-run for the modelling and appraisal purpose at this stage.

8.2.26 It is noted that the assessments of the Accident benefits were not carried out for the Low Growth and Transformational scenario. Reliability benefits calculation however adopts the methodology as described in **Chapter 8** (i.e. 10% of the TUBA time saving benefits)

8.3 TRANSFORMATIONAL GROWTH SCENARIO

INTRODUCTION

8.3.1 The vision of a transformed North was set out in the Northern Powerhouse Independent Economic Review (NPIER) in 2016[11]. This review concluded that transformational growth in the North will require investment and improved performance in a number of critical areas, including education, skills, innovation and inward investment, alongside transport infrastructure and services for passengers, business and freight. The conclusions of the NPIER are reinforced by the Government's Industrial Strategy, which sets out the need to support the growth of businesses and trade in the UK's world-leading sectors.

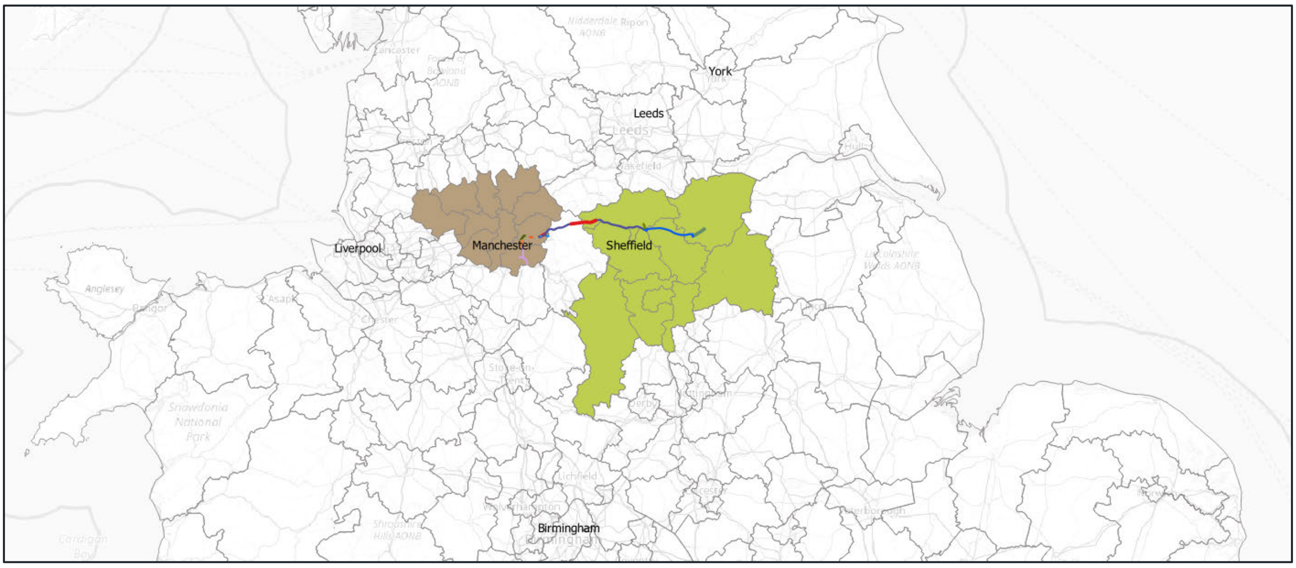
8.3.2 The TPTS+ Transformational Scenario has been specified collaboratively by TfN, Transport for Greater Manchester (TfGM), Sheffield City Region (SCR) and Highways England. The scenario is designed to represent a future in which Greater Manchester and Sheffield City Region achieve higher levels of population, employment and productivity as a result of complementary policies, such as spatial planning, skills and industrial strategy. The allocation of the total growth within each City Region to districts was determined by representatives of TfGM and SCR, based on local economic strategies. The agreed narrative for this scenario is that this policy support and associated additional

[11] SQW (2016) Northern Powerhouse Independent Economic Review, available at https://transportforthenorth.com/reports/northern-powerhouse-independent-economic-review-scenarios-future-growth/

growth is focused in districts most in need of support and regeneration, as identified by TfGM and SCR.

8.3.3 The scenario has been set up as a reallocation of economic activity, so total growth is balanced at a UK level, with the additional levels in GM and SCR taken evenly from elsewhere in the UK. The Local Authority Districts (LADs) included in the TfN Transformational scenario is presented in **Figure 8-4** below.

Figure 8-4 LADs Included in TfN Transformational Scenario



8.3.4 The representation of freight in the TPTS+ Transformational Scenario has also been updated to reflect the higher population and employment, as well as extrapolation of existing trends in the freight and logistics likely to continue in a transformed North. The two key trends included are:

- a shift to larger ferries, which increases East-West freight movements in the UK; and
- warehouse clustering around freight hubs, which helps to prioritise rail freight and load consolidation.

8.3.5 The assumptions of population, employments and Gross Values Added (GVA) per workers that have been used for the purpose of modelling and appraisal of the TfN Transformational Scenario is provided in **Table 8-7** below.

Table 8-7 Percentage Uplift Relative to NTEM Core

Area	LAD	Population		Employment		GVA/worker	
		2031	2041	2031	2041	2031	2041
Greater Manchester	Bolton	1.0%	1.9%	0.0%	1.2%	1.5%	7.1%
	Bury	9.1%	18.1%	0.0%	11.1%	0.0%	3.0%
	Manchester	2.1%	4.1%	0.0%	1.6%	5.4%	11.9%
	Oldham	7.3%	14.4%	0.0%	9.2%	0.0%	0.9%
	Rochdale	8.3%	16.9%	0.0%	10.9%	0.4%	5.0%
	Salford	1.1%	2.0%	0.0%	1.1%	3.5%	9.6%
	Stockport	3.9%	7.7%	0.0%	4.1%	2.4%	7.7%
	Tameside	9.3%	18.1%	0.0%	13.2%	0.0%	3.7%
	Trafford	1.3%	2.6%	0.0%	1.0%	2.0%	6.9%
	Wigan	2.6%	5.4%	0.0%	3.3%	0.0%	2.6%
Sheffield City Region	Barnsley	0.0%	6.4%	0.0%	7.6%	0.2%	3.6%
	Doncaster	0.0%	3.3%	0.0%	3.6%	0.3%	1.3%
	Rotherham	0.0%	5.2%	0.0%	5.7%	0.0%	3.1%
	Sheffield	0.0%	1.6%	0.0%	1.4%	3.1%	6.8%
	North East Derbyshire	0.0%	3.5%	0.0%	4.2%	0.0%	0.0%
	Chesterfield	0.0%	1.9%	0.0%	1.9%	0.0%	0.0%
	Derbyshire Dales	0.0%	1.5%	0.0%	1.4%	0.0%	0.0%
	Bassetlaw	0.0%	2.1%	0.0%	2.3%	0.0%	0.0%
	Bolsover	0.0%	3.6%	0.0%	4.8%	0.0%	0.0%

8.3.6 It should be acknowledged the approach set out here is not entirely consistent with the original NPIER narrative or with the approach taken for other major schemes, due to its focused geographical scope. Despite these limitations, we believe this is the best course of action available, given the limited timescales and the fact that the scheme is at Stage 0 of development.

METHODOLOGY

8.3.7 To understand the impacts of the Transformational scenario on the performance and subsequently appraisal of the TPTS+ interventions, it was necessary to derive a set of travel demand matrices from the assumptions in terms of change in population, employment and GVA as set out by TfN. As such, two separate processes have been developed for car and freight which take into account the uplift in population, employment and GVA for the GM and SCR areas to produce the Transformational scenario travel demand for the purpose of the modelling and appraisal.

8.3.8 For car demand, it was agreed that equivalent growth factors were applied to the NTEM Core demand matrices at Production (P) Attraction (A) trip-end levels, then carrying out Furnessing process to produce PA demand matrices for the Transformational scenario. This process includes the following steps:

- Apply growth factors to P and A trip-ends for LADs in GM and SCR areas using change in population and employments as provided by TfN;
- Calculate total increase in P and A trip-ends for LADs in GM and SCR areas;
- Calculate total reduction for P and A trip-ends separately for the remaining LADs in the model to ensure zero net change;
- Calculate equivalent percentage reduction and apply percentage reduction to P and A trip-ends to the zones within the remaining LADs; and

- Carry out Furness process to distribute new P/A trip-ends to produce Transformation scenario demand matrices.

8.3.9 For P/A growth factors to be applied for LADs within GM and SCR areas, the following assumptions were made for each of the demand segments, as provided in **Table 8-8** below.

Table 8-8 Assumption of Growth Factors

Segment	Description	PA/OD	P/O Growth	A/D Growth
HBEB	Home-Based Business	PA 24-hour	Employment	Employment
HBW	Home-Based Commute	PA 24-hour	Population	Employment
HBO	Home-Based Other	PA 24-hour	Population	Population
NHBEB	None Home-Based Business	OD Period	Employment	Employment
NHBO	None Home-Based Other	OD Period	Population	Population
Business	Airport trips (Business)	OD Period	NA	NA
Commute	Airport trips (Commute)	OD Period	NA	NA
Other	Airport trips (Other)	OD Period	NA	NA
LGV	Light Goods Vehicle	OD Period	From MDST	From MDST
HGV	Heavy Goods Vehicle	OD Period	From MDST	From MDST

8.3.10 An example of the production of the Transformational car demand process can be illustrated in **Figure 8-5** below.

Figure 8-5 Production of Transformational Car Demand - Example

Example with HBW

Zone	Population	Employment
Manchester	4.1%	1.6%
Sheffield	1.6%	1.4%

P growth assumes change in population
A growth assumes change in employment

NTEM Core Trip-end

Zone	P	A
Manchester	1,051,091	1,043,409
Sheffield	776,179	778,911
External	18,717,379	18,722,329
Total	**20,544,649**	**20,544,649**

Step 1 - Apply Growth to Internal Zones

Zone	P	A	
Manchester	1,094,186	1,060,103	
Sheffield	788,598	789,816	
External	18,717,379	18,722,329	Freeze External
Total	**20,600,163**	**20,572,248**	
Net Change	**55,514**	**27,599**	
Reduction	-0.3%	-0.1%	

Step 2 - Apply net reduction to Ext. Zone

			Growth	
Zone	P	A	P	A
Manchester	1,094,186	1,060,103	4.1%	1.6%
Sheffield	788,598	789,816	1.6%	1.4%
External	18,661,865	18,694,730	-0.3%	-0.1%
Total	**20,544,649**	**20,544,649**	**0.0%**	**0.0%**
Net Change	0	0		

Step 3 - Furnessing

Zone	Manchester	Sheffield	External	Total (P)
Manchester	1,021,060	865	72,261	1,094,186
Sheffield	510	753,080	35,008	788,598
External	38,533	35,871	18,587,461	18,661,865
Total (A)	**1,060,103**	**789,816**	**18,694,730**	**20,544,649**
Check	0.000	0.000	0.000	

%Change from NTEM Core

Zone	Manchester	Sheffield	External	Total (P)
Manchester	2.7%	26.7%	28.8%	4.1%
Sheffield	-17.7%	1.5%	3.3%	1.6%
External	-20.5%	-1.9%	-0.2%	-0.3%
Total (A)	**1.6%**	**1.4%**	**-0.1%**	**0.0%**

8.3.11 With this approach, the target P and A trip-ends for the LADs within GM and SCR will be ensured while allowing trip-ends at external LADs to vary to ensure zero net change at the matrix totals level.

8.3.12 **Table 8-9** below provides summary of the TfN transformational car demand in comparison to the NTEM Core demand at the three aggregate sector systems: Greater Manchester, Sheffield City Region, and External.

Table 8-9 TfN Transformational Scenario Car Demand 2041

Home-Based Business - PA 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	116,694	845	52,005	**169,544**
Sheffield	2,223	83,605	23,987	**109,815**
External	69,077	17,844	1,611,911	**1,698,832**
Total	**187,994**	**102,294**	**1,687,903**	**1,978,190**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	6,557	44	1,330	**7,931**
Sheffield	95	3,498	816	**4,409**
External	582	217	-13,140	-12,340
Total	**7,234**	**3,760**	**-10,994**	**0**

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	123,251	889	53,335	**177,475**
Sheffield	2,318	87,103	24,803	**114,223**
External	69,660	18,061	1,598,771	**1,686,492**
Total	**195,228**	**106,053**	**1,676,909**	**1,978,190**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	5.6%	5.2%	2.6%	**4.7%**
Sheffield	4.3%	4.2%	3.4%	**4.0%**
External	0.8%	1.2%	-0.8%	-0.7%
Total	**3.8%**	**3.7%**	**-0.7%**	**0.0%**

Home-Based Commute - PA 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	457,833	268	73,793	**531,894**
Sheffield	336	308,348	45,071	**353,755**
External	63,353	34,296	11,850,596	**11,948,246**
Total	**521,522**	**342,912**	**11,969,460**	**12,833,894**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	29,791	206	12,728	**42,726**
Sheffield	-122	10,573	883	**11,334**
External	-6,165	992	-48,887	-54,060
Total	**23,505**	**11,771**	**-35,276**	**0**

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	487,624	474	86,521	**574,620**
Sheffield	214	318,921	45,954	**365,089**
External	57,189	35,288	11,801,709	**11,894,186**
Total	**545,027**	**354,683**	**11,934,184**	**12,833,894**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	6.5%	77.2%	17.2%	**8.0%**
Sheffield	-36.2%	3.4%	2.0%	**3.2%**
External	-9.7%	2.9%	-0.4%	-0.5%
Total	**4.5%**	**3.4%**	**-0.3%**	**0.0%**

Home-Based Other - PA 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	994,324	683	56,084	**1,051,091**
Sheffield	620	741,659	33,900	**776,179**
External	48,465	36,569	18,632,345	**18,717,379**
Total	**1,043,409**	**778,911**	**18,722,329**	**20,544,649**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	79,102	130	4,814	**84,046**
Sheffield	-37	25,206	936	**26,105**
External	-443	234	-109,942	-110,151
Total	**78,622**	**25,570**	**-104,191**	**0**

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	1,073,426	813	60,898	**1,135,137**
Sheffield	582	766,865	34,837	**802,284**
External	48,022	36,803	18,522,403	**18,607,228**
Total	**1,122,030**	**804,481**	**18,618,138**	**20,544,649**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	8.0%	19.0%	8.6%	**8.0%**
Sheffield	-6.0%	3.4%	2.8%	**3.4%**
External	-0.9%	0.6%	-0.6%	-0.6%
Total	**7.5%**	**3.3%**	**-0.6%**	**0.0%**

None Home-Based Business - OD 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	19,231	144	5,590	**24,965**
Sheffield	87	16,258	2,489	**18,835**
External	5,341	3,003	363,702	**372,047**
Total	**24,660**	**19,406**	**371,781**	**415,847**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	977	7	106	**1,090**
Sheffield	5	585	55	**644**
External	90	68	-1,892	-1,734
Total	**1,071**	**660**	-1,732	0

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	20,208	151	5,696	**26,055**
Sheffield	92	16,843	2,543	**19,479**
External	5,431	3,072	361,810	**370,313**
Total	**25,731**	**20,066**	**370,049**	**415,847**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	5.1%	5.0%	1.9%	**4.4%**
Sheffield	5.3%	3.6%	2.2%	**3.4%**
External	1.7%	2.3%	-0.5%	-0.5%
Total	**4.3%**	**3.4%**	-0.5%	0.0%

None Home-Based Other - OD 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	73,795	86	5,370	**79,251**
Sheffield	46	48,671	4,397	**53,114**
External	5,750	4,718	1,692,576	**1,703,044**
Total	**79,592**	**53,475**	**1,702,343**	**1,835,410**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	5,324	2	135	**5,461**
Sheffield	4	1,560	66	**1,629**
External	203	82	-7,375	-7,091
Total	**5,531**	**1,643**	-7,174	0

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	79,120	88	5,505	**84,713**
Sheffield	50	50,231	4,463	**54,744**
External	5,953	4,800	1,685,201	**1,695,953**
Total	**85,122**	**55,118**	**1,695,169**	**1,835,410**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	7.2%	2.4%	2.5%	**6.9%**
Sheffield	8.0%	3.2%	1.5%	**3.1%**
External	3.5%	1.7%	-0.4%	-0.4%
Total	**6.9%**	**3.1%**	-0.4%	0.0%

8.3.13 The TfN Transformational growth scenario is forecast to produce 4-8% and 3-4% uplift in demand in Greater Manchester and Sheffield City Region areas respectively from the NTEM Core scenario with larger uplifts for the Commuting and Other trips compared to Business trips. This is in-line with larger increase in population relative to increase in employments for GM and SCR areas as provided by TfN.

8.3.14 In terms of absolute change in demand as a result of the TfN Transformational scenario, it is however noted that significant uplift in demand is forecast for trips travelling entirely within Greater Manchester and Sheffield areas whereas only small increases in trips between Manchester and Sheffield. This is the product of the majority of trips being intra-Manchester and intra-Sheffield as opposed to significantly smaller demand between Manchester and Sheffield areas. This would potentially result in marginal increase in benefits of the Trans-Pennine tunnel interventions under the Transformational scenario.

8.3.15 For Transformational Scenario's freight demand, a separate process was developed that the NTEM Core freight demand was produced by applying the 'delta change' or absolute change approach at zonal level to:

- Adjust the NTEM Core freight demand matrices to represent the Transformational scenario; and
- Subsequently adjust the Transformational scenario to account for the impacts of larger ferries and clustered warehousing assumptions.

8.3.16 To assist the production of the freight demand data, TfN commissioned MDS Transmodel (MDST) to carrying number of model runs using the Great Britain Freight Model (GBFM) version 6.1. Three of which are used for the production of the freight demand for the purpose of the modelling and appraisal of the TPTS+ studies, as below:

- 2041 Non-transformational economic growth, without larger ferries, without clustered warehousing, and without TPT (equivalent to NTEM Core freight demand) (1);
- 2041 transformational economic growth, without larger ferries, without clustered warehousing, and without TPT (2); and
- 2041 transformational economic growth, with larger ferries, with clustered warehousing, however without TPT (3).

8.3.17 For the purpose of assessment of the TPTS+ under the transformation scenario, it was agreed that the cumulative impacts, i.e. (3) minus (1), was to be used whereas the impacts of the transformational economic growth, i.e. (2) minus (1), was only used to verify the output freight matrices (i.e. to ensure zero net change similarly to the car demand).

8.3.18 Comparisons of LGV and HGV demand at 24-hour level between NTEM Core, TfN Transformational economic only and TfN transformational economic plus larger ferries and clustered warehousing for the 2041 is provided **Table 8-10** in below.

Table 8-10 Transformational Scenario – Freight Demand 2041

LGV Demand - OD 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	77,322	314	15,500	**93,135**
Sheffield	226	50,109	10,015	**60,350**
External	15,127	10,509	2,430,807	**2,456,443**
Total	**92,675**	**60,932**	**2,456,322**	**2,609,929**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	23,432	33	828	**24,292**
Sheffield	33	9,503	249	**9,785**
External	830	231	-25,963	**-24,902**
Total	**24,295**	**9,767**	**-24,887**	**9,175**

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	100,754	346	16,327	**117,427**
Sheffield	259	59,612	10,264	**70,135**
External	15,957	10,740	2,404,844	**2,431,542**
Total	**116,969**	**70,699**	**2,431,436**	**2,619,104**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	30.3%	10.5%	5.3%	**26.1%**
Sheffield	14.5%	19.0%	2.5%	**16.2%**
External	5.5%	2.2%	-1.1%	**-1.0%**
Total	**26.2%**	**16.0%**	**-1.0%**	**0.4%**

HGV Demand - OD 24-hour

RTM Core Demand				
OD	Manchester	Sheffield	External	**Total**
Manchester	22,013	346	25,479	**47,838**
Sheffield	271	15,779	9,839	**25,889**
External	22,091	11,939	987,093	**1,021,123**
Total	**44,375**	**28,064**	**1,022,411**	**1,094,850**

Abs. Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	2,436	100	1,196	**3,732**
Sheffield	123	272	-231	**163**
External	1,331	-424	14,600	**15,507**
Total	**3,890**	**-52**	**15,565**	**19,402**

Transformational Scenario				
OD	Manchester	Sheffield	External	**Total**
Manchester	24,449	446	26,675	**51,569**
Sheffield	394	16,051	9,608	**26,053**
External	23,422	11,515	1,001,693	**1,036,630**
Total	**48,265**	**28,011**	**1,037,976**	**1,114,252**

% Change from NTEM Core				
OD	Manchester	Sheffield	External	**Total**
Manchester	11.1%	28.8%	4.7%	**7.8%**
Sheffield	45.2%	1.7%	-2.3%	**0.6%**
External	6.0%	-3.5%	1.5%	**1.5%**
Total	**8.8%**	**-0.2%**	**1.5%**	**1.8%**

8.3.19 Under the transformational scenario with larger ferries and clustered warehousing, freight demand is forecast to increase overall compared to NTEM Core, with larger increase in the Greater Manchester areas compared to Sheffield City Region area (26% for LGV and 8% for HGV in Manchester vs. 16% LGV and 1% HGV in Sheffield areas). This is again in-line with larger increase in population, employment and GVA in Manchester relative to Sheffield City Region areas.

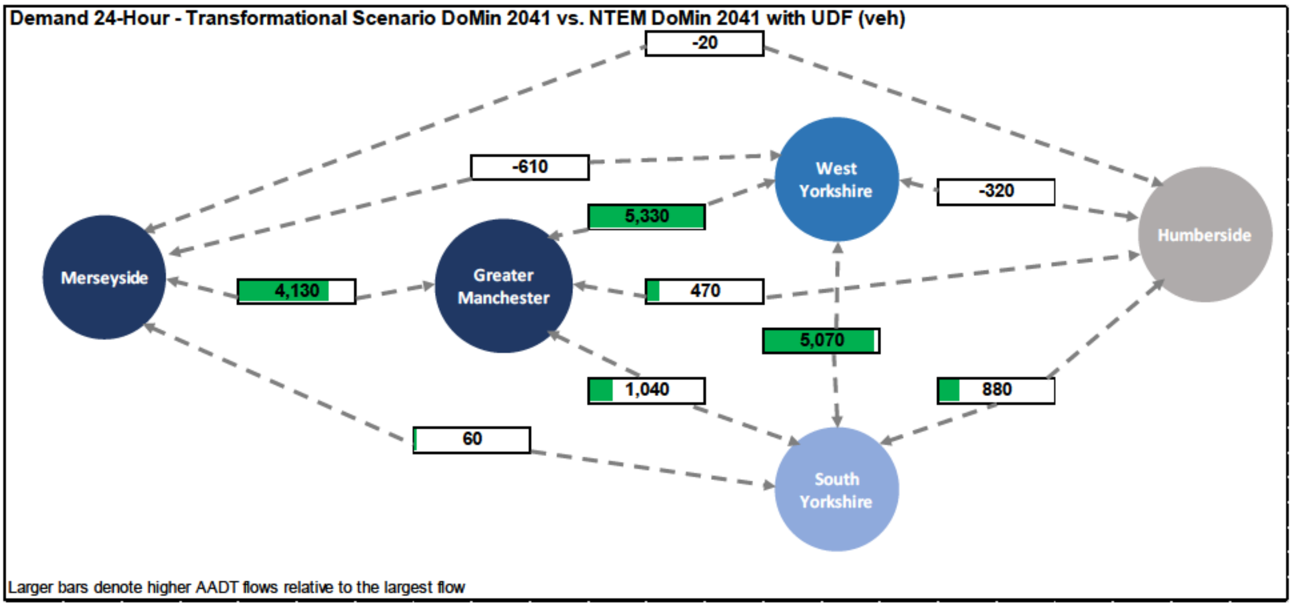
VARIABLE DEMAND MODEL

8.3.20 The transformational scenario forecast demand produced from the was then used for the VDM process for both Do-Minimum and Do-Something scenarios. As agreed with TAG, the modelling and appraisal of the Opening year 2031 was not carried out since little or no relative change in employments and populations compared to the NTEM Core scenario.

MODELLING OUTPUTS

8.3.21 The percentage uplift in employment, population and GVA as provided by TfN in **Table 8-7** suggests that the majority of the transformational impacts is forecast to be in 2041 with little or no change in terms of population, employment and GVA in 2031. As a result, it is anticipated that in terms of modelling and appraisal, the impact of transformational scenario would be negligible in 2031. As agreed with TAG the forecast model runs were to be carried out on the 2041 model only and the appraisal will be based on the 2031 NTEM Core and 2041 Transformational scenario. This section therefore provides summary of the modelling and appraisal outputs for the TfN Transformational scenario with the modelling outputs from the 2041 VDM models.

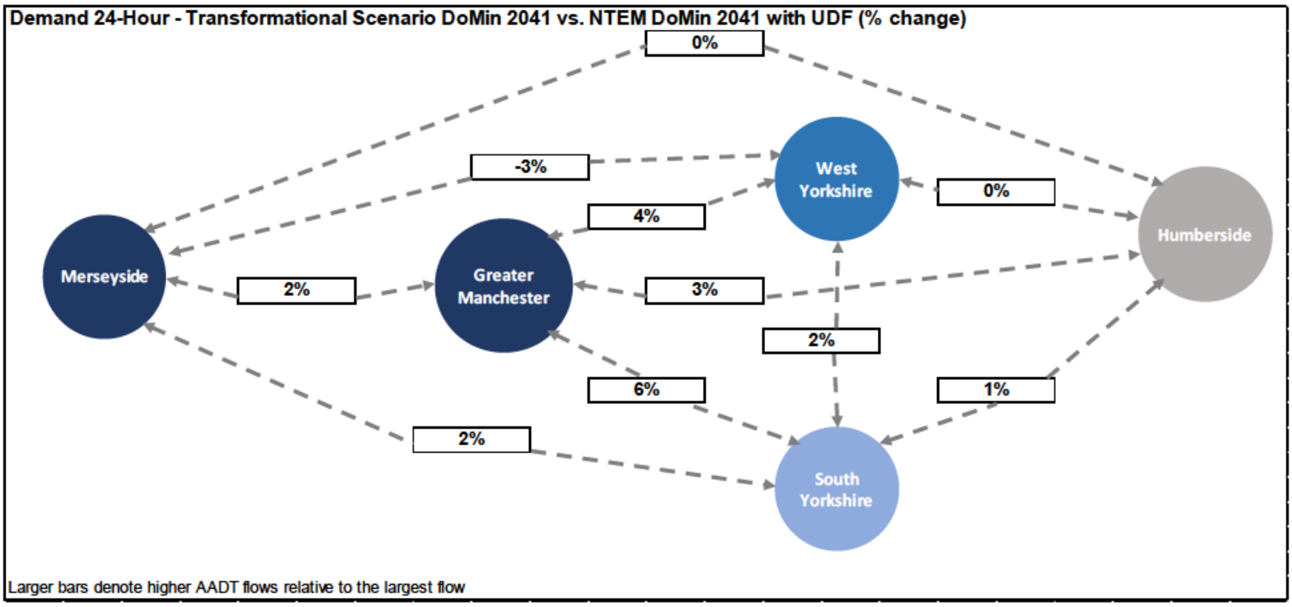
Figure 8-6 Impacts of Transformational Scenario on Demand



8.3.22 **Figure 8-6** above presents the change in demand across the major conurbation areas under the Transformational scenario. It can be seen that the transformational scenario is forecast to create additional demand Greater Manchester and West Yorkshire, between Greater Manchester and Merseyside, and between South Yorkshire and West Yorkshire. Demand change between Greater Manchester and South Yorkshire (where the TPTS+ improvements are focused on) however only produces a small increase (i.e. 20% of the increase between Greater Manchester and West

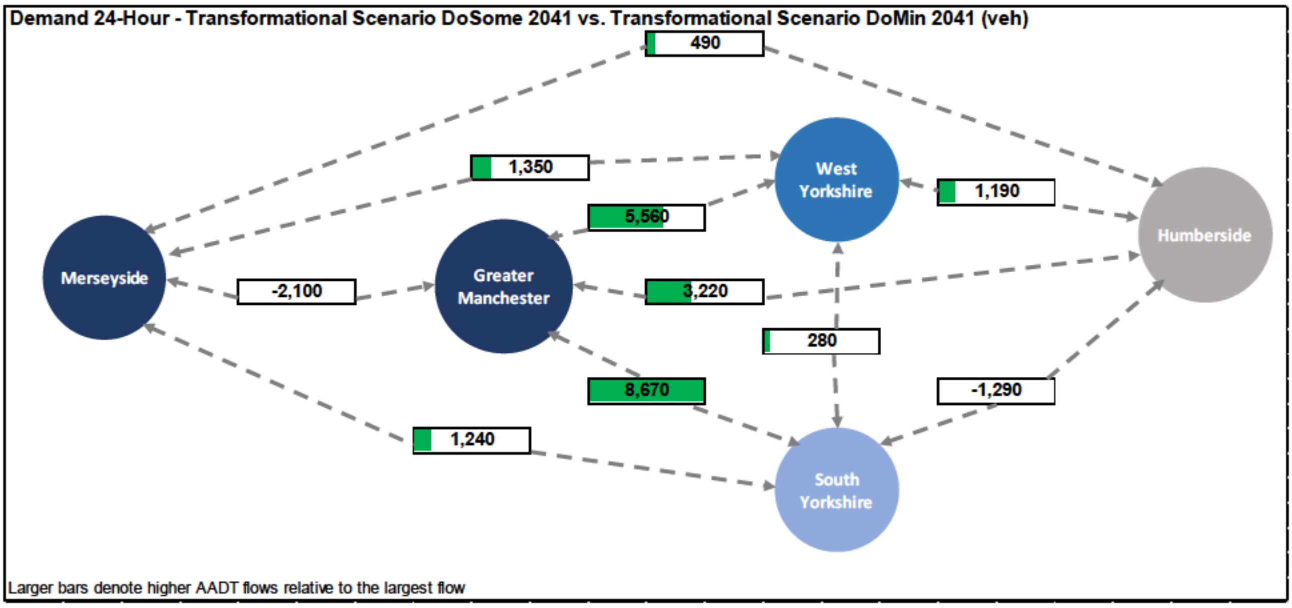
Yorkshire). In terms of percentage change in demand, the transformational scenario is forecast to produce uplift between 2% to 6% from the NTEM Core scenario as can be seen in **Figure 8-7** below.

Figure 8-7 Impacts of Transformation Scenario - Percentage Change



8.3.23 Under the transformational scenario, GM is forecast to produce an uplift between 2%-4% to Merseyside, West Yorkshire and Humberside whereas South Yorkshire is forecast to produce a1%-2%. This is anticipated as assumptions of larger uplift in employment and population was made for GM areas compared to Sheffield City region areas. It is noted that the largest %uplift is forecast between GM and South Yorkshire areas which is anticipated given the uplifts in employment and population were assumed to focus on GM and South Yorkshire areas.

Figure 8-8 Impact of TPTS+ on Demand under Transformational Scenario



8.3.24 With the Optimised Package introduced, the Transformation scenario is forecast to create additional trips across the three major conurbation areas of Greater Manchester, West Yorkshire and South Yorkshire as can be seen in **Figure 8-8**. It is noted that the change in demand across the major conurbation areas resulted from the Transformational scenario is similar to that from the NTEM Core. That suggests the TPTS interventions under the Transformational scenario is not likely to produce significantly larger benefits compared to the NTEM Core.

8.3.25 Flow difference between TfN Transformational scenario and the NTEM Core for Car and Freight can be seen in **Figure 8-9** and **Figure 8-10** respectively below.

Figure 8-9 Flow Difference (2041) - Transformational vs. NTEM Core – Car

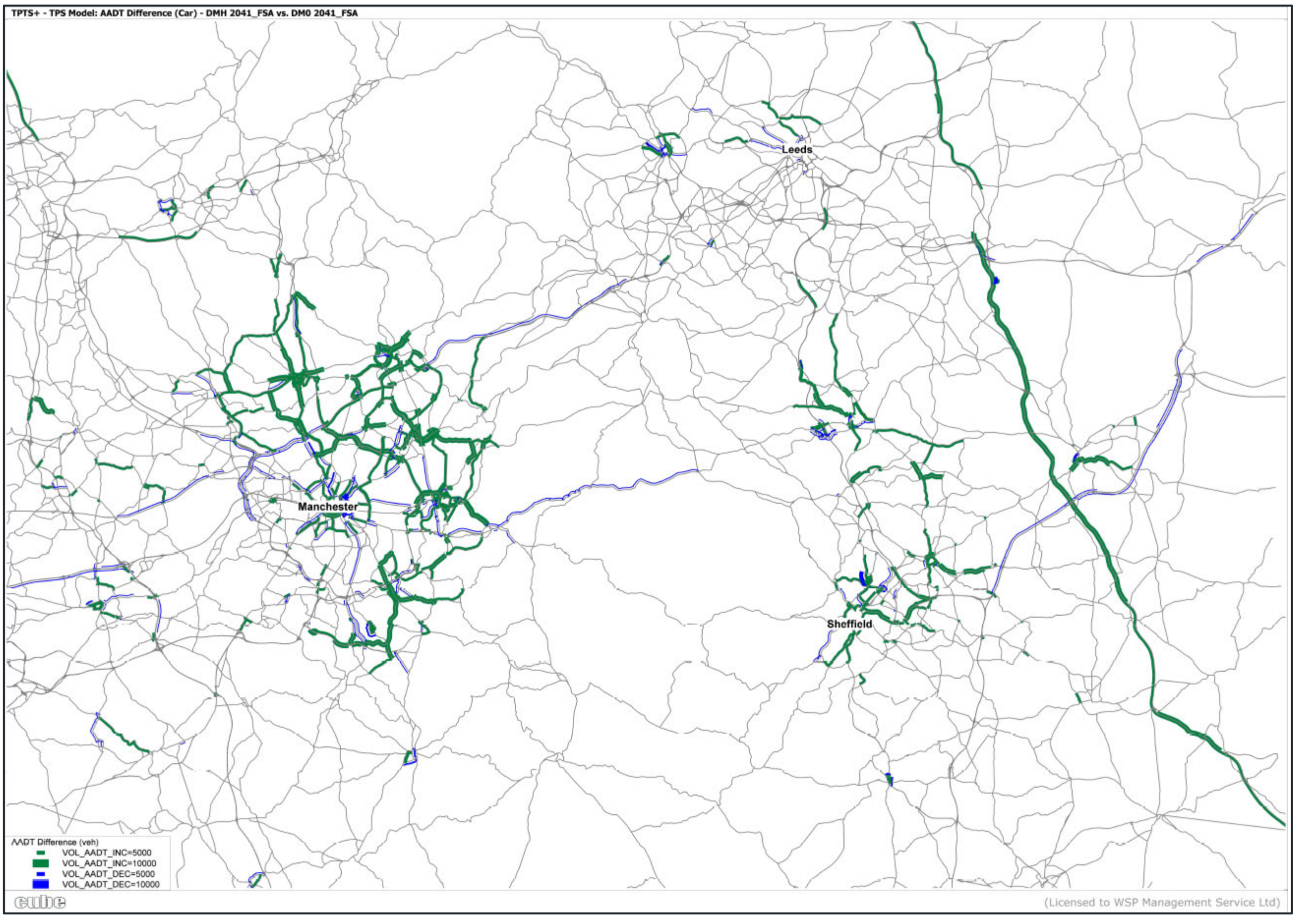
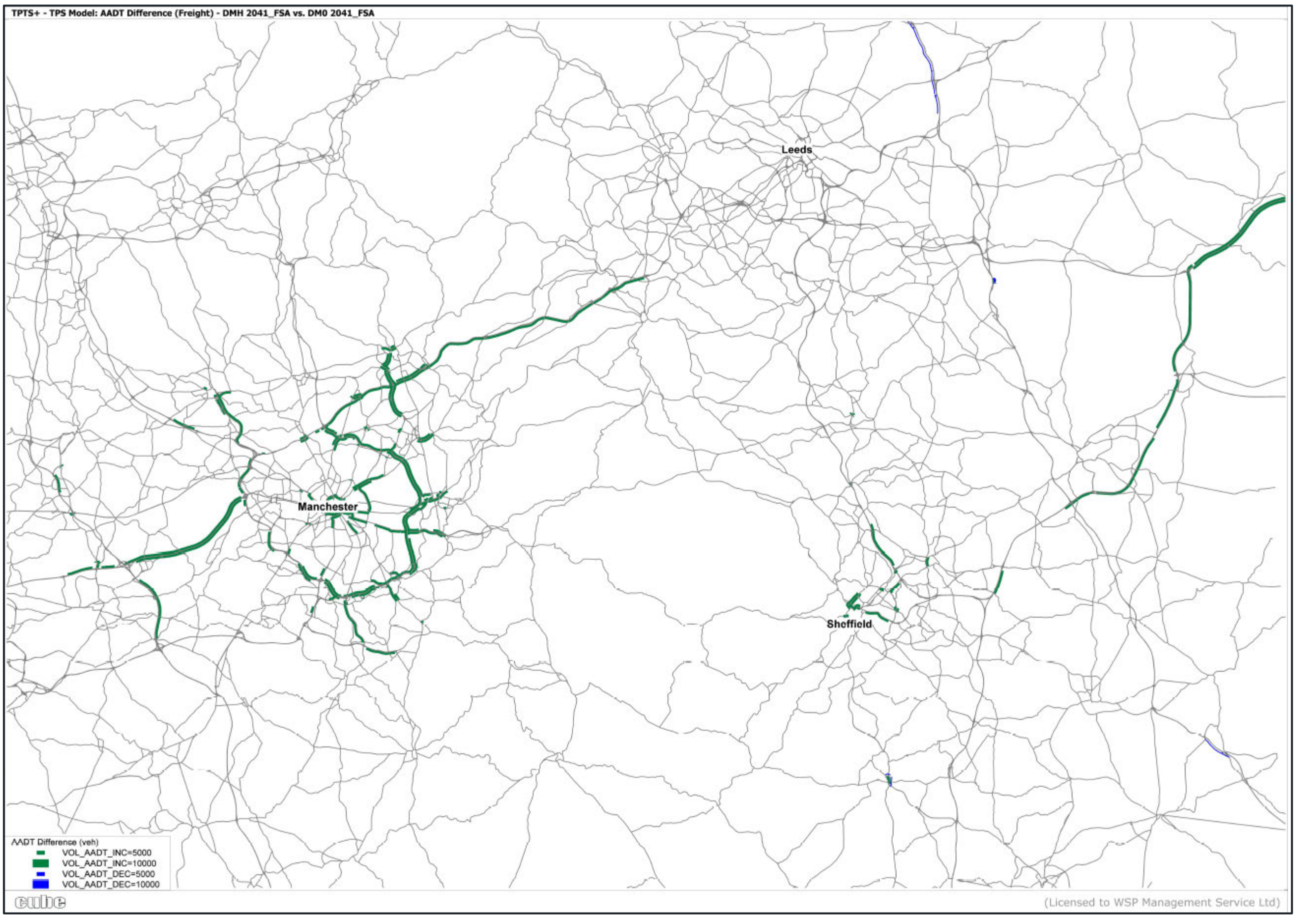


Figure 8-10 Flow Difference (2041) - Transformational vs. NTEM Core – Freight



8.3.26 In comparison to the NTEM Core, the Transformational scenario is forecast to produce increase in demand for the LADs where TfN's assumptions on the transformational growth were made. It is however noted that the growth in car appears to primarily focus entirely within GM and Sheffield areas without increase in trips crossing the M62 and M628 between Manchester and Leeds and between Manchester and Sheffield. Whilst increase in demand entirely within GM and SCR areas are anticipated, slight reduction of car demand crossing the Pennine between GM and SCR is not, particularly in the context of the TfN's aspiration on the transformational scenario, i.e. promoting reallocation of economic activity to GM and Sheffield areas from the rest of the UK.

8.3.27 For Freight, the modelling outputs from MDST suggests that majority of the uplift in freight demand are as expected between major ports, for example, along M62 to Liverpool and M60 between Manchester and Leeds, and along M18/M62 to Hull.

APPRAISAL OUTPUTS

8.3.28 **Table 8-11** below provides a summary of the TUBA benefits for the Transformational scenario in comparison with the NTEM Core.

Table 8-11 TUBA Benefit Summary – Transformational Scenario vs. NTEM Core

Package	Optimised Package - Core Scenario			Optimised Package - Transformational		
	VDM	with UDF	%Diff	VDM	with UDF	%Diff
Consumer User (Commute)	531,941	608,806	14%	673,153	699,992	4%
Consumer User (Other)	619,692	755,689	22%	833,258	840,552	1%
Business User and Provider	3,014,825	3,273,272	9%	3,188,763	3,322,482	4%
Private sector provider (Toll revenues)	-4,395	-4,437	1%	-5,613	-3,883	-31%
Indirect Tax Revenue	381,819	372,293	-2%	306,369	311,184	2%
Greenhouse Gas	-227,459	-195,078	-14%	-172,181	-162,429	-6%
Total	**4,316,423**	**4,810,544**	**11%**	**4,823,749**	**5,007,898**	**4%**

8.3.29 It can be seen the Transformational scenario only produces extra £200m user benefits compared to the NTEM Core, which is not anticipated given the assumptions on the uplift in population, employments within the GM and SCR areas.

8.3.30 As mentioned in the previous paragraph, the majority of increases in demand are primarily focused entirely within either GM or SCR, meaning greater congestion is on the local network as opposed to the Pennine link. As a consequence, the TPTS interventions are not forecast to produce significantly higher benefits compared to the NTEM Core.

8.3.31 It is also noted that the application of the Urban Delay function only results in 4% increase in user benefits, as compared to 11% uplift for the NTEM Core scenario.

8.3.32 **Table 8-12** provides a more detailed break-down of the user benefits for the Post-UDF application for the Transformational and the NTEM Core scenario.

Table 8-12 TUBA Benefit Summary (£000s at 2010 prices and values)

Purpose	NTEM Core				TfN Transformational				Difference from NTEM Core			
	Time	Charges	VOC	Total	Time	Charges	VOC	Total	Time	Charges	VOC	Total
Commuting	641,950	-149	-32,996	608,806	708,264	-95	-8,177	699,992	66,314	53	24,819	91,187
Other	995,696	-349	-239,659	755,689	1,019,051	-328	-178,172	840,552	23,355	21	61,487	84,863
Business (Car)	2,270,285	672	80,511	2,351,467	2,279,182	1,030	70,639	2,350,851	8,897	359	-9,872	-616
Business (Freight)	831,223	2,516	88,066	921,804	889,837	2,728	79,067	971,631	58,614	212	-8,999	49,827
Operators				-4,437				-3,883				553
Greenhouse Gas				-195,078				-162,429				32,648
Indirect Tax				372,293				311,184				-61,108
Total	**4,739,154**	**2,690**	**-104,078**	**4,810,544**	**4,896,334**	**3,335**	**-36,643**	**5,007,898**	**157,180**	**645**	**67,435**	**197,353**

8.3.33 The modelling and appraisal outputs from the Transformational scenario suggests the limitation of the approach that was adopted for the production of the transformational scenario demand, i.e. the use of NTEM Core matrices as the starting point, apply uplift adjustment at trip-end levels based on uplift in employment and population for GM and SCR areas, and subsequently produce transformational forecast demand using 'Furnessing' method.

8.3.34 The 'Furnessing' method is based on row and column balancing which is heavily dependent on the 'base' trip matrices, i.e. NTEM Core demand. Whilst this approach is suitable for uplifting demand with small increments, e.g. to produce a NTEM Core forecast from a Base year demand, it would potentially result in unexpected outcomes where significant growth assumption is made, particularly if significant growths are contained within small geographical areas. Due to the current scope of the project, the option of exploring explicit distribution assumptions (based on land-use change or targeted distribution to better reflect transformational scenario) instead of relying on the Furnessing could be considered and implemented to better represent change in demand under the transformational scenario.

WIDER IMPACT BENEFITS

8.3.35 **Table 8-13** below presents the Wider Impact – level 2 benefits that was produced for the TPTS+ interventions for the Transformational scenario. This shows similar benefits compared to the NTEM Core scenario, which suggests the Transformational growth scenario focuses on local movements and not much of inter-regional movements.

Table 8-13 WITA Level 2 Benefits (£000s at 2010 prices and values)

Package	NTEM Core		Transformational	
	WITA	Adjusted	WITA	Adjusted
Agglomeration impacts	3,853,884	3,083,107	3,833,207	3,066,566
Change in imperfectly competitive market	235,147	235,147	235,085	235,085
Labour supply impacts	20,024	20,024	22,434	22,434
Move to more/less productive jobs	0	0	0	0
Total	**4,109,055**	**3,338,278**	**4,090,726**	**3,324,084**

8.3.36 Similar to the Low growth scenario, the assessments of the Accident benefits were not carried out for the Low Growth and Transformational scenario whereas Reliability benefits calculation adopts the methodology as described in Chapter 8 (i.e. 10% of the TUBA time saving benefits).

8.4 ALTERNATIVE GROWTH SUMMARY

8.4.1 As agreed with TAG, in addition to the NTEM Core scenario, the modelling and appraisal for the Low Growth and Transformation scenario were also undertaken to understand the impacts of various demand growth assumptions on the performance of the TPTS+ interventions.

8.4.2 The Low Growth scenario refers to change in travel behaviour, with assumptions based on a declining trend in road-based trips and increase in rail-based trips over the last 15 years. To reflect the impacts of this scenario, the DfT scenario 6, 'Extrapolated trip rates' scenario reference demand (Car, Rail, and freight) was provided to the TPTS+ team for the purpose of modelling and appraisal of the TPTS+ interventions.

8.4.3 Modelling and appraisal outputs produced for the Low Growth scenario shows that whilst the change in traffic volume across the network are plausible, the assumptions of growth for freight included within the reference demand was not consistent with the growth assumptions applied for cars and therefore overestimated the benefits of the TPTS+ interventions. As agreed with TAG, the corrected Low Growth scenario was not required at this stage and the current appraisal outputs was to be used in this document.

8.4.4 The Transformational scenario, on the other hand, represents the vision of a transformed North as set out in the Northern Powerhouse Independent Economic Review, where investment and improved performance in a number of critical areas, including education, skills, innovation and inward investment, alongside transport infrastructure and services for passengers, business and freight will be needed to support the growth of businesses and trade in the UK's world-leading sectors. This scenario has been specified collaboratively by TfN, Transport for Greater Manchester (TfGM), Sheffield City Region (SCR) and Highways England that is designed to represent a future in which Greater Manchester and Sheffield City Region achieve higher levels of population, employment and productivity as a result of complementary policies, such as spatial planning, skills and industrial strategy.

8.4.5 Modelling outputs from the Transformational scenarios show that changes in demand as a result of transformational scenario assumptions primarily focus entirely within either GM or SCR areas with little or no change in demand travelling between GM and SCR. That would explain a marginal increase in user benefits from the Transformational scenario compared against the NTEM Core, as can be summarised in **Table 8-14** below.

Table 8-14 Benefit Summary - Alternative Scenarios (Opening Year 2033)

Appraisal Summary	Optimised Package	Low Growth	Trans-formational
Present Value of Cost (£m)			
CAPEX	4,401.99	4,401.99	4,401.99
OPEX	469.74	469.74	469.74
Total PVC	**4,871.73**	**4,871.73**	**4,871.73**
Level 1 PVB (£m)			
User Benefits	4,633.33	4,424.58	4,859.14
Indirect Tax Revenue	372.29	317.41	311.18
Greenhouse Gas	-195.08	-56.42	-162.43
Accident	134.00	134.00	134.00
Construction	-28.18	-28.18	-28.18
Total	**4,916.37**	**4,791.39**	**5,113.72**
Initial BCR	**1.01**	**0.98**	**1.05**
Level 2 PVB (£m)			
Reliability	473.92	448.99	489.63
Wider Impacts - Static Clustering	3,338.28	3,338.28	3,324.08
Total	**8,728.56**	**8,578.66**	**8,927.44**
Adjusted BCR	**1.79**	**1.76**	**1.83**

8.4.6 It is noted that **Table 8-14** presents the BCR summary with the Most Likely PVC cost estimates. To provide a range of uncertainty to the BCR of the interventions, the CAPEX costs with P2.5 and P97.5 are also prepared and shown in **Table 8-15** below.

Table 8-15 Benefit Summary with P2.5 and P97.5 (Opening Year 2033)

Appraisal Summary	Optimised Package	Low Growth	Trans-formational	Appraisal Summary	Optimised Package	Low Growth	Trans-formational
Present Value of Cost (£m)				**Present Value of Cost (£m)**			
CAPEX P2.5	2,172.65	2,172.65	2,172.65	CAPEX P97.5	8,205.60	8,205.60	8,205.60
OPEX	469.74	469.74	469.74	OPEX	469.74	469.74	469.74
Total PVC P2.5	**2,642.39**	**2,642.39**	**2,642.39**	**Total PVC P97.5**	**8,675.34**	**8,675.34**	**8,675.34**
Level 1 PVB (£m)				**Level 1 PVB (£m)**			
User Benefits	4,633.33	4,424.58	4,859.14	User Benefits	4,633.33	4,424.58	4,859.14
Indirect Tax Revenue	372.29	317.41	311.18	Indirect Tax Revenue	372.29	317.41	311.18
Greenhouse Gas	-195.08	-56.42	-162.43	Greenhouse Gas	-195.08	-56.42	-162.43
Accident	134.00	134.00	134.00	Accident	134.00	134.00	134.00
Construction	-28.18	-28.18	-28.18	Construction	-28.18	-28.18	-28.18
Total	**4,916.37**	**4,791.39**	**5,113.72**	**Total**	**4,916.37**	**4,791.39**	**5,113.72**
Initial BCR	**1.86**	**1.81**	**1.94**	**Initial BCR**	**0.57**	**0.55**	**0.59**
Level 2 PVB (£m)				**Level 2 PVB (£m)**			
Reliability	473.92	448.99	489.63	Reliability	473.92	448.99	489.63
Wider Impacts - Static	3,338.28	3,338.28	3,324.08	Wider Impacts - Static	3,338.28	3,338.28	3,324.08
Total	**8,728.56**	**8,578.66**	**8,927.44**	**Total**	**8,728.56**	**8,578.66**	**8,927.44**
Adjusted BCR	**3.30**	**3.25**	**3.38**	**Adjusted BCR**	**1.01**	**0.99**	**1.03**

9 INDIVIDUAL SCHEME ASSESSMENTS

9.1 OVERVIEW

9.1.1 Following the Board Investment and Commercial Committee (BICC) meeting in September 2019 there was an instruction to the TPTS+ team to consider the affordability of the scheme. This was to be based on considering the Value for Money (VfM) of three packages of small, medium and large interventions based on scheme costs. It was agreed by Project Board that the three packages should be derived by looking at component parts of the Optimised Package. Therefore, the Optimised Package had to be broken down in to around ten individual schemes which were independently appraised to enable the three packages to be configured based on the best performing schemes within the cost for each package.

9.1.2 It is noted that it was not considered practical or proportionate to undertake the ten scheme assessments using the full VDM process. The relatively small scale of some of the smaller schemes was not considered appropriate for modelling in the vRTM model due to its strategic nature. In particular, there was a relatively high risk that the model noise in the VDM process would mask the scheme impact. For these reasons the analysis was based on a fixed assignment approach using the 2041 Do Minimum demand which was output from the Do Minimum VDM modelling. The TUBA benefits for the 2041 single year model assignments, following the UDF adjustments, were calculated for each scheme separately and were used the same to rank them based on benefits and costs.

9.1.3 The assurance of this process was therefore considered lower than the Optimised Package appraisal runs and associated appraisal but was considered appropriate for informing the process of developing the three packages.

9.1.4 This chapter provides a detailed summary of ten individual schemes and analysis carried out for each scheme. This included the presentation of traffic volumes on the scheme and the A628, Volume to Capacity (V/C) ratios on the scheme itself to show residual capacity, and a single year TUBA appraisal expanded to a 60 year period. The provisional costs (at the time of the assessment) for the schemes were used to create a proxy BCR and rank the schemes.

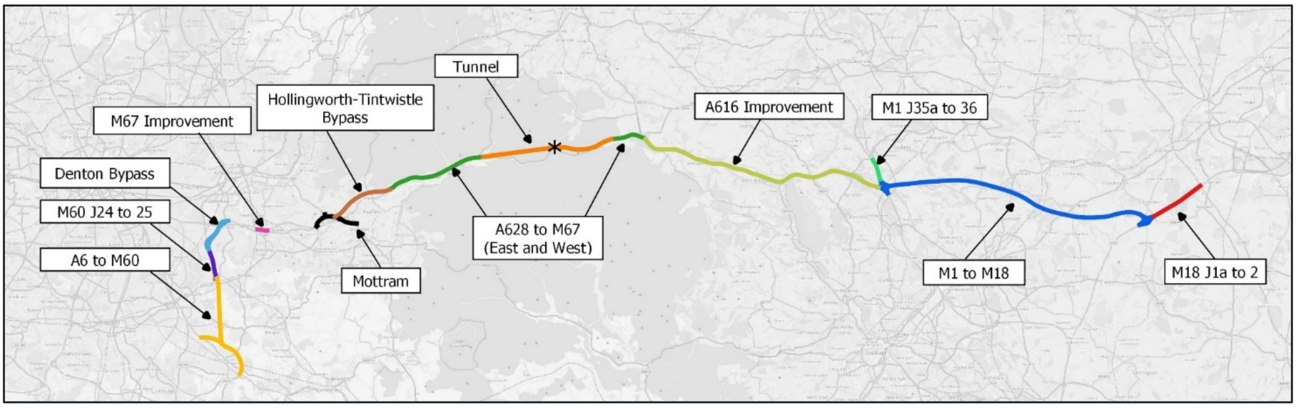
9.2 INDIVIDUAL SCHEME DETAILS

9.2.1 As mentioned in the previous section, the individual packages which formed part of the TPTS+ Optimised Package were broken down into 10 individual schemes (excluding the Tunnel section) for the purpose of analysis the benefits of each scheme separately. List of 10 schemes that formed part of the TPTS+ Optimised Package is provided below as well as presented graphically in **Figure 9-1**:

- **M67 Junction 3 improvements** – additional lane on M67 J3 Through Junction section
- **A6 to M60 link** – new dual carriageway connecting A6 and M60 J25;
- **M60 J24-J25 capacity improvements** – additional lane on either side of the mainline M60 between J24 and J25;
- **M1 J35a-J36 capacity improvements** – additional lane on each side of M1 between J35a (where the proposed A616 dualling ties in to M1) and J36
- **Denton Bypass** – dual carriageway running over M60 J24, connecting M60 J24a and M67 J1

- **A616 to M1 improvements** – dualling of existing A616 between A628 Flouch roundabout and M1 J35A
- **M1 to M18 link** – new dual carriageway connecting M1 J35A and M18 J1A
- **M18 J1a-J2 capacity improvements** – additional lane on each side of the M18 J1a-J2
- **Hollingworth Tintwistle Bypass** – a 3.9km long dual carriageway starting from Coach Road, goes around Armfield reservoir and joins back to the existing.
- **A628 to M67** - proposes to improve the capacity by adding an extra lane on either side of main line between J4 of M67 to Junction between A628 and B6105.

Figure 9-1 Individual Scheme Locations



9.3 SCHEME PRIORITISATION AND PACKAGE SELECTION

9.3.1 As mentioned in the previous section, for the purpose of assessment of 10 schemes individual to help inform the packages, the fixed demand assignment approach was implemented for each individual scheme using the post-VDM DM2041 demand matrices.

9.3.2 The modelling and appraisal outputs produced from each individual scheme were used to assist with development of the three packages, using the key considerations as below:

- Value for Money (based on a proxy BCR);
- Ranking of schemes based on VfM;
- Residual capacity to allow for future growth (V/C ratios);
- Impacts on flows on A628 through the Peak district national park; and
- Network dependency and continuity (i.e. proximity of complementary schemes).

9.3.3 For the purpose of a proxy BCR, single year TUBA runs were undertaken for each individual scheme using the 2041 fixed demand assignment modelling outputs, subsequently expanded to 60 years using a factor that was derived from the analysis of the Optimised Package TUBA benefits.

9.3.4 The factor was calculated by comparing the benefits produced from the single year fixed demand assignment against benefit produced for 60 years full VDM assignments of the Optimised Package. This method, whilst crude, would still allow for a consistent expansion approach to 60 year appraisal periods across all individual schemes and also can be directly compared to the benefits of the Optimised Package.

9.3.5 **Table 9-1** and **Table 9-2** below provide high-level summaries of the modelling and appraisal in terms of AADT flow, V/C ratios and proxy BCR for each individual scheme.

Table 9-1 Indicative AADT Flow by Individual Schemes

Scheme	AADT on Scheme link (2-way)	Scheme V/C Ratios	AADT on A628 (2-way)	Location
M67 J3 only	46,675	30	22,319	Western Scheme
A6 to M60	41,677	61	22,613	Western Scheme
M60 J24 to J25	156,750	79	22,350	Western Scheme
M1 J35a to 36	143,500	72	22,500	Eastern Scheme
Denton Bypass	31,500	31	23,500	Western Scheme
A616 to M1	49,000	40	25,000	Eastern Scheme
A628 to M67	64,000	40	34,800	Western Scheme
Tunnel	30,000	34	27,500	
M1 to M18	27,500	27	22,500	Eastern Scheme
M18 J1a to 2	114,500	83	22,200	Eastern Scheme
Tintwistle Bypass	27,549	24	26,793	Western Scheme

Table 9-2 Proxy BCR Summary by Individual Schemes

Scheme	Scheme Opening	PVC(£m)	Proxy PVB (£m)	Proxy BCR
M67 J3 only	Jan 2041	£44	£131	3.0
A6 to M60	Jan 2041	£403	£803	2.0
M60 J24 to J25	Jan 2041	£24	£589	24.5
M1 J35a to 36	Jan 2041	£17	£203	12.0
Denton Bypass	Jan 2041	£307	£151	0.5
A616 to M1	Jan 2041	£326	£704	2.2
A628 to M67	Jan 2041	£725*	£1,271	1.8
Tunnel	Jan 2041	£2,221	£246	0.1
M1 to M18	Jan 2041	£773	£623	0.8
M18 J1a to 2	Jan 2041	£31	£373	11.9
Tintwistle Bypass	Jan 2041	£725*	£885	1.2

**Internal estimate*

9.3.6 With those analysis of modelling and appraisal outputs, together with input provided by the Project Board that a balanced investment on both the east and west of the Pennine should be considered when developing packages, it was proposed that the three packages were to be formed from 10 individual schemes, as provided in **Table 9-3** below.

Table 9-3 Forming Packages from Individual Schemes

Scheme	Rank	VfM	Package 1	Package 2	Package 3
M67 J3 only	4	High	1	2	3
A6 to M60	7	Medium		2	3
M60 J24 to J25	1	Very High			
M1 J35a to 36	2	Very High	1	2	3
Denton Bypass	10	Poor			
A616 to M1	5	High	1	2	3
A628 to M67	6	Medium			
Tunnel	11	Poor			
M1 to M18	9	Poor			3
M18 J1a to 2	3	Very High			3
Tintwistle Bypass	8	Poor	1	2	3

9.3.7 With due consideration given to the cost of the schemes and proximity of the schemes to one another, the ranks and the benefits from individual schemes provided a sound methodology to package the schemes to be delivered for different opening years and also to understand the synergy of benefits between packages.

9.3.8 It should be noted that the creation of the three packages (a phased approach toward the Optimised Package) was based on the quantitative benefits which have a relatively low assurance and involved some judgement. The process was not guaranteed to deliver a unique solution and therefore there is inherent uncertainty in the outcomes. However, the process itself was developed to provide evidence if that VfM could be delivered for three different levels of affordability.

9.3.9 The analysis is robust enough to achieve this, but once a package is selected, there is scope to further refine the schemes to improve the VfM. This is further explained in the **Chapter 10**.

10 PACKAGE ANALYSIS

10.1 OVERVIEW

10.1.1 As agreed with Highways England, the schemes were added incrementally to the Do-Minimum networks. These tests were undertaken using the 'Variable demand' assignment approach with demand matrices produced from the post-VDM models for each of incrementally packaged networks. The Urban Delay function was applied post-assignment. Therefore, the level of assurance for the model runs for the three packages is consistent with the Optimised Package. However, there is a residual level of uncertainty for the small and medium packages because although they are large interventions, there are still relatively small compared to the Optimised Package and the scale of the vRTM. There uncertainty relates to model noise relative to the impact of the packages. The outputs should be reviewed in this context and the switching value should be considered in the decision-making process; i.e. how much would the benefits need to change by to result in a different VfM category.

10.1.2 This chapter provides a high-level summary of the tests that were carried out for finalising the packages.

10.2 PACKAGE DESCRIPTION

10.2.1 As mentioned in the previous chapter, three packages were formed from 10 individual schemes and Variable demand modelling were undertaken to understand performance of each package in terms of network congestion and economic appraisal.

10.2.2 **Package 1** consists of following transport schemes

- **Capacity improvements to M67-J3 Only** - Includes addition of an extra lane on either side on the main line of M67;
- **Hollingworth Tintwistle Bypass** - It is a 3.9 km long bypass starting from Coach Road, goes around Arnfield reservoir and joins back A628. The bypass is dual carriageway and ties into Mottram moor junction improvements in the west;
- **Capacity improvements along the A616 to M1** - Includes dualling of the existing road between A628 Flouch Roundabout and M1 J35A; and
- **Capacity improvements between M1-J35a to M1-J36** - Includes addition of an extra lane on either side on the main line of M1 between these junctions.

10.2.3 **Package 2** consists of all the improvements from Package 1 and additionally includes A6-M60 Link Road Scheme. **A6-M60 Link road** scheme proposes a new dual carriageway road connecting A6 and M60-J24 measuring about 3.5 kms.

10.2.4 **Package 3** consists of all the improvements from Package 2 with additional transport schemes namely:

- **M1-M18 Link Road** – A new dual carriageway link road between M1 J35A connecting to M18-J1A is proposed to be constructed measuring 17.5 kms in length; and
- **Capacity improvements between M18 J1a to M18 J2**- Includes addition of an extra lane on either side on the main line of M18 between these junctions.

10.2.5 **Figure 10-1** to **Figure 10-3** below provide locations and descriptions of the schemes included in each of the three packages.

Figure 10-1 Package 1 - Schemes Included

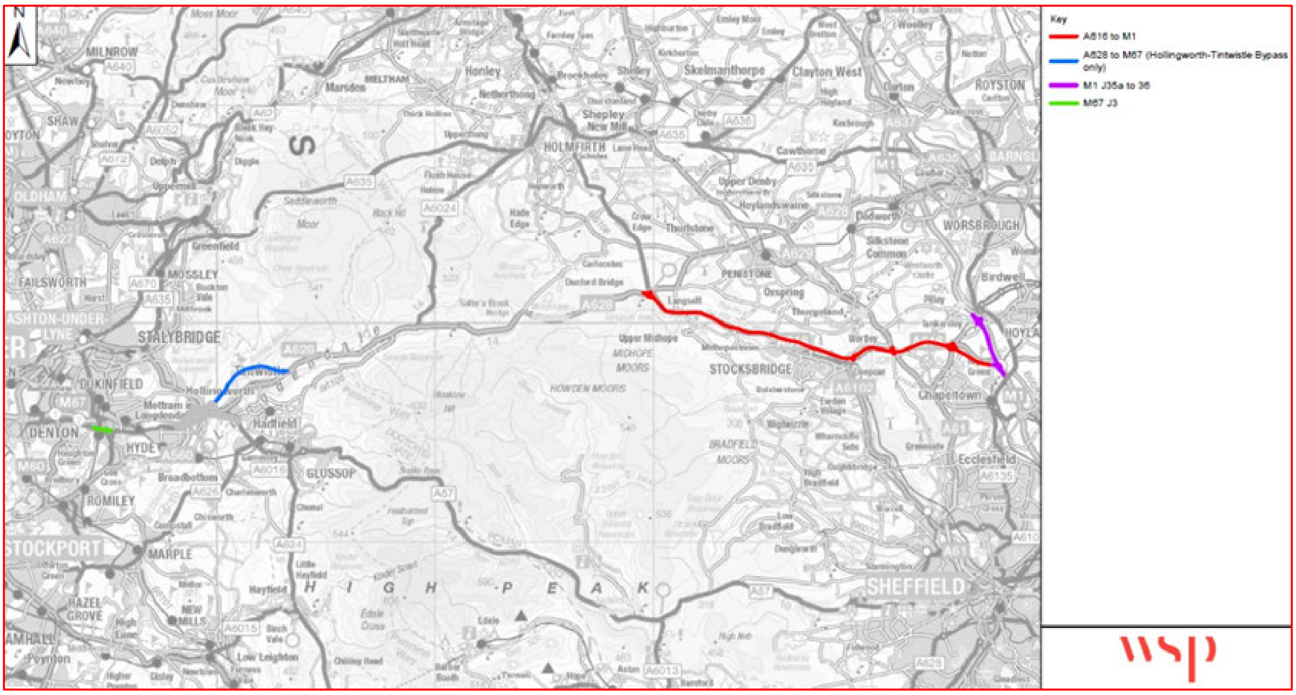


Figure 10-2 Package 2 - Schemes Included

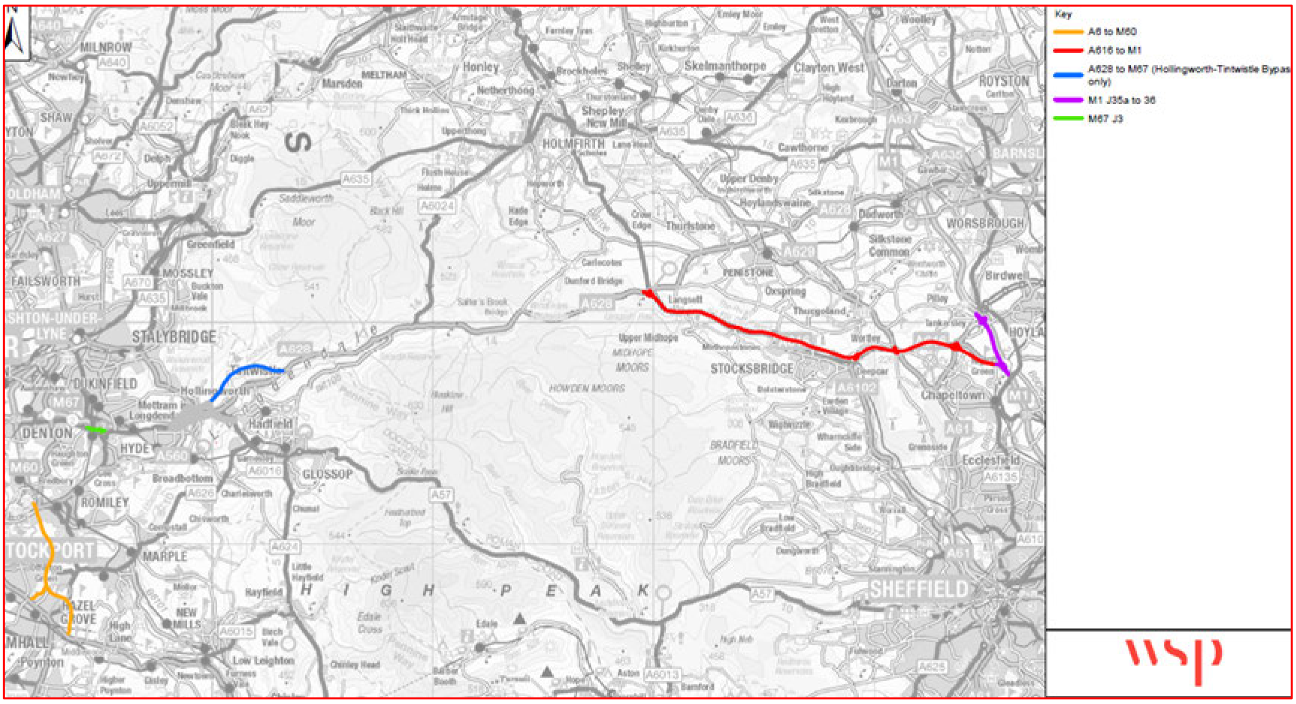
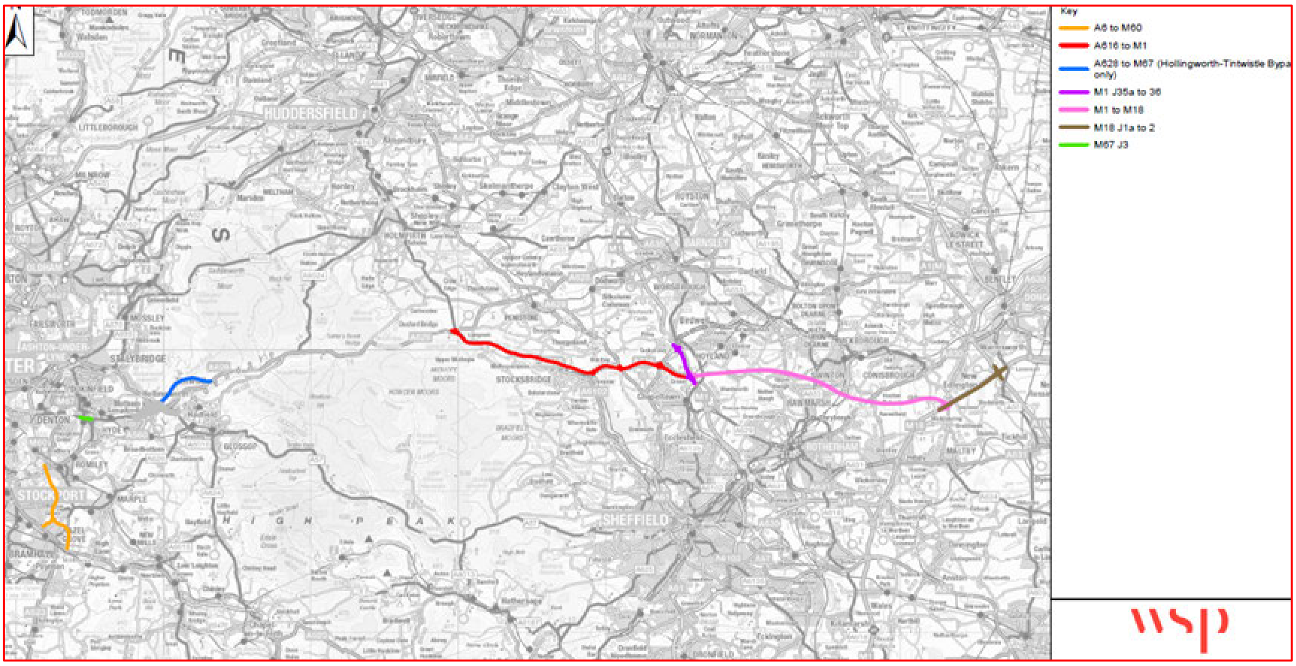


Figure 10-3 Package 3 - Schemes Included



10.2.6 Sections below provide summary of the modelling and appraisal outputs of the proposed packages 1, 2 and 3.

10.3 MODELLING AND APPRAISAL ANALYSIS

10.3.1 This section provides a high-level summary of the modelling and appraisal outputs for each of the three test packages, in terms of AADT flow difference for the modelled year 2041 and TUBA/WITA outputs calculated from the modelling.

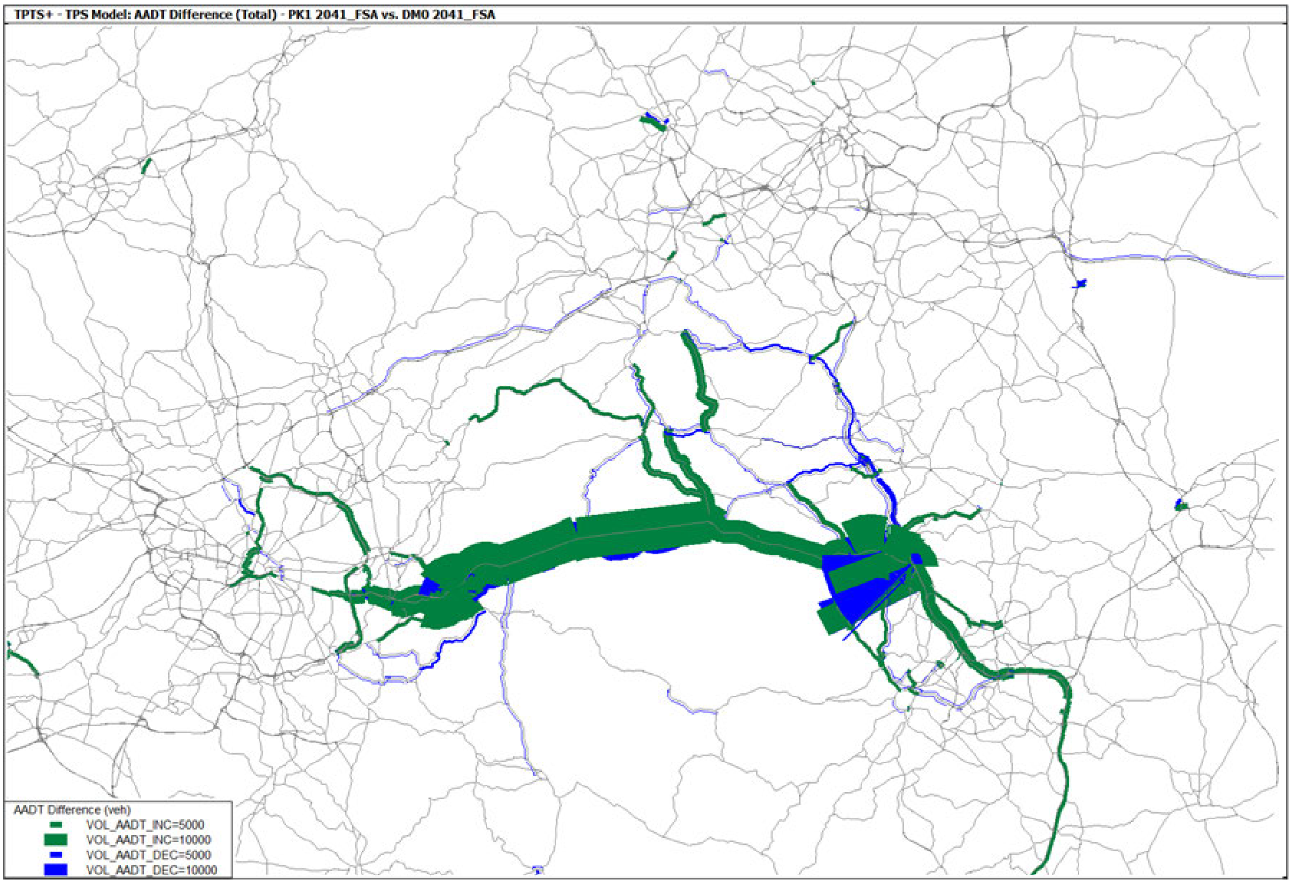
10.3.2 As mentioned above, the modelling and appraisal outputs were produced from the VDM modelling with Urban Delay function applied to account for change in travel speeds in urban areas.

10.3.3 It is noted that during this stage, TUBA and WITA benefits were calculated with the assumption that the scheme Opening year of all packages are 2041. The updated TUBA, WITA and other economic appraisals for the earlier scheme Opening year is reported later in this document (Chapter 11).

MODELLING OUTPUTS

10.3.4 **Figure 10-4** provides a representation of flow difference on the network between Package 1 and Do-Minimum in terms of AADT.

Figure 10-4 AADT Difference - Package 1 vs. Do-Minimum (2041)



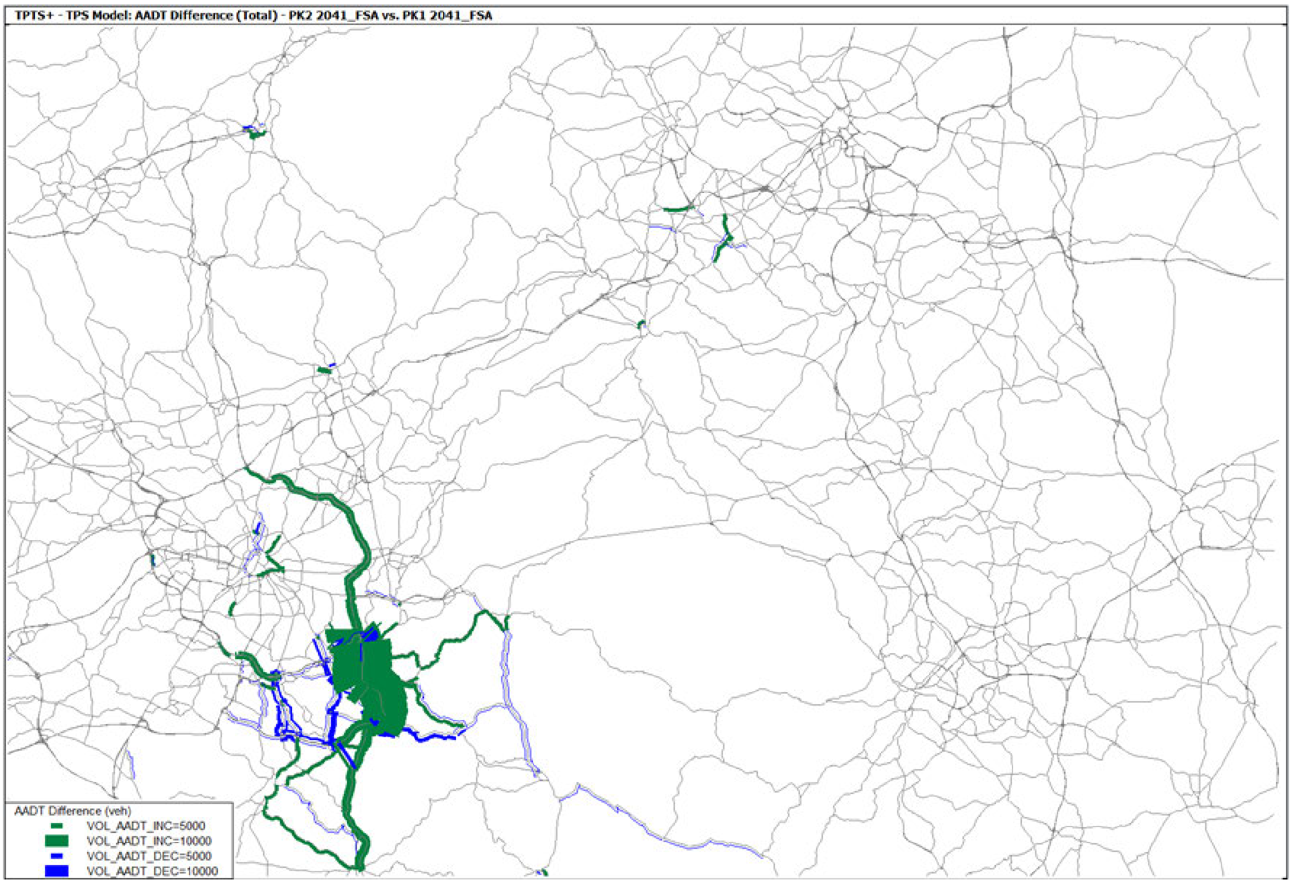
10.3.5 As can be seen, the Package 1 interventions would result in significant flow changes along the M67, A628 and A616 to M1, more specifically:

- About 38,000 2-way AADT flows forecast to travel on the A616 to M1 (a net increase of about 17,000 AADT from Do-Minimum traffic);
- About 69,000 2-way AADT flows are forecast to travel on M67(a net increase of about 10,000 AADT 2-way from Do-Minimum traffic);
- About 31,000 2-way AADT flows are forecast to travel on the A628 (a net increase of about 9,000 AADT from Do-Minimum traffic);
- A reduction of 5,000 2-way AADT would be anticipated on M1 north of J36, and a 1,000 2-way AADT reduction is also anticipated on M62.

10.3.6 In terms of travel time on across the Pennines, Package 1 interventions however would result in increase in delay on the existing A628 (about 3-4 minutes in the AM and PM peak) relative to Do-Minimum. This is anticipated due to bottle neck created by additional traffic would be added on the existing section of the A628 (single carriageway) between the Tintwistle Bypass and the proposed Tunnel section.

10.3.7 **Figure 10-5** provides a representation of flow difference on the network between Package 2 and Package 1 in terms of AADT.

Figure 10-5 AADT Difference - Package 2 vs. Package 1 (2041)



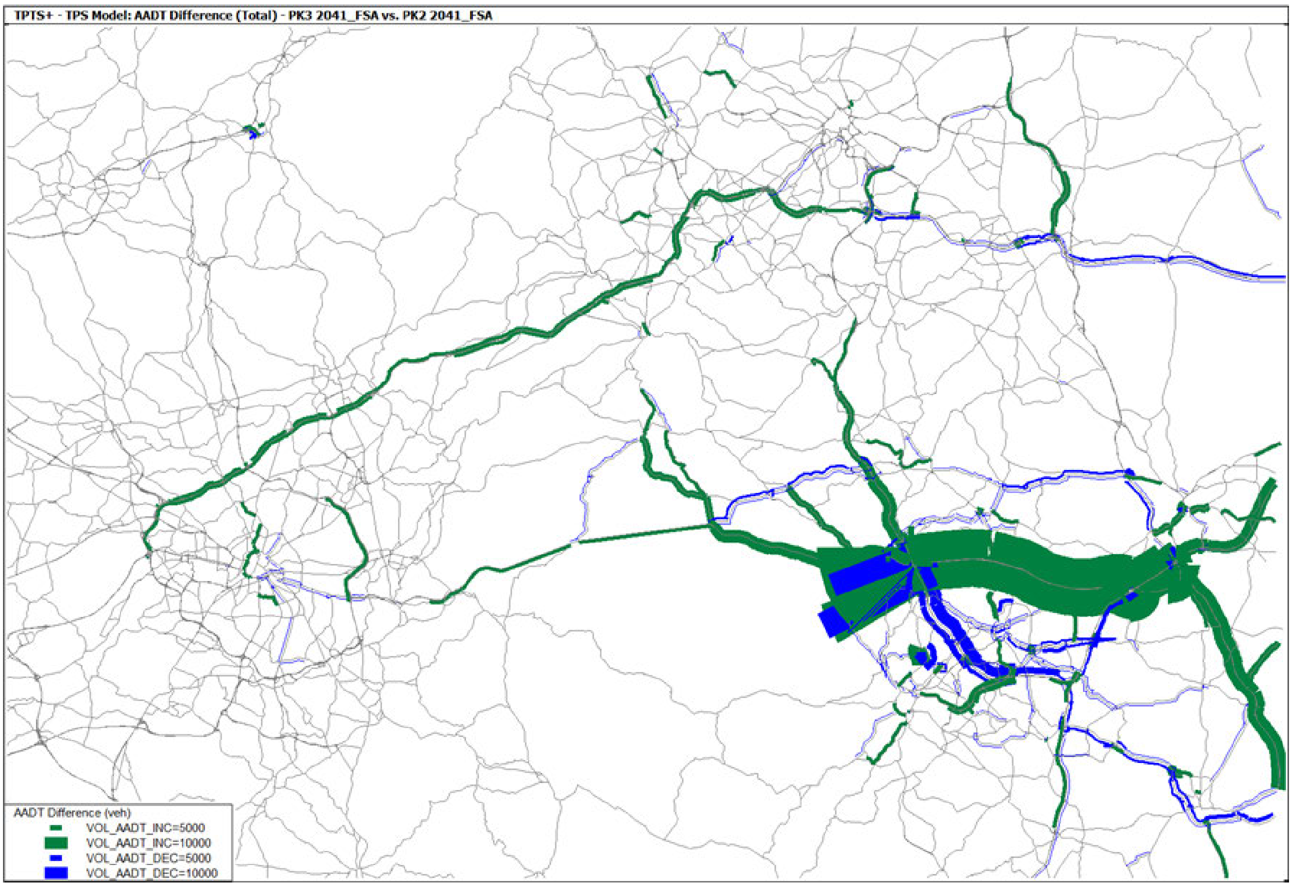
10.3.8 As expected, the Package 2 interventions at a high level would result in localised flow changes in the vicinity of the scheme (e.g. Stockport, M60 an Manchester airport) area when compared to package 1;

- Additional 3,000 2-way AADT traffic is forecast to travel on the M60 and A6 around Stockport/Manchester Airport area.
- A marginal increase of additional 200 and 300 2-way AADT is anticipated to travel on the A616 and A628 respectively when compared to Package 1.

10.3.9 With the A6-M60 scheme in place, small increase in delay on A628 and M60 networks is anticipated due to flow increase on the existing road networks resulted from the Package 2 interventions.

10.3.10 **Figure 10-6** provides a representation of flow difference on the network between Package 3 and Package 2 in terms of AADT.

Figure 10-6 AADT Difference - Package 3 vs. Package 2 (2041)



10.3.11 As seen, the Package 3 interventions would result in following flow changes in the vicinity of the interventions, more specifically:

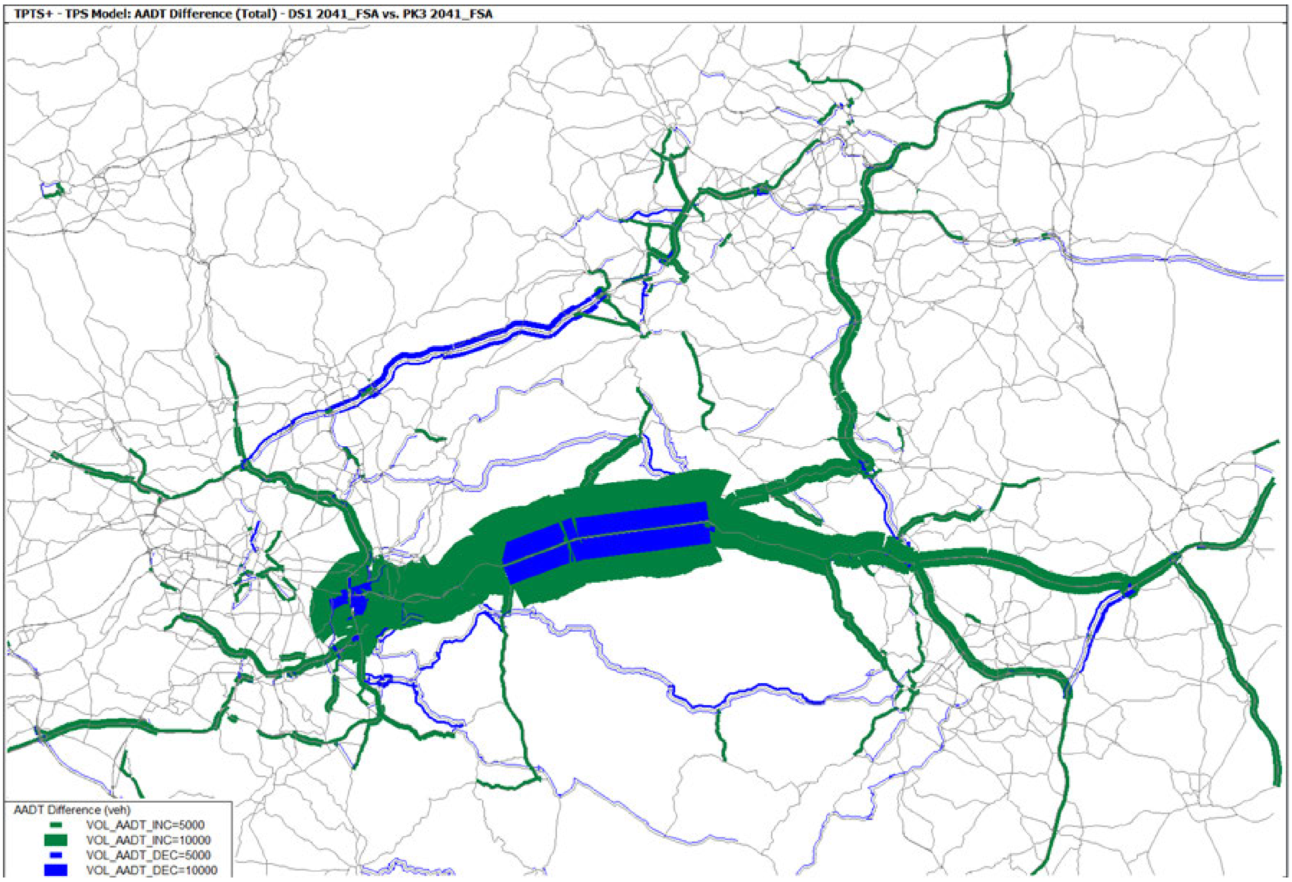
- About 44,000 2-way AADT flows forecast to travel on the A616 to M1 (a net increase of 6,000 2-way AADT additional compared to package 2).
- Due to addition of M1-M18 link road reduction of about 16,000 2-way AADT is forecast south of M1-J35A and an increase of 3,000 2-way AADT on south of M18-J4.
- About 1,000 2-way AADT increase is forecast on M62.

10.3.12 In terms of travel time change, it is forecast that:

- An increase in delay of about 1-2mins on A628 relative to Package 2 would however be anticipated as a result of increase in traffic on A616 from/to M1. This could be attributed to bottle neck on the existing A628 single carriageway.
- A reduction in delay on M1 J32-J35A between 1-2 mins also forecast, attributed to decrease of traffic levels on M1 due to M1-M18 link road.

10.3.13 **Figure 10-7** provides a representation of flow difference on the network between Package 3 and Optimised Package in terms of AADT.

Figure 10-7 AADT Difference - Optimised Package vs. Package 3 (2041)



10.3.14 As seen, the Optimised interventions would result in following flow changes in the vicinity of the interventions;

- About 80,000 AADT 2-way flows forecast to travel on the A628 in Optimised Package (a net increase of 48,000 2-way AADT additional compared to package 3). This can be attributed to combined effect of Denton bypass and tunnel.
- Impact of additional interventions on M1-M18 link on traffic flows is also anticipated there shows an increase of about 10,000 2-way AADT.
- A decrease of about 6,000 2-way AADT is anticipated on M62.

10.3.15 Decrease in delay on A628 by about 5-9 minutes against Package 3 is anticipated due to A628 widening and the Tunnel.

APPRAISAL OUTPUTS

10.3.16 A TUBA assessment was carried out for the three test packages (Package 1, Package 2 and Package 3) against the Do-Minimum. To provide a consistent approach in comparing performance of each package in terms of economic appraisal, as mentioned in previous section, the scheme Opening year of 2041 was assumed in the calculation of TUBA benefits at this stage. It is noted that Reliability and WITA impacts are not reported here but will be included at a later stage.

10.3.17 **Table 10-1** provides summary of the TUBA user-benefits for the three test packages with 2041 as opening year.

Table 10-1 TUBA Summary - Proposed Packages (assuming 2041 Opening Year)

Packages	Package 1	Package 2	Package 3
Commuting	215,900	238,832	300,542
Other	426,147	419,481	474,983
Business (Car)	385,656	413,966	872,199
Business (Freight)	169,614	178,574	470,749
Operator Revenues	-366	-386	-2,794
Greenhouse Gas	49,360	40,332	23,643
Indirect Tax Revenues	-99,183	-85,973	-43,984
Total TUBA Benefits	**1,147,129**	**1,204,827**	**2,095,338**

10.3.18 It can be seen from **Table 10-1** that Package 1 produces £1.1b user benefits, which is anticipated due to interventions on both the west and east of the Pennines. Package 2 however only produce marginal increase in benefits against Package 1, which suggest A6-M60 schemes would not offer additional benefits (to be discussed further in the subsequent section). Package 3 would produce significantly larger benefits compared to the Packages 2 and 1, by about £900m, which is anticipated, as a result of interventions on M1 and M18.

DETAILED ANALYSIS

10.3.19 In order to help analysing the benefits accrued by the individual packages, as agreed with DfT number of Select Link analysis (SLA) was undertaken on A628, M1-M18 Link road and on M18 main line between M18 J1 and J2. The analysis, as agreed, was undertaken on Do Minimum, Package 1, Package 2, Package 3 and Optimised Package 2041 AM peak model. Detailed analysis is provided in **Appendix E**, examples of the analysis is illustrated in **Figure 10-8** to **Figure 10-10**. Below provides a quick summary of the analysis:

- SLA performed on A628 revealed that majority of traffic in all moving from sectors 1 and 4 to sectors 6 and 9 that is from Greater Manchester to Sheffield and Humber side.
- A clear jump in movement of traffic was seen in Optimised Package when compared to other packages due to delivery of additional infrastructure.
- SLA on M18 also revealed majority of traffic is plying between Manchester and Humber Side Sections south of M1 J35A experience a jump of traffic when package 1 and package 2 are delivered, owing to increase of east-west traffic. This gets shifted to M1-M18 link road when package 3 or Optimised Package is delivered. This was confirmed by undertaking another SLA on M1-M18 link road.

Figure 10-8 Select Link Analysis - A628 Example

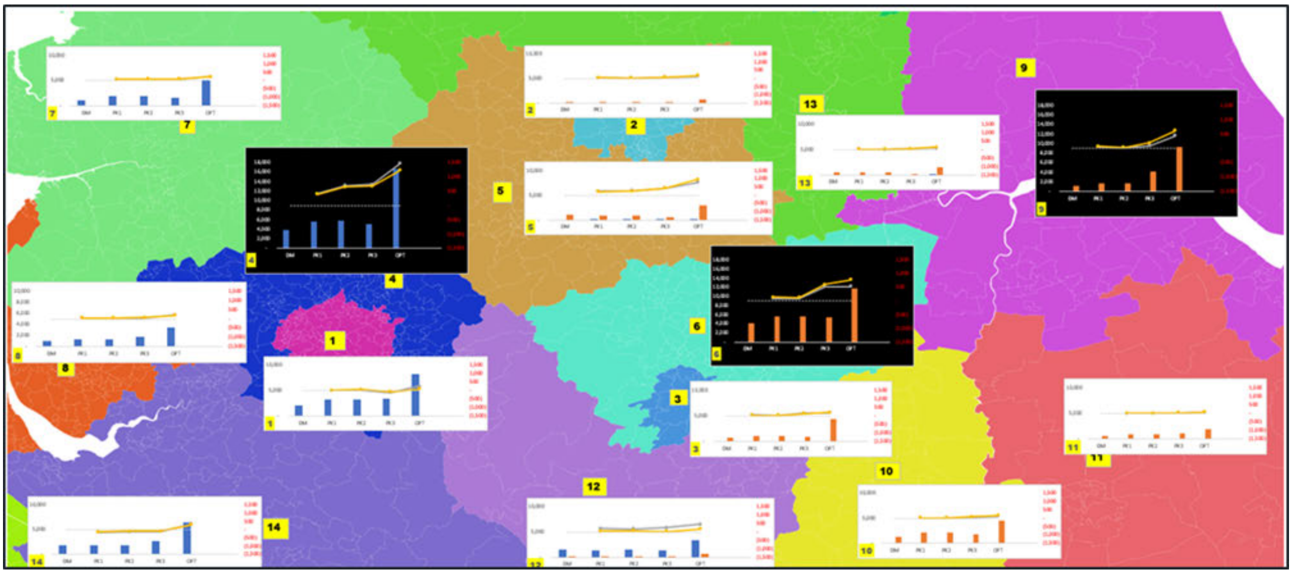


Figure 10-9 Select Link Analysis - M18 Example

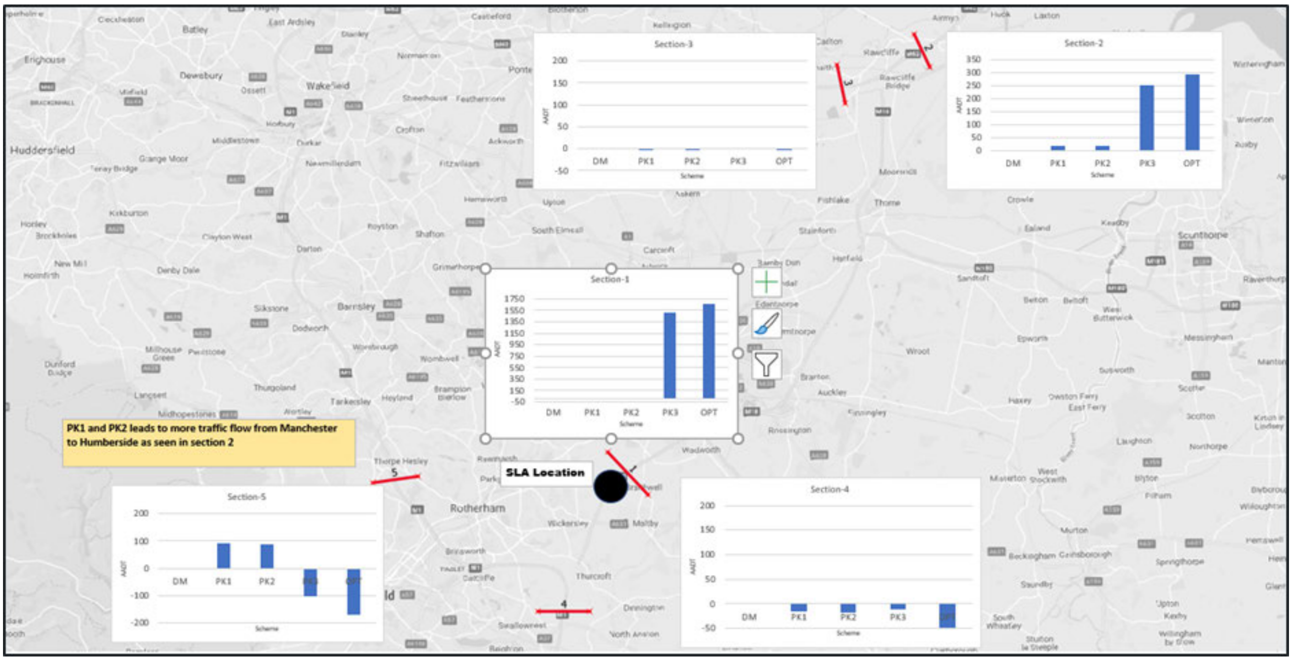
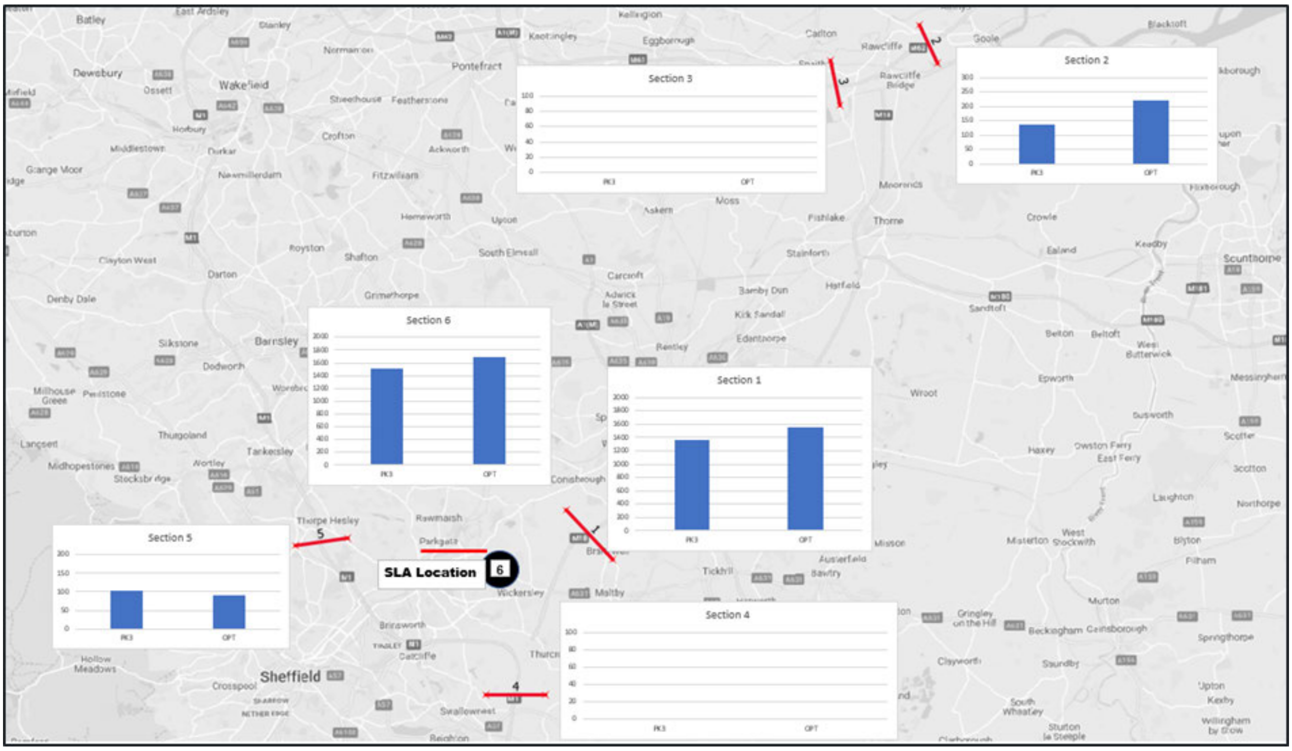


Figure 10-10 Select Link Analysis - M1-M18 Link



10.4 REVISION TO PACKAGES 2 AND 3

10.4.1 As mentioned in the previous section, the appraisal outputs show that Package 2 only produces marginal increase in benefits against Package 1. This suggests the A6-M60 scheme would only offer little extra benefits, contradicting with the findings from an existing SOBC works for that individual scheme.

10.4.2 Following discussion with TAG, an independent standalone scheme testing of A6-M60 was undertaken to understand the performance of the A6-M60 scheme on its own. It was found that, A6-M60, when tested on its own, would produce about £700m benefits.

10.4.3 Analysis of the modelling and appraisal outputs revealed that the A6-M60 interventions would produce increase in traffic on the M60 J24-J25 both directions and as a consequence would cause significant additional delays on the M60 motorways compared to the Do-Minimum thus unable to unlock full benefits of the scheme.

10.4.4 The analysis concluded that, full benefits of the A6-M60 would not be realised without the capacity improvements on the M60 J24- J25 section. These results were discussed with HE and it was agreed to test the inclusion of the M60 J24-J25 capacity improvements on to the Packages 2 and 3.

10.4.5 **Figure 10-11** and **Figure 10-12** provide summary of the revised Packages 2 and 3 with M60 J24-J25 included.

Figure 10-11 Revised Package 2 - Scheme Included

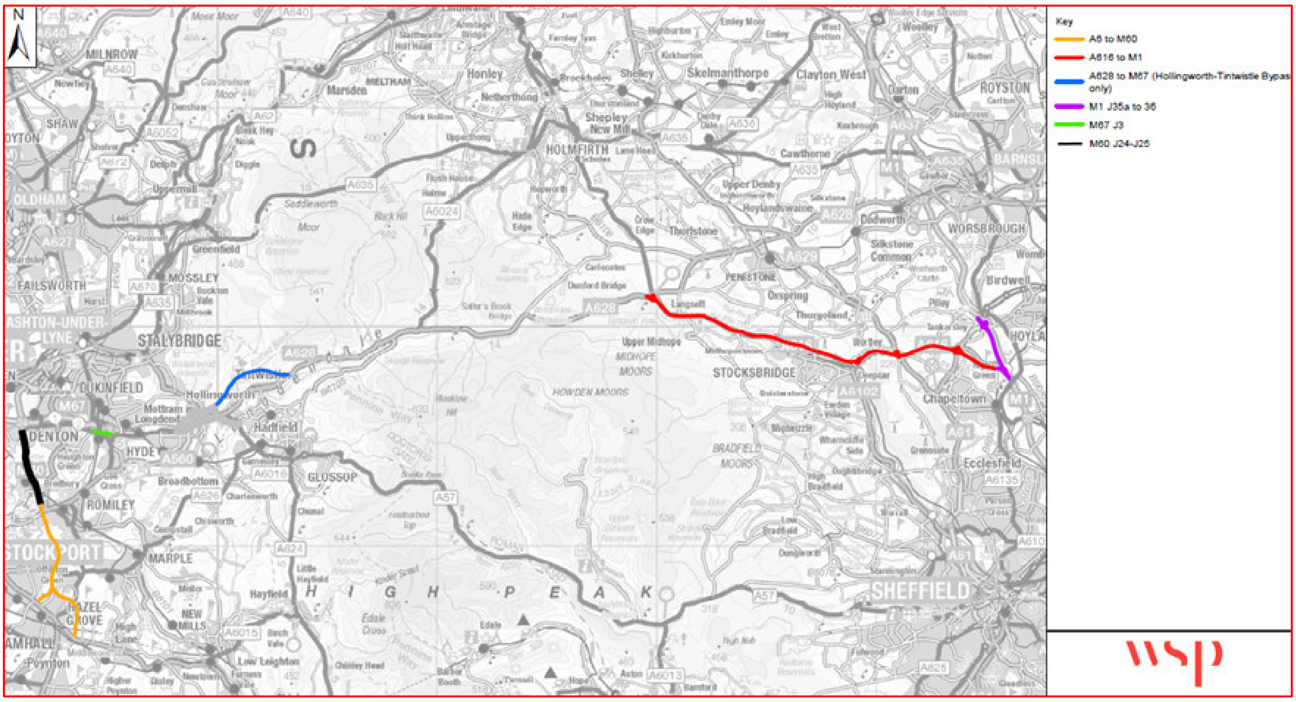
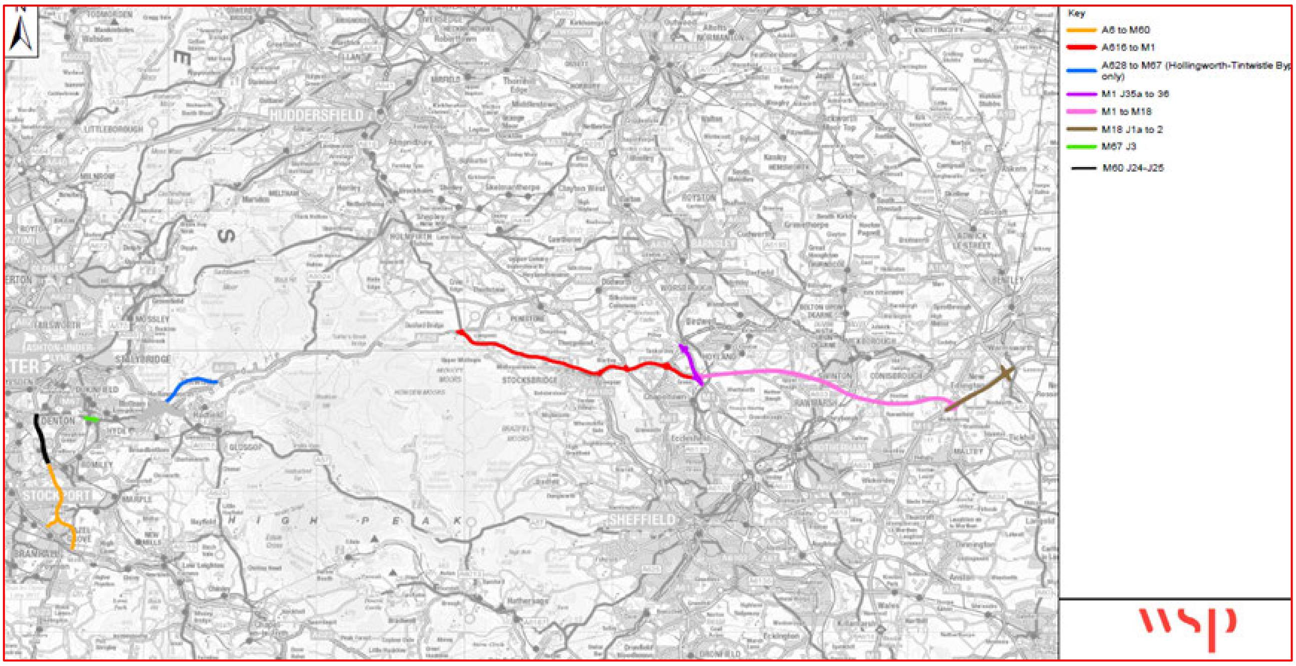


Figure 10-12 Revised Package 3 - Schemes Included

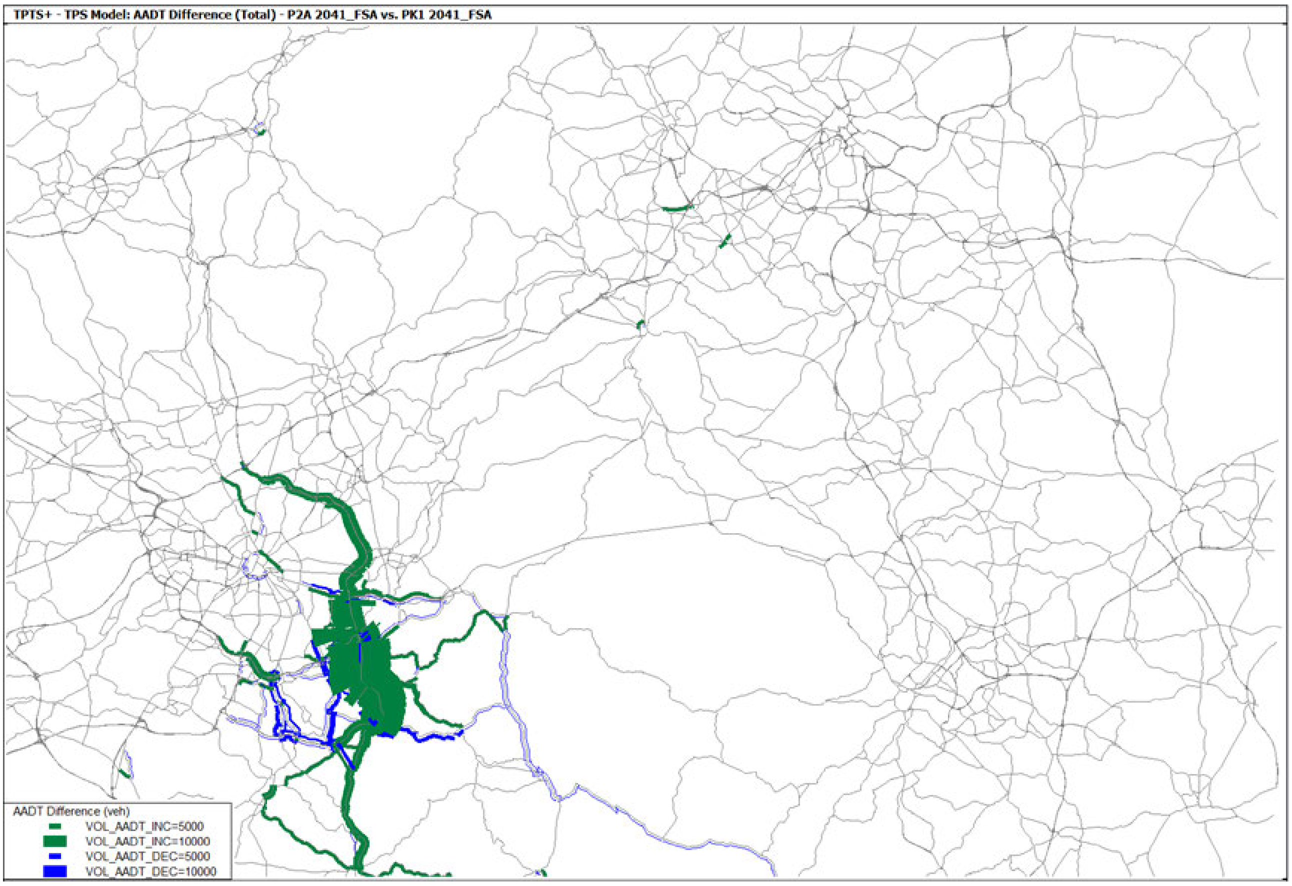


10.4.6 Variable demand modelling and Urban Delay Function were subsequently undertaken on the revised Packages 2 and 3 and summarised in the section below.

10.5 MODELLING AND APPRAISAL ANALYSIS – REVISED PACKAGES

10.5.1 **Figure 10-13** provides a representation of flow difference on the network between the revised Package 2 and Package 1 in terms of AADT.

Figure 10-13 AADT Difference – Revised Package 2 vs Package 1 (2041)

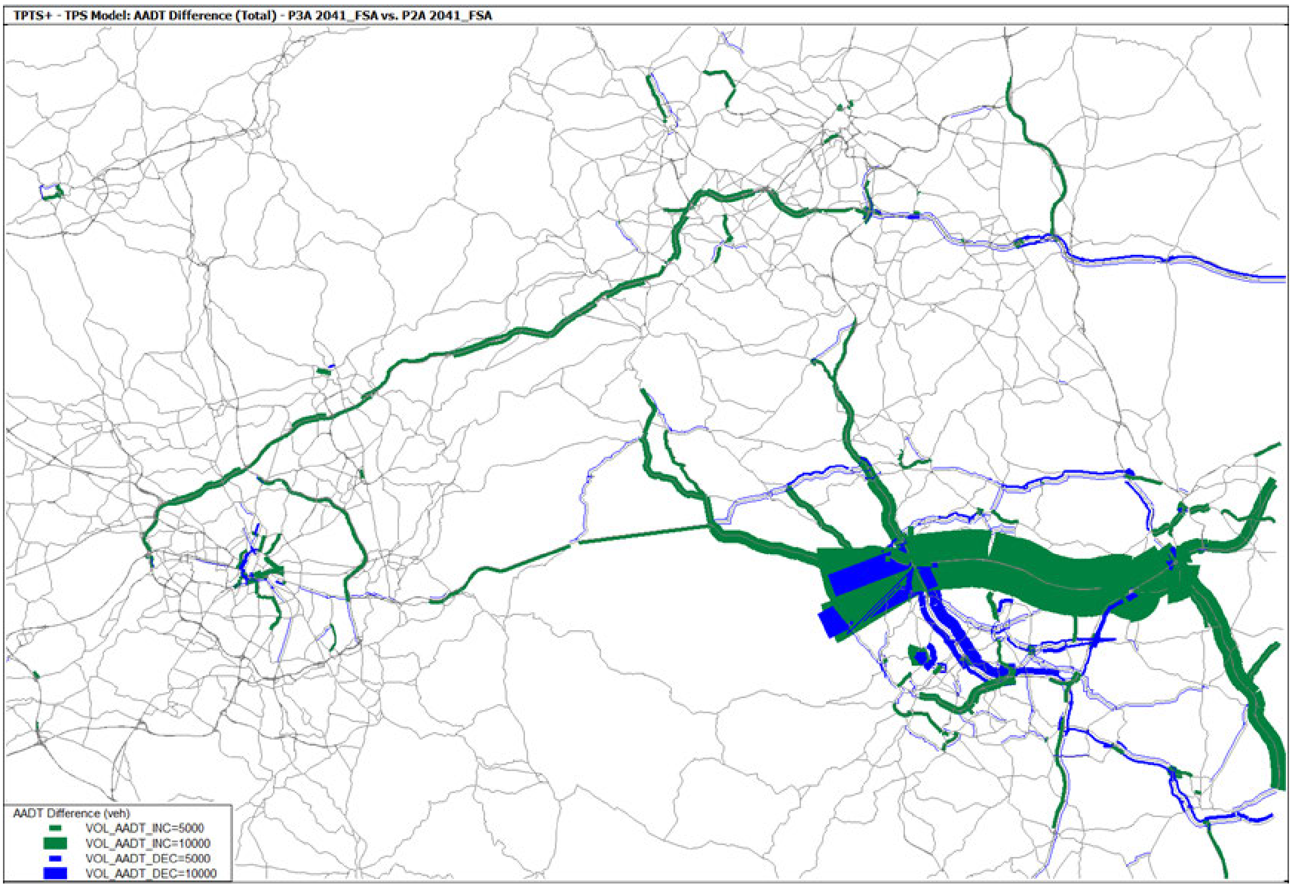


10.5.2 As seen, the Package 2 interventions would result in following changes in the vicinity of the interventions as compared to package 1, in particular:

- Major difference of traffic between the revised Package 2 and Package 1 is observed on links between M60 J24-J25 of about additional 22,000 2-way AADT (compared to package 2 an additional 19,000 2way-AADT is observed). This can be attributed to increase of capacity on M60 J24-J25 thus unlocking the benefits.
- As expected, a reduction in delay between M60 J24-J25 is anticipated. In AM peak a reduction of 63 seconds and in PM peak a reduction of 74 seconds is reported. Increase in delay of 40 seconds in AM peak and 21 seconds in PM peak is observed on A628.

10.5.3 **Figure 10-14** provides a representation of flow difference on the network between the revised Package 3 and revised Package 2 in terms of AADT.

Figure 10-14 AADT Difference – Revised Package 3 vs Revised Package 2



10.5.4 As seen, the Package 3 interventions would result in significant flow changes in the vicinity of the interventions;

- Major difference of traffic between the revised Package 3 and revised Package A is observed on M1-M18 link road. It is expected to carry about 47,000 2way AADT. Due to this a reduction of 16,000 2way-AADT is observed south of M1-J35A as most of east-west traffic has shifted to the M1-M18 link road.
- Due to delivery of additional infrastructure on the eastern side, an increase of about 6,000 2way AADT is observed on A616.
- As expected, a reduction in delay south of M1-J35 is observed due to reduction of traffic. In AM peak a reduction of 109 seconds and in PM peak a reduction of 60 seconds is reported.

10.5.5 A TUBA assessment was carried out for the revised Packages 2 and 3 against the Do-Minimum. Again, for purpose of comparison, the TUBA benefits were reported using the Opening year 2041. Again, Reliability and WITA benefits are not reported in this Table but will be included at a later stage when the correct scheme Opening year is used.

Table 10-2 TUBA Summary – Revised Packages (assuming 2041 Opening Year)

Packages	Package 1	Package 2	Package 3
Commuting	215,900	379,965	442,181
Other	426,147	476,068	586,374

Packages	Package 1	Package 2	Package 3
Business (Car)	385,656	483,165	974,830
Business (Freight)	169,614	240,845	538,882
Operator Revenues	-366	-2,173	-3,028
Greenhouse Gas	49,360	37,645	23,257
Indirect Tax Revenues	-99,183	-82,034	-42,297
Total TUBA Benefits	**1,147,129**	**1,533,482**	**2,520,200**

10.5.6 It can be seen from **Table 10-2** that the revised Packages 2 and 3 would produce about £300m to £400m additional benefits compared to the Package 2 and 3 respectively. This equates to additional £400m and £1,400m against Package 1.

10.5.7 WITA benefits have also show the similar trend with Package 3 showing the largest benefits.

10.6 UPDATED OPENING YEARS OF PACKAGES

10.6.1 Following discussion with Highways England at TAG meeting, it was agreed that the Opening of each Packages needed to be revised to account for individual scheme completion date. This is to allow for affordability of the scheme constructions.

- Package 1 – Opening Year 2034;
- Package 2 – Opening Year 2037; and
- Package 3 – Opening Year 2041.

10.6.2 **Table 10-3** provides the TUBA benefits summary with revised opening years for various packages.

Table 10-3 TUBA Summary of Packages with Updated Opening Years (£000s)

Packages	Package 1 – 2034	Package 2 – 2037	Package 3 - 2041
Present Value of Costs			
CAPEX	586,274	901,963	1,498,708
OPEX	70,239	99,384	163,615
Total	**656,512**	**1,001,347**	**1,662,323**
Present Value of Benefit – Level 1			
Commuting	243,418	402,450	442,181
Other	478,495	505,726	586,374
Business (Car)	422,556	508,102	974,830
Business (Freight)	187,600	255,177	538,882
Operator Revenues	-561	-2,550	-3,028
Greenhouse Gas	64,282	44,103	23,257
Indirect Tax Revenues	-121,237	-92,313	-42,297
Total Level 1 PVB	**1,274,552**	**1,620,696**	**2,520,200**
Level 1 BCR	**1.94**	**1.62**	**1.52**

Packages	Package 1 – 2034	Package 2 – 2037	Package 3 - 2041
Present Value of Benefit – Level 2			
Reliability Benefit	110,358	148,651	236,791
Agglomeration impacts	551,236	794,762	1,008,603
Change in imp. comp. market	42,256	50,810	97,483
Labour supply impacts	6,019	10,258	11,677
Total Level 2 PVB	**1,984,422**	**2,625,177**	**3,874,753**
Adjusted BCR	**3.02**	**2.62**	**2.33**

10.6.3 It is noted that PVC values are reported in **Chapter 11**, and Level 1 PVB does not include accident savings and delays during construction impacts. It is also noted that the Greenhouse Gas benefits provided in this Table are produced by TUBA. They have been subsequently recalculated using the more accurate method following TAG A3 guidance for each of the Packages and is reported later in the **Chapter 13** of this document.

10.6.4 It can be seen from **Table 10-3** with revised Opening years Package 1 and Package 2 deliver extra benefits when compared to their later Opening dates.

10.7 VDM AND ASSIGNMENT CONVERGENCE

10.7.1 Assignment convergence statistics of the peak hour models and demand model convergence of the individual packages are a good measure of the robustness of TUBA and WITA benefits realised from the packages.

Table 10-4 VDM Convergence Summary

Package	Modelled Year	VDM Loop	Full model Gap (%)	Sub-Area Gap (%)
Package 1	2031	8	0.08%	0.16%
	2041	8	0.10%	0.18%
Package 2	2031	8	0.08%	0.17%
	2041	8	0.11%	0.20%
Package 3	2031	8	0.08%	0.14%
	2041	8	0.1%	0.19%

10.7.2 VDM convergence indicate stability of solution has been achieved within the sub-area, hence results from the scheme can be used to appraise schemes within sub-area.

Table 10-5 Assignment Convergence Summary

Package	Period	2031 Assignments			2041 Assignments		
		Loop	%Flow	%Gap	Loop	%Flow	%Gap
Package 1	AM	46	98.1	0.020	55	98.5	0.018
	IP	64	98.8	0.007	120	98.8	0.020

Package	Period	2031 Assignments			2041 Assignments		
		Loop	%Flow	%Gap	Loop	%Flow	%Gap
	PM	120	95.7	0.024	104	98.3	0.021
Package 2	AM	52	98.0	0.011	45	98.3	0.012
	IP	64	99.1	0.005	120	98.8	0.009
	PM	92	98.3	0.011	94	98.4	0.022
Package 3	AM	38	97.6	0.021	48	95.5	0.011
	IP	64	99.2	0.006	68	99.0	0.010
	PM	79	97.7	0.012	102	97.9	0.017

10.7.3 It is acknowledged that there are assignment convergence issues predominately for the Inter-peak models which can be attributed to the stringent assignment parameters set compared to the other peaks.

10.7.4 As seen from **Table 10-5** there is poor convergence of Package 1 2031 PM model, but Package 1 2041 PM model has converged. As most of the benefits are realised from 2041 model, it can be accepted at this stage of analysis. Package 2 2041 Inter-Peak model hasn't converged as well but we can observe that flows are relatively stabilised, hence considered acceptable at this stage.

10.8 SUMMARY

10.8.1 The modelling and appraisal of the three sub-packages, as agreed with HE and DfT during the selection process, were undertaken using the 'Variable demand' assignment approach with demand matrices produced from the post-VDM models for each of incrementally packaged networks. The Urban Delay function was applied post-VDM assignment to account for the impacts of fixed speed changes in response to demand changes within the urban areas.

10.8.2 Level 1 (user benefits – TUBA only) and level 2 (Wider impacts with static clustering and reliability impacts) appraisals were carried out for each sub-package separate with revised assumption of each package's Opening year to produce economic performance for each sub-package.

10.8.3 In summary, the sub-packages produce Low to Medium Value for Money with the initial BCR is 1.9, 1.6 and 1.5 for the Packages, 2 and 3 respectively. With Level 2 benefits included, the adjusted BCR is 3.0, 2.6 and 2.3 for the Packages 1, 2 and 3 respectively.

11 APPRAISALS - UPDATED SCHEME OPENING YEAR

11.1 OVERVIEW

11.1.1 This chapter provides the results arising from assuming an alternate opening year of 2041 for the Optimised Package Core scenario. Additionally, the economic appraisal for the alternate growth scenarios i.e. DfT Low Growth scenario and TfN Transformational growth scenario have also been reworked with this revised Opening year of 2041 and the results are discussed below with the following sections.

- Updated scheme costs from Highway Commercial;
- Level 1 benefits with updated Opening Year;
- Level 2 benefits with updated Opening year;
- Appraisal summary with growth scenarios; and
- Appraisal summary with cost sensitivity.

11.2 UPDATED SCHEME COST ESTIMATES

11.2.1 The latest cost estimates were provided by Highways teams, Interim Forecasting Tools (IFT) and Highways England Commercial in March 2020. The outturn costs were extracted from the IFT for each individual scheme and provided in **Table 11-1** below.

Table 11-1 Estimated Outturn Costs

ID	Scheme	Package 1	Package 2	Package 3	Optimised Package	End date	Outturn Cost (£m)
1	M67, M60 to A57	✓	✓	✓	✓	Jul-2028	81.99
2	A6 to M60		✓	✓	✓	Aug-2036	1,093.44
3	M60 J24a-J25		✓	✓	✓	Mar-2041	69.31
4	M1 J35a-J36	✓	✓	✓	✓	Apr-2031	35.91
5	Denton Bypass				✓	Aug-2040	1,062.53
6	A616 to M1	✓	✓	✓	✓	May-2033	781.04
7	A628 to M67	✓	✓	✓		Aug-2030	641.05
8	A628 + Tunnel				✓	Nov-2041	8,779.55
9	M1 to M18			✓	✓	Sep-2039	2,394.81
10	M18 J1a-J2			✓	✓	Feb-2040	92.90
11	A628 Mottram				✓	Aug-2041	1,017.08

11.2.2 The costs provided from Highways Commercial were then converted to PVC for the purpose of economic appraisal, as listed in **Table 11-2** below. It is noted that the Economic Outputs provided by Highway Commercial includes three categories: Low Cost Estimates (P2.5), Central Estimates (P mean) and High Cost Estimates (P97.5).

Table 11-2 PVC Summary with Cost Sensitivity

ID	Scheme	CAPEX P50 (£m)	CAPEX P2.5 (£m)	CAPEX P97.5 (£m)	OPEX (£m)	PVC P50 (£m)	PVC P2.5 (£m)	PVC P97.5 (£m)
1	M67, M60 to A57	36.05	15.87	76.52	2.74	38.79	18.61	79.26
2	A6 to M60	299.49	124.53	784.71	27.36	326.85	151.89	812.07
3	M60 J24a-J25	16.20	6.52	38.28	1.79	17.99	8.31	40.06
4	M1 J35a-J36	14.61	7.53	28.02	0.63	15.24	8.16	28.65
5	Denton Bypass	227.84	71.69	537.43	1.83	229.66	73.51	539.26
6	A616 to M1	273.74	115.95	626.77	39.50	313.25	155.46	666.27
7	A628 to M67	261.88	109.69	587.59	27.36	289.24	137.06	614.95
8	A628 + Tunnel	1,939.16	692.71	4,259.03	331.66	2,270.82	1,024.38	4,590.70
9	M1 to M18	573.55	205.02	1,454.82	63.60	637.15	268.62	1,518.42
10	M18 J1a-J2	23.20	10.04	50.30	0.63	23.83	10.67	50.93
11	A628 Mottram	225.75	68.57	673.84	13.68	239.43	82.25	687.52

11.2.3 It is also noted that there is no updated OPEX costs produced with the updated scheme Opening year and scheme costs, the OPEX therefore adopt values from previous estimates for the purpose of production of the PVC. It is however anticipated that with the updated scheme Opening year the OPEX costs would change and likely to be lower than the values produced at this stage.

11.2.4 From the CAPEX and OPEX above, it was necessary to produce the PVC for Optimised Package and also three proposed packages, as provided in **Table 11-3** below.

Table 11-3 PVC by Individual Packages

Package	Outturn Cost (£m)	CAPEX P50 (£m)	CAPEX P2.5 (£m)	CAPEX P97.5 (£m)	OPEX (£m)	PVC P50 (£m)	PVC P2.5 (£m)	PVC P97.5 (£m)
Package 1	1,539.98	586.27	249.05	1,318.89	70.24	656.51	319.29	1,389.13
Package 2	2,702.73	901.96	380.09	2,141.88	99.38	1,001.35	479.48	2,241.27
Package 3	5,190.44	1,498.71	595.15	3,647.00	163.62	1,662.32	758.77	3,810.62
Optimised Package	15,408.55	3,629.57	1,318.43	8,529.72	483.42	4,113.00	1,801.85	9,013.14

11.2.5 In summary, PVC for each individual package are as below:

- **Package 1 – £657m**
- **Package 2 - £1,001m**
- **Package 3 - £1,662m**
- **Optimised Package - £4,113m**

11.2.6 The following sections only report the benefits for the Optimised Package and its alternative growth scenario assumptions. The BCR for each test package is reported in the previous chapter.

11.3 USER BENEFITS

11.3.1 Transport user benefits calculated for the TPTS+ studies used the DfT recognised TUBA software, which adopts May 2018 WebTAG DataBook parameters. The methodology and approach to determine the user benefits is as detailed in **Section 3**.

11.3.2 It is noted that there was no calculation of Greenhouse gas benefits using the more accurate TAG method for the Low and Transformational growth scenario, for consistency when comparing the benefits of the Optimised Package under forecast uncertainty, the Greenhouse Gas benefits that were produced from TUBA were used for reporting the TUBA benefit summary tables within this Chapter. The more accurate Greenhouse gas benefits for the Optimised Package Core scenario following the TAG guidance is provided in **Chapter 13** of this document.

11.3.3 The TUBA benefits produced from the Optimised Package, DfT Low Growth Scenario and TfN Transformation growth scenario is provided in **Table 11-4** to **Table 11-6** below.

Table 11-4 TUBA Benefit Summary - Core Scenario

Purpose	Time Savings	User Charges	VOC	Total
Commuting	594,732	-106	-30,790	563,836
Other	927,480	-245	-217,771	709,463
Business (Car)	2,115,604	465	91,455	2,207,524
Business (Freight)	774,311	1,751	176,328	952,390
Operator Revenues				-3,376
Greenhouse Gas				-77,895
Indirect Tax Revenues				138,049
Total	**4,412,126**	**1,865**	**19,221**	**4,489,990**

Table 11-5 TUBA Benefit Summary - DfT Low Growth Scenario

Purpose	Time Savings	User Charges	VOC	Total
Commuting	522,652	-53	-16,711	505,887
Other	719,545	-199	-193,992	525,355
Business (Car)	2,069,571	352	91,079	2,161,002
Business (Freight)	926,281	4,089	197,927	1,128,297
Operator Revenues				-3,408
Greenhouse Gas				-59,917
Indirect Tax Revenues				95,911
Total	**4,238,049**	**4,189**	**78,303**	**4,353,128**

Table 11-6 TUBA Benefit Summary - TfN Transformational Growth Scenario

Purpose	Time Savings	User Charges	VOC	Total
Commuting	658,801	-72	-9,961	648,768
Other	951,766	-242	-177,098	774,426
Business (Car)	2,129,071	755	87,177	2,217,003
Business (Freight)	831,538	1,997	176,939	1,010,474
Operator Revenues				-2,887
Greenhouse Gas				-59,088
Indirect Tax Revenues				100,631
Total	**4,571,176**	**2,437**	**77,057**	**4,689,326**

11.4 ACCIDENT SAVING BENEFITS

11.4.1 The methodology and assumptions for the estimates of accident benefits remain the same as discussed for the TPTS Only and the Optimised Package in **Section 7.5**.

11.4.2 The accident benefits have been recalculated only for Optimised Package Core growth (2041 Opening) and provided in **Table 11-7** below. At this stage of study, the accident benefits for the alternate growth scenarios are assumed to be the same as Core scenario.

Table 11-7 Accident Saving Benefits - Core Scenario

Element	Optimised Package		
Economic Summary (£000s)			
without-Scheme Accident Costs			23,817,888
with-Scheme Accident Costs			23,698,032
Accident Benefits			**119,856**
Accident Summary			
without-Scheme Accidents			677,046
with-Scheme Accidents			674,048
Accidents saved			**2,999**
Casualty Summary	Fatal	Serious	Slight
without-Scheme Casualties	7,363	83,540	847,584
with-Scheme Casualties	7,341	82,977	844,342
Casualties saved	**22**	**563**	**3,242**

11.5 DELAYS DURING CONSTRUCTIONS

11.5.1 The methodology and assumptions for the estimates the impact to road users during constructions remains the same as discussed for the TPTS Only and the Optimised Package in **Section 7.6.**

11.5.2 To represent the impacts of construction on the network, a reduction to free-flow speeds as coded in the Do-Minimum network have been applied at sections where speed restriction and narrow lane traffic management would be in place during construction.

11.5.3 As detailed in **Section 7.6**, it is assumed that the construction of the TPTS+ interventions would take place over a 2-year period. A TUBA run was therefore carried out for a single year 2041 for the Do-Minimum and Do-Minimum + roadworks and subsequently multiplied by 2 to produce estimate of delays for the 2-years construction periods. The outputs from the TUBA appraisal to produce delays during construction of the TPTS+ interventions are provided in the section below

11.5.4 Analysis of TUBA benefit at a sectoral level however shows that whilst the anticipated impacts of roadworks would be generally negative and limited to Sheffield areas where roadworks would take place, the sectoral benefits produced from TUBA shows number of counter-intuitive results (i.e. positive benefits) in number of sectors outside the influence areas of the roadworks, which was likely attributed to model noise.

11.5.5 A masking process was therefore carried out to remove the counter-intuitive values from TUBA, such as intra-sector of greater Manchester and Liverpool. The revised TUBA benefits with the masking process applied resulted in -£13.67m dis-benefits to road users during 1-year construction period

11.5.6 The revised TUBA results were then multiplied by 2 to reflect delays to road users during 2-year construction period, providing the total delays costs during construction of **-£27.34m**

11.6 WIDER IMPACT BENEFITS – STATIC CLUSTERING

11.6.1 Wider impacts – static clustering refers to the impacts that assumes fixed land-use (connectivity impacts) or do not require land-use change to be explicitly quantified. The wider impacts static clustering includes the following:

- Agglomeration impacts (fixed land-use);
- Output in imperfectly competitive market (10% of TUBA business user benefit); and
- Labour supply impacts.

11.6.2 This approach to assessing Static Wider Economic Benefits (WEBs) was previously approved for use on the Trans-Pennine Tunnel Study Stage 0 by Highways England and DfT and remains the same as detailed in **Section 7.7**.

11.6.3 The WEBS for Core growth, DfT Low growth and TfN Transformational growth for a revised opening year of 2041 is as shown in **Table 11-8** below.

Table 11-8 WITA Benefit Summary (£000s)

Package	Optimised Package		Low Growth		Transformational	
	WITA	Adjusted	WITA	Adjusted	WITA	Adjusted
Agglomeration impacts	3,056,389	2,445,111	3,506,268	2,805,014	3,018,181	2,414,544
Change in imperfectly competitive market	220,752	220,752	216,100	216,100	221,700	221,700
Labour supply impacts	18,315	18,315	24,472	24,472	20,213	20,213
Move to more/less productive jobs	0	0	0	0	0	0
Total	**3,295,456**	**2,684,178**	**3,746,840**	**3,045,587**	**3,260,094**	**2,656,458**

11.7 RELIABILITY IMPACTS

11.7.1 Reliability refers to variation in journey times that individuals are unable to predict. Such variation could come from recurring congestion at the same period each day or from non-recurring events such as incidents.

11.7.2 As detailed in **Section 7.8**, the reliability benefits for the TPTS+ Optimised Package with the Core and alternate growth scenarios having a revised Opening year 2041 were derived by applying 10% of the TUBA time savings benefits as provided in **Table 11-9** below.

Table 11-9 Reliability Benefit Summary (£000s)

Package	Optimised Package	Low Growth	Transformational
TUBA Time Saving benefits	4,412,126	4,238,049	4,571,176
Reliability Benefits (10%)	**441,213**	**423,805**	**457,118**

11.8 APPRAISAL SUMMARY

11.8.1 **Table 11-10** below provides the appraisal summary for the Optimised Package for the NTEM Core, DfT Low Growth and TfN Transformational growth scenarios.

Table 11-10 Appraisal Summary

Appraisal Summary	Core Growth Scenario	DfT Low Growth Scenario	Transformational Growth Scenario
Present Value of Costs – PVC (£m)			
Capital Expenditure	3,629.57	3,629.57	3,629.57
Operating Expenditure	483.42	483.42	483.42
Total PVC	**4,113.00**	**4,113.00**	**4,113.00**
Level 1 Present Value of Benefits - PVB (£m)			
User Benefits	4,429.84	4,317.13	4,647.78
Indirect Tax Revenue	138.05	95.91	100.63
Greenhouse Gas	-77.89	-59.92	-59.09
Accident Impacts	119.86	119.86	119.86
Delays during construction	-27.34	-27.34	-27.34
Total Level 1 PVB	**4,582.51**	**4,445.64**	**4,781.84**
Initial BCR	**1.11**	**1.08**	**1.16**
Level 2 Present Value of Benefits – PVB (£m)			
Reliability Impacts	441.21	423.80	457.12
Wider Impacts – Static	2,684.18	3,045.59	2,656.46
Total Level 1 & 2 PVB (£m)	**7,707.90**	**7,915.04**	**7,895.42**
Adjusted BCR	**1.87**	**1.92**	**1.92**

11.8.2 In addition to the Appraisal summary above, the impacts on scheme appraisal was also calculated with the cost sensitivity as provided by Highway Commercial, as shown in **Table 11-11** below.

Table 11-11 Alternative Cost Scenario

Appraisal Summary	Central Estimates CAPEX P Mean	Low Cost Estimates CAPEX P2.5	High Cost Estimates CAPEX P97.5
Present Value of Costs – PVC (£m)			
Capital Expenditure	3,629.57	1,318.43	8,529.72
Operating Expenditure	483.42	483.42	483.42
Total PVC	**4,113.00**	**1,801.85**	**9,013.14**
Level 1 Present Value of Benefits - PVB (£m)			
User Benefits	4,429.84	4,429.84	4,429.84
Indirect Tax Revenue	138.05	138.05	138.05
Greenhouse Gas	-77.89	-77.89	-77.89

Appraisal Summary	Central Estimates CAPEX P Mean	Low Cost Estimates CAPEX P2.5	High Cost Estimates CAPEX P97.5
Accident Impacts	119.86	119.86	119.86
Delays during construction	-27.34	-27.34	-27.34
Total Level 1 PVB	**4,582.51**	**4,582.51**	**4,582.51**
Initial BCR	**1.11**	**2.54**	**0.51**
Level 2 Present Value of Benefits – PVB (£m)			
Reliability Impacts	441.21	441.21	441.21
Wider Impacts – Static	2,684.18	2,684.18	2,684.18
Total Level 1 & 2 PVB	**7,707.90**	**7,707.90**	**7,707.90**
Adjusted BCR	**1.87**	**4.28**	**0.86**

11.8.3 Again, the Greenhouse Gas benefits provided in these two tables were produced from TUBA. This is to provide a consistent approach in comparing the benefits of the Optimised Package under forecast growth assumption and scheme cost uncertainties. The more accurate Greenhouse gas benefits using the TAG method are reported later in **Chapter 13** of this document.

12 OPTIMISED PACKAGE TOLLING TESTS

12.1 INTRODUCTION

12.1.1 Following finalisation of the three sub-packages and the revision of the economic appraisal for the Optimised Package to reflect an alternate scheme opening year, it was requested by DfT that a number of sensitivity tests were to be undertaken to understand the impacts of introducing a toll on the operational and economic performance, and subsequently potential revenue of the tolled scenario for the Optimised Package. This is to help DfT in developing a paper to support the commercial case and funding options for the scheme.

12.1.2 Detailed methodology, assumptions and modelling and appraisal outputs of the tolling sensitivity tests are provided in Technical Note '**1-998 Tolling Test Technical Note 200520 v1.8.pdf**', this section of the document provides a high-level summary of the approach taken for the analysis and a summary of the outputs. It also highlights the limitations of the analysis and any lessons that can be applied from the on-going Lower Thames Crossing (LTC) study which is at a more advanced stage of analysis for the PCF Stage 3 tolled tunnel assessment.

12.2 TOLLING SENSITIVITY TEST

12.2.1 The tolling structure was agreed based on the vehicle classification in the transport model and the charging regime on the Dartford Crossing[12] and the M6 Midland Expressway[13] (M6 Toll) tolls, which charge different values for Car, LGV and HGV vehicles. The charges for the TPTS+ sensitivity tests were adopted so that the values could be understood in today's prices and therefore can be compared directly with tolls at these assets.

12.2.2 As agreed with DfT, two tolling sensitivity tests were undertaken, in which: a) an initial set of toll values were tested to review the model responses, and b) a second set was later specified as a supplementary test to provide indication of the range of impacts on operational and economic performance. The tolling sensitivity tests were undertaken on the Optimised Package with an Opening Year of 2041.

12.2.3 The values of the tolls used in the tests are provided in **Table 12-1** below. In sensitivity test 1, the toll charges are similar to the M6 Toll which is of a similar in length (between M1 and M60). The values of tolls in sensitivity test 2 is similar to the Dartford Crossing. This should help to provide context when discussing the impact on traffic volume and revenue.

Table 12-1 Toll Charges Modelled (2020 Prices)

Vehicle Class	Sensitivity Test 1	Sensitivity Test 2	Dartford	M6 Toll
Car	£5.00	£2.50	£2.50	£6.70
LGV	£7.50	£3.75	£3.00	£11.80
HGV	£10.00	£5.00	£6.00	£12.00

[12] https://www.gov.uk/pay-dartford-crossing-charge/charges-fines
[13] https://www.m6toll.co.uk/pricing/

12.2.4 The assumptions considered for the tolling sensitivity tests were:

- The toll values modelled are assumed to be for a one-way trip (i.e. per individual journey), with the same toll applied in each direction of travel;
- These toll values were not devised to optimise performance of the scheme, i.e. not representing a benefit, revenue or operational performance optimisation scenario as such analysis would require a different, more detailed modelling tool to provide an acceptable level of assurance;
- Toll values are based on 2020 prices and adjusted to the modelled year 2041 to account for inflation, and subsequently discounted to 2010 prices for the modelling and appraisal purpose.
- The inflation has been applied using growth in Value of Time (VoT) from the TAG DataBook;
- Car demand response is based on RTM VDM responses; and
- LGV and HGV demand response is based on RTM which is fixed i.e. the only response is assignment route choice.

12.3 LIMITATIONS OF MODELLING AND APPRAISAL

12.3.1 It should be noted that there are some caveats/uncertainties in modelling the impacts of tolls due to the current limitation of the vRTM modelling system, as outlined below:

Limitation of Model	Impact on Outputs
Five vRTM standard user classes without disaggregation by income segmentation in the demand and assignment models.	Uncertainty in demand and assignment model responses: catchment and distribution of trips and route choice effects would impact traffic volumes for “Commute” and “Other” user classes, thus not appropriately modelled without income segmentation.
A single set of VoT modelled, or one user class for “Business” trips has been modelled independent of distance travelled.	Uncertainty in “Business” user response to the toll: the longer distance (i.e. higher VoT) may have a higher propensity to pay the toll but are not modelled separately in the demand and assignment models.
The responses of freight users to tolls cannot be modelled within the demand model and only routeing effects can be forecast in the assignment model.	Known limitation in the freight response likely to underestimate freight users in the Optimised Package and overestimate freight users for the tolled scenarios. Current TAG does not provide guidance on freight responses within a VDM model.
Final modelled year of 2041 is also the proposed scheme Opening year with no change in traffic volumes assumed beyond this point.	Expected underestimate in network congestion and demand for the proposed scheme. However, impact on user benefits cannot be quantified (i.e. not known if the net effect over the whole network is positive or negative), and if tolling will improve network performance by reducing congestion.
The projection of toll value to 2031 and 2041 is an approximation based on VoT growth forecast. This creates the desired model response to maintain user responses to the toll expected at 2020 prices.	The actual toll value applied in 2031 and 2041 may differ from the calculated value and lead to a different user response and different traffic volumes and revenues.

12.3.2 It is also recognised that the approach undertaken to appraise the impact of tolls on the Optimised Package may not be robust due to number of limitations, including:

Limitation of Appraisal	Impact on Outputs
Components of the Level 1 and Level 2 impacts are excluded: Accident savings benefits (COBALT) and delay impacts during construction.	No material impacts.
No growth in traffic beyond the last modelled year (i.e. 2041) resulting in the 60-year appraisal being based on the single year 2041 forecast.	The appraisal is independent of traffic volume changes which will occur (user benefits, vehicle operating costs and toll revenues are based on 2041 traffic). The expectation is that growth would occur beyond 2041, which applies equally to the toll and un-tolled scenarios. It is noted that the user benefits and vehicle operating costs in TUBA are adjusted beyond 2041 using DfT forecasts. However, user charges and toll revenues are not adjusted in TUBA (see below).
Toll values after the last modelled year are not adjusted (constraint in TUBA).	Underestimate in both user charges incurred and operator revenue collected. Uncertainty to the BCR calculation (a sensitivity test has been undertaken to estimate the impact of toll prices increasing with inflation beyond 2041).
Sensitivity tests on all input variables are not considered, including willingness to pay values (which are included), costs, inflation, operating efficiencies (including synergies with other tolled assets).	Only a central value is presented for comparison and decision making.
Costs of the implementation and administering to toll is excluded. This include periodic restructuring the toll operating company.	The cost of the toll scenario is underestimated (not this is addressed separately in the Study).
Compliance is not considered in the appraisal.	Impact of cost and revenue of enforcement and Penalty Charge Notices (PCN) is not allowed for. The cost of the scheme is underestimated (note the PCN revenue cannot be included in an economic appraisal which assumes 100% compliance).

12.3.3 The model limitations are inherent in the modelling of the un-tolled Optimised Package. These are recognised limitations and form part of standard practice for use of the RTM. However, the introduction of the tolled scenario results in the model responses becoming increasingly uncertain. The net impact on scheme traffic forecasts and transport user benefits is not quantifiable. This introduces a level of uncertainty into the BCR and revenue calculations. For this reason, the analysis carries a lower level of assurance.

12.3.4 Despite these caveats, the model outputs provide an insight into the potential responses to the application of a toll and the implications for traffic volumes and network impacts (i.e. generalised costs required for appraisal). The reporting of the appraisal assumes that the benefits accrued to the operator (toll revenues) can be removed from benefits (PVB) and subtracted from the costs (PVC) to present the BCR, which is a standard practice with TUBA outputs. These costs include the changes in charges that occur on other tolled assts in the models (e.g. M6 Toll), but these effects are considered marginal.

12.4 ASSURANCE OF THE MODELLING AND APPRAISAL

12.4.1 The tolling sensitivity tests have not been undertaken as part of the main scenario. Instead, they are designed to inform considerations for scheme affordability and to provide an indication of the level of toll revenue that could be generated as a contribution towards the costs of the scheme.

12.4.2 As a result, the tests are only reported in the SOBC as a sensitivity test and should not be used for other purposes without revisiting the analysis. The level of assurance required is therefore lower than for the main scenario forming the core of the SOBC.

12.5 MODELLING OUTPUTS

12.5.1 The traffic volumes on the tunnel section of the scheme (or A628 in the Do-Minimum) are provided in **Table 12-2** below (it is noted that the figures are rounded to 000s).

Table 12-2 Forecast 2-Way AADT Flows (2041)

Do Minimum	Optimised Package	Toll Sensitivity 1	Toll Sensitivity 2
23,000	80,000	40,000	60,000

12.5.2 As shown in **Table 12-2**, with the higher toll charges (Test 1), the traffic flow along the tunnel section of the scheme is about half the level compared to without any toll (Optimised Package). The implementation of the toll results in reduction in traffic on the scheme and an increase in traffic on parallel routes including the M62 and A57. It has a regional impact with longer distance traffic rerouting from the scheme corridor including the M1 and A1(M) to the M62 towards the North-East as can be seen in **Figure 12-1**.

12.5.3 With the lower level of toll charges (Test 2), traffic across the tunnel section of the scheme is roughly 75% of that with the un-tolled scenario. The impacts in the scheme corridor are similar to the higher toll with traffic rerouting on the M62 and A57. However, at the regional level, the impact is less pronounced as can be seen in **Figure 12-2**.

12.5.4 **Figure 12-3** shows the change in traffic flows between the two toll scenarios. This highlights the difference in terms of the regional impact, with the green bands showing where the lower toll would result in an increase in traffic on the tunnel section and blue bands showing a slight reduction in traffic on the M62 and M1.

Figure 12-1 AADT Difference (All Vehicles) - Toll Test 1 vs. without Toll (2041)

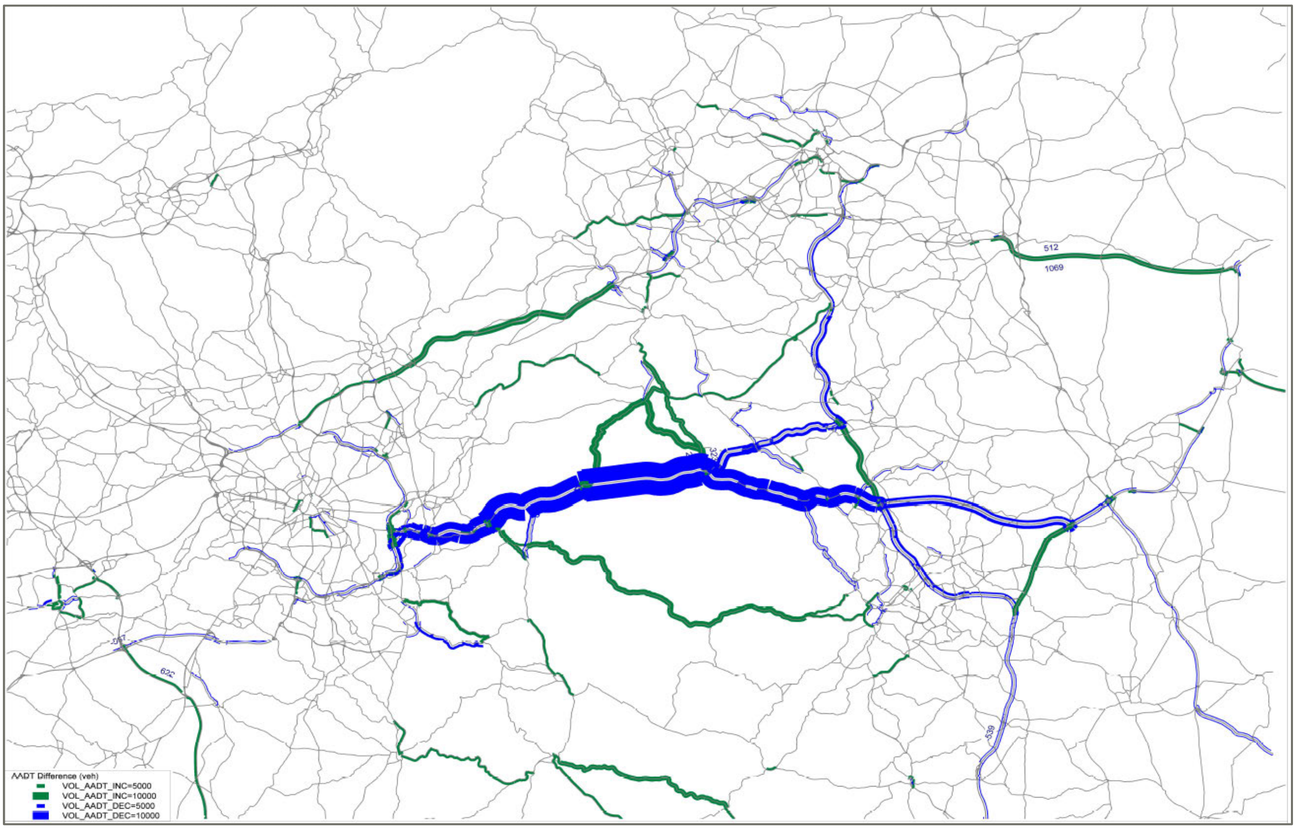


Figure 12-2 AADT Difference (All Vehicles) – Toll Test 2 vs. without Toll (2041)

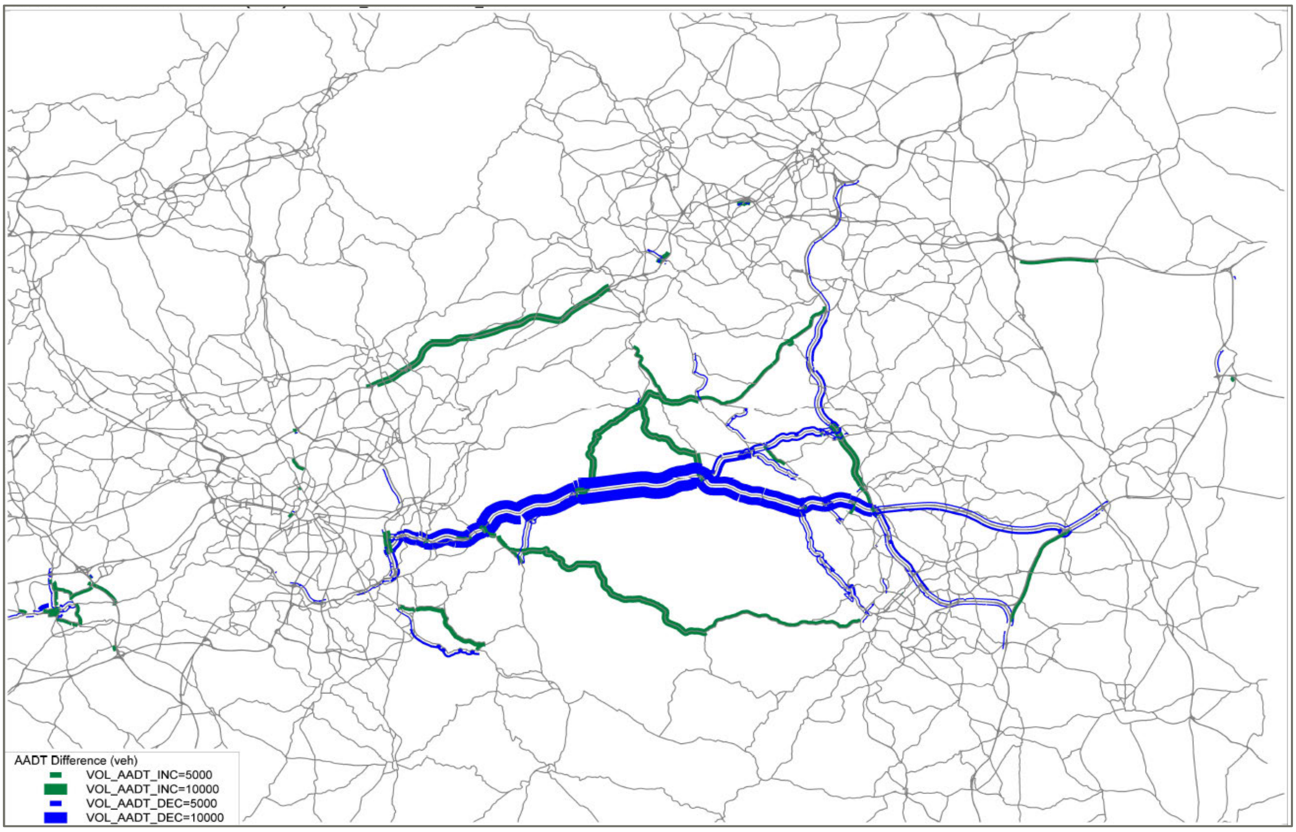
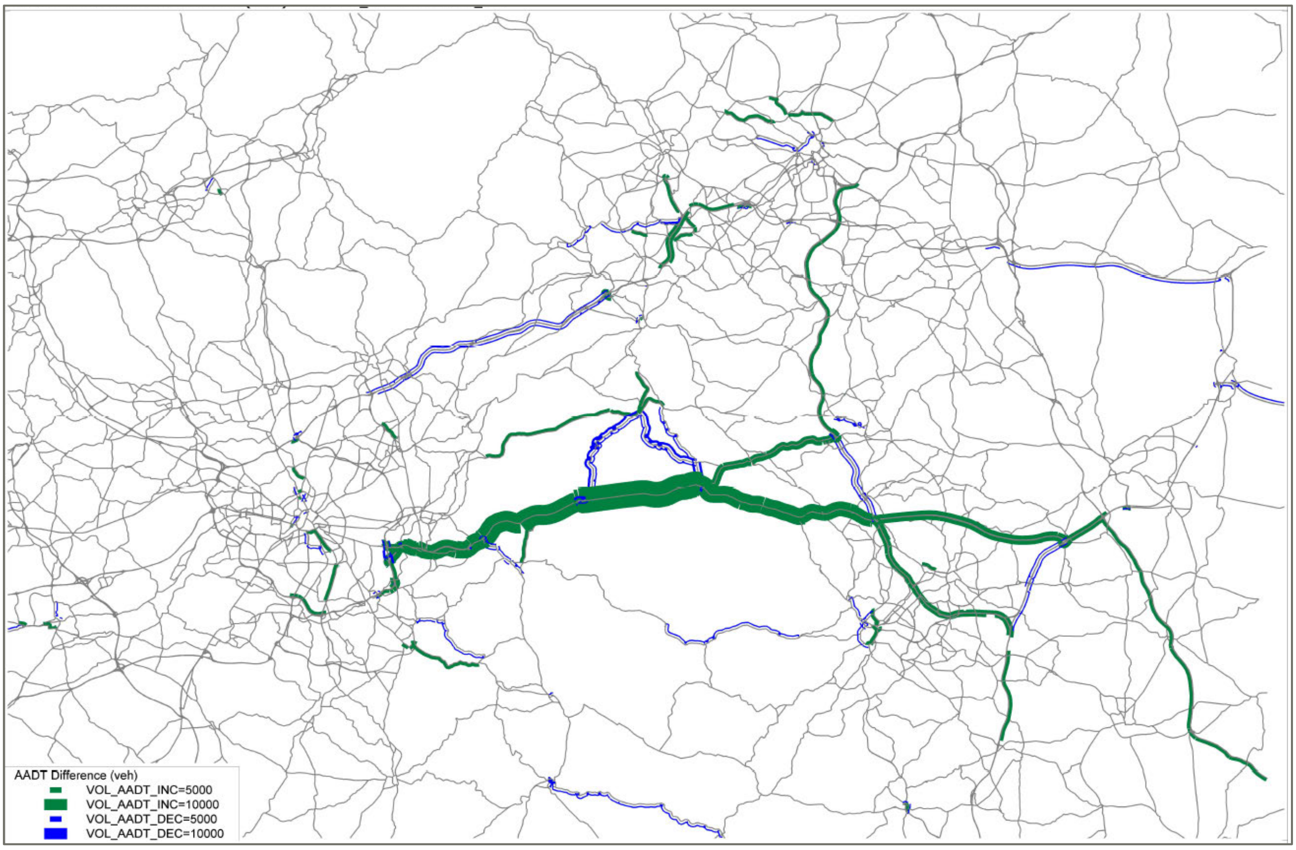


Figure 12-3 AADT Difference (All Vehicles) – Toll Test 2 vs. Toll Test 1 (2041)



12.5.5 **Figures 12-4** to **12-7** below present impacts of toll on the traffic volume travelling on the network for the Optimised Package, in terms of AADT difference at individual user class levels between the Toll Test 1 and the Un-tolled scenario. Similar patterns are also seen with the Toll Test 2 vs. the un-tolled scenario.

12.5.6 As can be seen the major impacts in terms of traffic flow changes are associated with Business trips and Other purpose. This is anticipated as long distance trips would be normally associated with "Business" and "Other" trips where they can take the advantage of significant time and distance savings through the tunnel to travel across the Pennines. The impact on freight is primarily rerouting effects from the A628 to the M62.

Figure 12-4 AADT Difference (Car Business) - Toll Test 1 vs. without Toll (2041)

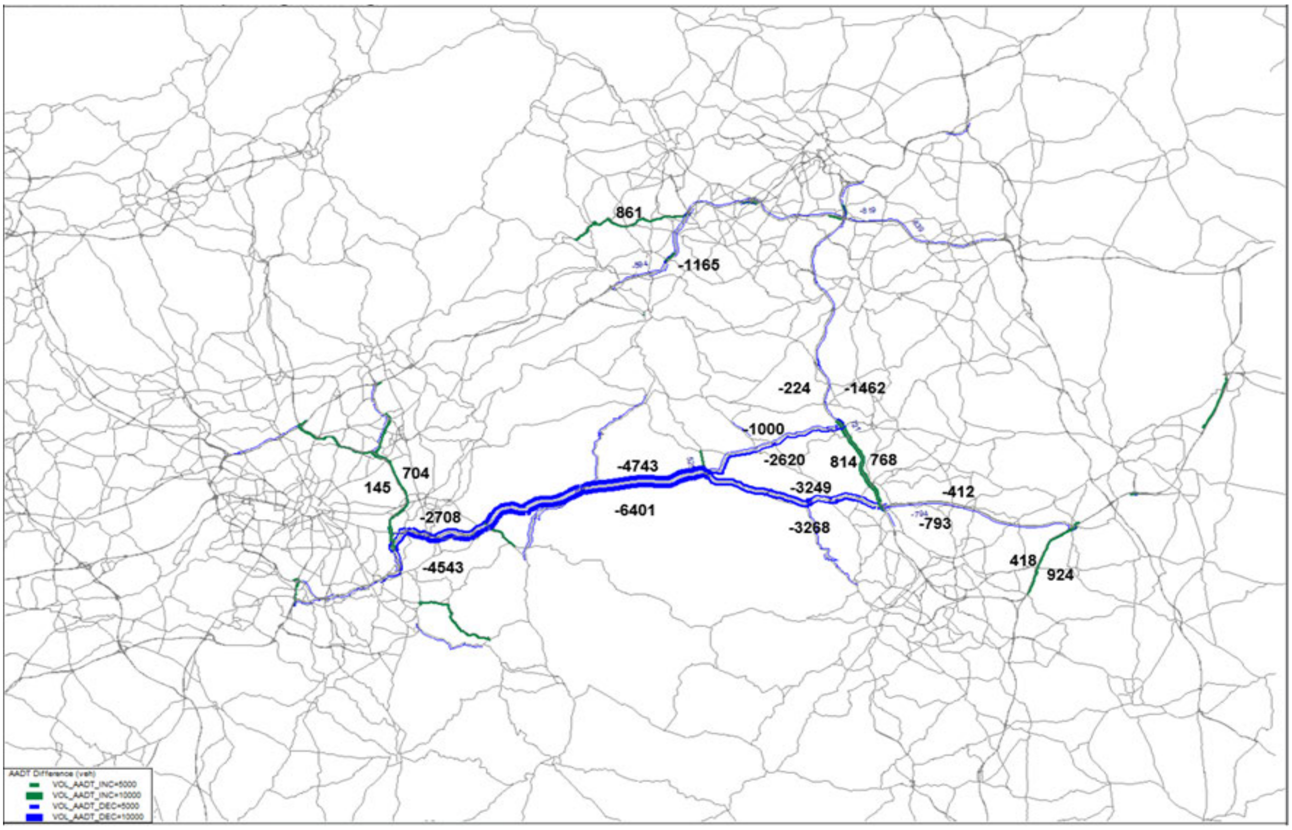


Figure 12-5 AADT Difference (Car Commute) - Toll Test 1 vs. without Toll (2041)

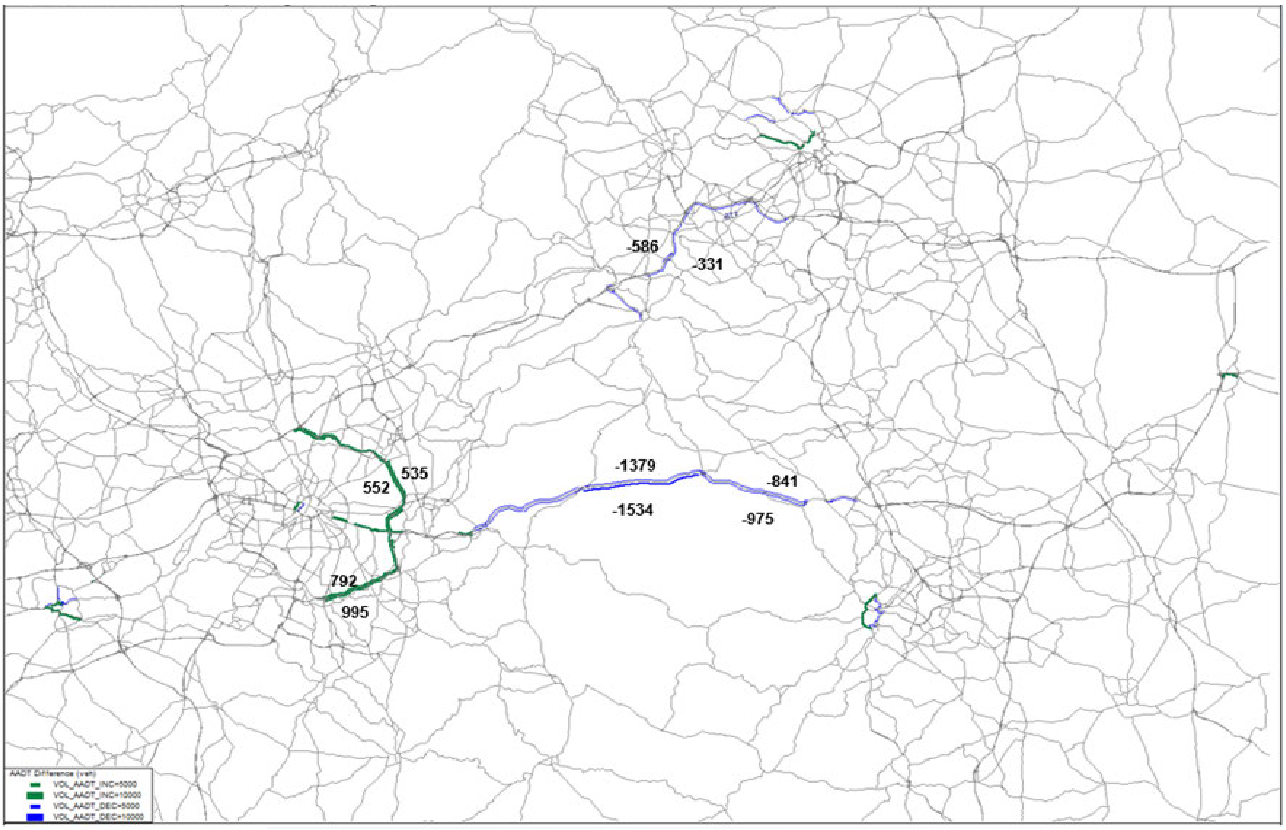


Figure 12-6 AADT Difference (Car Other) - Toll Test 1 vs. without Toll (2041)

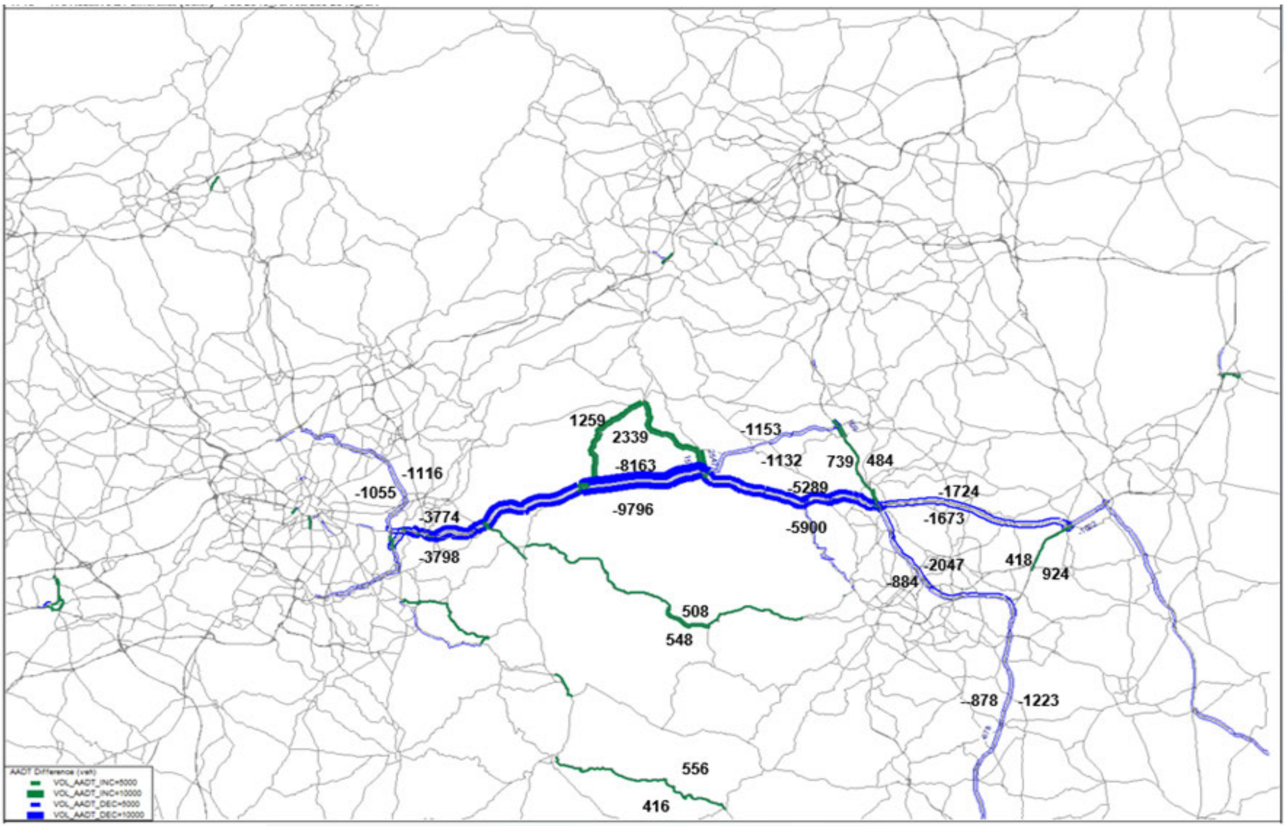
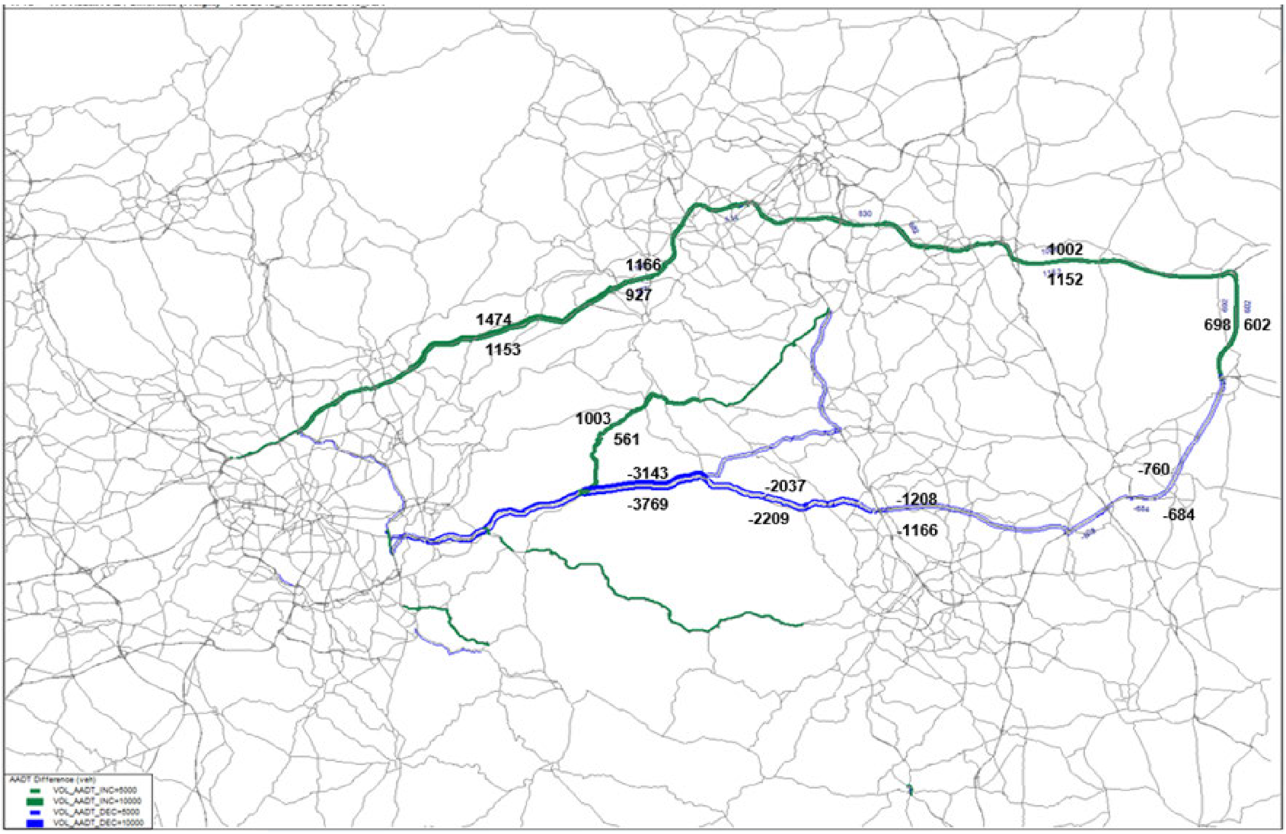


Figure 12-7 AADT Difference (Freight) – Toll Test 1 vs. without Toll (2041)



12.6 APPRAISAL OUTPUTS

12.6.1 The appraisal of the toll sensitivity has been simplified to include only the main components of the impacts, as below:

- Level 1 – TUBA user benefits;
- Level 2 – WITA wider impacts static clustering + reliability impacts (10% of TUBA time savings).

12.6.2 The accident saving benefits and delays during construction were excluded as these impacts are small and therefore deemed to have no material impact on the conclusions.

12.6.3 It is noted that no Greenhouse gas calculation using the TAG method was undertaken for the tolling sensitivity tests, for the purpose of comparison of the performance of each tolling scenario, the Greenhouse gas values produced from TUBA were therefore used for the Economic appraisal summary tables within this Chapter. Given the small difference of the Greenhouse gas benefits between the TUBA and the TAG method relative to the total scheme benefits, the impacts to the change in overall Levels 1 and 2 BCRs remain negligible.

12.6.4 The outputs from the TUBA and WITA assessments are calculated for a 60-year appraisal period for each of the toll and un-tolled scenarios against the Do-Minimum to produce a comparison in terms of performance economically of the scheme between the un-tolled and toll scenario. The appraisal of the Optimised Package with toll and un-tolled options against the Do-Minimum excluding the accident and construction impacts is provided in **Table 12-3** below.

Table 12-3 Summary of Economic Appraisal (£000s)

	Optimised Package	Toll Sensitivity 1	Toll Sensitivity 2
PVC			
CAPEX	3,629,572	3,629,572	3,629,572
OPEX	483,424	483,424	483,424
Toll revenues	0	-588,720	-426,477
Total PVC	**4,112,996**	**3,524,277**	**3,686,519**
Level 1 PVB			
Time savings	4,412,126	4,219,034	4,446,844
VOC	19,221	274,362	250,426
User charges	1,865	-545,586	-385,323
Greenhouse gas	-77,895	22,708	5,475
Indirect tax	138,049	-39,634	-9,701
Total PVB	**4,493,366**	**3,930,884**	**4,307,721**
Level 1 BCR	**1.09**	**1.12**	**1.17**
Level 2 PVB			
Reliability	441,213	421,903	444,684
WITA	2,684,178	1,770,354	2,182,202
Total PVB	**7,618,757**	**6,123,141**	**6,934,607**
Level 2 BCR	**1.85**	**1.74**	**1.88**

12.6.5 For Sensitivity test 1, the toll revenues calculated by TUBA are around £0.59bn at 2010 prices discounted to 2010. The user charges incurred are of a similar order and this is reflected in the reduction in benefits (PVB). The Level 1 BCR is marginally higher than for the Optimised Package. However, the WITA benefits are significantly lower and therefore the Level 2 BCR is lower compared with the un-tolled scenario.

12.6.6 For Sensitivity test 2, the toll revenues are around £0.42bn at 2010 prices discounted to 2010 (the user charges are of a similar magnitude). The user benefits (excluding the impact of charges) are higher compared with the un-tolled scenario. The net impact is a small further improvement in the Level 1 BCR. The WITA benefits are lower compared with the un-tolled scenario, however, the Level 2 BCR is still marginally better.

12.6.7 Part of the reduction in WITA benefits can be attributed to the increase in generalised costs created between origins and destinations by the addition of the toll. For example, if the value of time of a user is £10/hour, the £5 toll will equate to 30 minutes being offset from the journey time savings created by the Optimised Package. This results in a large reduction in WITA benefits for Sensitivity Test 2 and a proportionate reduction, i.e. about twice the value, for Sensitivity Test 1.

12.6.8 The cost for the tolling sensitivity tests excludes the capital and operational costs of implementing and operating toll collection. This has been taken into account separately as part of the DfT's work in developing its paper.

12.7 ESTIMATE OF REVENUES FROM TOLLS

12.7.1 The main purpose of this analysis was to understand the potential revenues that could be generated from tolling, as well as the impact of tolling on the Value for Money of the Optimised Package. The TUBA assessment of toll revenue excludes any increase in toll from the toll values set in 2041. Without the ability to index link these values, the toll charge used by TUBA is diminishing in real terms. This in turn leads to a significant under-estimate in both the likely revenue generated from the tolls and the user charges incurred by users paying the toll. An adjustment to this underestimate would change the gearing of the BCR relationship by reducing the benefits and the costs in the calculation.

12.7.2 Given the limitations of the TUBA analysis to estimate the index-linked toll revenue, an external calculation of the likely toll revenue from the two toll tests has been undertaken, which is based on recalculating both the operator revenue (tolls collected) to offset costs in the BCR calculation and user charges (tolls paid by users) to reduce the benefits in the BCR.

12.7.3 Since there is no recognised method for selecting the values for the indexation of the toll values, the two alternative methods have been undertaken to test the sensitivity of the BCR to represent alternative assumptions for the indexation of the toll values beyond 2041:

- General inflation at 2.5% per annum; and
- GDP inflation based on the TAG DataBook May 2019.

12.7.4 **Table 12-4** below provides a summary of the estimates of toll revenues using the two alternative methods with a benchmark against the outputs directly from TUBA.

Table 12-4 Toll Revenue Estimates with Alternative Methods

Method	Toll Sensitivity 1			Toll Sensitivity 2		
	TUBA	Inflation	GDP	TUBA	Inflation	GDP
PVC						
CAPEX	3,629,572	3,629,572	3,629,572	3,629,572	3,629,572	3,629,572
OPEX	483,424	483,424	483,424	483,424	483,424	483,424
Toll revenues	-588,720	-2,080,591	-2,226,964	-426,477	-1,503,058	-1,608,800
Total PVC	**3,524,277**	**2,032,405**	**1,886,032**	**3,686,519**	**2,609,939**	**2,504,196**
Level 1 PVB						
Time savings	4,219,034	4,219,034	4,219,034	4,446,844	4,446,844	4,446,844
VOC	274,362	274,362	274,362	250,426	250,426	250,426
User charges	-545,586	-1,928,153	-2,063,802	-385,323	-1,358,016	-1,453,555
Greenhouse gas	22,708	22,708	22,708	5,475	5,475	5,475
Indirect tax	-39,634	-39,634	-39,634	-9,701	-9,701	-9,701
Total PVB	**3,930,884**	**2,548,317**	**2,412,668**	**4,307,721**	**3,335,028**	**3,239,489**
Level 1 BCR	**1.12**	**1.25**	**1.28**	**1.17**	**1.28**	**1.29**
Level 2 PVB						
Reliability	421,903	421,903	421,903	444,684	444,684	444,684
WITA	1,770,354	1,770,354	1,770,354	2,182,202	2,182,202	2,182,202
Total PVB	**6,123,141**	**4,740,574**	**4,604,925**	**6,934,607**	**5,961,914**	**5,866,375**
Level 2 BCR	**1.74**	**2.33**	**2.44**	**1.88**	**2.28**	**2.34**

12.7.5 The sensitivity test shows that modelling the revenue stream by projecting an increase in toll values beyond 2041 could increase the BCR from 1.74 to 2.44 in Toll Sensitivity 1 and from 1.88 to 2.34 in Toll Sensitivity 2. However, this result must be considered together with the uncertainty related to this analysis, in particular the core analysis using TUBA outputs directly is consistent with industry practice for reporting tolling and charging analysis (e.g. for the ongoing LTC analysis). These tests are merely indicative and of low assurance and it is therefore not appropriate or proportionate to place reliance on the outputs without further work.

12.8 SUMMARY

12.8.1 Based on the TUBA analysis, the tolling sensitivity tests show that the Level 1 and Level 2 BCR can be maintained under a scenario where the Optimised Package is tolled. This improves the affordability of the scheme but the toll revenue under any scenario will not cover the scheme costs. The tests indicate that high volumes of additional traffic across the Pennines can be achieved under a tolled scenario which is set at the lower toll values tested (toll sensitivity 2).

12.8.2 The analysis has limitations that need to be caveated in presenting the results. The main caveats relating to the modelling are the lack of income segmentation in the model and the fixed demand for LGVs and HGVs.

12.8.3 The analysis is also limited by the constraints in TUBA of dealing with toll revenues. The exogenous adjustment to account for these would introduce a level of uncertainty that would lower the assurance of the output to an unacceptable level. This work has therefore been presented as a sensitivity analysis.

12.8.4 The externally calculated estimate of toll revenues indicate that a higher VfM category could be achieved if a fuller analysis is undertaken to project increases in toll values beyond 2041.

12.8.5 These toll sensitivity tests have been developed to look at a potential upside relating to revenue streams due to a known limitation in the appraisal tools. There are likely to be other limitations in the tools but as all schemes are compared on an equal basis there is an understanding that these effects are assumed neutral in the decision-making process. Therefore, this particular upside should be considered within this context, noting that other limitations could result in either upsides or downsides if they were also considered.

13 FINAL ECONOMIC APPRAISAL

13.1 OVERVIEW

13.1.1 Following agreement with HE and DfT, a more accurate method that calculates Greenhouse gas emission using a "link-based" approach with traffic volume and speed were extracted from the modelling outputs as opposed to the TUBA method. The link-based approach calculates fuel consumption using traffic volume and speeds on individual links together with the emission data from the TAG DataBook that is in line with the TAG A3 guidance for the Do-Minimum and each of the sub-packages. The emission results were then input into the TAG "Environmental impacts worksheets" to quantify the net present values of CO2 emission over the lifecycle of the scheme. As a result, the economic appraisal for each of the sub-packages and the Optimised package is required to be updated. This chapter therebefore provides summaries of the economic appraisal for each of the sub-packages and the Optimised package with the revised Greenhouse gas benefits.

13.1.2 Within this Chapter, the incremental impacts of each sub-packages are also provided as per agreed with HE and DfT.

13.2 FINAL APPRAISAL SUMMARY

13.2.1 **Table 13-1** below provides summary of the Level 1 and Level 2 BCRs with the revised Greenhouse gas benefits calculated from the "link-based" method.

Figure 13-1 Final Appraisal Summary

Packages	Package 1 (2034)	Package 2 (2037)	Package 3 (2041)	Optimised Package (2041)
Present Value of Costs				
CAPEX	586,274	901,963	1,498,708	3,629,572
OPEX	70,239	99,384	163,615	483,424
Total	**656,512**	**1,001,347**	**1,662,323**	**4,112,996**
Present Value of Benefit – Level 1				
Commuting	243,418	402,450	442,181	563,836
Other	478,495	505,726	586,374	709,463
Business (Car)	422,556	508,102	974,830	2,207,524
Business (Freight)	187,600	255,177	538,882	952,390
Operator Revenues	-561	-2,550	-3,028	-3,376
Greenhouse Gas	43,401	20,860	-67,590	-255,444
Indirect Tax Revenues	-121,237	-92,313	-42,297	138,049
Accident				119,856
Construction				-27,340
Total Level 1 PVB	**1,253,672**	**1,597,452**	**2,429,352**	**4,404,957**
Level 1 BCR	**1.91**	**1.59**	**1.46**	**1.07**
Present Value of Benefit – Level 2				
Reliability Benefit	110,358	148,651	236,791	441,213

Packages	Package 1 (2034)	Package 2 (2037)	Package 3 (2041)	Optimised Package (2041)
Agglomeration impacts	551,236	794,762	1,008,603	2,445,111
Change in imp. comp. market	42,256	50,810	97,483	220,752
Labour supply impacts	6,019	10,258	11,677	18,315
Total Level 2 PVB	**1,963,541**	**2,601,934**	**3,783,906**	**7,530,348**
Adjusted BCR	**2.99**	**2.59**	**2.28**	**1.83**

13.2.2 It can be seen that in comparison to **Table 10-3** and **Table 11-10** for the sub-packages and Optimised Package respectively, the overall Levels 1 and 2 benefits remain similar with no switching values in the Level 2 benefits.

13.3 INCREMENTAL IMPACTS OF SUB-PACKAGES

13.3.1 The final appraisal summary provided in Table 13-1 was produced by comparing each of the sub-packages and the Optimised package to the Do-Minimum scenario. it was used to provide understanding of what each sub-package could achieve as an initial phase should they are to be selected against the Do-Minimum.

13.3.2 As per requested by HE, the incremental impacts of the sub-packages are provided in this section in order to provide understanding how benefits would have changed if each sub-package was to be delivered in sequence. **Table 13-2** below provides the incremental impacts of the sub-packages.

Figure 13-2 Incremental Impacts of Sub-Packages (£000s)

Packages	Package 1 vs. Do-Minimum	Package 2 vs. Package 1	Package 3 vs. Package 2	Optimised vs. Package 3
Incremental PVC	656,512	347,219	658,592	2,450,673
Incremental PVB (Level 1)	1,253,672	343,780	831,900	1,883,089
Incremental Initial BCR	**1.91**	**0.99**	**1.26**	**0.77**
Incremental PVB (Level 2)	709,869	294,612	350,073	1,770,836
Incremental PVB (Level 1+ 2)	1,963,541	638,392	1,181,973	3,653,925
Incremental Adjusted BCR	**2.99**	**1.84**	**1.80**	**1.49**

14 SUMMARY AND CONCLUSIONS

14.1 OVERVIEW

14.1.1 Under the view that Manchester and Sheffield are currently the two worst connected cities in the North, the Highways England Delivery Plan 2015-2020 is therefore committed to examine Trans-Pennine routes and subsequently develop solutions that could improve connectivity between Manchester and Sheffield.

14.1.2 A number of studies have been undertaken with various options for Trans-Pennine improvements to help inform decision making, with the conclusion to date indicating that the economic case is currently weak. The two recent studies of the Trans-Pennine Tunnel and the Wider Transport Connectivity Assessment (WTCA) indicated a poor to low value for money.

14.1.3 The objectives of the proposed TPTS+, as stated in the Appraisal Specification Report, are to take the identified package from the WTCA project and undertake additional wider economic modelling works to enhance both the economic and strategic case. The package of interventions contains a shorter tunnel option coupled with number of interventions at either end of the tunnel (known as the test package). The interventions have been refined to form an Optimised Package.

14.1.4 Initially, the study was commissioned on the understanding that a suitable variant of the Highways England Trans-Pennine South Regional Transport Model (TPS RTM), referred to as vRTM, would be made available for modelling and appraisal purposes. However, the vRTM was not made available within the specified study programme, and as such, the TPS RTM Design Freeze (DF) 7 has been used with number of adjustments to the base year and forecast year models prior to carrying out modelling and appraisal for the TPTS+ study.

14.2 BASE YEAR MODEL REVIEW

14.2.1 The review of the TPS-RTM base year DF7 models revealed that whilst the TPS RTM model generally shows weaknesses on number of links crossing the Pennines, the level of error in the model relating to modelled flow and journey time are primarily focused on the Mottram area and the most significant flow differences are related to local traffic and not the through traffic that would potentially divert to the TPT scheme. The RIS1 scheme (i.e. Mottram bypass) that is included in the forecast network would improve journey times along these sections prior to the TPTS+ interventions and therefore the level of errors in the base year model is less relevant as through traffic bypasses this section of the network to travel across the Pennines. The flow and journey time validation on the M62 between Manchester and Leeds which carries a significant amount of traffic and the impacts of the TPTS+ would result in a significant reduction of traffic on the motorways. This is deemed acceptable according to WebTAG criteria and therefore would represent accurately the impacts of the TPTS+ on travel time savings. It is therefore considered that the base year model is deemed to be acceptable for the TPTS+ study at PCF Stage 0.

14.2.2 Following the review of the Base year model, a number of corrections have been made that improved traffic routeing and also flow validation on A1079/A166 east of York and A585, M55/M6 in the Preston area. Following discussion with Highways England, it was decided that the changes made to the TPS RTM models were to be included in the forecast models prior to the modelling and appraisal of the TPTS+ study.

14.3 FORECAST MODELS

FORECAST NETWORKS

14.3.1 As agreed with Highways England, the TPTS+ study includes Reference Case (or Do-Minimum) networks on which different options of interventions were to be built upon. Building on the 2015 Base Year network, number of Local Authority and Highways England RIS1 schemes were included to represent the Reference Case networks.

14.3.2 Three options of interventions (referred to as Test packages) were identified and tested using the Fixed demand assignment approach to help inform the 'Optimised Package' that was then used for the modelling and appraisal of the TPTS+ study.

14.3.3 The modelling and appraisal tasks undertaken on the test packages under the Fixed demand assignment approach determined the 'Optimised Package' to be taken forward for the Variable Demand process.

FORECAST DEMAND

14.3.4 To produce the modelling and appraisal of the TPTS+ interventions, the NTEM Core scenario demand was provided by RTM maintenance consultants with the revised NTEM 7.2 dataset for Car and PT and RTF 2018 database for freights.

14.3.5 In addition to the NTEM Core scenario, the two alternative growth scenarios: Low growth scenario that reflects DfT's reduced trip-rates trend scenario; and a TfN transformational scenario, reflecting TfN's aspiration to increase population and employment within Greater Manchester and Sheffield City Region areas whilst retaining balance at the UK level. The two alternative scenarios were used in addition to the NTEM Core scenario to understand the impacts in terms of performance and economic appraisal of the TPTS+ interventions.

VARIABLE DEMAND MODELLING

14.3.6 A Variable Demand Modelling process is required to produce forecast demand for the Do-Minimum and Do-Something for the TPTS+ study.

14.3.7 The Highways England VDM structure (HEIDI) developed for the RTM models was adopted for this study, with DIADEM software to be implemented for the Variable Demand, SATURN for the highway's costs and a set of fixed PT rail costs.

14.3.8 VDM runs were undertaken for NTEM Core and two alternative growth scenarios for the Do-Minimum, Trans-Pennine improvements only and the Optimised Package for each of the two modelled years 2031 and 2041.

URBAN DELAY FUNCTION

14.3.9 The Urban Delay Function was initially developed on behalf of TfN for the SDC studies and has been refined for the purpose of the TPTS+ study. The objectives of the Urban Delay Function were to address the issue with the fixed speed coding mechanism that was implemented in the RTM urban areas.

14.3.10 As agreed with Highways England, the Urban Delay Function was applied to the Post-VDM assignments to ensure minimal risk of repetitive works whilst offering additional information such as change in speed and user benefits as a result of the Urban Delay Function.

14.3.11 Modelling outputs from the 'without' and 'with' Urban Delay Function shows that a more plausible routeing was forecast with the urban delay function applied, particularly for trips routeing through city centres as opposed to on the SRN network. In addition, user benefits produced for the TPTS+ interventions show a 6%-11% increase with the Urban Delay Function applied. As agreed with Highways England, the forecast assignments with the Urban Delay Function applied was used to report the modelling and appraisal outputs of the TPTS+ interventions.

14.4 APPRAISALS – PREVIOUS ASSESSMENT

14.4.1 As part of the TPTS+ study, transport user benefits were calculated to provide an estimate of the performance of the interventions in terms of appraisal. In addition to the transport user benefits, delays during construction and accident impacts as a result of the interventions were also calculated to provide the Level 1 impacts of the scheme. It is noted that the modelling and appraisal undertaken during this assessment were based on the assumption of the scheme Opening year 2033.

14.4.2 Overall, the TPTS+ interventions produce low values for money in terms of Level 1 benefits, with the user benefits for the Optimised Package being **£4.9bn** with an initial BCR of **1.01**.

14.4.3 The Level 2 impacts of the TPTS+ interventions were also calculated which includes reliability benefits and wider impacts static clustering, which added in a further £0.45bn and £3.3bn respectively to the Level 1 benefits. With Level 2 benefits included, the total benefits are **£8.8bn** with the adjusted BCR of **1.80**, bringing it into the medium value for money category.

14.4.4 Level 1 and Level 2 benefits were also produced for the Low Growth and Transformational scenarios to help understand the impacts of different growth scenarios to the performance of the TPTS+ interventions. The modelling and appraisal outputs for the low and transformational scenario show only marginal change to the initial and adjusted BCR, with the adjusted BCR of **1.77** and **1.84** for the Low and Transformational scenario respectively.

14.4.5 It is noted that for the Low growth scenario, it was revealed that the freight demand was not correctly used (i.e. using an older version of the RTF) therefore the user benefits were overestimated by about £200m. The issue was discussed with Highways England at a TAG meeting and it was agreed that the re-run of the Low growth scenario was not required but instead to report the modelling and appraisal outputs in this report.

14.4.6 For the transformational growth scenario, on the other hand, the increase in user benefits were not anticipated given TfN's aspirations for the uplift in employment and population within the Greater Manchester and Sheffield City Region areas. Analysis of the modelling outputs shows that the transformational scenario is forecast to produce an increase in demand, however this is contained within either GM or SCR areas without any increase in traffic crossing the Pennines. As a result, additional delays were forecast to be located primarily within the localised network in the GM and SCR areas and as a consequence not likely to be benefited from the TPTS+ interventions.

14.5 SUB-PACKAGE ASSESSMENT

14.5.1 Following BICC in September 2019, there was an instruction to the TPTS+ team to consider the affordability of the scheme. Further works have been therefore undertaken to break down the Optimised Package into 10 individual schemes to allow three sub-packages to be configured that is based on the best performing schemes within the cost of each package. Modelling and appraisal of the three sub-packages, namely Packages 1, 2 and 3 that were derived from ten individual schemes, were undertaken to produce analysis of the performance of each individual Packages in terms of network operational and economic appraisal performance. Detail of the analysis and summary of the traffic volume and appraisal is provided in **Chapter 10**.

14.6 APPRAISALS – REVISED ASSESSMENTS

14.6.1 As the individual schemes being refined in terms of affordability and configuration, the Opening year and costs of the schemes have also been revised. **Chapter 11** provides an update to the benefits and thus BCRs for the Optimised Package with the revised costs and Opening year of 2041. This works leads to a revised initial and adjusted BCR for the Optimised Package Core scenario of **1.11** and **1.87** respectively. The revised BCRs are slightly higher than the previous assessment due to the slight reduction in the overall investment costs PVC relative to previous estimates.

14.7 TOLLING SENSITIVITY TESTS

14.7.1 Following requests by DfT in early 2020, two tolling sensitivity tests have been undertaken on the Optimised Package to provide an indication of impact on the operational and economic performance, and potential revenue of a tolled scenario for the Optimised Package. The methodology, assumptions and summary of the tolling sensitivity tests are provided in **Chapter 13** of this document.

14.7.2 Given the number of limitations with modelling and appraisal, the outcomes from the tests will not form part of the main SOBC document but will serve as a sensitivity test to help understand potential performance in terms of network operation and appraisal as well as revenues that could be generated towards contribution to the costs of the scheme.

15 APPENDICES

15.1 APPENDIX A – TECHNICAL NOTES

15.2 APPENDIX B – UNCERTAINTY LOG

15.3 APPENDIX C – SECTORAL ANALYSIS

15.4 APPENDIX D – APPRAISAL SUMMARY (PREVIOUS STUDY)

15.5 APPENDIX E – TEST PACKAGE ANALYSIS

15.6 APPENDIX F – APPRAISAL SUMMARY (REVISED OPENING YEAR)

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