TRANS-PENNINE TUNNEL STUDY PLUS

FIXED SPEED ADJUSTMENT FOR URBAN AREAS

OCTOBER 2018

Project:	1-551 Trans-Pennine Tunnel Study Plus
Subject:	Fixed Speed Adjustment for Urban Areas - Addendum
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1. INTRODUCTION

1.1.1 WSP was commisioned by Highways England (HE), Department for Transport (DfT), and Transport for the North (TfN) to carry out assessment of the Trans-Pennine Tunnel Study Plus (TPTS+). The assessment makes use of the Trans-Pennine South Regional Traffic Model (TPS RTM) models as the starting point to produce vaious forecasting scenarios to assess the feasibility of the proposed TPTS+ packages.

1.1.2 The primary objectives of the TPS RTM was to focus on the HE scheme interventions on the Strategic Road Network (SRN) and less forcus on the urban areas. As such, detailed simulation coding was primarily focused on and adjacent to HE's SRN where change in delays in response to flow changes were fully captured. In constrast to the SRN network, majority of the urban areas within the TPS RTM was not the priary focus of the RTM model development and therefore were coded in a form of reduced simulation with more aggregate zone system and fixed speed network coding.

1.1.3 WSP's work on the earlier stage of the Trans-Pennine Tunnel Study project identified the issue with the fixed speed networks in urban areas in the context of the TPS RTM model (i.e. not being able to capture fully the impacts to local traffic as a result of interventions), however, no solution was proposed due to the scope of the work.

1.1.4 The on going works on the TfN Strategic Development Corridor (SDC) studies proposed a method to deal with the fixed speed coding in urban areas by applying the 'fixed speed adjustment for urban areas' process which was been developed for the TfN SDC studies. The process was developed to primarily deal with increase in demand as a result of transformational growth as defined by TfN demand scenarios, therefore only produce reduction of fixed speed in the urban areas if the flow increase and therefore did not take into account the impacts of travel speed in an event of flow reduction.

1.1.5 For the purpose of the TPTS+ work, it was therefore agreed that the process of 'fixed speed adjustment for urban areas' would need to be refined to account for the impacts of reduction in traffic on the fixed speed network. This note, as an addendum to the original note '**TfN RTM Fixed Speed Network Update'** (issued to TfN in June 2018), therefore sets out the refinement and change to the process to be able to apply for the TPTS+ works. The note '**TfN RTM Fixed Speed Network Update'** is also provided as an Appendix within this note for reference purpose.

2. UPDATE TO THE URBAN SPEED-DECAY FUNCTION

2.1. Introduction

2.1.1 As stated in the previous chapter, the previous ‘fixed speed adjustment for urban areas’ (thereby namely ‘urban speed-decay function) process developed for the TfN SDC only produces reduction in speed as a result of flow increase in the context of the transformational growth scenarios as defined by the TfN, and therefore did not calculates increase in fixed speed as a result of flow reduction.

2.1.2 For the purpose of the TPTS+ work, it was identified that there would be no transformation growth scenario to be assesed, the previous urban speed-decay function as developed for the TfN SDC would therefore need to be refined to be able to deal with change in speed as a result of flow reduction in order to be used for the purpose of the TPTS+ studies.

2.1.3 Following discussion with HE, it was agreed that WSP would further refine the urban speed-decay function to take into account the reduction of traffic on the network in order to provide a full response in travel speed as a result of flow changes.

2.1.4 M60SM base year 2013 models that were used in the previous development of the urban speed-decay function have been used for the refinment purpose.

2.2. Update of the Urban Speed-Decay Function

2.2.1 The speed-decay function adopts the same curves as from the previous development, which is presented by the equation below:

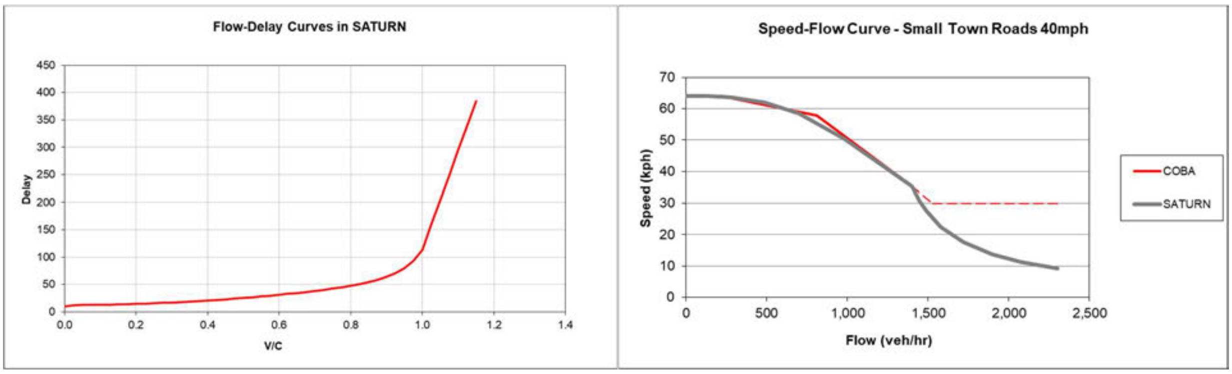
$$V_{new} = A + B\left(2 - \exp\left(\lambda\left(\frac{\mathrm{NF}}{\mathrm{RF}} - 1\right)\right)\right)$$

where:

- A, B and λ are parameters that could be calibrated from the ‘donor’ M60SM models in order to best fit the modelled data.
- NF is the new flow (forecast flow) and RF is the reference (or base) flow.
- $A + B = V_{RF}$ where V_{RF} is the speed at reference flow (base year speed).

2.2.2 The equation derived above was based on the principle of the COBA speed-flow curve and the flow-delay curve that is implemented within SATURN software. And example of the COBA speed-flow curve and the flow-delay curve that is implemented in SATURN is provided in Figure 1 below.

Figure 1 COBA Speed-Flow Curve and Flow-Delay Curve



2.2.3 The following steps describe changes that have been made to the updated urban speed-decay function:

- Step 1 : utilise the M60SM models with different growth in demand to derive the speed-flow relationship for both flow increase and reduction
- Step 2 : improvements made to the python script to:
  a Allow for the full response in speed as a result of flow changes; and
  b Change the process to write out adjusted speed in the card 11111 as opposed to writing out additional turn penalty in the card 44444 of the SATURN dat file.
- Step 3 : apply the updated function to the TPS RTM models with similar growth in demand to verify the fitness of the updated curves; and
- Step 4 : apply the updated function to the previous TPTS work to evaluate the impacts of the updated urban speed-decay function to journey time saving benefits.

2.2.4 The following sections describe each step in more detail.

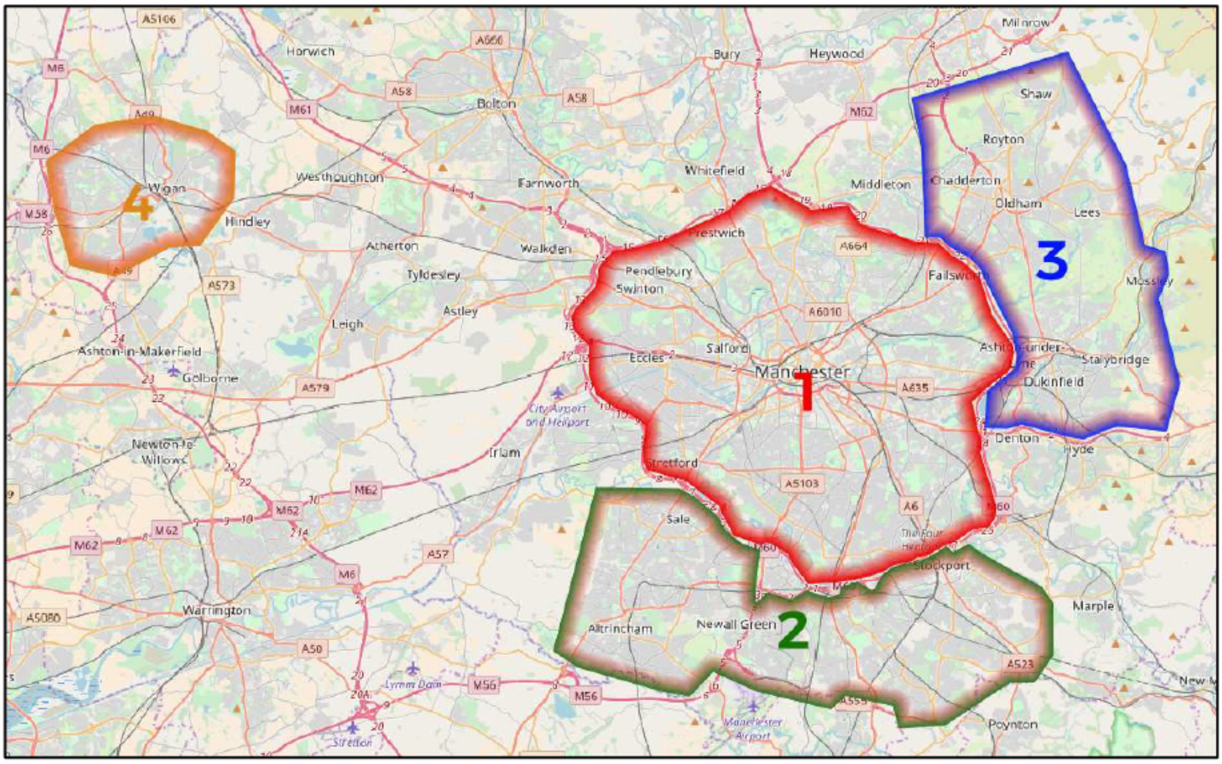
2.2.5 Update to the Speed-Decay Curves

2.2.6 To update the speed-decay curve to account for the change in speed as a result of flow reudction, the same M60SM 2013 base year model that was used to derive the original speed-decay curve has been used. The trip matrix was multiplied by factors ranging from 0.5 to 2.0 with 0.1 increment in demand growth in order to represent change in demand.

2.2.7 The 4 areas that was used in the derivation of the original curves has been selected to represent 4 distinct characteristics, as below:

- (1) The core area, reflecting major urban area with moderate or high congestion;
- (2) A higher income area with expected significant growth in demand in future;
- (3) A lower income area with potential for growth; and
- (4) A free standing town distinct from the continuous conurbation.

Figure 2 Four Distinct Areas Used for Speed Decay Curves



2.2.8 For all the links that fall within each of the 4 selected areas, the following selection criteria were applied:

- $V/C > 0.1$;
- Non zero flow;
- Free flow speed not equal to congested speed; and
- Free flow speed below 50 kph

2.2.9 The first three criteria were chosen in order to make sure that links for which the speed flow curve was calculated had traffic on and had delays of some description. The 50kmph limit was chosen to exclude roads that have a speed limit greater than 30 mph. Only links that met the criteria across all the growth assignments were used in the calculation. Weighted averages of the congested speed across all the links and the actual flow were found using the following equations. For speed:

$$V_{ave} = \frac{\sum_i^N F_i d_i}{\sum_j^N F_j(\frac{d_j}{V_j})}$$

2.2.10 Where V_i is the congested speed, F_i is the actual flow, and d_i is the distance of link i^{th}. Similarly the weighted average for the flow across all links is calculated below:

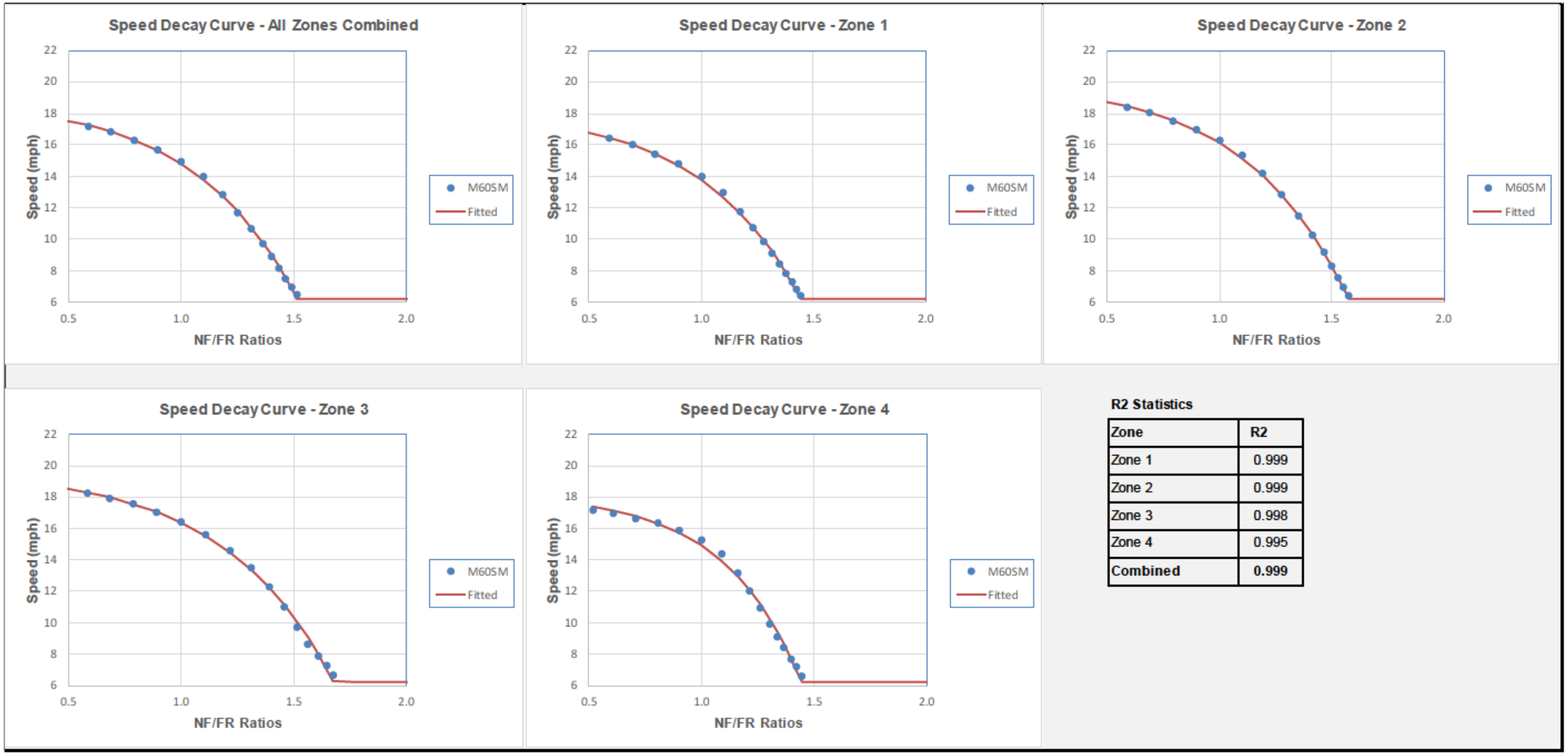
$$F_{ave} = \frac{\sum_j^N F_i d_i}{\sum_j^N d_j}$$

2.2.11 The equation was fitted using average speed and flows calculated for each area by time period and for each demand growth point. Table 1 below summarises the parameters for each area on its own and also for the 4 areas combined. Figures 3 to 5 show the speed decay shapes for each of the three modelled periods (AM, IP and PM) that was produced by applying different demand growth to represent increase in traffic flow for the aggregated 4 areas overall.

Table 1 Fitted Curve Coefficients

Zone	AM Peak			Inter-Peak			PM Peak		
	A	B	lambda	A	B	lambda	A	B	lambda
Combined	17.09	6.72	2.174	23.82	5.12	1.971	16.18	7.85	2.143
Zone 1	14.99	7.21	2.244	23.08	4.82	2.147	14.80	7.74	2.457
Zone 2	19.76	6.24	2.216	25.62	5.41	1.859	20.43	6.49	2.023
Zone 3	20.89	5.48	2.043	25.19	5.32	1.635	20.75	5.90	2.167
Zone 4	18.90	5.17	2.974	23.31	3.97	2.758	12.75	9.45	2.441

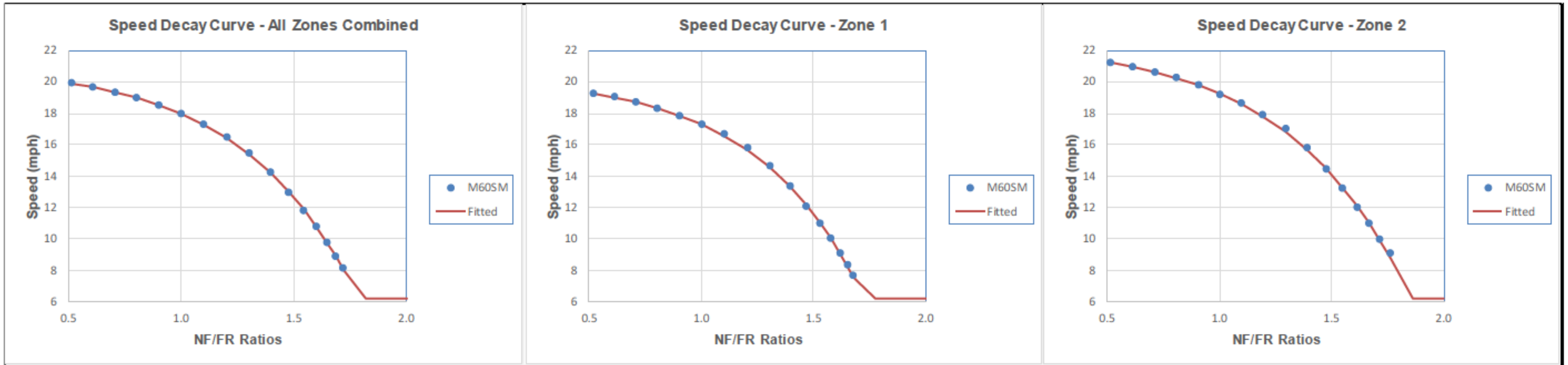
Figure 3 Fitted Curves Derived from M60SM Model – AM Peak

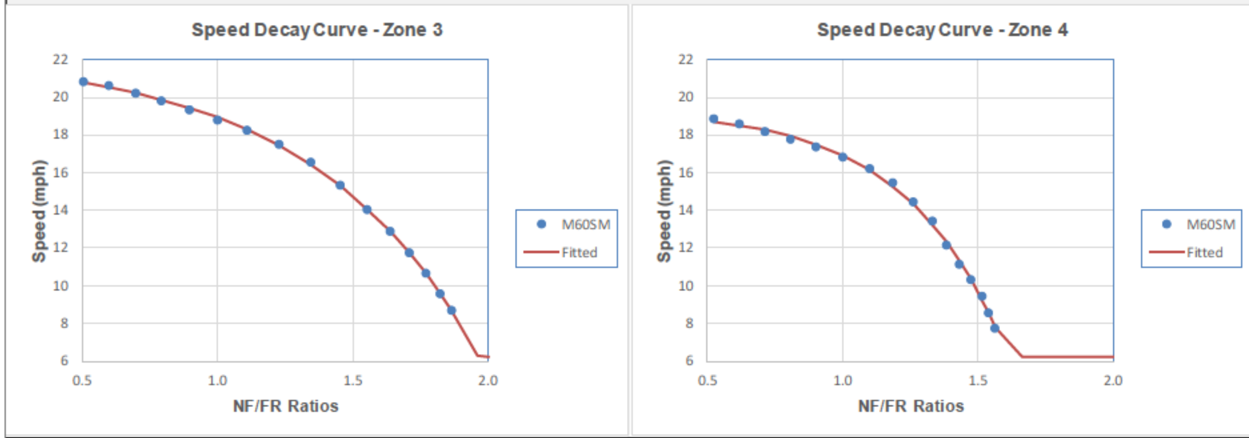


R2 Statistics

Zone	R2
Zone 1	0.999
Zone 2	0.999
Zone 3	0.998
Zone 4	0.995
Combined	**0.999**

Figure 4 Fitted Curves Derived from M60SM Model – Inter-Peak

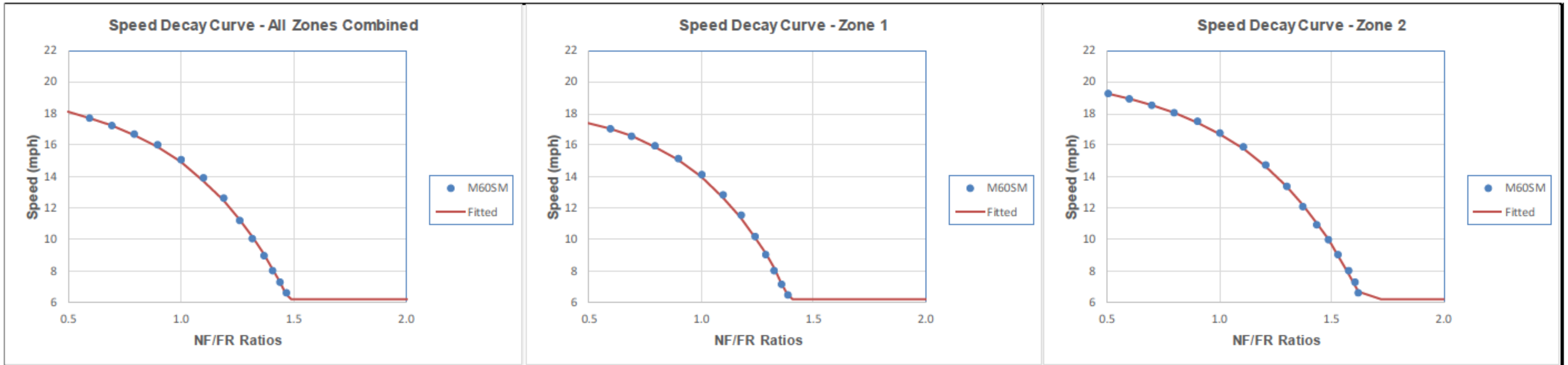


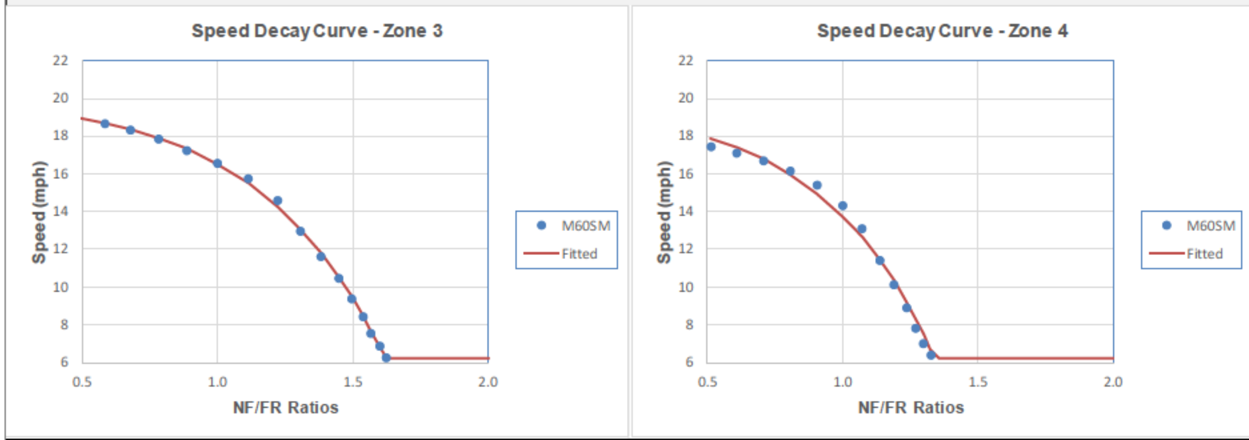


R2 Statistics

Zone	R2
Zone 1	1.000
Zone 2	0.999
Zone 3	1.000
Zone 4	0.999
Combined	**1.000**

Figure 5 Fitted Curves Derived from M60SM Model – PM Peak





R2 Statistics

Zone	R2
Zone 1	0.999
Zone 2	1.000
Zone 3	0.999
Zone 4	0.993
Combined	**0.999**

2.2.12 It can be seen that the derived flow-delay curves were able to match very well the modelled delays produced from the M60SM base year models for different growth across all the three time periods and at each individual area levels. It is therefore concluded that the derived speed decay curves can be used for Step 2 as describe below.

2.3. Improvements to Python Scripts

2.3.1 As stated in previous section, the python script was required to be updated to allow for number of changes below:

- Updated speed-decay curves to represent the full responses to travel speed as a result of both flow increase and decrease;
- Change of the mechanisim to write out fixed speed adjustment in a form of free-flow speed in the card 11111 as opposed to writting out as turn penalty in the card 44444 in the SATURN dat file (i.e. SATURN does not allow negative turn penalty in the card 44444, resulted by increase in speed if flow reduces); and
- Other improvements to the python scripts (e.g. read in $include files to SATURN network, function to deal with network structure changes)

2.3.2 The improved python script was then used for the Step 3 below.

2.4. Verification of the Updated Curves on TPS RTM Model

2.4.1 As the speed decay curves were calibrated from the M60SM Base year models for each of the zones defined, it was necessary to carry out tests on the TPS RTM base year models to:

- Verify that the application of the speed-decay curves that was derived from the M60SM model can represent similar change in speed compared to the M60SM model as a result of the flow changes; and
- Assess whether an issue with traffic routeing through city centre as previously observed in the original TPS model has now been improved.

2.4.2 The updated base year 2015 TPS RTM Design Freeze 7 (DF7) which was issued to WSP for the purpose of the TPTS+ was used as the starting point and assignments were then carried out on demand matrices with similar growth. The process was carried out in the python script, with steps as below:

- Initial assignments were carried out on the TPS RTM base year models with -50%, -40%, -20%, 20%, 40%, 60% and 75% growth in demand matrices to represent change in flows on the network (it is noted that tests carried out with higher growth in demand on the TPS RTM models crashed therefore it was decided to stop at 75% growth in demand);
- The python script was then employed to :
  a. extract flows from the initial assignments, compare to the base year link flows for each of the 4 areas;
  b. calculate speed decay using the fitted curve for each area, then calculate delta change to the free-flow speed for individual links within each area; and
  c. adjust free-flow speed to the simulation network coding (card 11111) and re-run the assignments with speed adjustment applied;
- Extract data from the final assignments, calculate overall change in speed and compare against the change in speed as produced from M60SM models.

Refinement of the Speed Decay Curves' Parameters

2.4.3 During the realism test process, number of refinement was made to the original speed decay curve, preventing excessive increase in delays due to a) low traffic volume; and b) significant increase in forecast flows compared to the base year flow. The Ratios of NF/RF were refined by the equation below to take into account individual link flows against the area-based average flows.

- $\left(\frac{NF}{RF}\right)' = 1 + \left(\frac{NF}{RF} - 1\right)\frac{LF}{AF}$

Where:

- LF is the base year flow on a particular link; and
- AF is the base year average flow of an area that link belongs to

2.4.4 A range of value of $\frac{NF\prime}{RF}$ was set between 0.5 and 2.5 to allow for differential change in demand at individual link level and also to prevent excessive delays being introduced to the system following analysis of the speed and demand changes resulted from the M60SM model tests.

2.4.5 The adjusted free-flow speed were then calculated using the following formula:

- $V = V_{ff} - 0.5 * (V_{ref} - V_{SDC})$

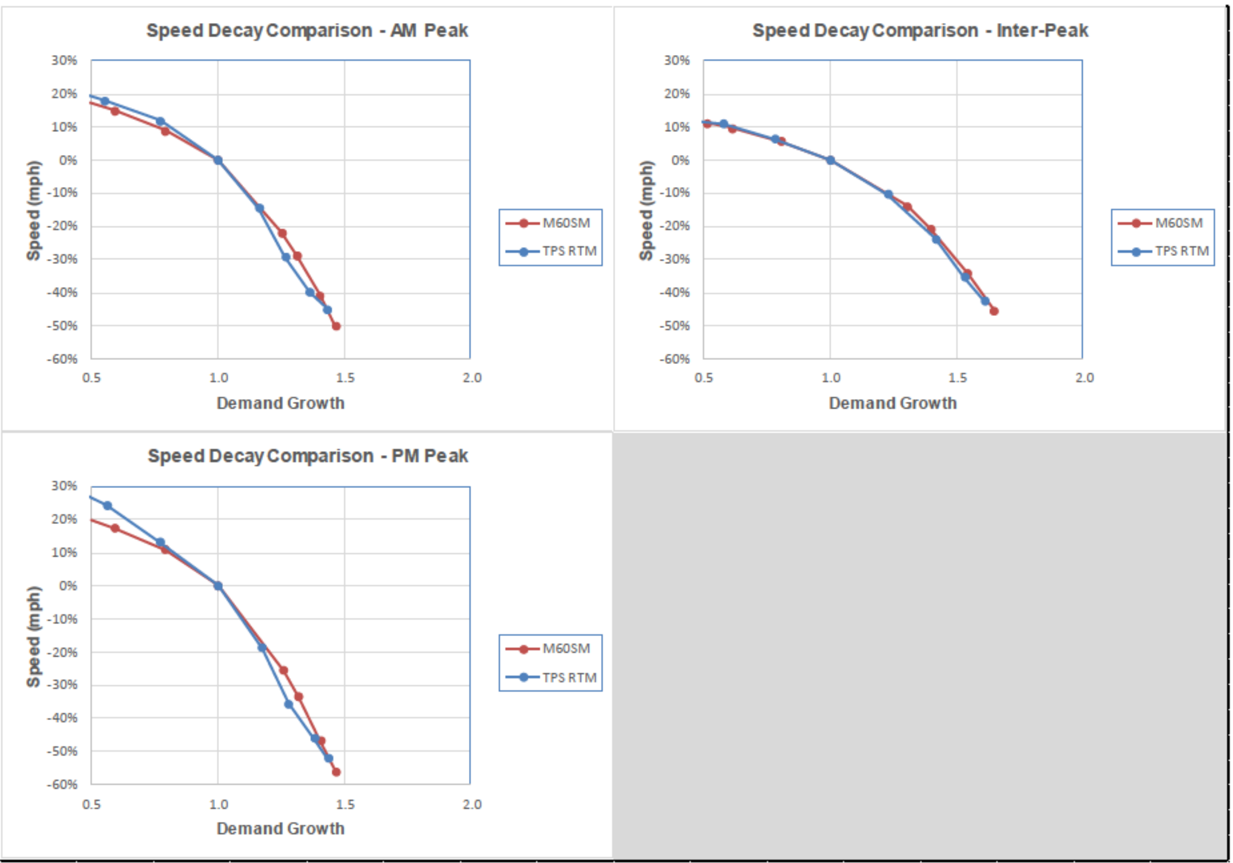
Where:

- V_{ff} is the free flow speed from the original model,
- V_{ref} is the reference speed from the speed flow curve calculated when $\frac{NF}{RF} = 1$ and
- V_{SDC} is the value calculated from the speed-decay curves. A minimum speed value of 10kph was used in order to prevent very low traffic speeds from occurring.

2.4.6 The 'half of the delta change' method in the formula above was adopted as a simplified mechanism to account for responses in rerouteing effects of traffic travelling on the network when the fixed speed adjustment has been applied.

2.4.7 Figure 6 below shows the comparison in terms of speed reduction between the M60SM model and the TPS RTM Model, in response to similar demand growth.

Figure 6 Speed Decay Comparison M60SM vs. TPS RTM



2.4.8 The TPS RTM models show similar reduction in speed compared to the M60SM in response to the similar demand growth. It is however noted that the TPS RTM models show slightly larger change in speed as demand changes for the AM and PM peak periods. It is anticipated as:

- The M60SM base year model was 2013 whereas the TPS RTM base year was 2015, i.e. lower demand compared to the TPS RTM models. Therefore with the same percentage change in demand would result in larger change in absolute trips, thus resulted in slightly larger change in speed in the TPS RTM compared to the M60SM model outputs; and
- Network coverage within the M60SM is denser compared to the TPS. This gives a higher number of route choices in the M60SM compared to TPS in order to avoid congestion.

2.4.9 The good fit of the speed decay curves produced for the TPS RTM models against the M60SM models show that the urban speed-decay function was satisfactorily verified and therefore recommended to be used for the next step, i.e. applying the function to test the impacts of travel time savings in urban areas to the previous TPTS works.

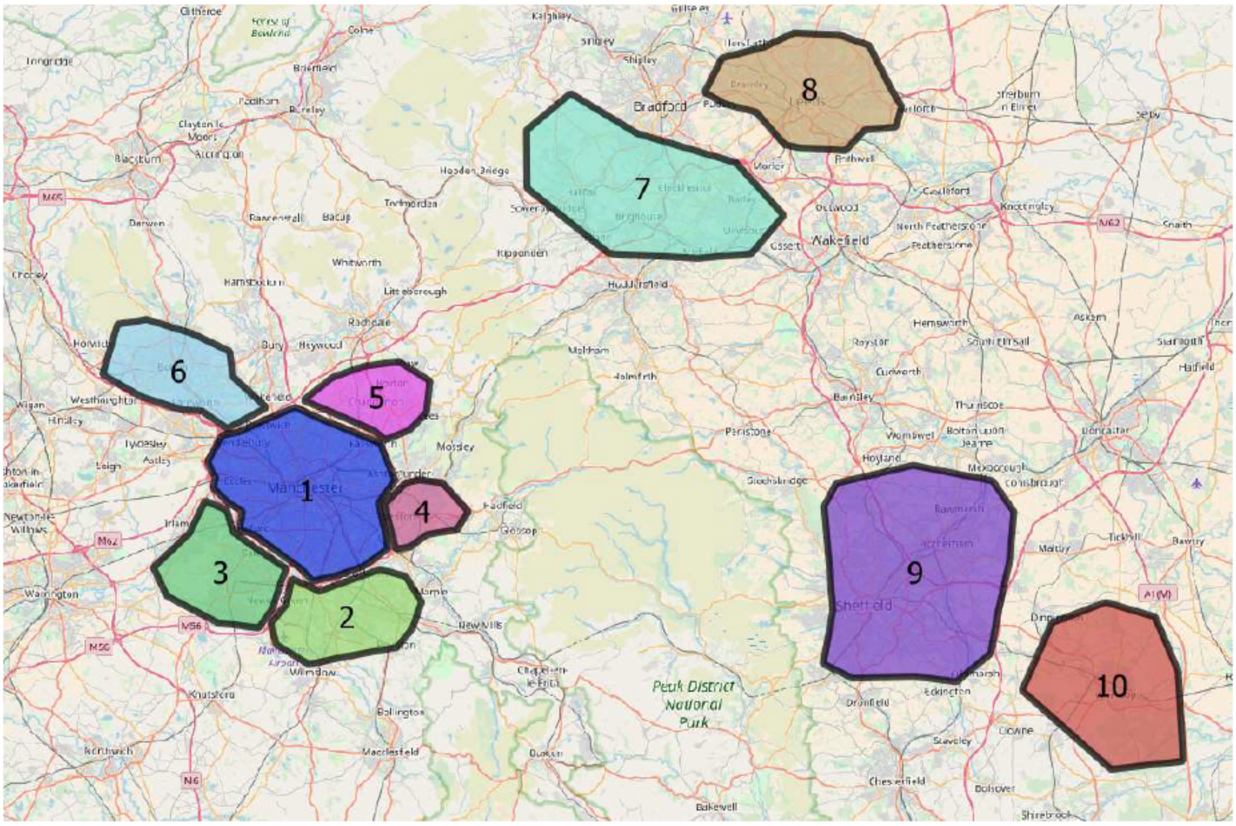
2.5. Applying Urban Speed-Decay Function to the Previous TPTS Work

2.5.1 Similarly to the previous analysis that was carried out for the orginal speed-decay function, the updated urban speed-decay function was applied to the previous work on the Trans-Pennine Tunnel + Wider Transport Connectivity Assessment schemes as a test to assess the impacts of the adjustnment of the fixed speed in urban areas on to the travel time saving benefits in comparison to the previous TUBA results.

2.5.2 For this purpose, the 2041 forecast models were run with the urban speed-decay curves applied for both Do-Minimum and Do-Something networks for AM, IP and PM periods. The model outputs from this test were subsequently used for TUBA calculation and compared against the TUBA benefits without the urban speed-decay curves applied.

2.5.3 Figure 7 below shows the areas that have been chosen for the fixed speed adjustment for the TPT+WTCA models. The areas selected are the same as

Figure 7 Areas Selected for Fixed Speed Adjustment



2.5.4 Each of the areas correspond to one of the 4 distinct speed-decay curves as summarised in Table 2 below.

Table 2 Areas and Speed-Decay Index

Area	Index Used	Speed-Decay Curve Area's Description
1, 8 and 9	1	Core metropolitan areas, major urban area with moderate or high congestion
2 and 3	2	High income area with expected significant growth in demand in future
4, 5, 7 and 10	3	Lower income area with potential for growth
6	4	Free standing town

2.5.5 Table 7 below shows the change in TUBA benefits as a result of the application of the speed-decay function in urban areas.

Table 7 TUBA Benefit with Fixed Adjustment to the Forecast Network's Speed (£000s)

Period	Travel Time	Fuel VOC	Non-Fuel VOC	Indirect Tax	Total
Original TPTS works - without Fixed Speed Adjustment					
AM Peak	28,282	-139	-1,485	2,683	**29,341**
Inter-Peak	38,084	-1,572	-3,877	5,491	**38,126**
PM Peak	24,224	-181	-2,961	2,941	**24,023**
Total	**90,590**	**-1,892**	**-8,323**	**11,115**	**91,490**
Revised - with Fixed Speed Adjustment applied					
AM Peak	30,124	71	-1,336	2,575	**31,434**
Inter-Peak	41,492	-1,414	-3,759	5,409	**41,728**
PM Peak	25,435	31	-2,748	2,833	**25,551**
Total	30,124	71	-1,336	2,575	**31,434**
Difference					
AM Peak	7%	-151%	-10%	-4%	**7%**
Inter-Peak	9%	-10%	-3%	-1%	**9%**
PM Peak	5%	-117%	-7%	-4%	**6%**
Total	**7%**	**-31%**	**-6%**	**-3%**	**8%**
%Difference					
AM Peak	1,842	210	149	-108	**2,093**
Inter-Peak	3,408	158	118	-82	**3,602**
PM Peak	1,211	212	213	-108	**1,528**
Total	**6,461**	**580**	**480**	**-298**	**7,223**

2.5.6 As can be seen, the application of the fixed speed adjustment in urban areas results in an overall 8% increase in TUBA benefits. This compares to the 7% increase in benefits as produced from the original speed-decay function that was developed for TfN SDCs.

2.5.7 Although the increase in TUBA benefits is similar to the previous development of the speed-decay function, WSP believes that the increase is more plausible than the previous version of the curve since the verification process was able to produce a better fit on the TPS RTM models.

2.5.8 In addition to TUBA benefits, the flow difference between the 'original' and the 'revised' models were produced to show that traffic routing issues have now been improved. Figures 8 and 13 below shows the flow difference between the original and the revised models for the Do-Minimum and Do-Something respectively.

Figure 8 Flow Difference: with vs. without Speed-Decay Function – DM2041 AM Peak

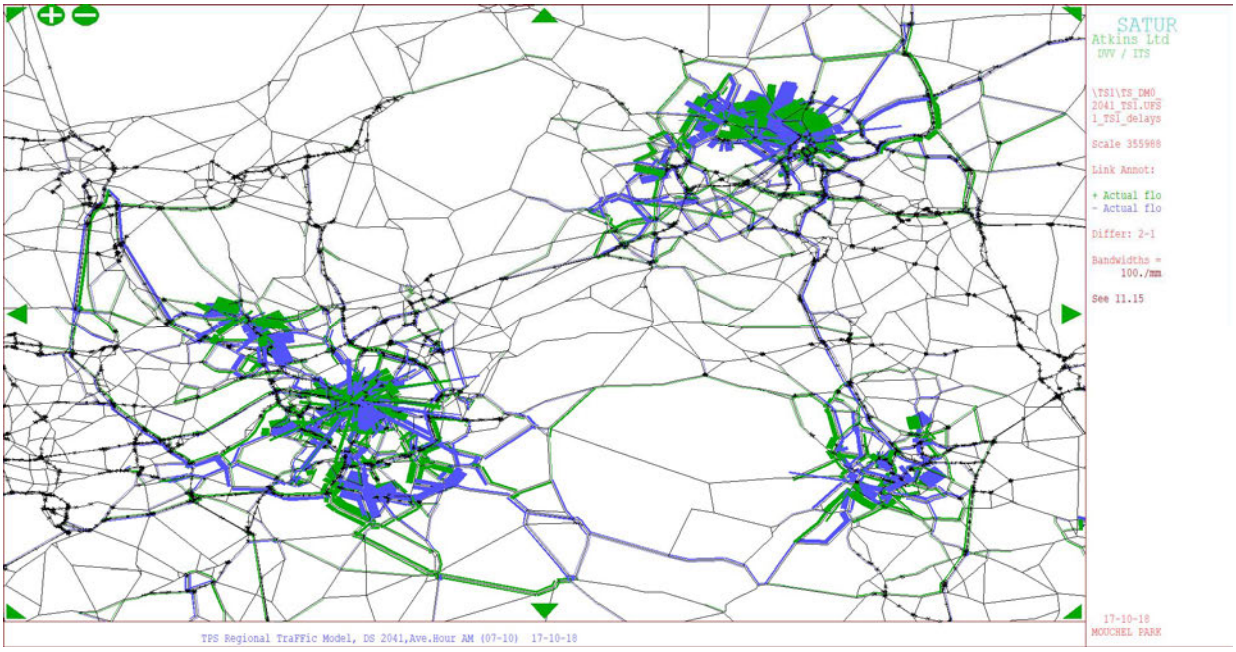


Figure 9 Flow Difference: with vs. without Speed-Decay Function – DS2041 AM Peak

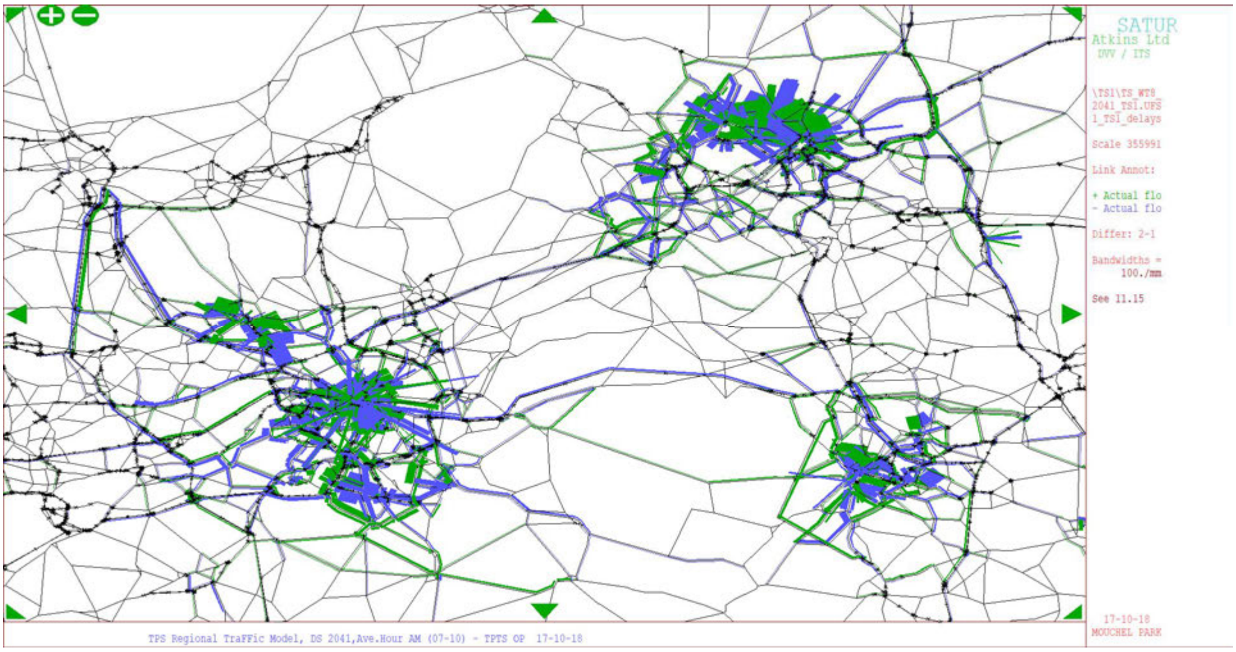


Figure 10 Flow Difference: with vs. without Speed-Decay Function – DM2041 Inter-Peak

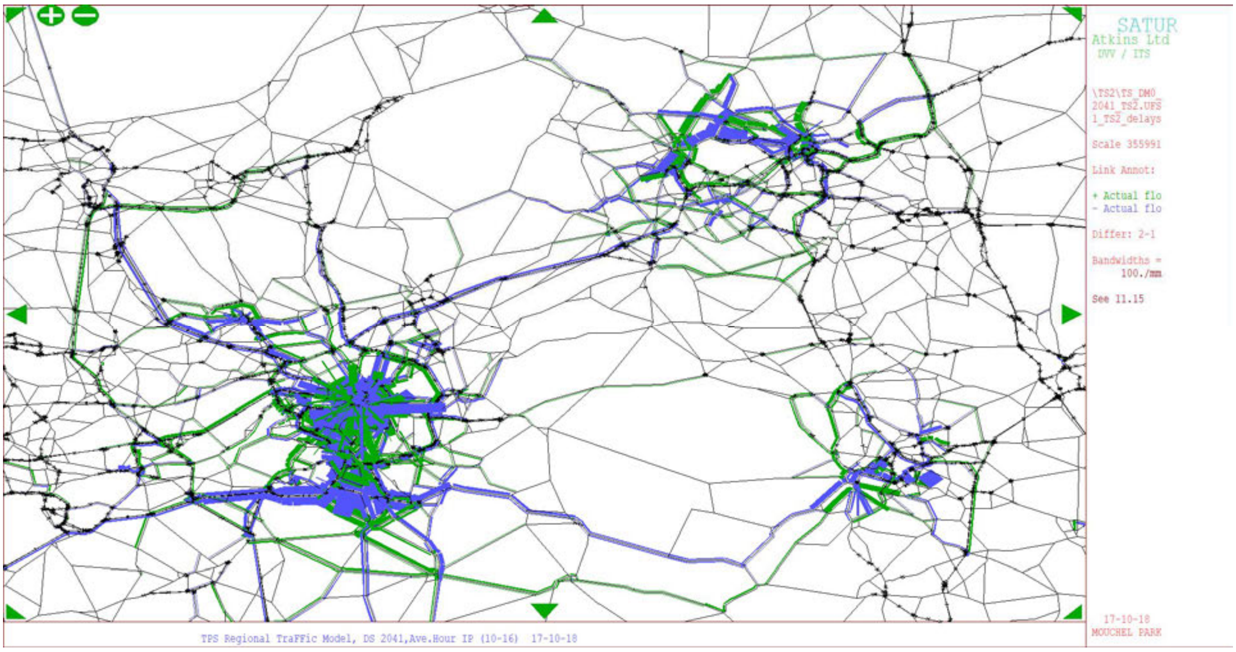


Figure 11 Flow Difference: with vs. without Speed-Decay Function – DS2041 Inter-Peak

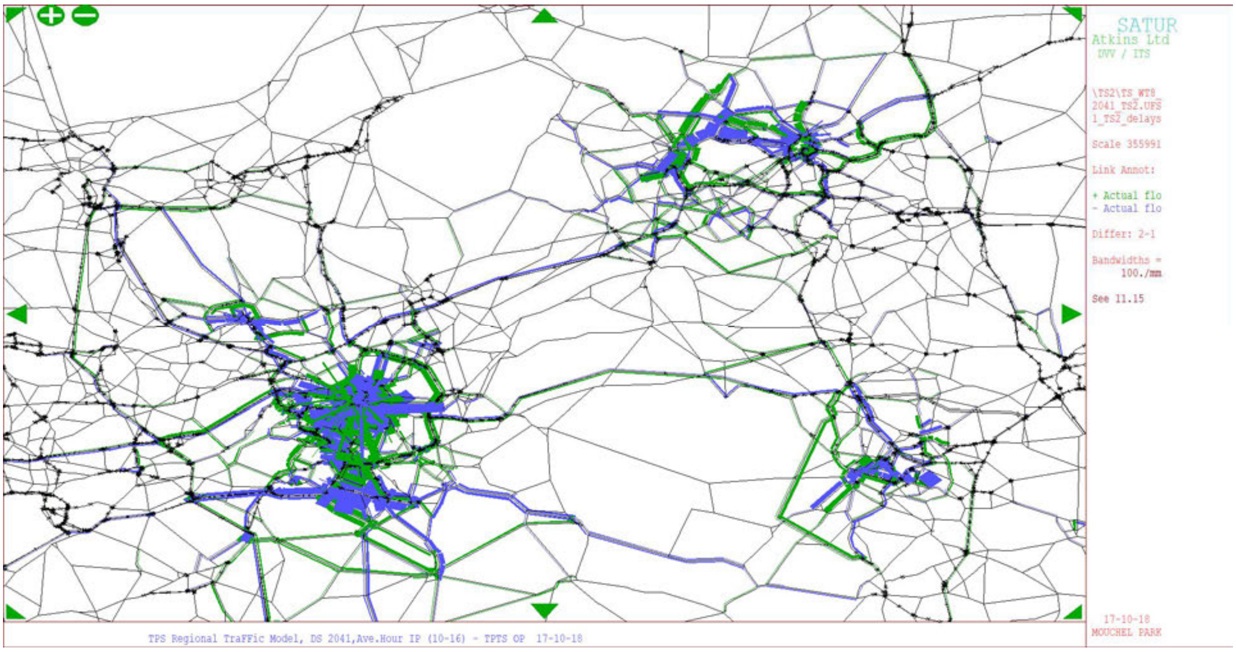


Figure 12 Flow Difference: with vs. without Speed-Decay Function – DM2041 PM Peak

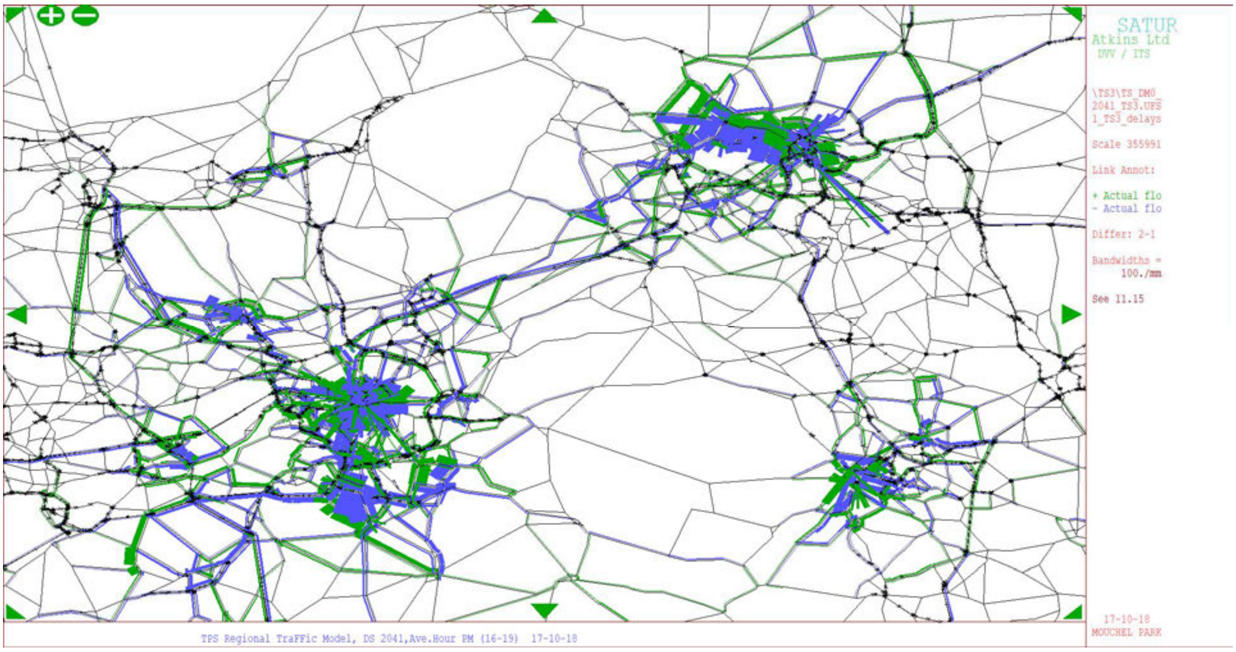
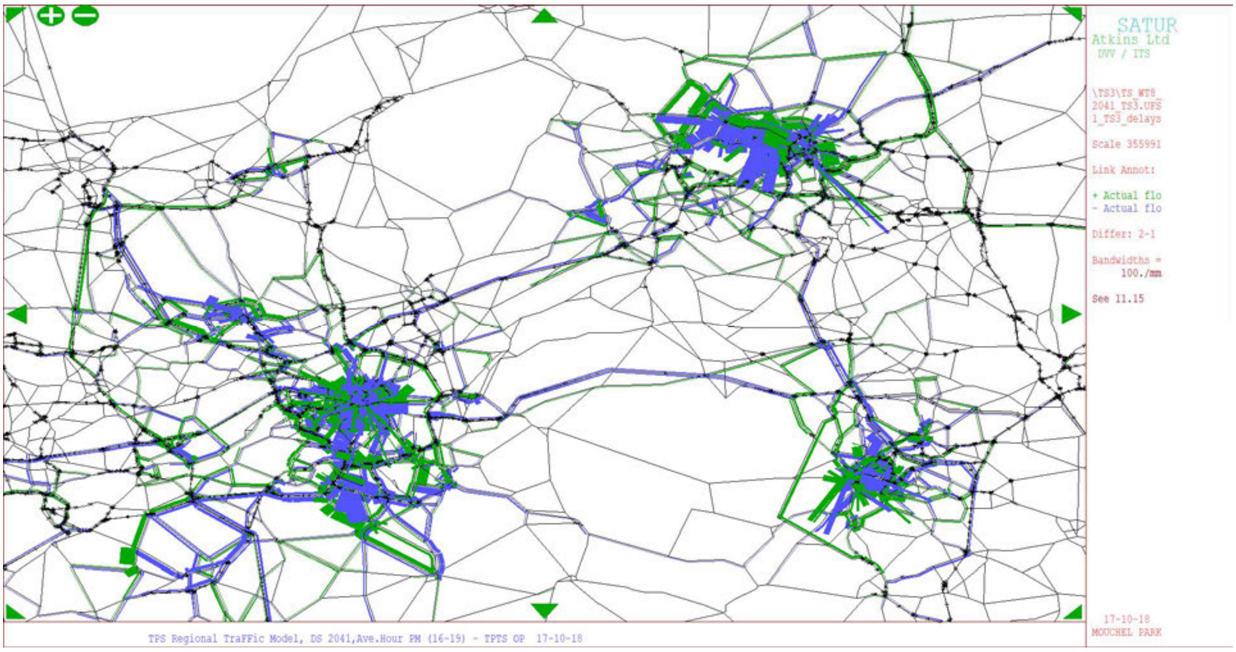


Figure 13 Flow Difference: with vs. without Speed-Decay Function – DS2041 PM Peak



2.5.10 For both Do-Minimum and Do-Something models, across all three modelled periods, the adjustment of fixed speed in urban areas implemented in the updated speed-day function produced similar response to the original curves that was developed for the TfN SDC i.e. resulted in more using the motorway rather than routing through the urban areas, for example, on the M60 in Manchester and on M1 near Sheffield. The extra traffic travelling on the motorway network compared to the ‘without fixed speed adjustment’ explain why the benefits produced do not increase an initially anticipated. This was due to the fact that extra traffic correctly routed via motorways results in more delays on the network, thus reducing the benefits claimed for the WTCA schemes.

2.5.11 Analysis shows that the increase in benefits in the models with the fixed speed adjustment for urban areas applied are deemed to be acceptable. The more important aspect to note is that the results of the tests show that the routeing are more sensible compared to 'without fixed speed adjustment' in urban areas, paritularly in terms of routeing of traffic through the urban areas as opposed to using motorway networks.

2.5.12 Select Link Analysis on both 'with' and 'without' the speed-decay function also shows similar responses to the previous speed-decay curves that was developed for the TfN SDC, i.e. traffic that travelled through Manchester city centre in the 'without' network has been improved in the 'with' speed-decay function applied, as provided in Figure 14 below.

Figure 14 Select Link Analysis: without (top) vs. with (bottom) Speed-Decay Function

2.6. Conclusion and Proposed Approach for the TPTS+

2.6.1 Overall, with the updated speed-decay function with taking into account the flow reduction and further enhancement, WSP view is that the speed-decay function generally produces plausible outcomes in terms of routeing and impacts on travel times on the network and therefore recommend to adopt the updated speed-decay function for the purpose of the TPTS+ assessment.

2.6.2 WSP therefore proposes, following the Option 2 as recommended in the note '**TfN RTM Fixed Speed Network Update**' (i.e. applying speed-decay function post-VDM runs), the approach to adopt the updated speed-decay function for th purpose of the TPTS+ as below:

- Step 1 : Carry out VDM runs without speed-decay function application;
- Step 2 : Use the final assignments and demand matrices produced from the VDM, carry out speed-decay function to produce revised assignments with fixed speed adjustment applied.
- Step 3 : Use the revised assignments from step 2 as final outputs and for appraisal purpose

3. SUMMARY

3.1.1 Following the eralier development of the speed-decay function in urban areas for the purpose of the TfN SDC studies, it was agreed that WSP would futher refine the speed-decay curves to account for the impacts on to travel speed as a result of reduction in traffic.

3.1.2 A number of additional tests were carried out on the 'donor' M60SM highway models to derive te second half of the curve in order to represent the full responses to travel speed as flow changes.

3.1.3 During the verification process against the TPS RTM models, number of changes have been made so that the updated speed-decay function was able to produce better fit in representing the speed decays as the flow changes resulted from the TSP RTM models.

3.1.4 TUBA analysis was also conducted on the TPT+WTCA models to provide an indication of increase in benefits as a result of the fixed speed adjustment to the urban areas.

3.1.5 The outcome from these tests show that the fitted curves produced plausible speed decays leading to improved routingcompared to the original model assignments, paricularly in terms of traffic routeing through the urban areas. The outcome has also demonstrated modest additional economic benefit. Although by virtue of the process adopted there are some risks around assurance to suit WebTAG style analysis the technique provides a plausible and proportionate approach.

3.1.6 WSP proposes to adopt option 2: applying the fixed speed adjustment to post-VDM assignments to help reduce risks and provide extra information where applicable.The proposed option offers reduced risks of repetitive works, loss of additional time required to setting up model runs, thus keeping up with the planned devilvery of the projects. Furthermore, it also offers potential comparison of economic appraisal results between 'with' and 'without' fixed speed adjustments to the urban areas.

4. APPENDIX