SYSTRA

A6 TO MANCHESTER AIRPORT RELIEF ROAD

MODEL DEVELOPMENT REPORT

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1. SUMMARY

1.1.1 This report documents the development and subsequent update to the A6 to Manchester Airport Relief Road (A6MARR) Variable Demand Model (VDM), a multi-modal demand modelling system covering the geographical areas of Stockport, south Manchester and north Cheshire. This model was originally developed with the aim of delivering a Major Scheme Business Case (MSBC) for the A6MARR scheme. In Autumn 2013 the scheme was granted Programme Entry status by the Department for Transport (DfT) subject to a number of conditions. During 2014, the model has been updated and revalidated to address these conditions and to bring the model into line with the latest DfT guidance.

1.1.2 A6MARR VDM contains three components; SYSTRA's bespoke variable demand model (VDM), SATURN highway assignment models and PT-TRIPS public transport models. This report documents the functionality of the model system, the production of the travel demand matrices, together with the calibration and validation of the A6MARR VDM.

1.1.3 The demand model uses matrices that have been derived from validated matrices associated with the highway model and the public transport models. Those sub-models have their own demand matrices that have been calibrated and validated to local data including traffic counts, passenger counts and journey times.

1.1.4 The highway and public transport models are used to provide generalised cost matrices to the VDM as a basis for forecasting changes in travel choices relative to a reference case situation. The reference case reflects the impacts of demographic changes, but not the costs of travel. In turn the VDM modifies the assignment model matrices. The system iterates until supply and demand are in equilibrium.

1.1.5 This report also describes the calibration and validation of the demand model. It presents results from standard 'realism tests', as specified in the Department for Transport's Transport Analysis Guidance (TAG). The realism tests set target values for the elasticity of demand to cost changes. The approach taken to calibration of the demand model was to import parameters from the illustrative values presented in TAG and adjust them to produce reasonable results in the realism tests. This approach produced a reasonable model, with overall elasticity values within the target range for both the realism tests.

1.1.6 With the parameters taken from within the ranges of the illustrative values, the elasticity of car vehicle kilometres to fuel price was -0.28, within the target range of -0.25 to -0.35. The public transport fare trip elasticity of -0.37 was within the target range of -0.2 to -0.9. Acceptable elasticity values disaggregated by purpose and time of day are presented. The car journey time trip elasticity of -0.20 was much less than the maximum allowable value of -2.0.

1.1.7 As described in the remainder of this report we judge that A6MARR VDM is a suitable tool to inform the appraisal of a major road scheme such as A6MARR.

2. INTRODUCTION

2.1 Context

2.1.1 A consortium of local authorities (Stockport Metropolitan Borough Council, Manchester City Council and Cheshire East Council) and Manchester Airport Group has been working since 2010 to prepare a submission to DfT for part-funding of the A6 to Manchester Airport Relief Road (see Figure 1). The scheme is based on the recommendations of the South East Manchester Multi Modal Strategy (SEMMMS) commissioned by central government in 1998, which highlighted a number of transport improvement opportunities that would benefit the local area. The relief road was a key element of that strategy and is designed to improve surface access to, from and between Manchester Airport and local town and district centres and employment sites, reduce the impact of traffic congestion on communities in Stockport, South Manchester and Northeast Cheshire, regenerate these communities through reduced severance and improved accessibility, and provide an improved route for freight.

2.1.2 The proposed scheme, illustrated schematically in Figure 1, will connect the A6 at Hazel Grove with the M56 at Manchester Airport. It consists of approximately 10 km of new dual two lane carriageway and seven new junctions, and will also incorporate the existing 4 km section of the A555 dual carriageway to the south of Bramhall.

Figure 1. A6 to Manchester Airport Relief Road

2.1.3 To this end, SYSTRA was initially commissioned in February 2010 to construct a transport model system fit for the purpose of providing modelling inputs for a Major Scheme Business Case (MSBC) of A6MARR to the Department for Transport (DfT), which was submitted in February 2012. This system has been developed and subsequently used to provide demand forecasts for A6MARR, as well as inputs for operational analyses, and economic and environmental appraisal. SYSTRA considers this system fit for the purpose of assessing the impacts of A6MARR and a primary consideration during the preparation of this report has been to demonstrate how the system complies with the DfT modelling requirements, as set out in the Transport Analysis Guidance (TAG).

2.1.4 This latest version of the report has been updated to include changes made throughout summer 2014 during which time the model was extended to cover a wider area to the south east of the scheme as well as updating model inputs to ensure compliance with the latest versions of TAG. This involved an increase to the number of model zones and a recalibration of the base year model. The subsequent forecasts produced during this tranche of work are known as "Test Run 2" (TR2).

2.2 A6MARR Variable Demand Model

2.2.1 A6MARR VDM combines SYSTRA's bespoke demand model with validated SATURN highway (Atkins / Leeds ITS software) and PT-TRIPS public transport (Citilabs software) average hour assignment models. The base year matrices represent 2009. Further detail on the model structure and algorithms are included in subsequent chapters of this report.

2.3 This and Associated Reports

2.3.1 This report describes the development and calibration of A6MARR VDM and contains the following chapters:

- chapter 3 – The Need for Variable Demand Modelling;
- chapter 4 – Geographic Scope and Zoning;
- chapter 5 – Model Dimensions;
- chapter 6 – Base Year Travel Demand;
- chapter 7 – Demand Model Processes; and
- chapter 8 - Demand Model Calibration.

2.3.2 Three other documents should be read in conjunction with this report and provide supporting information about the A6MARR VDM system:

- A6MARR SATURN Local Model Validation Report (LMVR) produced by Transport for Greater Manchester (TfGM) Highways Forecasting & Analytical Services (HFAS) in August 2014;
- A6MARR PT-TRIPS LMVR produced by SYSTRA in February 2012; and
- Forecasting Note produced by SYSTRA in October 2014.

3. THE NEED FOR VARIABLE DEMAND MODELLING

3.1 Introduction

3.1.1 In this chapter we review the need for and scope of variable demand modelling to support the appraisal of A6MARR.

3.2 Area of Influence

3.2.1 SYSTRA has specifically designed A6MARR VDM with a view to providing supporting evidence for the MSBC of A6MARR. The A6MARR scheme connects the M56 at Manchester Airport with the A6 at Hazel Grove. Although A6MARR VDM contains demand and supply representations covering much of the north of England, the primary focus of the model system coincides with the smaller Area of Influence (AoI) of the scheme (see Figure 2), covering parts of South Manchester, Cheshire East and High Peak. The AoI was originally determined using a preliminary version of the SATURN model to identify the area over which traffic flows changed significantly when the A6MARR scheme was introduced. For the latest model update, the AoI has been extended south and east to include Macclesfield and parts of the High Peak region (including Whaley Bridge, Chapel-en-le-Frith and Buxton) where the model has been extended and new survey data has been incorporated.

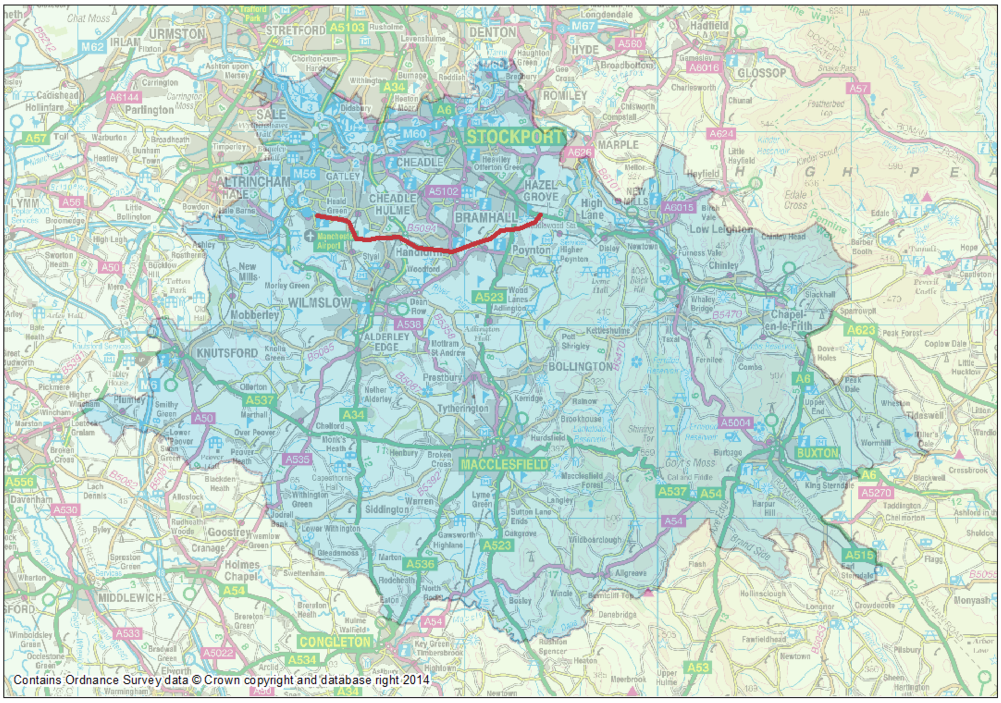

Figure 2. A6MARR Area of Influence

3.2.2 The AoI is the part of the model for which most attention has been placed on network coding, density and validation. Beyond the AoI, network coding and demand representation extends, albeit with decreasing levels of detail, across the rest of Greater Manchester, Cheshire, Yorkshire, Humberside and the East Midlands. The remainder of Great Britain is represented at a very coarse level of detail. Computing restrictions (memory and run times), and the availability of data on travel patterns, inevitably limit the spatial detail to which travel can be represented.

3.3 VDM Applications

3.3.1 The system of models has been configured to allow the scheme to be assessed under a number of scenarios that reflect the interaction of changes in incomes, car ownership, household structure, development patterns and travel costs (time and money) for future years.

3.3.2 The primary outputs from A6MARR VDM include:

- levels of travel demand by time of day, mode of travel, geographic distribution, reason for travel and the availability of a car;
- time and money costs of travel; and
- levels of traffic on roads within the modelled area.

3.3.3 These outputs can be used to analyse:

- road speeds and congestion;
- traffic related noise and emissions;
- transport economic impacts of the scheme, accounting for changes in travel time and cost;
- road traffic accidents;
- the accessibility of workplaces for employees, and conversely the available supply of labour for employers; and
- wider economic benefits resulting from the scheme.

3.4 The Need for and Scope of Variable Demand Modelling for A6MARR

3.4.1 TAG unit M2 states that any change in transport conditions causes, in principle, a change in demand. The purpose of variable demand modelling is to predict and quantify these changes. The Standing Advisory Committee on Trunk Road Appraisal (SACTRA) reporting in 1994 emphasised the importance of establishing a realistic scenario in the absence of the scheme or strategy, the extent of travel suppression in the 'without-scheme' case, and the extra traffic induced in the 'with-scheme' case.

3.4.2 A6MARR VDM reflects distribution, mode choice and macro time of day responses to changing travel conditions. The inclusion of these travel choice responses is arguably most important for producing realistic future year forecasts 'without-scheme', which reflect travellers response to changes in for example congestion, vehicle operating costs and public transport fares. However, one would also expect distributional impacts and to a lesser extent modal and time responses in the 'with-scheme' case due to the changes in travel cost as a result of A6MARR.

3.4.3 TAG unit M2 suggests that fixed demand (rather than variable) assessments may be acceptable if the following criteria are satisfied:

- The scheme is quite modest both spatially and in terms of its effect on travel costs. Schemes with a capital cost of less than £5 million can generally be considered as modest.
- There is no congestion on the network in the forecast year.
- The scheme will have no appreciable effect on competition between private and public transport in the corridor containing the scheme.

3.4.4 Assessing these criteria in the context of the A6MARR scheme indicates the need for variable demand modelling as:

- the scheme is likely to have considerable effects on travel costs and has capital costs very much greater than £5 million;
- there is traffic congestion in the base and forecast year network; however
- the scheme might be expected to have a small effect on competition between private and public transport in the corridor containing the scheme.

3.4.5 TAG Unit M2 provides guidance on the specification of VDMs under different circumstances. This unit is clear that when a VDM is required:

- destination choice modelling must be undertaken, and the zone system should be designed to support this;
- representing demand in production/attraction (PA) format is strongly preferred to origin/destination (OD) format;
- the forecasting process should first use socio-economic data to modify the base year demand matrices, and then a VDM to represent the impact of changes in travel costs;
- demand must be adequately segmented (by car availability and journey purpose) into groups for which the impacts of changes in travel conditions over time and of policies can be assumed to be similar;
- a highway assignment model must be included so that changes in route choice, traffic levels and highway travel times and costs can be predicted;
- the model must be divided into time periods so that variations in travel conditions across the day can be represented; and
- travel demand choices should be influenced by the generalised cost of travel which is a combination of both time and money costs.

3.4.6 A6MARR VDM is designed to be consistent with the requirements summarised above, and the detailed specification is provided in subsequent chapters of this report. A number of decisions were required regarding the functionality which we have taken after consulting TAG and which are summarised below:

- Walk and cycle trips are included in the model so that there is no requirement to include a trip frequency (how often to travel) response. Transfer between these ‘slow modes’ and public transport can be significant, its inclusion makes the model more realistic and assists with calibrating the model’s response to fare changes.
- A mode choice model is included. TAG includes recommendations on the appropriate fuel cost elasticity which should be achieved but which assume that all demand responses are available. We are not aware of any evidence regarding the appropriate elasticity for a model which omits mode choice. Inclusion of a mode choice model will also allow for potential impacts of the change in competition between car and public transport to be assessed.
- Inclusion of a mode choice response requires a matrix of public transport demand and for a mechanism to calculate public transport generalised costs. We have therefore included a PT-TRIPS assignment model which provides a transparent and internally consistent method for calculating public transport costs reflecting changes in fares and bus speeds over time and as a result of the scheme.
- Choice between ‘macro’ time periods (of several hours) is included as the travel costs in each period will be expected to change over time, and potentially to a lesser extent as a result of the scheme. Travel demand in the peak periods is more constrained by capacity than in the off peak periods, so over time we would anticipate that peak and off peak travel times would change at different rates.

- Peak spreading or micro time period choice describe the phenomenon whereby peaks in demand occur over longer durations when demand grows in a congested network. Whereas macro time period choice represents the choice between broad modelled time periods, micro time period choice represents choices within a modelled time period. TAG Unit M2, 4.8.2 states that "variable demand models only usually include macro time period choice if at all, to represent transfer of traffic between broad time periods". Any treatment of micro time period choice would require the inclusion of more time periods in the supply and demand models and necessarily lead to very substantial increases in run times. Further, SYSTRA's bespoke software deals with micro time period choice using logit models for which there are behavioural theory objections and therefore SYSTRA have chosen not to explicitly model shoulders of the morning and evening peaks or to include a peak spreading response in the model system.

3.5 Model System Overview

3.5.1 The A6MARR VDM system operates using an 'aggregate' modelling approach as shown in Figure 3. The system consists of SYSTRA's demand model and average hour SATURN highway and PT-TRIPS public transport assignment models, representing 4 time periods cumulatively covering 16 hours of the day.

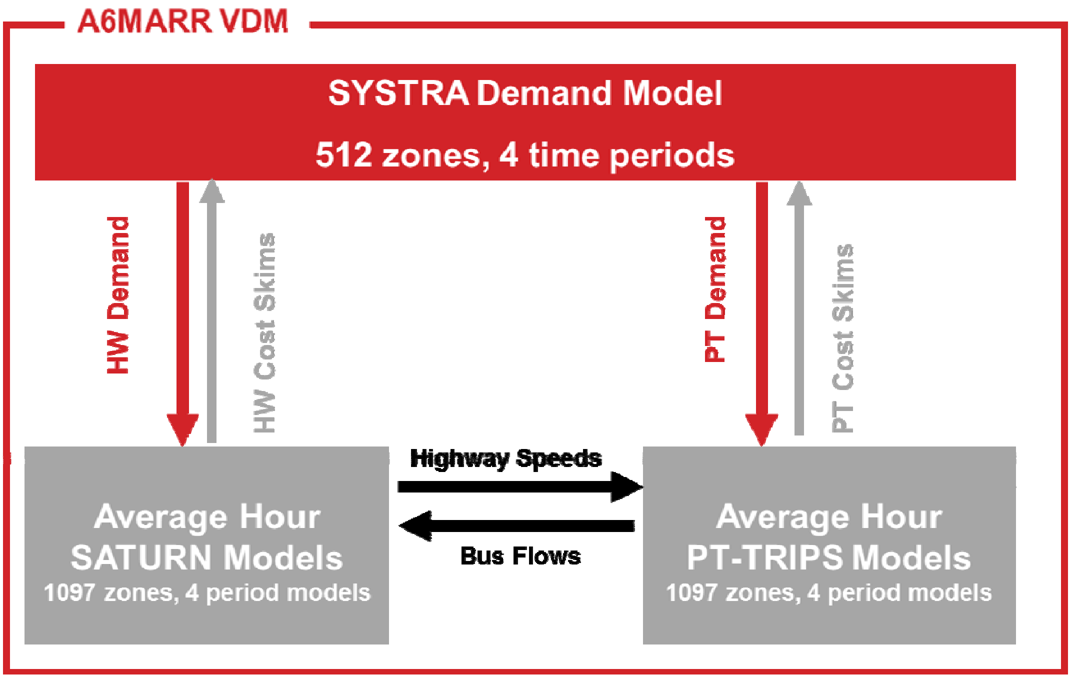

Figure 3. A6MARR Variable Demand Model (A6MARR VDM)

3.5.2 The assignment models are used to provide cost skims for input to the demand model with forecast demands from the demand model being reassigned in the assignment models. The demand and supply models are run iteratively until a converged solution is reached (as measured using the %GAP indicator specified by DfT).

3.5.3 A question therefore arises whether to input costs skims from average hour assignment models into the demand model or cost skims from peak hour assignment models. Use of cost skims from the average hour assignment models will likely underestimate congestion impacts within the demand model for peak hours whereas use of cost skims from peak hour assignment models will overestimate congestion impacts in the shoulders of the peaks. SYSTRA is of the opinion that neither approach is ideal, each being a simplification of the traffic profiles that occur across a peak period. We have chosen to develop average hour assignment models to incorporate into the iterative supply/demand loops so that the travel costs for a time which are input to the demand model are derived by assigning the level of demand in that time period. This decision has added benefits in terms of reducing run time as assignments with lower flows tend to converge more quickly.

3.5.4 SYSTRA has recently been in consultation with the Department for Transport regarding the choice between average or peak hour assignment models, since this was raised as a question by DfT representatives in October 2013, following the submission of the Major Scheme Business Case. SYSTRA provided an information note documenting the rational for the choice of average hour models in February 2014 and it was subsequently agreed that further sensitivity tests would be carried out on the latest forecasts using peak hour assignment models. Results of these sensitivity tests will be reported in a separate note.

3.5.5 Demand changes from the converged A6MARR VDM demand/supply system are then used to adjust the peak hour A6MARR SATURN models (see Figure 4[1]) which were developed by TfGM HFAS. Cost skims from the peak hour A6MARR SATURN models are ultimately used in the economic appraisals. SYSTRA proposed to use average hour modelling in A6MARR VDM and peak hour modelling for final analysis so that:

- A6MARR VDM includes demand for all times of day where there is significant trip making;
- A6MARR VDM can be used to predict allocation of travel between time periods;
- peak hour A6MARR SATURN assignment models can provide information for analysing operational conditions in the peak hours; and
- travel time changes used for economic appraisal are taken from the peak hour A6MARR SATURN assignment models, being more accurate because traffic levels are more constant within the peak hours than across periods.

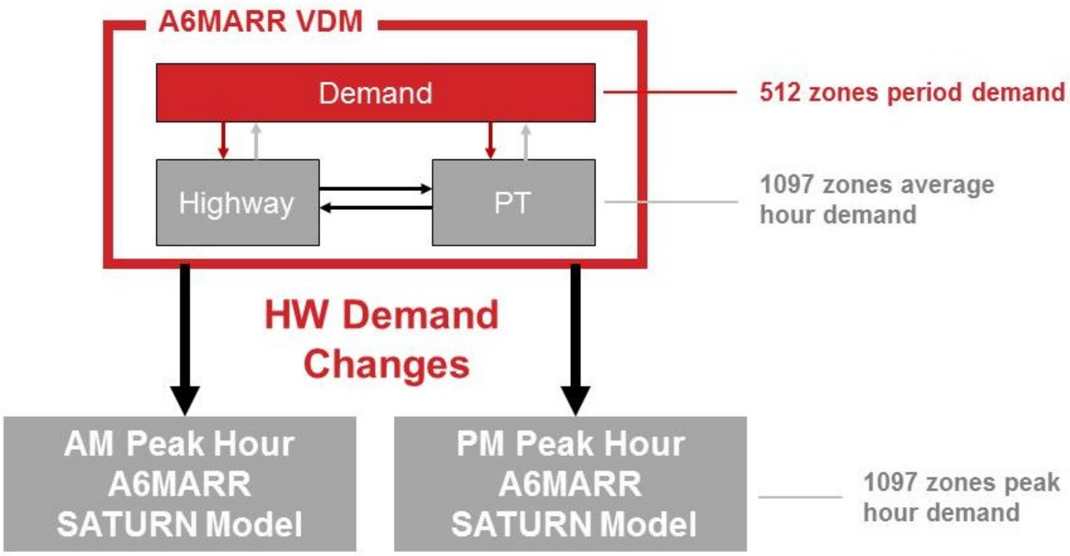

Figure 4. Forecast Demand Changes from A6MARR VDM applied to peak hour matrices

[1] The interpeak (0930-1600) period is not shown in the figure as the there is no separate "peak hour" version.

4. GEOGRAPHIC SCOPE AND ZONING

4.1 Introduction

4.1.1 This chapter describes the spatial coverage of A6MARR VDM, summarises the functionality of the model in different areas and presents the zone systems used.

4.2 A6MARR VDM Geographical Coverage

4.2.1 At an early stage of the original model development in 2010, the A6MARR modelling team identified an 'Area of Influence' (AoI) of the scheme, within which assignment model validation would be focussed. This is also the area for which base model network coding and density is most detailed.

4.2.2 The network coding and demand representation is most detailed within the AoI and extends, albeit with decreasing levels of detail across the rest of Greater Manchester, Cheshire, Yorkshire, Humberside and the East Midlands. The remainder of Great Britain is represented at a very coarse level of detail.

4.2.3 The AoI was originally identified using the GM SATURN 2008 networks, which were an earlier version of the SATURN networks covering Greater Manchester than A6MARR. Flow difference plots were examined for assignments with and without the A6MARR scheme. The version of the scheme used in this work was an early version, known as Design Freeze 2. The AoI was defined by the set of links for which the flow difference was +/- 250 pcus.

4.2.4 Although assignment model validation has focused on the AoI of the scheme, supply and demand representation has been extended over a much wider area covering much of the north of England. The primary reason for including full representations of demand and supply processes over such a wide area is to allow for trip redistribution effects when making future year do minimum and scheme forecasts.

4.2.5 Following consultation with stakeholders and in order to be able to demonstrate the impact of A6MARR on the High Peak area including Chapel-en-le-Frith, Chinley, Buxton and Whaley Bridge, it was decided that the model should be enhanced to include this region as part of the update to be carried out during 2014. This included addition of simulation SATURN coding and additional zoning to enable the model to more accurately predict future year travel patterns in this area.

4.2.6 To this end, the AoI has been extended for the latest model update to include a larger area to the south east of A6MARR. The full extent of the revised AoI can be seen in Figure 5 (section 4.4).

4.3 A6MARR Highway Assignment Model Zoning

4.3.1 The zone system developed for use in the A6MARR 2009 highway assignment models made extensive use of a zone system developed for the GM SATURN 2005 highway assignment models, used to provide supporting evidence of the 2007 AGMA TIF bid. The GM SATURN 2005 zone system was developed using the following principles:

- Based on local authority areas and, within these, wards to facilitate the compilation of input planning and land-use data.

- Computational constraints restricted the number of zones that could be accommodated within the demand model to around 300. From the outset of the TIF work it was decided that an appropriate ratio between the number of zones in the demand model and those in the GM SATURN 2005 assignment models would be around 1:3.
- Important traffic generators such as large superstores and hospitals were treated as separate zones.

4.3.2 For the A6MARR assignment models, zoning both within and outside Greater Manchester was reviewed. Within Greater Manchester, GM SATURN zones within Stockport, south Manchester and east Trafford were checked, and where necessary, existing zones were disaggregated to better represent key generators and future development sites.

4.3.3 The area surrounding Manchester Airport was looked at in detail. The zoning in the Airport area was reworked based on the location of car parks and pick-up/drop-off areas and with reference to several documents including 'Manchester Airport Masterplan', 'Manchester Airport Ground Transport Strategy' and 'Manchester Airport: the need for land', which outlines Manchester Airport Groups future parking requirements in some detail.

4.3.4 In the GM SATURN model, the zones in Cheshire East were significantly larger than those within Greater Manchester. As the AoI includes parts of Cheshire East and High Peak which is now coded in simulation detail and is in close proximity to the proposed A6MARR scheme the zoning was reviewed and disaggregated. In particular, the more built up areas around Wilmslow, Alderley Edge and Poynton required a more extensive rezoning to better reflect loading points on the network.

4.3.5 The additional zoning within the AoI resulted in a final number of zones in the A6MARR highway assignment models of 1097. This includes an additional 13 zones compared to the previous version of the model due to the extension of the SATURN model simulation area to the south east.

4.4 A6MARR Variable Demand Model Zoning

4.4.1 As discussed above, the average hour highway and PT assignment models in A6MARR VDM are used to provide cost skims for input to the demand model with forecast demands from the demand model being reassigned in the assignment models. This requires the zones in the highway and PT supply models to nest within the VDM zones to allow costs from the supply models to be passed to the VDM. However, it does not necessarily require a 1:1 correspondence between zone systems of the assignment models and the demand model. Operating the demand model at a more aggregate level than the assignment models speeds up demand model run time, reduces model data storage requirements and is beneficial when matrices are lumpy, i.e. subject to a degree of sampling bias.

4.4.2 The A6MARR VDM zone system was developed using the following principles:

- Identical zone system in assignment and demand models across the AoI, which covers parts of Stockport, south Manchester, Cheshire East and High Peak, allowing for accurate representations within the demand model of travel patterns associated with future developments and their loading points in the assignment models.

- Demand for travel to/from Manchester Airport terminals was aggregated from the eight zones in the assignment models to a single zone in the VDM. Whereas a highly disaggregate zoning system across Manchester Airport improves accuracy of traffic loading in the assignment models, this level of aggregation is not appropriate for demand response modelling. Air travellers' response to changing Airport access costs can be thought of in terms of the whole journey from home to the check-in desk as opposed to a particular car park or public transport terminus. This is particularly important for mode choice so that the total costs of travel by car to the desk can be compared with public transport costs, rather than comparing costs to reach a car park. For this reason a single demand model zone is used to represent demand to/from Manchester Airport terminals.
- Approximately 3:1 ratio between assignment and demand model zones across the rest of Greater Manchester, making use of the existing GM zone system as developed for the original GMSPM2 model used for the TIF bid. These zones correspond to wards so that planning data could be readily compiled, and can therefore be easily mapped to TEMPRO zones for forecasting purposes.
- For much of the north of England, which is beyond the AoI, full representations of travel demand are included in the demand matrices for these zones although supply coverage becomes progressively simplified further away from the AoI. Simplifying the zoning system for this area between the demand and assignment models speeds up run time, significantly reduces model data storage requirements and can be beneficial if matrices are lumpy.
- Identical zone system in assignment and demand models for the external zones, defined as those for which only fully observed travel demand is included in the demand matrices.

4.4.3 Table 1 shows the nesting relationship between the zone systems of the highway assignment models and A6MARR VDM. In total there are 512 demand model zones in A6MARR VDM. This is an increase of 28 zones compared to the 484 zones in the previous version of the model. This is a larger increase than the assignment models because previously many of the zones which have been split in the assignment models as part of the model update were not within the AoI and therefore didn't have 1:1 correspondence with the demand model. So in some cases demand model zones had to be split into 3 or 4 zones in order to retain the 1:1 correspondence in the new extended AoI.

Table 1. A6MARR VDM Zoning and Nesting Relationship with the Zoning of the A6MARR Highway Assignment Models

MODEL AREA	NUMBER OF A6MARR HIGHWAY ASSIGNMENT ZONES	NUMBER OF A6MARR VDM ZONES	RATIO
Area of Influence	233	233	1 : 1
Rest of Greater Manchester and North of England	849	264	3.2 : 1
External Zones	15	15	1 : 1
All Zones	1097	512	2.1 : 1

4.4.4 The VDM zone system is shown in Figures 5 with the extent of the AoI shown in blue.

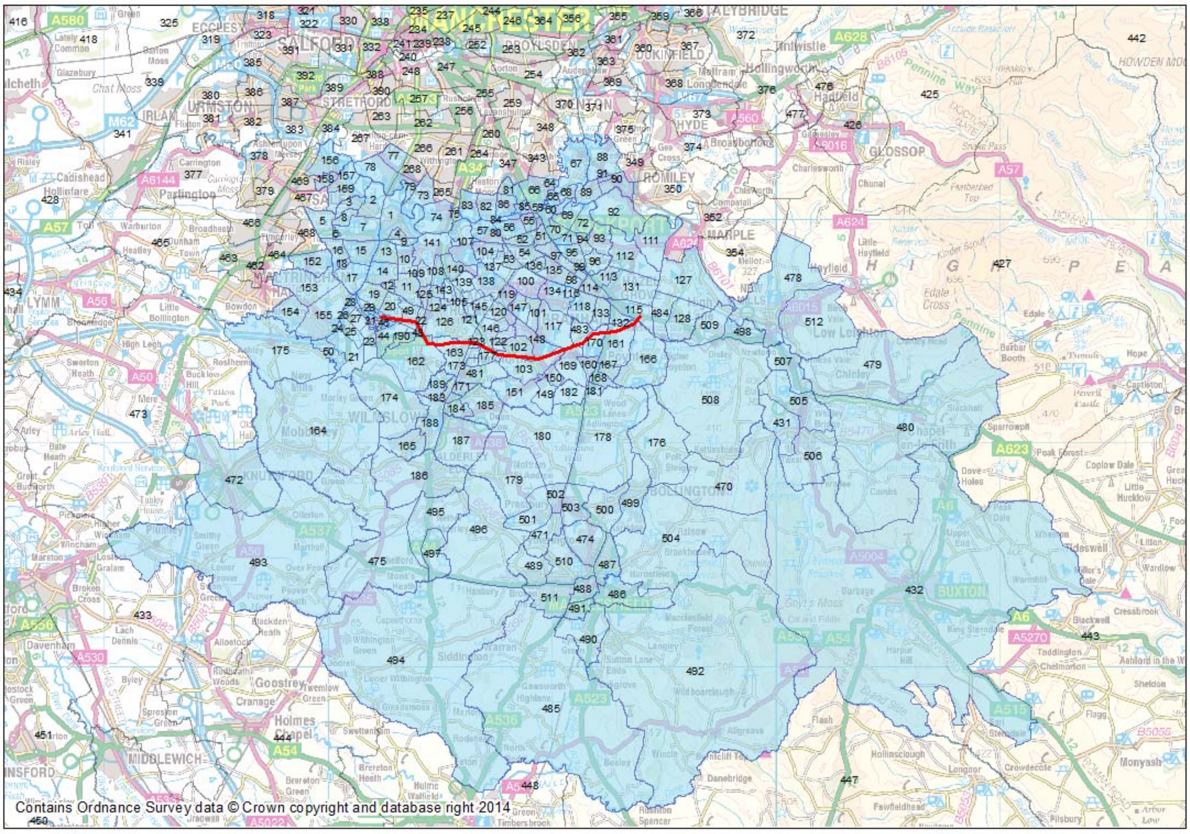

Figure 5. A6MARR VDM demand model zoning and AoI boundary. Zoning is identical within AoI for demand and assignment models

4.5 A6MARR PT Assignment Model Zoning

4.5.1 The zones in each supply model must nest within the VDM zones to allow costs from the supply models to be passed to the VDM. In theory the PT and highway models could have different zones so long as both systems could be aggregated to the zone system used in VDM. In the Area of Influence the VDM and highway model use the same zone system so that the demand changes which results from cost changes in generalised costs can be most accurately estimated. So:

- the PT model zones must nest within the VDM zones; and
- it has been decided that the same zones will be used in the highway model and VDM in the AoI.

4.5.2 These two factors mean that the PT model zones in the AoI must either be the same as, or nest within, the highway model zones. As the model is not designed to appraise PT schemes it would not be appropriate for the PT model zones to be more detailed than the highway model zones. The A6MARR PT assignment models will therefore have the same 1097 zones as the A6MARR highway assignment models.

4.6 Modelling of Intrazonal Trips

4.6.1 TAG M2, 2.4.4 states that 'the size of internal zones will need to be carefully considered in relation to intrazonal trips in order to avoid any biases in the demand model. At the distribution stage it is important to be able to redistribute intrazonals to become interzonals, and interzonals to become intrazonals, if relative costs change. If the zone sizes are small this is less of a problem, but for large zones it is important that the average intrazonal costs are as realistic as possible.'.

4.6.2 We have decided to treat intrazonal trips using four different approaches depending on the relative size of the demand model zones, which is primarily governed by their geographical distance from the AoI of the scheme. The four approaches are:

- Within the AoI where assignment and demand model zones are identical, intrazonal costs are fixed at zero. As discussed later the choice models have an incremental form, are influenced by changes in travel costs rather than the costs per se, and so it does not matter whether the costs are fixed to zero or a different value. This is considered appropriate as zone sizes are small, changes in costs would therefore also be small and the assignment models cannot predict intrazonal costs.
- For the zones across the rest of Greater Manchester for which assignment and demand model zones are in approximate 3:1 ratio, intrazonal costs in the demand model are derived by demand weighting the relevant inter-zonal costs from the assignment models.
- For external zones only demand observed travelling within the AoI and Greater Manchester is included in the demand matrices and therefore no intrazonals are modelled.
- For all other zones covering the north of England, i.e. those not in the AoI, Greater Manchester or external zones, the network coverage of the assignment models becomes progressively sparser. For this area of the model it is less appropriate to derive average intrazonal costs for use in the demand model from assignment model cost skims. Here, SYSTRA have implemented an alternative method in which intrazonal demand for each of these zones is split into a series of distinct 1km distance bands based on a distribution calibrated for each mode and segment on base travel demand data for zones within the AoI and Greater Manchester. These separate bands of intrazonal demand are then included in the distribution model along side the usual interzonal demands. This can be thought of as replacing the single intrazonal movement in the destination choice model with a number of extra zones representing 1 km bands. Costs associated with these intrazonal distance bands are calculated using an average cost per kilometre derived for each mode and segment for zones within AoI and Greater Manchester. These costs are updated for each model run to reflect changes in congestion over time. This approach allows the trip length of intrazonal movements to change in the large zones, resulting in a more realistic destination choice model.

5. MODEL DIMENSIONS

5.1 Introduction

5.1.1 This chapter summarises the dimensions defined for A6MARR VDM, i.e.:

- modes;
- car availability and journey purpose; and
- time periods.

5.2 Modes

5.2.1 As previously discussed the following modes are included in A6MARR VDM:

- car;
- light goods vehicles – variable demand responses do not apply but included in the highway assignment process as a contributor to congestion and to predict route changes;
- other goods vehicles – treated in the same way as light goods vehicles;
- walk/cycle – as mode shift between slow modes and public transport can occur, to remove the need for a frequency response, and to assist with model calibration; and
- public transport – to allow for the modelling of mode shift over time and in response to the scheme, and to enable the appraisal of impacts of A6MARR on public transport users.

5.2.2 Park-and-ride journeys are not included in A6MARR VDM. These represent a small number of trips in the AoI and across Greater Manchester, their inclusion would greatly complicate the model, and no changes to park-and-ride provision are proposed as part of the scheme or in the without scheme scenarios.

5.3 Car Availability and Journey Purpose

5.3.1 Appropriate choice of demand and supply model dimensions is essential to the success of any complex transport model covering a large spatial area. Trade-offs need to be made between the segmentation of demand and spatial aggregation; this is critical in creating a model capable of addressing the policy question of interest with constraints in model run time and memory requirements. However, recent development in computer processing power, available RAM, hard disk space and the ability to perform parallel processing across multiple processors means that significantly more segmentation can be accommodated in a model system than was possible five to ten years ago.

5.3.2 The model dimensions selected for A6MARR VDM were chosen in order to satisfy each of the following key requirements of the model, whilst creating a model which had an acceptable run time and call on computing resources (TAG M2, Table 2.1 Minimum Segmentations for a Multi-Stage Demand Model):

- TAG compliant demand responses and parameters;
- model run times of under 24 hours for a single policy forecast in the base year; and
- the A6MARR SATURN models developed by TfGM HFAS have 1097 zones.

5.3.3 Travel demand in the demand model is grouped into 'segments'. Within each segment demand responds to changes to transport supply in the same manner, i.e. the following characteristics are constant:

- value of time; and
- sensitivity of travel demand responses (time of day, mode and distribution) to changes in travel costs.

5.3.4 Demand is also segmented to facilitate the estimation of the quantity of travel produced by each zone, and how these quantities change over time. The following factors were considered in establishing a preferred set of demand segments:

- data must be available to reliably segment and forecast demand, and to specify values of time and demand response sensitivities;
- the chosen segments should reflect variation of values of time and sensitivity of demand responses to changes in travel costs;
- demand response sensitivity parameters must be available from published sources such as TAG;
- no segment should represent a small proportion of total journeys in both base and future years;
- different levels of segmentation may be appropriate within the demand and the assignment models; and
- model run times must be manageable.

5.3.5 With reference to TAG M2 Table 2.1, the minimum model system demand segmentation appropriate for appraisal of A6MARR would be:

- 2 categories of household car availability – no car and car available;
- 3 trip purposes – commute, business and other; and
- 2 modes – car and public transport.

5.3.6 Thus, in A6MARR VDM all personal travel demand has been segmented into two household car availability categories:

- no car available households; and
- car available households.

5.3.7 Demand has been further segmented into five purposes (see below) resulting in a total of 10 demand segments:

- home based commute;
- home based employers' business;
- home based other;
- non home based employer's business; and
- non home based other.

5.3.8 In addition to the dimensions discussed above, demand is further segregated into airport or non-airport segments. All non-commuting travel associated with Manchester Airport is stored in separate demand segments to allow a different hierarchy to be used which includes only mode choice, owing to the fact that if people are travelling to the airport they are doing so because they have a flight to catch and are unlikely to change destination or time of day despite any changes in travel cost.

5.3.9 For the purposes of route choice in the assignment models purposes with similar values of time can be combined, and the distinction between home based and non-home based trips is not relevant. Therefore the highway assignment models operate with a more aggregate segmentation than the demand model. The three highway assignment user classes are business, commute and other.

5.3.10 In the public transport assignment model demand for all segments is combined and a single set of routes is chosen using an average value of time.

5.4 Time Periods

5.4.1 Four time periods covering 16 hours for a weekday have been included A6MARR VDM, which allows the impacts of macro time period shifting over time and for the preferred scheme to be assessed given consideration. The time periods are:

- AM Peak 0700-0930 2.5 hrs
- Inter-peak 0930-1600 6.5 hrs
- PM Peak 1600-1900 3.0 hrs
- Off-peak 1900-2300 4.0 hrs
- Total 16.0 hrs

5.4.2 These time periods are compatible with the typical 12 hour time period 07:00-19:00 for which observed highway and public transport travel patterns are available.

5.4.3 The A6MARR VDM time periods fall within those of the validated A6MARR SATURN highway assignment models which are:

- AM Peak 0800-0900 peak hour
- Inter-peak 0930-1600 average hour (identical to A6MARR VDM)
- PM Peak 1700-1800 peak hour

5.4.4 Within SYSTRA's demand model home based travel demand is held by 'tour' which is defined as a combination of the from-home and to-home time period. Ten tours were modelled as shown in Table 2.

Table 2. Definition of Tours

		TO HOME PERIOD			
		AM Peak	Inter Peak	PM Peak	Off Peak
FROM HOME PERIOD	AM Peak	1	2	3	4
	Inter Peak		5	6	7
	PM Peak			8	9
	Off Peak				10

5.4.5 Linking the outward and return elements of home-based journeys to form tours preserves the integrity of the 'travel out, undertake activity, and travel back' sequence whereby response to policies and changes over time is on the basis of the revised total cost of travel for the outward (from home) and the return (to home) journeys combined. Tours modelling enables the effects of transport policies to be represented accurately and consistently across the whole day so that, for example, somebody who travels to work by public transport cannot return by car.

5.4.6 Non-home based movements are represented as one-way trips between origin and destination zones.

6. BASE YEAR TRAVEL DEMAND

6.1 Introduction

6.1.1 In this Chapter, we describe the processes that have been undertaken in developing and calibrating the demand matrices required for the A6MARR VDM system. These are:

- A6MARR highway SATURN assignment peak hour matrices;
- A6MARR highway SATURN assignment average hour matrices;
- A6MARR PT-TRIPS assignment average hour matrices; and
- A6MARR VDM car, PT and slow mode demand model period matrices.

6.1.2 The car matrices used in the VDM and assignment models have been developed as part of an integrated process, which was intended to ensure consistency. Similarly the public transport matrices in the VDM and PT assignment model were developed using an integrated process. The approach taken to calibrating the supply models in order to maximise consistency was:

- SYSTRA and TfGM HFAS jointly developed prior car matrices for both average and peak hour SATURN models;
- TfGM HFAS collated car and goods vehicle count data for peak and average hours;
- TfGM HFAS calibrated and validated the peak hour highway models;
- SYSTRA took the calibrated highway network, prior average hour matrices and average hour count set from TfGM HFAS and calibrated the AM and PM average hour highway models;
- SYSTRA calculated bus speeds from the calibrated average hour highway assignments for input to the PT-TRIPS models;
- SYSTRA developed the PT prior matrix, collated count data and calibrated and validated the PT models;
- SYSTRA processed the validated car and PT matrices for input to the VDM; and
- SYSTRA developed active mode matrices for input to the VDM.

6.2 A6MARR Highway SATURN Assignment Peak Hour Models

Matrix Building Overview

6.2.1 In 2009, TfGM HFAS was commissioned to build a SATURN model to provide traffic forecasts to inform the development of the business case for the A6MARR Relief Road. TfGM HFAS's LMVR of February 2012 provides a thorough description of the development and calibration of this model.

6.2.2 The SATURN model represents traffic movements in average weekday by road. Three separate time period models were developed:

- AM Peak 0800-0900 peak hour
- Inter-peak 0930-1600 average hour
- PM Peak 1700-1800 peak hour

6.2.3 The initial ('prior to matrix estimation') trip matrices constructed for the A6MARR SATURN assignment peak hour models for journeys to and from work were built using information from the 2001 National Census. For other purposes data was taken from roadside interview surveys (RIS) undertaken for A6MARR in October 2009 and for Hazel Grove in 2011, supplemented by other RIS undertaken since the completion of the final section of the M60 Manchester Outer Ring Road in October 2000. Other elements of the matrices were taken from synthetic matrices developed by SYSTRA.

6.2.4 The A6MARR RIS data was collected at 45 sites on screenlines or cordons near the proposed scheme in October 2009. The other roadside interview data was collected in phases over the period June 2001 to April 2004, with interviews being conducted with drivers of private vehicles crossing a series of screenlines and cordons within Greater Manchester.

6.2.5 Trip matrices were built for car, Light Goods Vehicles (LGV) and Other Goods Vehicles (OGV) trips. During matrix construction, observed PA information has been retained for all fully observed car trips, facilitating the construction of assignment demand matrices for the following 12 journey purposes:

- home to work;
- work to home;
- home to employers' business;
- employers' business to home;
- home to education;
- education to home;
- home to shop;
- shop to home;
- home to other;
- other to home;
- non home based employers business; and
- non home based other.

6.2.6 Constructing assignment matrices for these 12 journey purposes in OD format retaining the distinction between from home and to home trips enables matrices in PA format for use in the demand model to be readily derived. However, these 12 journey purposes were ultimately aggregated to many fewer user classes for use in the assignment models. Three user classes have been retained in the assignment model for car (commute, business and other). LGVs and OGVs have separate user classes, giving five user classes in total.

Prior Matrices

6.2.7 During early 2010, TfGM HFAS collated all the available data from the RIS, expanding the journey records to traffic counts and creating observed peak hour travel matrices. These peak hour matrices were converted to average hour matrices using peak hour to average hour conversion factors derived from the survey data. These matrices were then required 'infilling' for unobserved movements to provide a full representation of travel movements.

6.2.8 RIS cannot feasibly capture all the movements made across such a wide geographical area and therefore inevitably some movements remain wholly or partially unobserved. The approach to synthesising these movements is documented in a technical note produced in February 2012 which is reproduced in Appendix A. A gravity model is one of two methods suggested in the Design Manual for Roads and Bridges (DMRB) for in-filling trip matrices, the alternative being to in-fill using data from another (fully documented and validated) model. Unobserved movements in A6MARR have been estimated using a gravity model, as there is no other suitable model from which to obtain data. Synthetic demand estimates were produced through use of the following data sources and processes:

- population and land use data from National Statistics website;
- 2001 Census data and travel to work matrices;
- trip rates from GMATS Household Interview;
- gravity models based on distance and calibrated to give mean trip lengths suggested by Transport Statistics Great Britain.

6.2.9 These synthetic matrices were adjusted to ensure that the synthetic trip end estimates (which are consistent with land use data) and trip length distributions were maintained when the demands for observed and unobserved movements were combined.

6.2.10 The processes described above originally produced average hour assignment matrices at the 1084 zone system of A6MARR as it was in 2012. During early 2014, TfGM HFAS disaggregated the existing prior matrices where assignment zones were split to the south east of A6MARR to extend the SATURN model. The calibration and validation exercises described below were then repeated using the new prior matrices.

6.2.11 These matrices were then converted to peak hour demand matrices using average hour to peak hour conversion factors derived from the survey data.

6.2.12 TfGM HFAS created freight matrices using data from the RIS and from the Great Britain Freight Model (GBfMv5), developed by MDS Transmodal.

Matrix Estimation

6.2.13 Initial assignment validation statistics for the peak hour prior matrix assignment indicated that the validation fell short of DMRB guidelines for all time periods, as is commonly found. Matrix estimation was therefore used to enhance the prior trip matrices and improve the match between observed and modelled flows. The following sections describe the outcomes of the final calibration and validation of the peak hour SATURN assignment models.

6.2.14 Traffic counts for both assignment validation and matrix estimation were drawn from TfGM HFAS's count database and from data held by Cheshire East Council and Manchester Airport. The counts considered were mainly post-January 2008, excluding those affected by known 'special' events (eg, accidents, road works and holidays). The final calibration of the peak hour models selected 916 counts for matrix estimation and validation purposes of which 834 were used in the matrix estimation runs and 82 were used to provide an 'independent' (of ME) check on the calibrated model. The counts were factored to 2009 average October weekday values using locally developed factors.

6.2.15 A number of matrix estimation strategies were explored, using different combinations of counts and parameter values. The final matrix estimation strategy changed the size of the individual vehicle (pcu) matrices by between -2.9% and -0.6%. Changes of this magnitude were considered acceptable.

6.2.16 During early 2014, as part of the model update to extend the SATURN simulation coding to the south east of the scheme, a number of new counts were included in the matrix estimation process covering the High Peak region.

Assignment Validation

6.2.17 The SATURN model was validated by comparing modelled link flows and journey times with observed data across the A6MARR AoI, for the 2009 base year. In total, 72 cordons and screenlines were formed for the link flow validation within the AoI and Greater Manchester, whilst journey times were compared on 15 (two-way) routes covering key radials and orbitals crossing or parallel to the scheme. Percentages of calibration and validation counts that meet the DMRB criteria are summarised in Table 3 below.

Table 3. Calibration and Validation Overview (% of Links Meeting DMRB Criteria)

PERIOD	CALIBRATION	VALIDATION
AM	88%	71%
Interpeak	92%	80%
PM	89%	73%

Assignment Validation On Cordons and Screenlines

6.2.18 DMRB suggests that at least 85% of screenlines and cordons should have a GEH value of 4 or less. Considering the 15 calibration cordons and sceenlines in the Area of Influence together, the percentage with GEH values less than 4 is 69% in the AM peak, 94% in the inter peak and 78% in the PM peak.

6.2.19 The above figures show that the model meets DMRB criteria with regard to cordon and screenline validation.

Regression Analysis

6.2.20 TfGM HFAS undertook regression analysis to compare modelled and observed counts. The slopes of the regression lines and the R-squared values are within the guideline ranges specified in the DMRB for all time periods. DMRB indicates that the slope should fall between 0.9 and 1.1 and the R-squared should exceed 0.95.

Journey Time Validation

6.2.21 The primary source of journey time data for this validation was the TrafficMaster database.

6.2.22 The DMRB guideline for journey time validation is that modelled times should be within 15% (or 1 minute if this is higher) of the observed time on more than 85% of routes.

6.2.23 The percentages of routes within 15% of the observed time ranges are 93%, 98% and 93% in the AM peak hour, inter-peak hour and PM peak hour respectively. All three time periods comfortably meet DMRB criteria.

6.3 A6MARR Highway SATURN Assignment Average Hour Models

6.3.1 SYSTRA did not undertake matrix estimation on the average hour prior matrix until after TfGM HFAS had completed validation of the peak hour assignment models. Using final versions of the AM and PM peak network, prior matrix and count data ensured maximum consistency was maintained between the peak and average hour assignment models. SYSTRA's calibration of the average hour models consequently achieved comparable levels of validation to those TfGM HFAS's achieved for the peak hour models. Calibration and validation of the inter peak was not required for the average hour SATURN models since the inter peak is identical in both cases, i.e. the average hour of 0930 to 1600.

6.3.2 Limited origin/destination survey data were available for the off-peak period (1900 – 2300), as no RIS surveys were undertaken after 1900 and HIS does not contain the required origin/destination data. For this reason, the off-peak demand matrix was synthesised using local population and trip rate data, and gravity models in the same way unobserved movements in other time periods.

6.3.3 The average hour SATURN models were validated by comparing modelled link flows with observed data across the A6MARR AoI, for the 2009 base year. The same 72 cordons and screenlines were used for link flow validation of the average hour models as were used in the validation of the peak hour models.

6.3.4 In the AM and PM average hour models the percentages of all motorway and local road sites used in calibration of the average hour models which met DMRB validation criteria were 91% and 92% respectively. These results compare favourably with those for the peak hour models (88% and 89%), reflecting the lower level of traffic in the average hour models than the corresponding peak hour models.

6.3.5 For the independent count set as a whole, the percentage meeting DMRB criteria was 80% and 73% in the AM and PM average hours respectively. Again, these results were comparable with those for the peak hour models (71% and 73%).

6.4 A6MARR PT-TRIPS Assignment Average Hour Models

6.4.1 The development, calibration and validation of the PT-TRIPS assignment model is documented in SYSTRA's PT model validation report of February 2012. The primary sources of data for the PT model were those used to develop the SPM2-PT model for the TIF study. Passenger interview survey data dates from 2003/4 and provides information on travel into Manchester Regional Centre and other Greater Manchester town centres. Calibration and validation data such as passenger boarding, alighting and on-vehicle counts are of a similar vintage.

6.4.2 Within the AoI SYSTRA refined the SPM2-PT network representation, checked and revised bus and rail service coding, and introduced zoning which matched the A6MARR SATURN model.

6.4.3 SYSTRA re-built the PT demand matrix used for SPM2-PT in a manner that was consistent with the A6MARR highway matrices. As part of the matrix development we ensured that total trip making was consistent with land use data.

6.4.4 During April and May 2014, SYSTRA updated the post matrix estimation PT base year matrices to be consistent with the new, more disaggregate, zoning in the SATURN highway matrices. SYSTRA used the same splitting factors as were used by TfGM HFAS to split the highway matrices. The validation of the PT model was checked to ensure it still met the appropriate criteria. The updated model validation statistics are included below.

Matrix Development

6.4.5 The collection of new origin/destination data was not possible in the time available, nor warranted given the purpose of the model for the appraisal of a road scheme such as the proposed A6MARR link road. However, SYSTRA did approach Cheshire East Council to ascertain whether additional data were available to enhance the PT model in the AoI. No data were available.

6.4.6 The matrix development process was therefore based largely on the matrices developed for GMSPM2 and the SPM2-PT model. The following steps were implemented in the development of the A6MARR-PT matrices.

Step 1

- The following processes were adapted from those used in the matrix development of SPM2-PT, producing average hour matrices of observed public transport movements for each time period. In summary:
  - GMATS and M60 After origin / destination surveys were used to estimate trips in the observed direction (outbound from district centres and northbound across M60 After survey cordons) with expansion factors derived by TfGM HFAS;
  - GMATS and M60 After origin / destination surveys were transposed;
  - movements which were observed on more than one cordon or partially observed were identified using the network model;
  - an initial matrix for movements not captured by GMATS or M60 After origin / destination surveys was developed from available data (eg local origin / destination surveys, CAPRI data, Metrolink Ticket data, Census, etc);
  - matrices from GMATS / M60 data were combined with the infill matrix; and
  - matrix smoothing techniques were applied.
- The matrices represent "true" origin and destination. For example, in the case of a home-to-work trip consisting of a car access leg to a rail station and a public transport leg the origin is recorded as the home zone and the destination recorded as the workplace zone. A separate TRIPS process is implemented prior to assignment which modifies the matrices such that the origin zone in the above example will be re-allocated to the rail station.

Step 2

- synthetic demand matrices for all unobserved movements were created using Census data, observed trips rates and distributions developed from the 2001 Census Journey to Work data; and

Step 3

- the observed and synthetic matrices were combined to produce the initial average hour assignment matrices for input to the calibration of the public transport model.

6.4.7 The AoI trip ends were distributed using the Census travel to work matrix for all purposes, including for non-commute purposes. This was the most pragmatic solution to deriving robust prior matrices as quickly as possible. For most large buffer zones we wanted PT demand to be distributed mostly within the local area, and gravity models were liable to produce a large number of long distance PT trips (Sheffield to Liverpool etc. which is particularly unsuitable for purposes such as education). This could have been tempered by using a "stronger" parameter in the gravity model but it is not obvious how strong it would need to be or how such a parameter could be calibrated. Using the travel to work matrix therefore appeared more defendable in this scenario, given the purpose of the public transport model for this study and the timescales for model development.

6.4.8 As the data used to develop the A6MARR PT model are from 2003/4 and no data were available for the Cheshire East area SYSTRA does not consider the model to be suitable for appraisal of public transport measures. However, as it does provide an estimate of public transport demand SYSTRA consider that it is suitable for use in appraisal of a major road scheme, which is anticipated to have a modest impact on public transport use.

Model Validation

6.4.9 In general it is more difficult to establish patronage estimates by service or link for public transport than for road links, as for the latter continuous automated counts are often available. Therefore TAG suggests the following validation targets for comparison of modelled and observed passenger flows:

- modelled flows should be within 15% of the observed values on screenlines and cordons; and
- modelled flows should be within 25% of individual counts except where observed flows are less than 150 passengers.

6.4.10 The above targets are for public transport models that would be used in the assessment of public transport schemes. There are no such targets for public transport models used to facilitate a reasonable mode choice in the assessment of a highway scheme, such as A6MARR. The validation within the area of influence was the main focus, with the wider model validation a secondary concern.

6.4.11 A summary of the validation against the GMATS District Centre Cordon bus counts in the AoI (Altrincham and Stockport) is presented in Table 3 and Table 4. All modelled crossing flows are within 15% of observed total screenline crossing flows except for Stockport outbound PM and inbound IP which are only a few percentage points away from the target. The absolute numbers of passengers on the Altrincham cordon are low and therefore small differences in absolute numbers result in large percentage changes. This validation is greatly improved compared to the prior ME validation.

Table 4. Bus District Centre Cordons Screenline Summaries (AoI) after Matrix Estimation

	AM			IP			PM		
	Obs	Model	% Diff.	Obs	Model	% Diff.	Obs	Model	% Diff.
Outbound Cordon									
Altrincham	171	153	-10%	330	357	8%	559	515	-8%
Stockport	1757	1896	8%	1942	1802	-7%	2695	3124	16%
Inbound Cordon									
Stockport	2365	2619	11%	1960	1622	-17%	1624	1690	4%

Table 5. Bus Summary District Centre Cordons Individual Counts (AoI) after Matrix Estimation

	AM	IP	PM
Outbound Cordon			
No. links with >150 pax / hr	6	6	10
No. links with >150 pax / hr and difference <25%	4	5	8
% links with >150 pax / hr and difference <25%	67%	83%	80%
Inbound Cordon			
No. links with >150 pax / hr	8	7	4
No. links with >150 pax / hr and difference <25%	5	5	3
% links with >150 pax / hr and difference <25%	63%	71%	75%

6.4.12 The rail boarding and alighting validation in the area of influence is presented in Table 5. Modelled boardings and alightings are within 15% of observed counts in the majority of cases. The model has considerably more passengers modelled for Stockport than were observed in the surveys. However the counts used are from 2004, and were not uplifted to the model base year of 2009. Published data from the Office of the Rail Regulator indicate that passengers using Stockport increased by over 70% between 2004 and 2009, and therefore the observed data used in the validation may be too low. The ORR data could not be used directly in the validation because it is only available as total annual patronage.

Table 6. Rail Boarding and Alighting Validation (AoI) after Matrix Estimation

	AM			IP		
	Obs	Model	% Diff.	Obs	Model	% Diff.
Boardings						
Airport	315	287	-9%	358	298	-17%
Heald Green	204	193	-5%	56	47	-15%
Bramhall	99	96	-3%	35	28	-21%
Cheadle Hulme	323	322	0%	56	68	22%
Davenport	117	114	-3%	22	21	-7%
Woodsmoor	71	64	-10%	18	12	-32%
Stockport	1009	1891	87%	349	622	78%
Total	**2138**	**2967**	**39%**	**894**	**1096**	**23%**
Alightings						
Airport	450	405	-10%	259	219	-15%
Heald Green	46	49	6%	30	27	-11%
Bramhall	8	9	16%	11	10	-6%
Cheadle Hulme	85	114	34%	29	43	50%
Davenport	23	20	-11%	13	11	-19%
Woodsmoor	18	16	-12%	9	2	-76%
Stockport	671	1658	147%	257	541	111%
Total	**1301**	**2271**	**75%**	**608**	**854**	**40%**

6.4.13 The summary presented in Table 6 shows that for the larger stations with over 150 passengers per hour 60% of modelled flows are within 25% of observed passengers which is a large improvement from the prior to matrix estimation case (10%).

Table 7. Rail Boarding and Alighting Summary (AoI) after Matrix Estimation

	AM	IP
Boardings		
No. Stations with boardings >150 pax / hr	4	2
No. Stations with boardings >150 pax / hr and difference <25%	3	1
% Stations with boardings >150 pax / hr and difference <25%	75%	50%
Alightings		
No. Stations with alighting >150 pax / hr	2	2
No. Stations with alighting >150 pax / hr and difference <25%	1	1
% Stations with alighting >150 pax / hr and difference <25%	50%	50%

6.4.14 Table 7 presents the Metrolink boarding and alighting validation within the area of influence. Prior to ME, at a summary level, the modelled patronage is of the right order of magnitude, however, at a detailed level, some station's modelled patronage are significantly different from observed data. Table 8 presents the summary Metrolink validation for stations with larger passenger flows and shows that overall 73% of these have modelled flows within 25% of the observed values showing an improvement over the prior ME case (64%).

Table 8. Metrolink Boarding and Alighting Validation (AoI) after Matrix Estimation

	AM			IP			PM		
	Obs	Model	% Diff.	Obs	Model	% Diff.	Obs	Model	% Diff.
Boardings									
Altrincham	361	346	-4%	208	200	-4%	369	359	-3%
Navigation Road	100	186	86%	31	44	42%	34	70	107%
Timperley	251	279	11%	135	74	-45%	131	55	-58%
Brooklands	418	284	-32%	84	47	-43%	91	58	-36%
Sale	104	480	362%	87	185	112%	148	172	16%
Dane Road	38	115	200%	35	32	-8%	77	18	-77%
Total	**1273**	**1691**	**33%**	**580**	**583**	**1%**	**850**	**732**	**-14%**
Alightings									
Altrincham	487	467	-4%	158	177	12%	306	332	9%

Navigation Road	33	53	61%	23	34	48%	79	141	77%
Timperley	105	40	-62%	115	67	-42%	287	126	-56%
Brooklands	64	24	-62%	60	50	-15%	265	289	9%
Sale	165	116	-30%	73	134	84%	109	336	209%
Dane Road	95	29	-69%	50	34	-32%	97	70	-28%
Total	**948**	**730**	**-23%**	**478**	**496**	**4%**	**1142**	**1294**	**13%**

Table 9. Metrolink Boarding and Alighting Summary (AoI) after Matrix Estimation

	AM	IP	PM
Boardings			
No. Stations with boardings >150 pax / hr	3	1	1
No. Stations with boardings >150 pax / hr and difference <25%	2	1	1
% Stations with boardings >150 pax / hr and difference <25%	67%	100%	100%
Alightings			
No. Stations with alighting >150 pax / hr	2	1	3
No. Stations with alighting >150 pax / hr and difference <25%	1	1	2
% Stations with alighting >150 pax / hr and difference <25%	50%	100%	67%

6.5 A6MARR VDM Demand Model Matrices

Forms of Trip Matrices

6.5.1 Travel demand matrices within A6MARR VDM are held in two alternative ways. The highway and PT assignment models contained within A6MARR VDM operate with travel demand held in OD format. Each trip in the OD matrix describes a one-way journey from the place the trip commences to the place the trip finishes. These matrices have been constructed primarily from survey data and are held by purpose and time of day of travel.

6.5.2 In the demand model, home based demand is held in tour format (TAG Unit M2, 2.5), which is an extension of the PA format where there is a further segmentation by from- and return-home time period. Home based trips are trips where the home of the trip maker is either the origin or the destination of the trip. Non home based trips are trips where neither end of the trip is the home of the trip maker. Trip production is defined as the home end of a home based trip or the origin of a non home based trip. Trip attraction is defined as the non home based end of a home based trip or the destination of a non home based trip.

6.5.3 Storing demand in PA or tour format is of primary importance when producing forecasts of future year travel patterns as changes in residential and employment locations are likely to be very different. Residential property is by definition the key driver of trip productions whereas employment, educational establishments, retail floorspace, etc are the key drivers of trip attractions. Particular attention has been given within A6MARR VDM to the modelling of Manchester Airport, which is the single most significant attractor within the AoI of the A6MARR scheme.

6.5.4 Using demand matrices held in tour format within the demand model whilst operating with demand held in OD format within the assignment models necessitates making a conversion between tour and OD formats. This conversion is undertaken after the demand model has been run and before assignment in each demand/supply loop of A6MARR VDM.

6.5.5 Use of the tour format simplifies the conversion of PA matrices to OD. The tour is broken into its constituent from-home and to-home trips, the to-home trip transposed and the trips combined into the respective OD trip time period matrices. For car demand a conversion from number of persons to number of vehicles is made using vehicle occupancy data derived from the TAG Data Book.

6.5.6 In contrast, demand models which use PA rather than tour matrices require PA to OD conversion factors to be defined disaggregated by time of day and trip purpose. These factors are typically assumed to remain unchanged over time, which is unlikely to be the case in reality.

6.5.7 Following assignments, OD trip costs are used to create tour costs for use in the demand model. This simply entails summing the cost of a trip from P-to-A in the outbound time period and A-to-P in the return-home time period.

Development of Tour Matrices

6.5.8 The main sources of data for creating tour matrices for the VDM were the SATURN highway and PT-TRIPS public transport validated average hour assignment matrices. These were disaggregated into the required purpose, household car availability and tour categories.

6.5.9 Conversion to tour requires the calculation of return home probability (RHP) and leave home probability (LHP) factors. RHPs are the proportions of trips which leave home in each time period that return in another. An example of RHP factors is presented in Table 9. Note that each row does not necessarily sum to 100% as trips may return after the off-peak period or on the following day. These trips were relatively few and were discarded.

Table 10. Example of Return Home Probabilities for a Commute Segment (NB 54% of demand leaving home in the PM peak is assumed to return home the next day)

		TO HOME PERIOD			
		AM Peak	Inter Peak	PM Peak	Off Peak
FROM HOME PERIOD	AM Peak	1%	15%	78%	6%
	Inter Peak		11%	40%	38%
	PM Peak			10%	36%
	Off Peak				10%

6.5.10 RHPs are applied to the calibrated from-home matrices and LHPs to the to-home matrices in order to estimate tour demand. This gives two different estimates of the home based matrices in tour format, each of which has half of the demand (either the return home legs, or the from home legs) synthesised by the probabilities. This means that when either set of tour matrices are converted back into OD trip format the calibrated OD matrices will not be recovered exactly. A process was developed to minimise this difference to ensure consistency between the OD and PA matrices, which is important when demand changes from the PA demand model matrices are applied to the OD assignment matrices.

6.5.11 This process involved creating a third set of tour matrices, which were calculated as a cell by cell average of the two sets calculated from the RHPs and LHPs. The three sets of tour matrices were then converted back into OD trip format and regression analysis was carried out between these and the original OD calibrated matrices. Based on the results of these regressions, the final tour matrices were built up by selecting the elements of the three versions which led to the best correlation with the original calibrated matrices. For example, car trips in tour 2 (out in the AM peak, return in the inter peak) were taken from the RHP matrix, PT trips in tour 6 (out in the inter peak, return in the PM peak) were taken from the average matrix, etc.

6.5.12 The return and leave home probability factors were calculated using data from the GMATS HIS data for the GM-TIF models using the process summarised below:

- HIS trip records were expanded using factors supplied by TfGM HFAS;
- home-based trips were grouped into sets of trips in chronological order between visits to home for each respondent;
- from-home and to-home trips were separated;
- corresponding from-home and to-home trips with the same attraction were matched;
- time periods were assigned to each record;
- trips were summed over O-D retaining segmentation by mode, purpose, car availability, forward time period, and return time period; and

- RHP and LHP factors were calculated for each combination of mode, purpose, car availability, forward period, and return period.

Segmentation of Demand by Household Car Availability

6.5.13 Demand matrices were segmented by household car availability for all purposes. Household car availability splitting factors were derived using data from GMATS. The resultant split between car available and no car available demand is show in Table 11.

Table 11. Car Availability Proportions by Mode

CAR AVAILABILITY	TRIPS	SHARE
CAR		
No car available	946,343	4%
Car available	22,072,476	96%
PUBLIC TRANSPORT		
No car available	1,571,935	49%
Car available	1,638,222	51%
ACTIVE MODES		
No car available	4,401,529	39%
Car available	6,848,154	61%
ALL MODES		
No car available	6,919,807	18%
Car available	30,558,852	82%

7. DEMAND MODEL PROCESSES

7.1 Introduction

7.1.1 This chapter discusses the functionality of the demand model in more detail. The demand model component of A6MARR VDM implements a hierarchical logit formulation, providing a choice set of travel responses containing the alternatives of destination, mode and macro time of day. The demand model utilises SYSTRA's bespoke demand model software, which is written in the C# programming language interfacing with a SQL Server database.

7.1.2 As shown in Figure 2.2 the demand model is integrated with SATURN and PT-TRIPS assignment models. Following each run of the demand model the reference case SATURN and PT-demand matrices are adjusted, reassigned and cost skims are fed back to the next run of the demand model. This process iterates until supply and demand are in equilibrium.

7.1.3 This chapter is structured under the following headings:

- input demand matrices and the role of the VDM;
- demand model functional form;
- generalised costs; and
- supply and demand model interface.

7.2 Input Demand Matrices and the Role of the VDM

7.2.1 The demand matrices input to A6MARR VDM represent a 'reference case' future year forecast reflecting changes in zonal demographics such as population, jobs and car availability. These reference case forecasts reflect a situation where the generalised costs of travel are identical to the generalised costs in the base year.

7.2.2 Demand for new developments is included in the reference case matrix. Development related demand is estimated by applying trip rates to estimates of population or floorspace and using either a gravity model to distribute trips or copying a distribution from nearby zones with similar land used. The process of forecasting reference case matrices is documented in the A6MARR Forecasting Note (SYSTRA, October 2014).

7.2.3 A6MARR VDM then modifies these reference case matrices to account for changes in generalised cost relative to the base which will result from changes to the components of generalised cost (see Table 12 later), values of time and vehicle operating costs.

7.2.4 Base year generalised costs are calculated by running the VDM in 'base model' mode which simply produces a reference set of costs for travel movements that are in equilibrium without applying any demand changes.

7.3 Demand Model Functional Form

Hierarchical Logit Formulation

7.3.1 The demand model component of A6MARR VDM represents the demand for travel using a mathematical mechanism which reflects how demand will change as costs change. The mathematical mechanism used in A6MARR VDM is a hierarchical logit formulation. The logit mechanism is applied in an incremental form, which predicts changes in demand (relative to a base case) as a function of changes in travel costs. However, an issue occurs with this approach in forecasting when a zone is redeveloped or has no trips it in the base situation. For new developments travel patterns are synthesised exogenously in the trip generation stage.

7.3.2 The travel responses included in the demand model are:

- macro time of day of travel;
- which travel mode to use (car, public transport or walk/cycle); and
- where to travel to (distribution).

7.3.3 The relative sensitivity of these responses to changes in generalised cost is as recommended in TAG with destination choice more sensitive than mode choice, which in turn is more sensitive than macro time of day choice (see Figure 6).

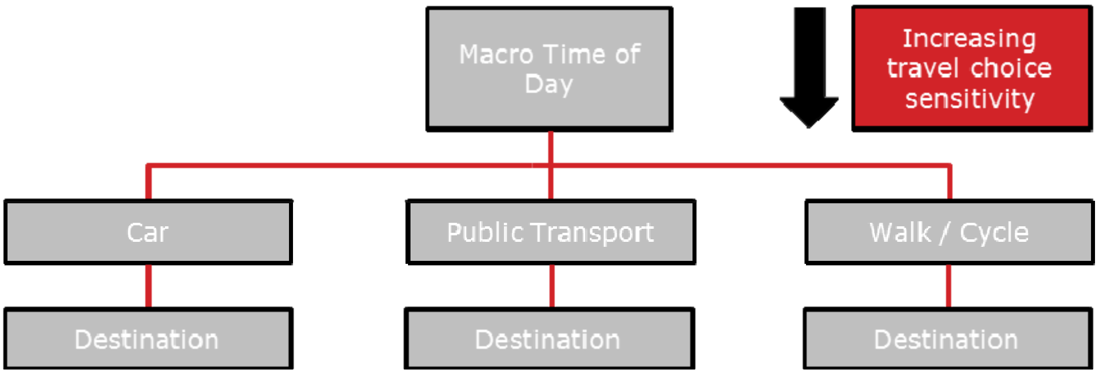

Figure 6. Demand model travel choice hierarchy

Mathematical Form

7.3.4 Appendix E of TAG Unit M2 describes how the incremental hierarchical logit model can be specified. The standard incremental multinomial logit model, implemented in A6MARR VDM, is given by the following equation:

$$p_i = \frac{p_i^0 \exp(\theta \Delta U_i)}{\sum_j p_j^0 \exp(\theta \Delta U_j)}$$

- p_i is the forecast probability of choosing alternative i;
- p_i^0 is the reference case probability of choosing alternative i (calculated from the input reference demand);
- θ is the scaling parameter (θ = 1 for the most sensitive level of the hierarchy and 0 ≤ θ ≤ 1 for less sensitive choices); and
- ΔU_i is the change in the utility of alternative i.

7.3.5 For the choice at the most sensitive level of the hierarchy the simplest form for a change in utility is given by:

$$\Delta U_i = \lambda (C_i - C_i^0)$$

- C_i is the forecast generalised cost, skimmed from the latest assignment;
- C_i^0 is the reference generalised cost; and

- λ is the spread or dispersion parameter; it should be negative.

7.3.6 For the choices above the most sensitive level of the hierarchy the change in utility is the composite change over the alternative in the level below calculated using the logsum formula:

$$\Delta U^* = \ln \sum_i p_i^0 \exp(\Delta U_i)$$

Double Constraint of Demand

7.3.7 As recommended in TAG M2, 4.9.3, the destination choice model for travel to work demand is doubly-constrained, whereas demand for other purposes is only singly (production-end) constrained. It is common to use doubly-constrained models for forecasting commuting, so that each zone attracts and generates a fixed total of work trip ends, and singly-constrained models for other purposes, where only the total number of trips produced from each zone is fixed, using the techniques described below.

Goods Vehicles Demand Responses

7.3.8 Changes in good vehicle demand are input to the model as exogenous forecasts such as the National Transport Model. No demand responses are modelled in A6MARR VDM for goods vehicles, although there is route choice within the A6MARR SATURN model.

Manchester Airport

7.3.9 Demand responses for trips associated with Manchester Airport have been restricted to mode choice only. Changes in generalised costs of travel are unlikely to strongly affect the choice of airport or the time of day of travel to the airport. These choices will be much more strongly determined by flight schedules and costs. In particular it was necessary to avoid re-distributing air passenger journeys to the airport to non-airport zones.

7.3.10 Restricting demand responses for Airport journeys has been achieved by doubling the number of demand segments, and allocating all trips to or from the airport to the additional demand segments.

7.4 Generalised Costs

Generalised Cost Formulation

7.4.1 Generalised costs used in the demand model are calculated by summing the monetary cost and time elements (Table 12) that are extracted from the assignment models. OD matrices of cost elements are calculated in the supply models and converted to 2-way tour matrices for use in the demand model.

Table 12. Components of Generalised Cost

CAR	PUBLIC TRANSPORT	WALK / CYCLE
Time	Walk time	Time

Fuel Cost (all segments)	Wait time	
Non-fuel operating cost (employers' business only)	In vehicle time	
Road user charges	Fare	
	Boarding and interchange penalty	

7.4.2 Monetary values of cost are converted to units of time using values of time, which are input to the demand model disaggregated by demand segment. Values of time for use in A6MARR VDM demand segments have been derived from values given in the TAG Data Book. Walk and wait time factors, and boarding and interchange penalties were calibrated as part of the PT model development and are documented in its validation report.

7.4.3 A6MARR VDM provides a facility to modify the generalised costs to reflect user perceptions that are not directly related to measurable time and money costs of travel, as calculated in the assignment models. This facility has proved useful in previous applications as a means to reflect improvements to interchanges, public transport vehicle quality and cleanliness, passenger information, marketing, etc. These adjustments can be varied by zone pair, time period and mode and have been used in the past to reflect improvements to station interchanges, for example, within future year forecasts by reducing generalised cost for all OD pairs which would use the interchange.

Values of Time

7.4.4 Values of time for inclusion in the demand model have been derived using data from the TAG Data Book. Values of time for each demand segment used for car, public transport and slow mode travel are shown in Table 13. As part of the model update during 2014, values of time have been updated from 2002 prices to 2010 prices to be consistent with the TAG Data Book.

Table 13. Values of Time by Demand Segment (£/hr, 2009 Values and 2010 Prices)

PURPOSE	VALUE OF TIME (£ / HR)
Commute	6.75
Business	22.55
Other	5.99

7.4.5 Values of time used for goods vehicles are shown in Table 14.

Table 14. Freight Values of Time (£/hr, 2009 Values and 2010 Prices)

FREIGHT CATEGORY	VALUE OF TIME (£ / HR)
Light goods	10.15

Other Goods	11.95

Vehicle Operating Costs

7.4.6 Vehicle operating costs for input to the demand and assignment models were derived by TfGM HFAS using the TAG Data Book and coded into the SATURN assignment networks. Base year values were input to the models in 2009 values and 2010 prices and are shown in Table 15.

Table 15. Vehicle Operating Costs (pence/minute, 2009 values and 2010 prices)

PURPOSE	AM PEAK	INTER PEAK	PM PEAK
Car Commute	6.8	6.5	6.8
Car Business	14.6	13.7	14.5
Car Other	6.8	6.5	6.8
Light Goods	15.4	14.9	15.3
Other Goods	48.4	44.9	48.3

Cost Damping

7.4.7 TAG Unit M2, 3.3 references evidence from Daly (2008) that suggests the sensitivity of demand responses to changes in generalised cost reduces with increasing trip length. We have included a representation of this variation to ensure that A6MARR VDM meets the requirements of the realism tests as specified in TAG Unit M2. By way of example, it seems unreasonable that a cost change of 3 minutes should have similar demand effects for a journey of 30km as for a journey of 150km.

7.4.8 The form of cost damping implemented in A6MARR VDM is damping of generalised cost as a function of distance. It has been applied to all person demand responses, identically for different modes and purposes. Therefore, factors are applied to damp cost differences in the model depending on their trip length. These factors are simply applied to the calculated costs differences (forecast – base). SYSTRA has implemented the damping function given in Unit M2, 3.10.2, 3.3.5 and given below.

$$g' = (d/k)^{-\alpha}.(t + c/v)$$

Where:

t, c	are the trip time and money cost, respectively;
v	is the value of time;
(t+c/v)	is the generalised cost;
g’	is the damped generalised cost;
d	is the trip length; and
α, κ	are parameters that need to be calibrated.

7.4.9 A6MARR VDM applies a minimum distance cut-off, below which the cost damping does not apply. The purpose of such a cut-off is to prevent short-distance trips, particularly intrazonal, becoming unduly sensitive to cost changes.

7.4.10 The parameter values given in TAG Unit M2, 3.3.10 of $\alpha=0.5$, $\kappa=30$ were shown to be appropriate for use in A6MARR VDM as part of the calibration process described in the following chapter.

7.5 Supply and Demand Model Interface

7.5.1 As discussed in the previous section generalised costs extracted from the supply models are input to the demand model. In the opposite direction, changes in travel demand predicted by the demand model are applied to the input demand matrices.

Applying Demand Changes

7.5.2 Forecasts of highway and PT assignment OD trip demand are derived by making adjustments to the validated base year assignment matrices, reflecting differences between the forecast demand model tour matrices and the equivalent base demand model tour matrices. This can be described as a ‘pivot’ and ‘adjusted’ model system (see Figure 7).

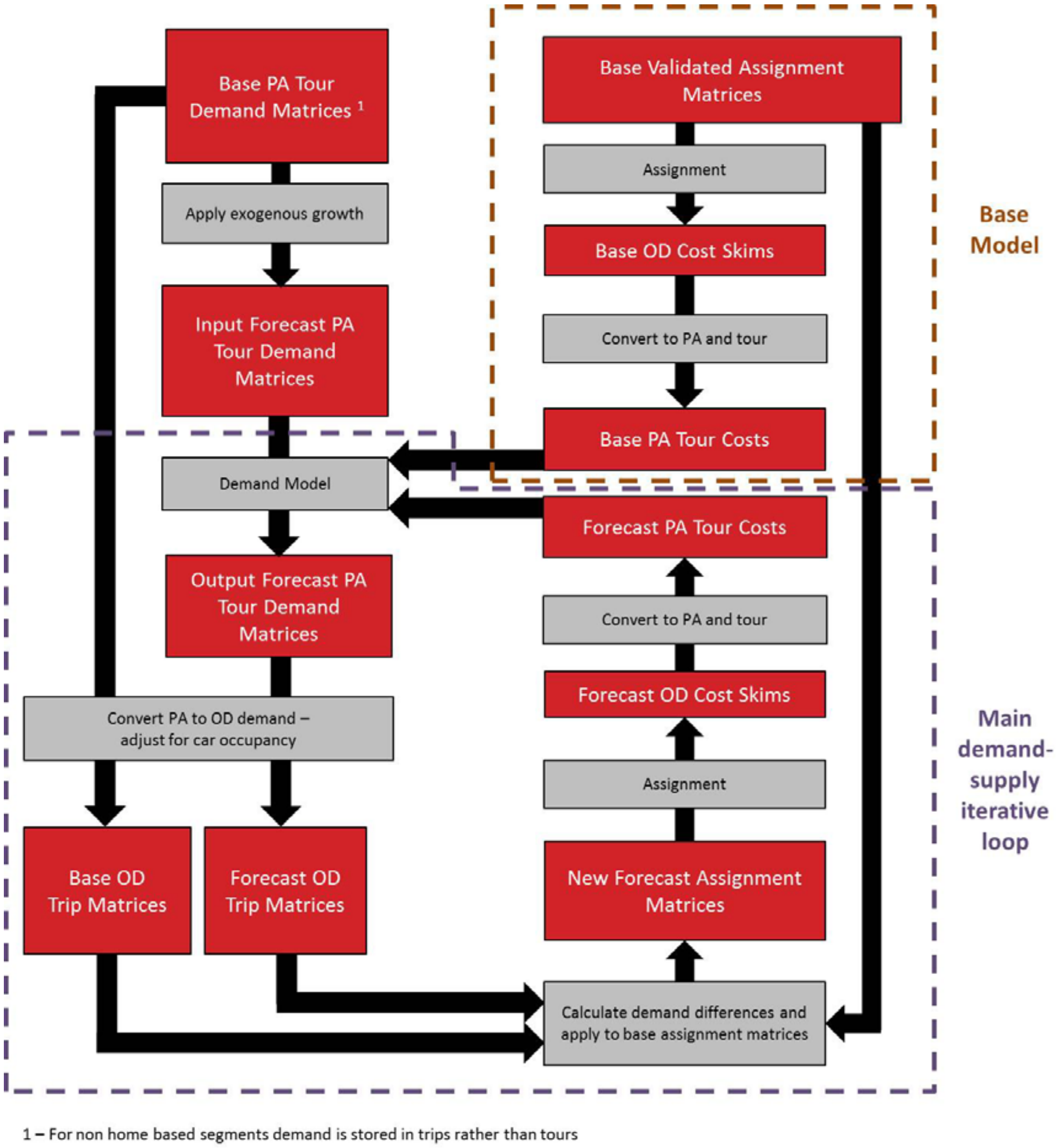

Figure 7. A6MARR VDM 'Pivot' and 'Adjusted' Model System

7.5.3 Adjustments to the validated base year assignment matrices could be made through either an additive or proportional approach. However, as recognised by TAG, problems can occur with both of these methods for certain parts of the matrix in situations where there is insufficient consistency between the demand model and the assignment matrices. This scenario is most apparent for new developments for which no representative travel patterns exist in the base matrices, where a proportional growth approach would not be appropriate.

7.5.4 The adjustment method used in A6MARR VDM is primarily additive, although further growth factor constraints are applied to the row and column trip ends, and finally to the whole matrix total. Applying a fundamentally additive approach enables travel patterns associated with new developments, which are explicitly input to the demand model matrices during the trip generation stage, to be properly reflected in the assignment matrices.

7.5.5 The full method of applying demand changes from the demand model matrices to the assignment matrices can be described as follows:

- calculate the difference between the forecast and base VDM matrices (by zone-pair);
- convert the VDM difference from period to hour (using a period to hour factor);
- add the VDM difference to the assignment matrix;
- if the ratio of forecast VDM to base VDM growth is less than 2 (at the trip end level) the algorithm assumes that the zone is not a new development area and applies a correction factor at the trip end level to match the proportional growth in the VDM (this step is designed to retain overall consistency between proportional changes in land use assumptions and proportional changes in assignment matrices);
- if the ratio of forecast VDM to base VDM growth is greater than 2 (at the trip end level) the algorithm assumes that the zone is a new development area and no correction factor is applied so that the change in demand for the zone is consistent with the proposed land use changes; and
- adjustment factors are applied across whole matrix by time period and userclass to ensure total matrix growth matches that of the VDM.

7.5.6 This method is adjusted slightly for Manchester Airport as a special case, since the demand in the VDM is aggregated into a single zone whereas demand in the assignment matrices is split between all zones, making an additive approach inappropriate. In this case the total demand growth is spread equally across the assignment zones which represent the terminal car parking zones, whilst those zones representing the terminal buildings themselves, i.e. pick up and drop off areas, are left equal to their base year values, to reflect MAG's intention to discourage use of these areas. This approach was agreed with Atkins and TfGM HFAS during the previous round of forecasts known as Test Run 1 (TR1).

7.5.7 Once the VDM system has iterated to convergence using the average hour assignment models, a final step is needed to apply demand changes from the VDM to the validated *peak* hour assignment matrices in order to create the forecast peak hour matrices which are used in the economic appraisal. These matrices are created using the same algorithm as described above, however the additive demand changes from the VDM are converted from average hour to peak hour using factors before being added to the base matrices.

Bus Speeds

7.5.8 The model system also has interfaces between the SATURN and PT-TRIPS models to pass highway speeds to the public transport model so that bus speeds vary with the highway speed, and to allow bus flows to impact on highway network performance. Link speeds in the time period PT-TRIPS public transport models are updated with those calculated in the respective SATURN highway assignments each time the supply components of the system are run. The highway network speeds are multiplied by a factor of 0.8 to reflect the fact that buses generally run slower than cars due to stopping at bus stops.

7.6 Iteration and Convergence

7.6.1 A6MARR VDM runs iteratively until it reaches equilibrium between the supply and demand components. After each run of the demand model, demand adjustment factors are calculated and applied to the SATURN highway and PT-TRIPS public transport base year demand matrices for reassignment.

7.6.2 Cost skims taken from the SATURN highway and PT-TRIPS public transport models are input to the demand model. The method of successive averages (MSA) is used to combine costs from successive demand/supply loops in order to hasten convergence (TAG Unit M2, 6.2.7). MSA is formulated as follows:

$$C_n' = \frac{1}{n}C_n + (1 - \frac{1}{n})C_{n-1}$$

where:

n is the loop number

C_n' is the average cost

C_n is the cost from the supply model for loop n

C_{n-1} is the cost from the supply model for loop n-1

7.6.3 The process ends when the convergence criteria are achieved. The convergence criteria are set with reference to the DfT %Gap statistic (TAG Unit M2, 6.3), which states that a value of 0.2% should be achieved. %Gap is defined as follows:

$$\%GAP = \frac{\sum_{ijctm} C(X_{ijctm}) \left| D(C(X_{ijctm}) - X_{ijctm} \right|}{\sum_{ijctm} C(X_{ijctm})\, X_{ijctm}} \times 100$$

where:

the index combination *ijctm* denotes a particular combination of origin zone *i*, destination zone *j*, demand segment *c*, time period *t* and mode *m*;

X_{ijctm} is the previous outer loop's set of trip matrices, in OD format, that are used by the assignment models;

$C(X_{ijctm})$ is a matrix of generalised costs derived from an assignment of the demand produced by the previous loop; and

$D(C(X_{ijctm}))$ is the current trip matrix, which results from running the demand model with the updated costs.

8. DEMAND MODEL CALIBRATION

8.1 Introduction

8.1.1 In Chapter 6 we described the key processes contained within the A6MARR VDM demand model. This chapter documents the model parameters that have been applied, how those parameters have been selected and how the fitness-for-purpose of the model has been established. The chapter is structured under the following headings:

- model calibration using illustrative parameters; and
- realism testing.

8.2 Model Calibration Using Illustrative Parameters

8.2.1 TAG Unit M2, 5.1 suggests three alternative approaches to choosing the parameter values that control the travel responses:

- use local data to calibrate parameter values;
- use parameter values obtained from other local models; or
- use 'illustrative' parameter values based on general modelling experience.

8.2.2 SYSTRA ruled out using local data to calibrate parameter values for A6MARR VDM due to timescale and cost. No other model was considered sufficiently similar in geographical coverage, demand segmentation and/or functionality to permit parameter values to be transferred to A6MARR VDM. The median 'illustrative' parameters provided in TAG Unit M2 were therefore taken as the starting point for the demand model calibration.

8.2.3 TAG Unit M2, 5.6.3 states that 'whatever [parameter] values are selected, whether from local knowledge or based on the illustrative values, it is essential to conduct 'realism tests' … to ensure that the actual behaviour of the model against variation in travel times and costs accords with experience'. In our view it is vital that a model achieves an appropriate level of model responsiveness, described in terms of the outturn elasticity values of the realism tests.

8.2.4 A check has been made that the incremental model does indeed forecast no change in demand from the base for no change in costs.

TAG Illustrative Spread Parameters

8.2.5 A set of illustrative spread parameters are given in TAG for use with the utility function presented in Chapter 4 on the basis that destination choice is more sensitive than mode for all travel purposes (TAG Unit M2, Table 5.1). These parameters are reproduced in Table 16 below.

Table 16. TAG Destination Choice Sensitivity Parameters

TRIP PURPOSE & MODE	MINIMUM	MEDIAN	MAXIMUM
Car			
Home-Based Work	-0.054	-0.065	-0.113

Home-Based Employers Business	-0.038	-0.067	-0.106
Home-Based Other	-0.074	-0.090	-0.160
Non-Home Based Employers Business	-0.069	-0.081	-0.107
Non-Home Based Other	-0.073	-0.077	-0.105
Public Transport			
Home-Based Work	-0.023	-0.033	-0.043
Home-Based Employers Business	-0.030	-0.036	-0.044
Home-Based Other	-0.033	-0.036	-0.062
Non-Home Based Employers Business	-0.038	-0.042	-0.045
Non-Home Based Other	-0.032	-0.033	-0.035

TAG Illustrative Scaling Parameters

8.2.6 Similarly, TAG provides illustrative scaling parameters which describe the sensitivity of main mode choice relative to destination choice. These are shown in Table 17. Consistent with destination choice being more sensitive than main mode choice, the main mode choice scaling parameters are all less than or equal to one.

Table 17. TAG Main Mode Scaling Parameters

TRIP PURPOSE	MINIMUM	MEDIAN	MAXIMUM
Home-Based Work	0.50	0.68	0.83
Home-Based Employers Business	0.26	0.45	0.65
Home-Based Other	0.27	0.53	1.00
Non-Home Based Employers Business	0.73	0.73	0.73
Non-Home Based Other	0.62	0.81	1.00

8.2.7 TAG does not explicitly provide parameters for use with macro time of day response. However, TAG Unit M2, 5.6.17 suggests that macro time of day response should be about the same as main mode choice. We have therefore included macro time of day response with a scaling parameter of 1.

8.3 Realism Testing

8.3.1 Model calibration has concentrated on calibrating the response to three tests:

- increasing fuel costs by 10%;
- increasing PT fare by 10%; and
- increasing car journey time by 10%.

8.3.2 The outturn elasticity values that TAG suggests should be achieved from these tests are fuel price elasticity between -0.25 and -0.35 (car-kms with respect to fuel price), with commute trips being less elastic than the more discretional purposes. The suggested medium term PT fare elasticity value should be in the range -0.2 to -0.9 (PT trips with respect to fare). Car travel time elasticities should be no stronger than -2. Elasticities have been measured using an arc formulation as recommended in TAG Unit M2:

$$e = \frac{\ln(d^1 / d^0)}{\ln(c^1 / c^0)}$$

where d^1 and d^0 represent demand in base and test scenarios, and c^1 and c^0 represent corresponding costs.

8.3.3 Calibration was undertaken in a structured fashion as follows:

- Test 1. Realism tests were run using the illustrative parameters, but without iterating the demand model. As recommended in TAG Distance Based Cost Damping (DBCD) was not used in Test 1. This gave a quick indication of how closely the model, with the illustrative parameters, would reproduce the target elasticities. The impact of converging the model system on parameters was established in a later step.
- Test 2. DBCD was introduced.
- Test 3. The VDM was run to convergence.
- Test 4. Adjustments were made to the parameters, within bounds recommended by TAG, in order to reproduce the target elasticities.

8.3.4 Appendix B presents the parameters and the elasticity values resulting from each of these tests as they were run for the previous version of A6MARR VDM. For the latest model update in 2014, the base year demand and supply was not extensively rebuilt or changed from the previous version of the model. Existing matrices were split where new zones were added and the values of time and vehicle operating costs were updated to reflect the latest TAG guidance. It was therefore appropriate to carry through the final set of model sensitivity parameters as used in the previous version of the model. The justification for these values is included in Appendix B and the values are replicated in Table 18 below. The lambda values quoted in TAG for home based purposes are halved for use in the A6MARR VDM. This is because 2-way tour costs are input to the VDM which will be approximately twice the value of 1-way costs which are assumed in TAG.

8.3.5 The realism tests were repeated using these existing values and the outturn elasticities are reported in Table 19. The final fuel price elasticity value aggregated over all purposes for the whole model was -0.27 and PT fare elasticity was -0.44.

8.3.6 Since these elasticities are very similar to previous versions of the model, show the expected relationships between purposes and time periods, and fall within the bounds specified in TAG, no further calibration of the demand model was deemed necessary for the updated version of the model. This outcome has the advantage of ensuring consistency between the different tranches of work on A6MARR over the life of the project.

8.3.7 As anticipated, elasticity values for both fuel price and PT fare are higher in the off-peak than other time periods due to the higher proportion of discretionary trips in this period.

Elasticity values in the inter peak are also slightly lower than in the peaks for the same reason.

8.3.8 Fuel elasticities for employer's business trips are close to zero. This is because the increase in fuel cost is a greater deterrent for the commute and other purposes, which have lower values of time than employers business and therefore the vehicle operating cost is a higher proportion of the total generalised cost. The resulting reduction in congestion and hence journey time counteracts the fuel cost rise for business travellers since the journey time element of the generalised cost is much more significant.

Table 18. Final Parameters Input to A6MARR VDM Demand Model (red values have been adjusted away from the median TAG values)

PURPOSE	LOGIT MODEL PARAMETERS				
	LAMBDA VALUES (Λ)			SCALING PARAMETERS (Θ)	
	CAR DEST'N	PT DEST'N	WALK/CYCLE DESTINATION	MODE	MACRO TIME
HB Commute	-0.0270	-0.0165	-0.0325	0.68	1
HB Employers Business	-0.0335	-0.0180	-0.0335	0.45	1
HB Other	-0.0563	-0.0225	-0.0450	0.53	1
NHB Employers Business	-0.0810	-0.0420	-0.0810	0.73	1
NHB Other	-0.0963	-0.0330	-0.0770	0.81	1

Table 19. Test 4 Fuel Price and PT Fare Realism Test Results

PURPOSE / TIME PERIOD	TEST 4: FINAL PARAMETERS, COST DAMPING (A=0.5, K=30,D'=30 KM), CONVERGED DEMAND MODEL			
	CAR FUEL VEHICLE KM ELASTICITY VALUES		PT FARE TRIP ELASTICITY VALUES	
	TO/FROM/WITHIN AOI	WHOLE MODEL	TO/FROM/WITHIN AOI	WHOLE MODEL
By Purpose				
HB Commute	-0.35	-0.27	-0.47	-0.39
HB Employers Business	-0.05	-0.02	-0.25	-0.19
HB Other	-0.53	-0.31	-0.60	-0.46
NHB Employers Business	-0.05	-0.02	-0.37	-0.37
NHB Other	-0.39	-0.30	-0.60	-0.55
By Time Period				
AM	-0.35	-0.23	-0.52	-0.43

IP	-0.40	-0.26	-0.54	-0.45
PM	-0.39	-0.25	-0.53	-0.43
OP	-0.52	-0.36	-0.71	-0.57
All	**-0.41**	**-0.27**	**-0.54**	**-0.44**

8.3.9 Table 20 shows the PT fare elasticity values disaggregated by household car availability category. TAG M2, 6.4.22 suggests elasticity values for car available segments might be expected to be greater than those of no car available segments, since the former have greater choice than the latter, and this is the case for A6MARR VDM.

Table 20. PT Fare Elasticity

	TO/FROM/WITHIN AOI	WHOLE MODEL
No car available	-0.49	-0.40
Car available	-0.58	-0.49
All categories	**-0.54**	**-0.44**

Car Journey Time Elasticity

8.3.10 TAG M2, 6.4.26 requires car journey time elasticity values to be calculated based on the change in car trips with respect to a 10% change in journey time. Car journey time elasticity values have been calculated by inputting a factored matrix of car travel times, skimmed from the base model, to a single run of the demand model.

8.3.11 Journey time elasticity values are shown in Table 21. Values are not disproportionately high and all are less than -2.0 as advised in TAG Unit M2.

Table 21. Test 4 Car Journey Time Realism Test Results

	CAR JOURNEY TIME ELASTICITY VALUES	
	TO/FROM/WITHIN AOI	WHOLE MODEL
By Purpose		
HB Commute	-0.27	-0.15
HB Employers Business	-0.23	-0.10
HB Other	-0.43	-0.22
NHB Employers Business	-0.17	-0.12
NHB Other	-0.28	-0.20
By Time Period		

AM	-0.36	-0.22
IP	-0.37	-0.23
PM	-0.37	-0.20
OP	-0.34	-0.11
All	**-0.36**	**-0.20**

Network Based Elasticity Values

8.3.12 TAG M2, 6.4.13 requires car fuel price elasticity values to be calculated on a network basis, as well as on an OD basis for which results are presented above. The network based elasticities are shown in Table 22 below. As suggested in TAG, these values are calculated only from links within the SATURN simulation coding for which validation was undertaken.

8.3.13 As suggested in TAG, the network based elasticity values are lower than the equivalent matrix based values.

Table 22. Test 4 Network Based Fuel Price Realism Test Results

TIME PERIOD	FUEL PRICE CAR VEHICLE KM ELASTICITY
AM	-0.19
IP	-0.19
PM	-0.18
Total	-0.18

8.4 Summary

8.4.1 In this Chapter we have described the processes of calibration and validation of the demand model. The approach taken to calibration of the demand model was to import parameters from the illustrative values presented in TAG and adjust them to produce reasonable results in the realism tests. The realism tests have been repeated for the latest updated version of the model and this produced very similar results, with overall elasticity values within the target ranges for all the realism tests.

8.4.2 With the parameters taken from within the ranges of the illustrative values and a cost damping curve employed, the elasticity of car vehicle kilometres to fuel price was -0.27, within the target range of -0.25 to -0.35. The public transport fare trip elasticity of -0.44 was within the target range of -0.2 to -0.9. Appropriate elasticity values disaggregated by purpose and time of day have been achieved. The car journey time trip elasticity of -0.20 was much less than the maximum allowable value of -2.0.

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