East Midlands Gateway Transport Model

15/10/2018

Reference number 106770






# PUBLIC TRANSPORT LOCAL MODEL VALIDATION REPORT



SYSTRA

# EAST MIDLANDS GATEWAY TRANSPORT MODEL

PUBLIC TRANSPORT LOCAL MODEL VALIDATION REPORT

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# 1. INTRODUCTION

## 1.1 Model Background and Application

1.1.1 SYSTRA has been commissioned by Nottingham City Council to develop the East Midlands Gateway Model (EMGM) to appraise a multi-modal access strategy to connect the East Midlands to the proposed HS2 station at Toton between Derby and Nottingham.

1.1.2 EMGM has been developed as a multimodal transport model built following the guidance in WebTAG. The structure of the model is based on the Greater Nottingham Transport Model (GNTM) however it has been developed using information from the existing Greater Nottingham Transport Model, Greater Derby Transport Model (GDTM) and the Leicester and Leicestershire Integrated Transport Model (LLITM). The model has been fully recalibrated and validated in line with WebTAG guidance.

1.1.3 In addition to being used to assess the HS2 access strategy, the model is likely to be used in the future to assess a wide range of development and highway and public transport scheme applications across the study area.

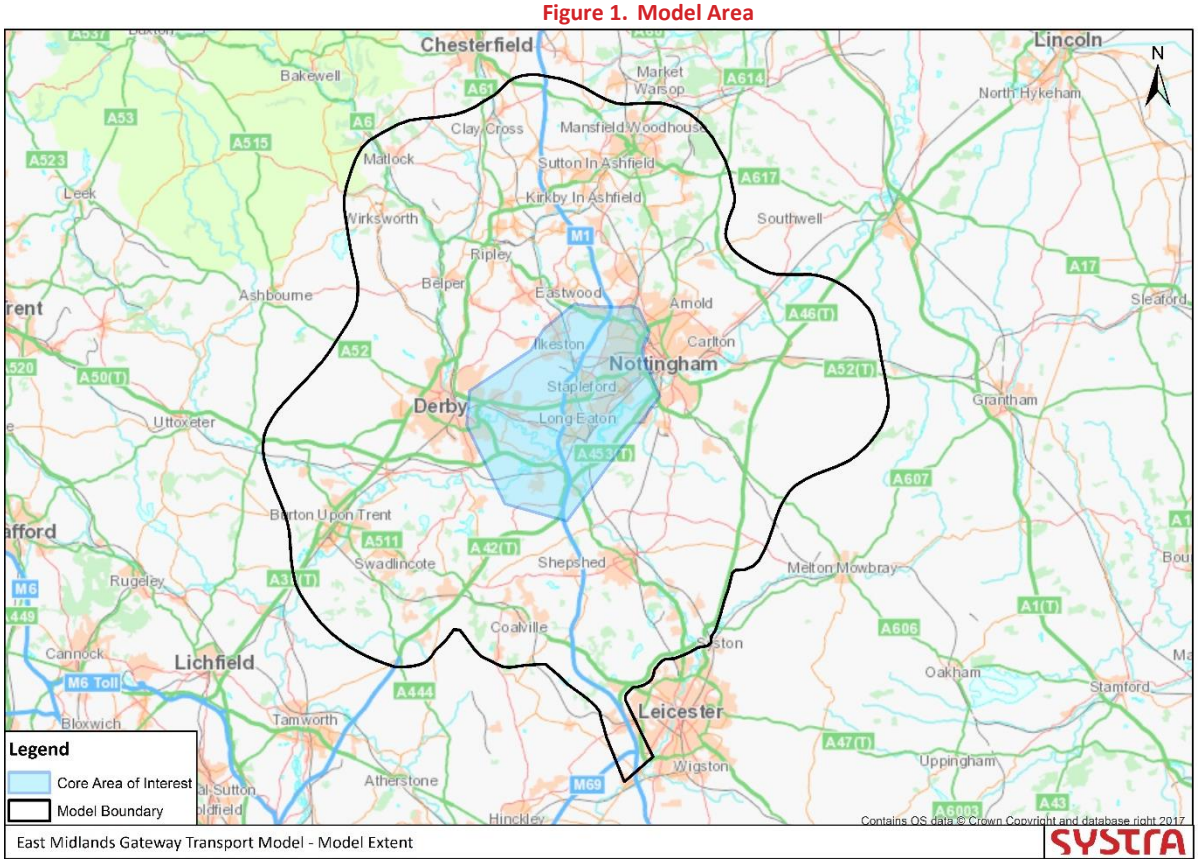
1.1.4 This report provides information on the public transport model development and the public transport calibration and validation performance.

## 1.2 Model Extent

1.2.1 The geographical extent of the model is shown in Figure 1. The model boundary is shown in black and represents the area of detailed modelling. This includes the authorities of Nottingham City, Ashfield, Broxtowe, Erewash, Gedling, Rushcliffe, Derby City, Amber Valley, South Derbyshire, Charnwood and North-West. Areas outside of this simulation area are modelled as a skeleton buffer network, this includes Leicester City and areas to the south of the A46.

1.2.2 Figure 1 also shows the Area of Interest boundary which has been specified for the purposes of assessing the impacts of the HS2 station at Toton.

Figure 1. Model Area



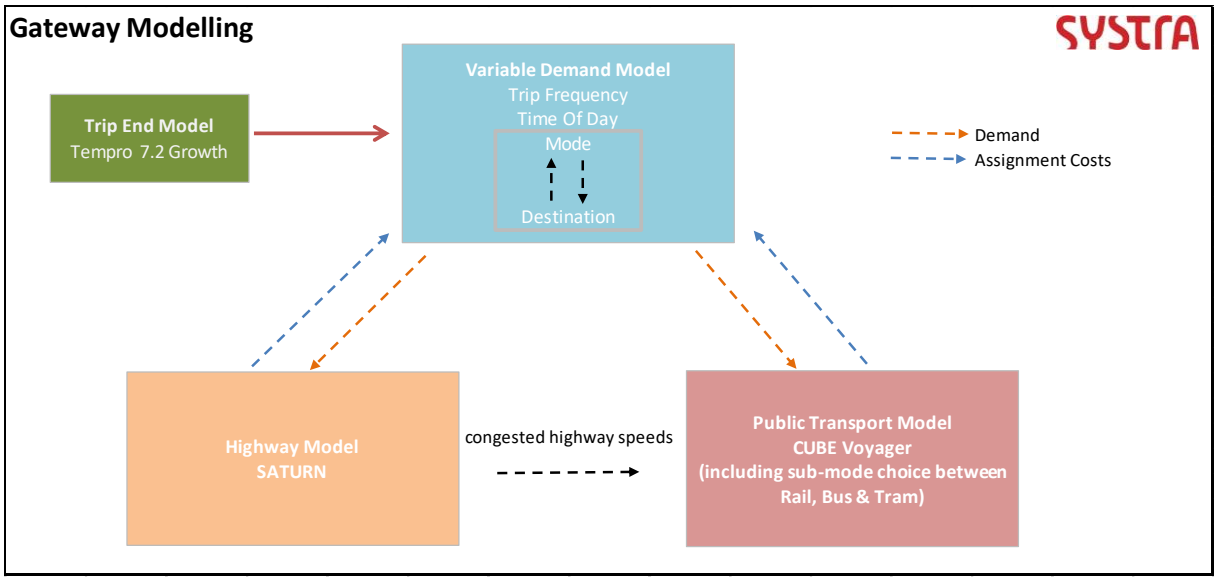

## 1.3 Structure of the Gateway Model

1.3.1 EMGTM has been developed as a multimodal transport model built following the guidance in WebTAG Unit M2. EMGTM has all the expected responses (time of day, main mode, destination, frequency, route/submode) arranged in the standard hierarchy order.

1.3.2 An overview of the structure of the East Midlands Gateway model is shown in Figure 2. It also shows the various responses described above, including the modelled hierarchy and the internal iterations between mode and destination choice. The Gateway modelling suite is comprised of the following elements:

- SATURN Highway Model;
- CUBE Voyager Public Transport Model;
- Cube Variable Demand Model including destination, mode choice, trip frequency and time of day responses; and,
- TRICs based Trip End Model.

Figure 2. EMGTM Overview




## 1.4 Cube Voyager Public Transport Model Overview

### 1.4.1 Time Periods

1.4.2 The public transport model has the following time periods. These time periods are consistent with those in the highway model:

- Morning Peak: 0800-0900
- Inter Peak: 1100-1400 average hour
- Evening Peak: 1700-1800

### 1.4.3 User Classes

1.4.4 The following user classes have been provided within the model:

- Commuting
- Employees Business
- Other (retail, leisure, education)

### 1.4.5 Modes

1.4.6 The following services are included in the in the Public Transport model:

- Local and inter-urban bus services with a frequency of at least 1 bus per hour;
- Nottingham Express Transit (NET) routes including those that commenced service in August 2015;
- Local and Interurban rail services including services to London, West Midlands and Leeds/Sheffield; and
- Park and Ride (rail, NET and bus).

1.4.7 School buses and coaches have not been included within the model. These are not typically considered as options as part of an average journey (e.g. to work, to the shops) and so should not have too large an impact the modelled routes. In addition, school buses are not available to the general public for use.

### 1.4.8 Assignment Methodology

1.4.9 WebTAG Unit M3.2 Section 2 provides guidance on the type of assignment methodology that should be implemented for different model situations. The primary decisions in this case are between frequency or schedule based assignments and whether crowding is included or not.

1.4.10 A frequency-based approach has been implemented. The services within the model are typically regular – the lowest frequency is one per hour – and generally will be higher than this, particularly on routes into the city centres. Therefore the added complications associated with a schedule-based methodology can be avoided (e.g. larger data requirements, difficulty with forecasting, uncertainty with Cube timetabling algorithm).

1.4.11 Crowding has not been included within the model. It is felt that the impact of over-crowding on services is not sufficient enough to warrant the extra run times associated with the inclusion of crowding. The impact of capacity constraints from highway network overcrowding are accounted for through the passing of congested speeds between the two assignments.

### 1.4.12 Cube Version and Network Dimensions

1.4.13 The public transport model has been built in Cube Voyager 6.4.3. The model has the following dimensions:

- 1056 zones;
- 26,174 highway links;
- 608 rail links;
- 258 walk links; and,
- 133 NET links.

# 2. DATA COLLECTION

## 2.1 Available Public Transport Data

2.1.1 There was limited information available for the development and validation of the expanded public transport model and information from the individual models has been used to supplement this information where required. The data that was available for the development of the EMGM public transport model is described in the remainder of this section, and is presented in the following sections:

- data for use in the development of the public transport supply;
- data for use in the development of the public transport matrices; and
- date for use in the validation of the public transport model.

2.1.2 Additional public transport surveys were undertaken throughout the modelled area in November 2017. These surveys included boarding, alighting and on board counts on a variety of cordons throughout the modelled area and journey time surveys. This data has been used in the validation of the Public transport model. Details of the locations of these surveys is detailed in the Data Specification report (Appendix A) which was agreed by the Local Authorities, Highways England and HS2 at the commencement of the development of this model.

2.1.3 A comprehensive description of the data used to build and validate the Public Transport model is provided below.

## 2.2 Supply Data

**Gateway SATURN Highway Model**

2.2.1 The basic network structure, in terms of highway links and nodes, was taken from the EMGM SATURN model which also has a 2016 base year. This highway model therefore consistent with the public transport model networks. The network has also been calibrated to a set of observed journey times to ensure highway speeds reflect reality.

2.2.2 This network contains highway link speeds which were used to derive appropriate public transport speeds. Two factors were used, depending on the road type. A factor of 0.9 was applied to Motorway congested speeds and a factor of 0.8 elsewhere. These factors represent the fact that buses are slower than cars due to regular stopping and starting to pick up passengers. For Bus Lanes a factor of 0.9 was applied to the Free Flow Speeds (i.e. the speed limit) for each network link. The factors were calibrated to ensure the services matched observed journey times.

**Public Transport Service Information**

2.2.3 The public transport service information for each area was taken from the most representative local model and from an existing 2016 base year or forecast year scenario where possible. Table 1 below outlines the source of the coding for each local authority within the model.

Table 1. **Network Coding Sources**

| AREA | SOURCE |
|---|---|
| Derby City | Greater Derby Transport Model |
| Amber Valley and South Derbyshire | Greater Derby Transport Model |
| Nottingham City | Greater Nottingham Transport Model |
| Nottinghamshire and Erewash | Greater Nottingham Transport Model |
| Leicestershire | Timetable information |

2.2.4 The bus and NET services were thoroughly reviewed against timetables provided on the following websites:

- Nottingham City Transport: http://www.nctx.co.uk/
- Travel Line: https://www.traveline.info/
- Derbyshire Bus Information: http://www.derbysbus.info/maps/
- NET: https://www.thetram.net/
- Derby Connected: http://www.derbyconnected.com/getting-around-derby/buses/

2.2.5 All regular bus services have been included in the model with all the major local bus operators represented. As mentioned above, both school buses and coaches were not included.

2.2.6 Rail services and timetable information were obtained from data held within Planet Midlands and Long Distance Base Models (Version 7.1) which were supplied by HS2 for the purpose of this model development and represented the most up to date version available at the time.

**Bus Speeds**

2.2.7 Bus journey time information was collated for the EMGM by an external company and supplemented with timetable information. The model uses congested highway speeds from the highway model and has applied a factor to these speeds to generate the realistic bus speeds which take account of the 'start-stop' nature and reduced journey speeds compared to a car.

**Public Transport Fares**

2.2.8 Public transport fares were derived using information on operator websites by looking at the fares between key origin and destination points over a range of distances to provide a distance based fare structure for each city area and operator within the modelled area. These fares were adjusted to take account of season tickets and concessions. Details of the resultant fares are provided in section 3.6 of this report.

## 2.3 Matrix Development

**Initial bus matrix**

2.3.1 The majority of the bus matrix was developed using trip end data from the National Trip End Model (NTEM) v7.2. The trip ends extracted from NTEM we rezoned to the EMGM zoning system using postcode data.

**Electronic Ticket Machine (ETM) bus data**

2.3.2 ETM data was available from Trent Barton which gave boardings and alightings by time period for selected services in the Derby and Nottingham area. ETM data was not available from other operators in the area. Details of the ETM data is provided in section 4.3 of this report.

**Rail matrix**

2.3.3 Rail demand was sourced from Planet Midlands (PM) and Planet Long Distance (PLD) models (version 7.1). The PLD data was an extract of demand to and from the EMGTM area.

**Tram matrix**

2.3.4 Tram demand was derived the Greater Nottingham Transport Model (GNTM), via a select link of movements using the tram network. Further details are provided in section 4.6 of this report.

## 2.4 Validation Data

2.4.1 The majority of the data in the individual models is pre 2008 and therefore not acceptable to use in the EMGM model calibration and validation. An extensive data collection exercise was undertaken to collect the following information:

- **Public transport surveys** for the areas around the cities of Derby, Nottingham and Leicester and within Nottinghamshire and Derbyshire.
- **Journey times** for key routes for each of the main urban centres.

2.4.2 2016 data was already available for a number of bus and NET counts and this was used to produce an outer cordon for Nottingham. Further counts were carried out by Nottingham City Council to create an inner cordon.

2.4.3 There was no current public transport information available for the remainder of the area and therefore public transport surveys were carried out for both Derby and Leicester inner and outer cordons. These are detailed in the Data Specification report (Appendix A).

# 3. PUBLIC TRANSPORT NETWORK DEVELOPMENT

## 3.1 Introduction

3.1.1 The EMGM public transport network was created using information from the Greater Nottingham Transport Model, Greater Derby Transport Model and the Derby Area Transport Model.

3.1.2 The network build required the following steps:

- Creation of the initial network by combining GDTM with GNTM.
- Model expansion to cover the rest of the modelled area.
- Review of bus lines and frequencies.
- Addition of Interurban rail services (based on Planet 7).
- Bus Speed Review.
- Review of Walking Links and Zone Connectors.

## 3.2 Initial Network

3.2.1 The public transport model network and zoning system were both developed to be consistent with the highway model. Key link and node based attributes such as link distances, congested speeds and coordinates were extracted from the SATURN assignment in an automated process and transformed into a CUBE Voyager EMGM base network. If either the highway network or the PT network were incompatible then an error message would be produced. Where these occurred these have been resolved.

3.2.2 Information on PT-specific links and nodes from the GDTM TRIPs based model was converted to a Cube Voyager format and combined with the current Cube-based GNTM public transport model. This information was then added to the EMGM base network to represent appropriate rail and NET links, walk connections to rail and NET stations, additional zone connectors (to those imported from the highway network) and walk links.

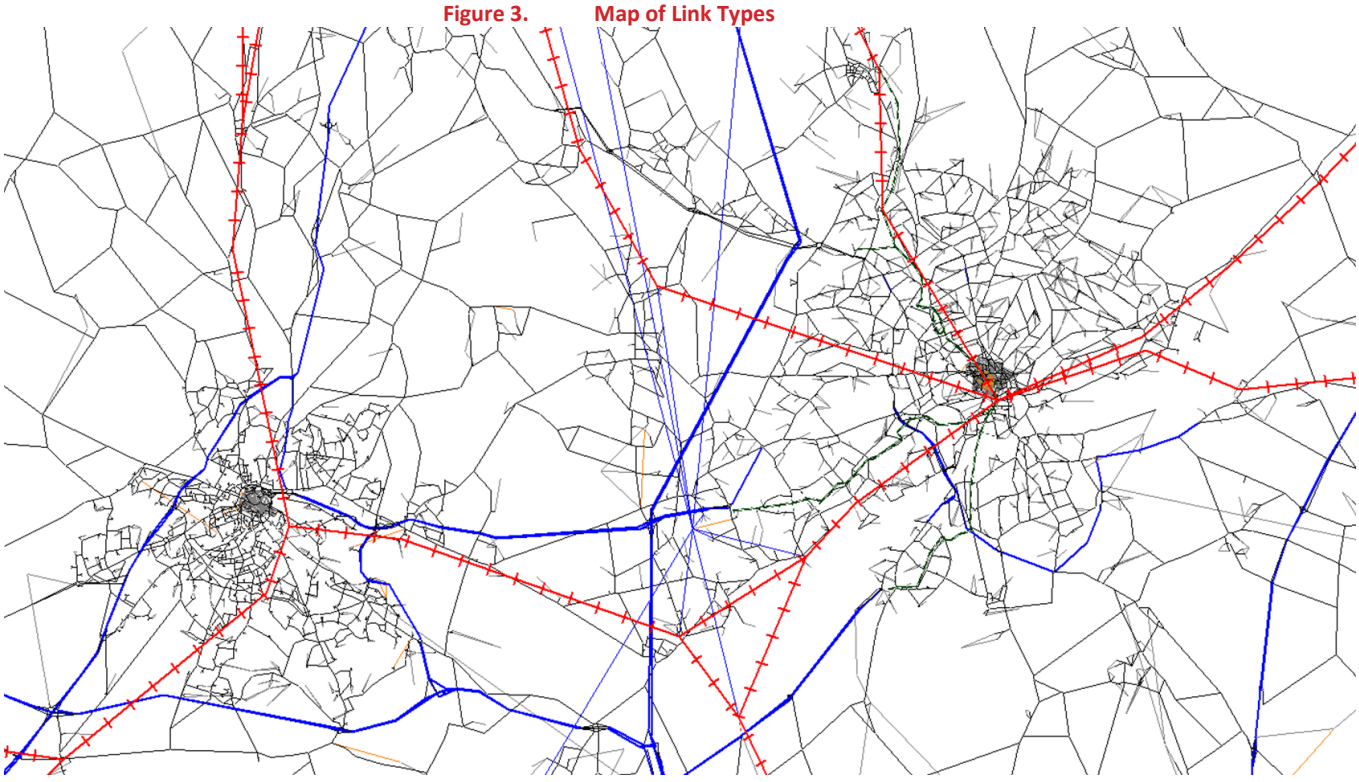
3.2.3 The additional links added to the model to represent rail and NET access/egress and walk links were sense checked and updated where necessary based on information provided by Google Maps and local area knowledge. A check was made against access/egress warnings in the Route Enumeration process to ensure that all zones had connectivity to nearby public transport services.

3.2.4 Table 2 provides details of the various link types within the model and **Error! Reference s ource not found.** shows a version of the network coloured by link type.

Table 2. **Link Types in Model**

| LINK TYPE | LINK ID | COLOUR IN FIGURE (IF VISIBLE) |
|---|---|---|
| Road (Most Roads) | 1 | Black |
| Road (Motorways and Major Roads) | 2 | Blue |
| Zone Connectors | 100 | Grey |
| Rail | 101 | Red |
| NET (Tram) | 102 | Green |
| Walk Only | 103 | Orange |
| High Speed 2 (future year only) | 110 | Thin Blue |
| Road to Rail Connectors | 111 | N/A |
| Road to NET Connectors | 112 | N/A |
| External Rail Connectors | 121 | N/A |

**Figure 3. Map of Link Types**



## 3.3 Review of Bus and NET Public Transport Services

3.3.1 Public Transport services were taken from the constituent models and extended to include services accessing Charnwood and North-West Leicester, including routes between these areas and Leicester City Centre.

3.3.2 The bus and NET services were thoroughly reviewed against timetables provided on the following websites, all bus services were reviewed and amendments made if required:

- Nottingham City Transport: http://www.nctx.co.uk/;
- Travel Line: https://www.traveline.info/;
- Derbyshire Bus Information: http://www.derbysbus.info/maps/;
- NET: https://www.thetram.net/; and
- Derby Connected: http://www.derbyconnected.com/getting-around-derby/buses/

3.3.3 All regular bus services were included in the model with all the major local bus operators represented, school buses and coaches were excluded. Figure 4 illustrates the spatial distribution of bus routes across the network. Figure 5 illustrates the NET services within Nottingham City. Higher frequency bus and NET routes are shown by a darker colour.

**Figure 4. Bus Routes**

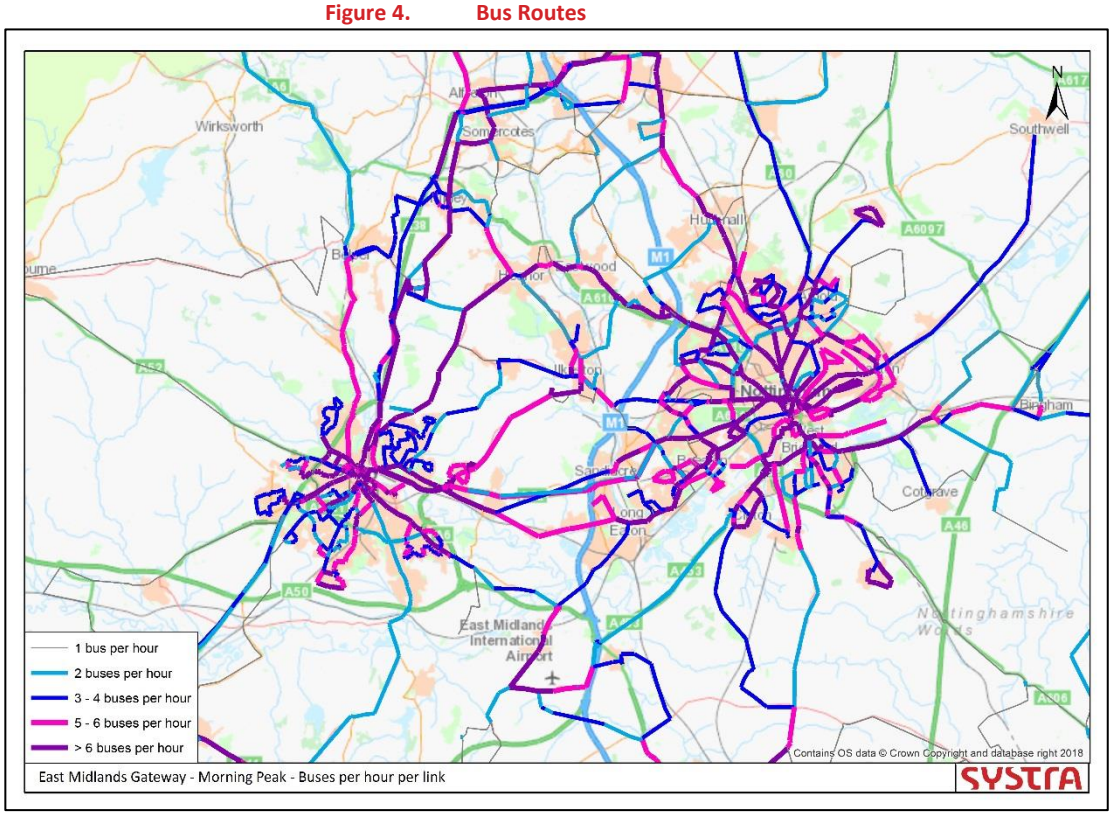
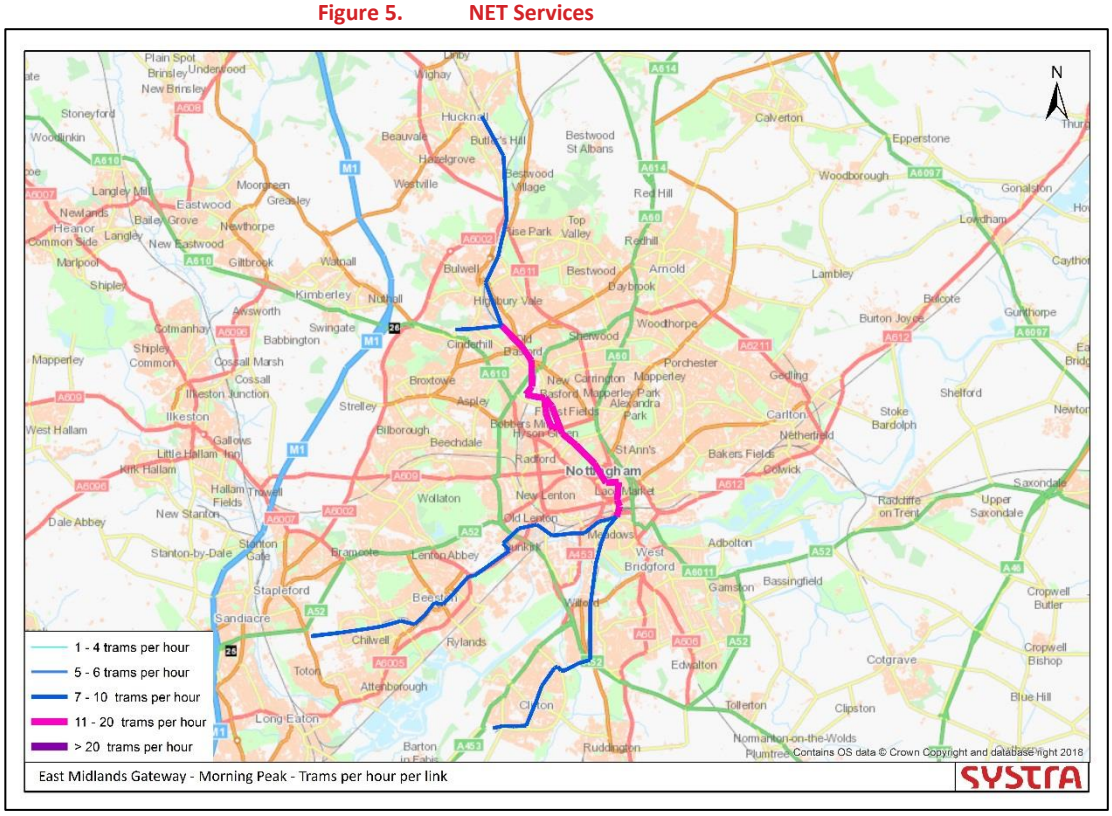


Figure 5. NET Services



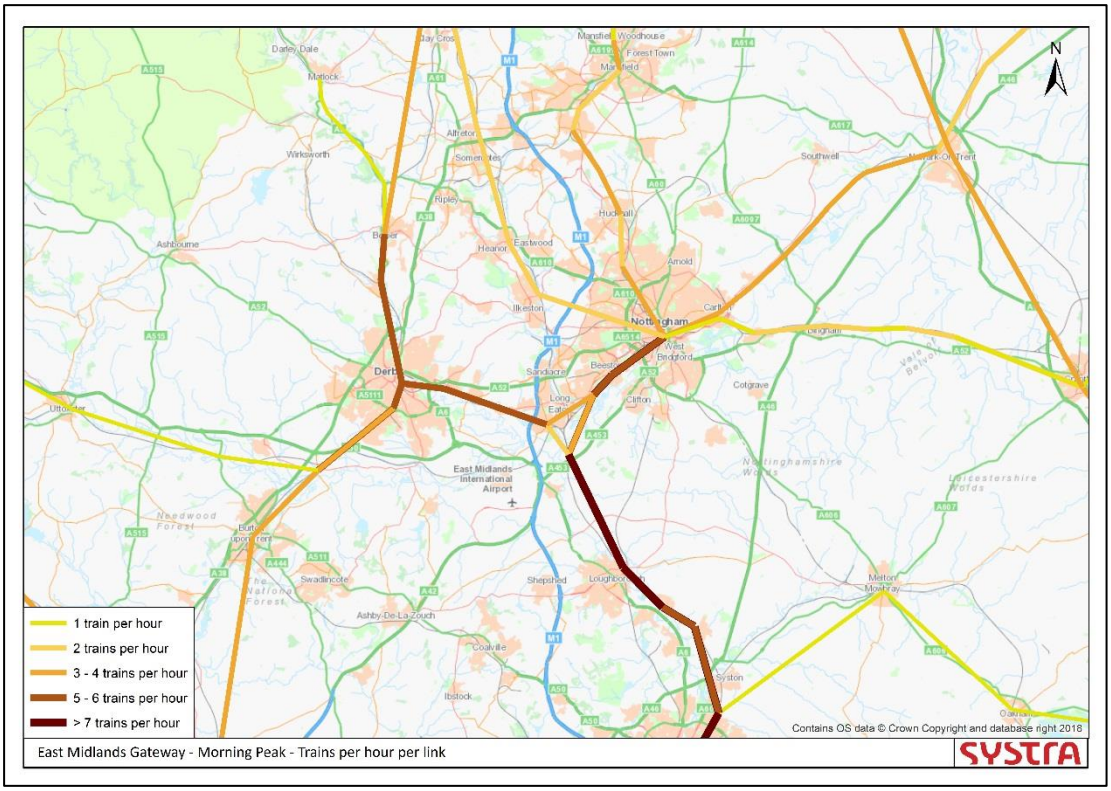

## 3.4 Rail Services

3.4.1 Rail services were taken from the Planet Midlands (PfM) Base Model (version 7.1) and converted from Emme format to CUBE Voyager. This approach was agreed with HS2 to ensure consistency of rail services between the two models. Both models have a 2016 base year and therefore services are comparable.

3.4.2 As the Planet Midland model represents a three hour AM peak, model services were reviewed against actual/public timetables for key stations around the network, particularly Leicester, Derby, Nottingham and Mansfield Town & Woodhouse. This information was used to derive typical AM, IP and PM peak hour services.

3.4.3 Figure 6 shows the distribution and frequency of AM peak hour rail services in the model.

Figure 6. AM Peak Hour Train Services




## 3.5 Bus speeds

3.5.1 Bus journey time information was collected for the EMGM by an external company and combined with timetable information and congested highway speeds from the highway model. Details of the locations of these surveys are provided in the Data Specification report (Appendix A)

3.5.2 The speeds on the highway links in the network are based on congested highway speeds taken from the SATURN model, the details of the journey time validation for the highway model is provided in the EMGM Highway LMVR Report. The public transport model recognises that the time taken for a bus to traverse a link will be a function of the time it takes a car to traverse the link, taking into account the level of congestion. Buses will travel along the link at lower average speeds than cars, as they will need to stop to pick up and set down passengers. Therefore, the bus speeds on links have been calculated by multiplying the car speed by a factor. The factor which is applied to the car speed has been calibrated by comparing modelled journey times with timings taken from timetables and observed information. The final factors used in the model are:

- motorway bus speed = Motorway SATURN link speed x 0.9
- non-motorway bus speed = Non-motorway SATURN link speed x 0.8

3.5.3 Bus lanes are treated differently to normal links, with the bus speed being 90% of the free-flow speed (i.e. uncongested).

3.5.4 Information on how modelled journey times compare to observed times are provided in the section on Modal Validation, below.

## 3.6 Public Transport Fares

3.6.1 The fare structure within the model was developed to represent the zonal fare bands in the modelled area on a distance range basis, similar to the existing Nottingham and Derby models. These distance bands have been enhanced to better represent the latest fare structures within the modelled area based on information for each operator obtained from their web sites. Different fare tables were set up for each of the public transport modes.

3.6.2 Actual fare levels were based on single ticket journeys; however, a global factor, for each ticket type was applied to take account of season ticket, smart card and multi ticket usage.

3.6.3 Table 3 to Table 5 show the calculations of the reduction factor for Bus, Tram and P&R Bus. The passenger shares were provided by Nottingham City Council and relate to Bus ticket shares, though were used for Tram in the absence of other information. No factor was applied to Rail fares.

Table 3. **Concessions/Seasons Fare Reduction Factor: Bus**

| | CONCESSIONS | PASSES/CARDS | FULL PRICE | WEIGTHED |
|---|---|---|---|---|
| Share | 20% | 45% | 35% | |
| Ticket Price | £0.00 | £0.85 | £1.00 | £0.73 |
| | | Factor Used (Weighted / Full Price) | | 0.73 |

Table 4. **Concessions/Seasons Fare Reduction Factor: Tram**

| | CONCESSIONS | PASSES/CARDS | FULL PRICE | WEIGTHED |
|---|---|---|---|---|
| Share | 20% | 45% | 35% | |
| Ticket Price | £0.00 | £1.80 | £2.20 | £1.58 |
| | | Factor Used (Weighted / Full Price) | | 0.72 |

Table 5. **Concessions/Seasons Fare Reduction Factor: P&R Bus**

| | CONCESSIONS | PASSES/CARDS | FULL PRICE | WEIGTHED |
|---|---|---|---|---|
| Share | 20% | 45% | 35% | |
| Ticket Price | £0.00 | £1.50 | £1.50 | £1.20 |
| | | Factor Used (Weighted / Full Price) | | 0.80 |

3.6.4 The final fare tables used within the model are shown in Table 6 for the peak hours and Table 7 for off peak.

Table 6. **Peak Hour Fares (£)**

| | TRENT BARTON | NCT BUS | BUS P&R | NET | RAIL |
|---|---|---|---|---|---|
| Fare Type | Distance | Distance | Flat | Flat | Distance |
| Board Fare | 1.61 | 1.61 | 1.03 | 1.58 | 2.20 |
| Distance Band* | | | | | |
| 0 (0) | 0 | - | - | - | 0 |
| 5 (8) | 0.44 | 1.25 | - | - | 0 |
| 10 (30) | 1.32 | - | - | - | 5.10 |
| 20 (80) | 2.49 | 1.83 | - | - | 18.65 |
| 99 (320) | 5.50 | 2.70 | - | - | 93.65 |

* () indicates rail distance bands

Table 7. **Off Peak Hour Fares (£)**

| | TRENT BARTON | NCT BUS | BUS P&R | NET | RAIL |
|---|---|---|---|---|---|
| Fare Type | Distance | Distance | Flat | Flat | Distance |
| Board Fare | 1.61 | 1.61 | 1.03 | 1.58 | 2.20 |
| Distance Band* | | | | | |
| 0 (0) | 0 | - | - | - | 0 |
| 5 (8) | 0.44 | 1.25 | - | - | 0 |
| 10 (32) | 1.32 | - | - | - | 3.65 |
| 20 (160) | 2.49 | 1.83 | - | - | 23.65 |
| 99 (320) | 5.50 | 2.70 | - | - | 58.65 |

* () indicates rail distance bands

# 4. MATRIX BUILDING

## 4.1 Development of Prior Matrices

4.1.1 PT assignment matrices were created individually for Bus, Rail and Tram, before being combined into a total PT matrix.

## 4.2 Initial bus matrix

4.2.1 The majority of the bus matrix is synthetic and was developed using trip end data from the National Trip End Model (NTEM). The trip ends extracted from NTEM we rezoned to the EMGTM zoning system using postcode data to proportion the demand as appropriate between the two zoning systems.

4.2.2 The NTEM trip ends represent trips to/from all zones in the country, including those that don't travel through the study area. The Census Journey-to-Work (JtW) demand matrix was used to produce proportions for each zone of the level of demand that travel through the study area. These factors were used to reduce the trip ends to reflect an appropriate level of demand from/to each zone. The JtW mask is based on commute trips only, but is applied to all modelled journey purposes.

4.2.3 The trip ends were distributed using a gravity model, using generalised cost matrices from the public transport model (run through with a matrix of ones). The generalised cost matrix was masked by a flag of the number of boardings, removing any zero-boarding movements from the gravity model outputs.

4.2.4 The equation used for the distribution process was

$$Deterrance = (GenCost)^{x_1} * e^{(x_2 * GenCost)}$$

where $x_1$ and $x_2$ are parameters calibrated, by journey purpose to match an average bus trip length of approximately 5km, matching observed national average trip lengths by bus. The final parameters used are shown in Table 8.

Table 8. **Gravity Model Parameters**

| JOURNET PURPOSE | $x_1$ | $x_2$ |
|---|---|---|
| Commute | -2 | -0.014 |
| Employers Business | -2 | -0.038 |
| Other | -2 | -0.018 |

## 4.3 Electronic Ticket Machine (ETM) bus data

4.3.1 ETM data was available from Trent Barton which gave boardings and alightings by time period for selected services in the Derby and Nottingham area. The data provided covered a weeks worth of data for a one-hour AM and PM period and a two-hour inter peak.

4.3.2 ETM data was not available from other operators in the area.

4.3.3 Figure 7 shows the bus stops covered by the ETM data. 0 lists the services data was provided for, by city.

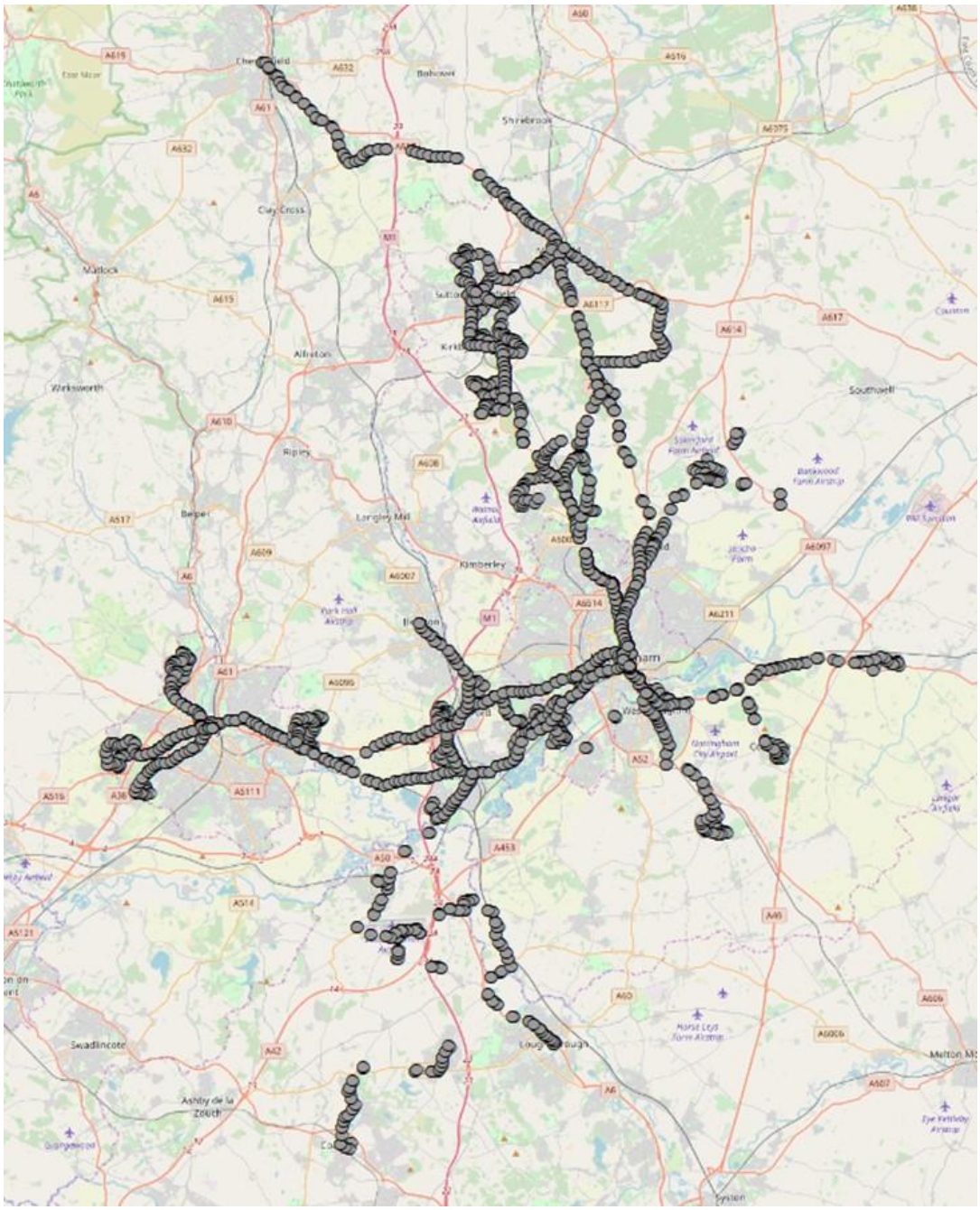



**Figure 7. Bus Stops covered by ETM data**

Table 9. **List of Services Contained in ETM Data**

| NOTTINGHAM | DERBY |
|---|---|
| 141 | Allestree |
| Calverton Connection | Harlequin |
| Cotgrave Connection | I4 |
| Eighteen | Indigo |
| Keyworth Connection | Mickleover |
| Mainline | Red Arrow |
| My15 | Spondon |
| Pronto | |
| Skylink | |
| Threes | |

4.3.4 The ETM data was provided at a boarding stage level, rather than for individual stops. The ETM data was split down to individual bus stops using the domestic points from Code Point postcode data that were within a 400m buffer of the stops. The more aggregate alighting data was initially disaggregated to the same level as the boardings using the distribution of the all-day boardings and then further disaggregated to stop-level using the same process as that used for the boadings.

4.3.5 The ETM data was then distributed for each service using a gravity model and a matrix of stop-to-stop distances, with parameters calibrated to provide an average trip length of 5km. The same distribution was used for all services and time periods.

4.3.6 This ETM stop to stop matrix was converted to EMGTM zoning using postcode data to share stop demand between EMGTM zones within a 400m walk buffer of each bus stop.

4.3.7 Finally, the ETM matrix was split into journey purposes and car availability classes using proportions from the NTEM data processes above.

4.3.8 Though the underlying ETM is actual ticketing data the final matrix has gone through a number of processes to convert from boardings stages to stops and then zones which effects the certainty of the detailed movements. However, at a wider level the match to observed flows should be reasonable.

## 4.4 Final bus matrix

4.4.1 A final bus matrix was created by combining the Synthetic NTEM-based demand with the ETM demand. As it was felt there was greater confidence in the ETM data, where

available, cells where the ETM value was greater than the gravity model value took the ETM value. Other nearby cells were factored down to maintain the gravity model matrix totals at a sector-sector-time period level.

4.4.2 Table 10 shows the demand totals from NTEM and ETM and the average factor applied to the NTEM demand so that adding the ETM in retains the same total. The actual factoring was undertaken at a 27 sector level. The table also shows the percentage of the final demand that is made up of the ETM data.

Table 10. **NTEM/ETM Demand Combining Summary**

| Time Period | NTEM | | Total To Match | ETM | | Factor for NTEM Keep | Remaining NTEM | ETM Keep | Combined Total | %ETM of Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Keep | Replace | | Keep | Lose | | | | | |
| AM | 13,098 | 639 | 13,736 | 3,974 | 410 | 0.75 | 9,763 | 3,974 | 13,736 | 29% |
| IP | 12,091 | 605 | 12,696 | 3,535 | 395 | 0.76 | 9,161 | 3,535 | 12,696 | 28% |
| PM | 10,214 | 513 | 10,727 | 3,492 | 324 | 0.71 | 7,235 | 3,492 | 10,727 | 33% |

## 4.5 Rail matrix

4.5.1 Rail demand was sourced from Planet Midlands (PM) and Planet Long Distance (PLD) models. The PLD data was an extract of demand to and from the EMGTM area.

4.5.2 Data from these models was re-zoned to EMGTM zones using postcode data to determine shares when a Planet zone was split or overlapped with EMGTM zones.

4.5.3 The PM and PLD data was converted to the required time periods, from AM-only and 24hr respectively, using period factors provided by HS2 and combined. Due to the nature of factoring a 12hr matrix and the factors provided the PLD time period matrices lack any tidality. The PM AM-only matrix was transposed after factoring to create the PM peak matrix. The inter-peak is a combination of the AM and PM patterns.

4.5.4 A mask was applied to remove any demand not travelling through the EMGTM area to create the final rail matrix.

## 4.6 Tram matrix

4.6.1 Tram demand was derived from the Greater Nottingham Transport Model (GNTM), via a select link of movements using any link in the tram network. The select link was undertaken individually for the three user classes and three time periods. This select link was undertaken in a 2016 version of GNTM and is therefore consistent with the base year of EMGTM.

4.6.2 This was re-zoned to EMGTM zones and a mask applied so only demand within Nottingham was included to exclude double-counting of multi-modal journeys (e.g. tram to rail station). Figure 12 shows the five sectors between which tram demand was kept. For movements to/from zones outside of these sectors it was assumed that the demand would involve either a rail or bus journey and so would be included in those model matrices.

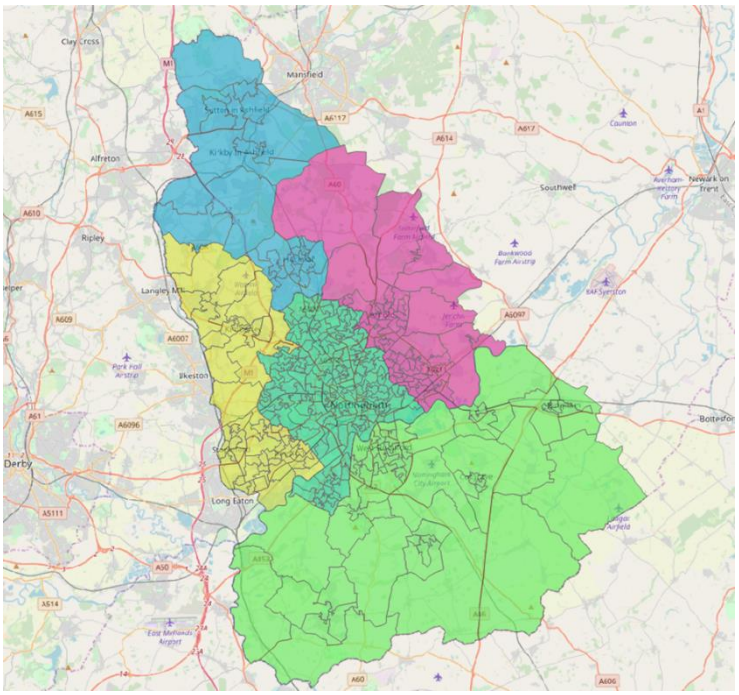



**Figure 8. Sectors Included in Tram Demand Mask**

## 4.7 Final PT Prior matrix

4.7.1 The bus, rail and tram matrices were combined to create the final PT matrix. Table 11 shows the final modal demand totals by time period and journey purpose and mode shares.

Table 11. **Final Matrix Totals and Shares by Mode, Period and Purpose**

| Bus | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 4,595 | 179 | 8,882 | 80 | 392 | 14,128 |
| IP | 1,116 | 121 | 9,360 | 185 | 2,009 | 12,791 |
| PM | 4,049 | 203 | 5,198 | 113 | 1,557 | 11,119 |
| 12hr | 32,624 | 1,873 | 98,398 | 1,690 | 17,903 | 152,488 |

| Bus | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 44% | 31% | 78% | 23% | 25% | 58% |
| IP | 58% | 25% | 77% | 44% | 58% | 69% |
| PM | 43% | 28% | 69% | 26% | 57% | 53% |
| OP | 46% | 27% | 76% | 35% | 53% | 62% |

| Rail | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 2,937 | 368 | 446 | 231 | 207 | 4,190 |
| IP | 453 | 326 | 870 | 205 | 404 | 2,258 |
| PM | 2,747 | 442 | 887 | 278 | 412 | 4,766 |
| 12hr | 19,769 | 4,387 | 9,217 | 2,756 | 4,284 | 40,412 |

| Rail | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 28% | 63% | 4% | 67% | 13% | 17% |
| IP | 24% | 66% | 7% | 48% | 12% | 12% |
| PM | 29% | 62% | 12% | 63% | 15% | 23% |
| OP | 28% | 64% | 7% | 56% | 13% | 16% |

| Tram | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 2,871 | 40 | 2,052 | 32 | 997 | 5,990 |
| IP | 349 | 44 | 1,887 | 33 | 1,058 | 3,371 |
| PM | 2,636 | 69 | 1,450 | 52 | 783 | 4,990 |
| 12hr | 18,615 | 590 | 21,826 | 447 | 11,689 | 53,167 |

| Tram | Home Based | | | Non Home Based | | All |
|---|---|---|---|---|---|---|
| | Commute | Business | Other | Business | Other | Purposes |
| AM | 28% | 7% | 18% | 9% | 62% | 25% |
| IP | 18% | 9% | 16% | 8% | 30% | 18% |
| PM | 28% | 10% | 19% | 12% | 28% | 24% |
| OP | 26% | 9% | 17% | 9% | 35% | 22% |

# 5. ASSIGNMENT AND CALIBRATION

## 5.1 Introduction

5.1.1 This section discusses the steps taken to calibrate and validate the public transport model. It covers:

- Assignment parameters including value of time, penalties, and wait curves;
- Calibration procedures;
- Matrix estimation;
- Network checks.

## 5.2 Assignment parameters

5.2.1 The assignment model parameters used in the public transport model are contained in Table 12 and reflect the perception that rail and tram are more attractive modes than bus. This is represented by higher penalties and factors applied to bus mode travel and transfers than are used for rail and tram.

5.2.2 The values of time have been derived from WebTAG databook, using the values of time for non work time commuting, non work time other and working time. The working time values are provided in TAG for bus, rail and Light Rail Transit (LRT), and an average value for working time has been calculated.

5.2.3 The values of time provided in TAG are in 2010 values and prices, and have been converted to 2016 values by the method suggested in TAG.

5.2.4 The parameters such as the in-vehicle time factors, boarding penalties, transfer penalties, walk time factors and wait time factors were taken from the GNTM and were adjusted during the calibration process in order to improve the validation of the model, with the in-vehicle time factors being left at the values set in the previous versions of the model. Details of which parameters have altered are provided below.

Table 12. **Assignment Parameters**

| PARAMETER | VALUE |
|---|---|
| Value of Time: In-Work | £20.04 per hour |
| Value of Time: Non-Work – Commute | £10.69 per hour |
| Value of Time: Non-Work - Other | £4.88 per hour |
| Walk Time Factor | 2 |
| Wait Time Factor – Bus | 1.9 |
| Wait Time Factor – Rail and Tram | 1.9 |
| Boarding Penalty | 5 minutes |
| In Vehicle Time Factor – Bus | 0.9 |
| In Vehicle Time Factor – Rail | 1 |
| In Vehicle Time Factor – Tram | 0.92 |
| Transfer Penalty – between buses | 6.6 minutes |
| Transfer Penalty – between rail | 0 minutes |
| Transfer Penalty – between tram | 0 minutes |
| Transfer Penalty – bus to rail, bus to tram, rail to bus, tram to bus | 3.3 minutes |
| Transfer Penalty – tram to rail, rail to tram | 0 minutes |

### 5.2.5 Wait Curves

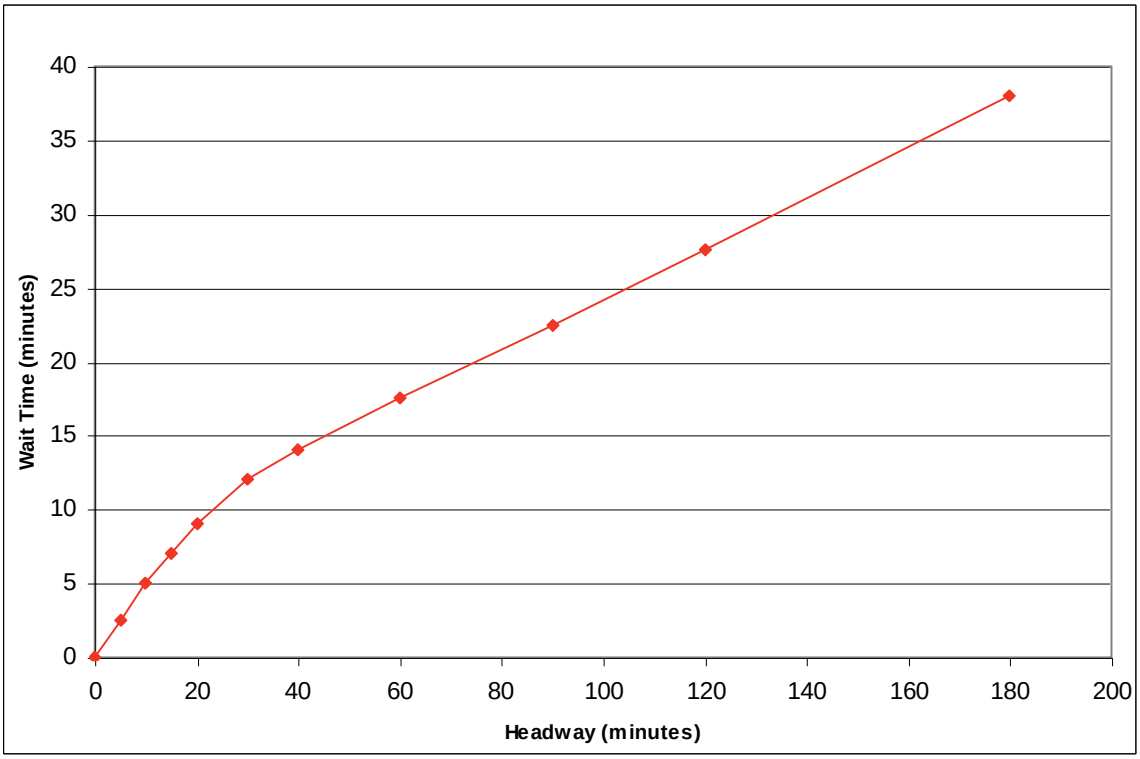
5.2.6 Voyager uses wait curves to calculate the time which a passenger will spend waiting for a service. These curves are functions of the service headways.

5.2.7 The calculated wait time reflects both the time spent waiting for the service and the inconvenience of having to schedule a journey around infrequent services. The model uses a wait curve derived from the Passenger Demand Forecasting Handbook (PDFH).

5.2.8 This assumes a half-headway wait time for services with up to a 10 minute headway (which would imply random arrival of passengers) and then tapers the wait time so that a 30 minute headway implies a 12 minute wait time, and a 2 hour headway implies a 27.5 minute wait time. This reflects the fact that passengers are unlikely to wait very long times for relatively infrequent services because they will schedule their arrival time at a stop so as to coincide with the arrival of the service.

5.2.9 The PDFH wait curve used in this model is shown in Figure 9. The same curve is used for all modes, journey purposes and time periods.

**Figure 9. Wait Curve**




## 5.3 Calibration procedure

5.3.1 TAG unit M3.2 recommends techniques with which the assignment model may be calibrated to produce a higher degree of validation. These are:

- adjustments to the zone centroid connector times and costs;
- adjustments to network and service details;
- adjustments to in vehicle time factors;
- adjustments to walk and wait time factors;
- adjustments to interchange penalties; and,
- path building and trip loading algorithm changes.

5.3.2 These are presented in the order in which they should be considered. Any adjustments must be plausible. The calibration of the model has followed these steps, in the order recommended.

5.3.3 Prior to matrix estimation the zone connectors, services and networks were all checked for accuracy and consistency in the calibration of the model. These checks predominantly concentrated on ensuring an accurate representation of access to major bus stops and rail stations, and ensuring that there were centroid connectors to represent access to the network.

5.3.4 New walk links and centroid connectors were added for the extended model area ensuring that these new networks provide an accurate representation of access to major bus stops and rail stations, as well as access to the network.

5.3.5 Paths between key origins and destinations were reviewed to ensure the demand was choosing appropriate sub modes and routes.

5.3.6 In addition, the In-Vehicle Time factors were adjusted to provide a more reasonable hierarchy between the modes (i.e. rail < tram < bus). The final values were also adjusted to obtain the observed modal splits within the model on corridors where there are competing modes.

5.3.7 Wait time factors, interchange penalties and the assignment algorithms were all left unchanged as the values were felt to be reasonable.

5.3.8 Table 13 shows the values of the parameters that have changed from the GNTM.

Table 13. **Changes in Assignment Parameters**

| PARAMETER | EMG VALUE | GNTM VALUE |
|---|---|---|
| Walk Time Factor | 2 | 1.60 |
| In Vehicle Time Factor – Bus | 0.9 | 1.06 |
| In Vehicle Time Factor – Rail | 1 | 0.80 |
| In Vehicle Time Factor – Tram | 0.92 | 0.756 |

**Matrix Estimation**

5.3.9 TAG unit M3.2 states that matrix estimation (ME) may be used to adjust the trip matrices if the matrices do not validate satisfactorily. Matrix estimation procedures have been applied to the prior EMGM matrix.

5.3.10 TAG Unit M3.1 provides criteria for judging the significance of the change brought about by matrix estimation. For X-Y scatters of the Prior and Post-ME matrices a linear model fitted to the data should have a slope between 0.98 and 1.02, and intercept near to zero and an $R^2$ in excess of 0.95.

5.3.11 Table 14 shows the R squared values between the Prior and Post ME matrices. Figure 10 to Figure 12 show the X-Y scatter plots for each time period, showing data for each userclass separately and the total demand. The equation of the linear model are also shown.

5.3.12 All of the intercepts are close to zero and the majority of the slopes are within the desired range. However, the $R^2$ values are all much lower than the criteria of 0.95, suggesting the ME is having a significant impact in some locations.

5.3.13 Details on the difference between the level of Validation are provided in the Model Validation section below.

Table 14. **Pre ME vs Post ME R Squared Values**

| TIME PERIOD | IW | NWC | NWO | TOTAL |
|---|---|---|---|---|
| AM | 0.808 | 0.822 | 0.802 | 0.808 |
| IP | 0.720 | 0.588 | 0.737 | 0.714 |
| PM | 0.778 | 0.772 | 0.717 | 0.741 |

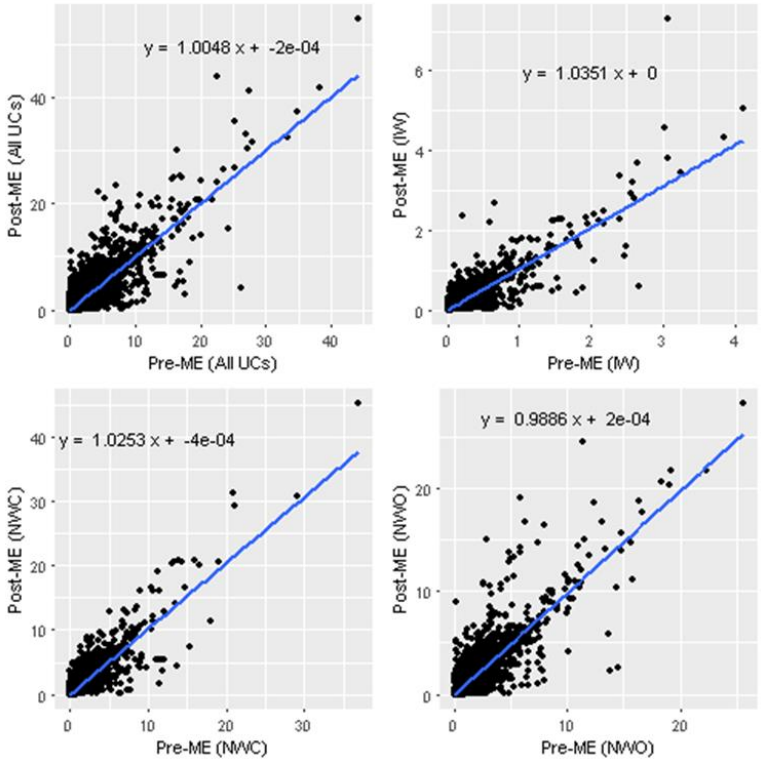



**Figure 10. Pre and Post ME X-Y Scatters: AM**

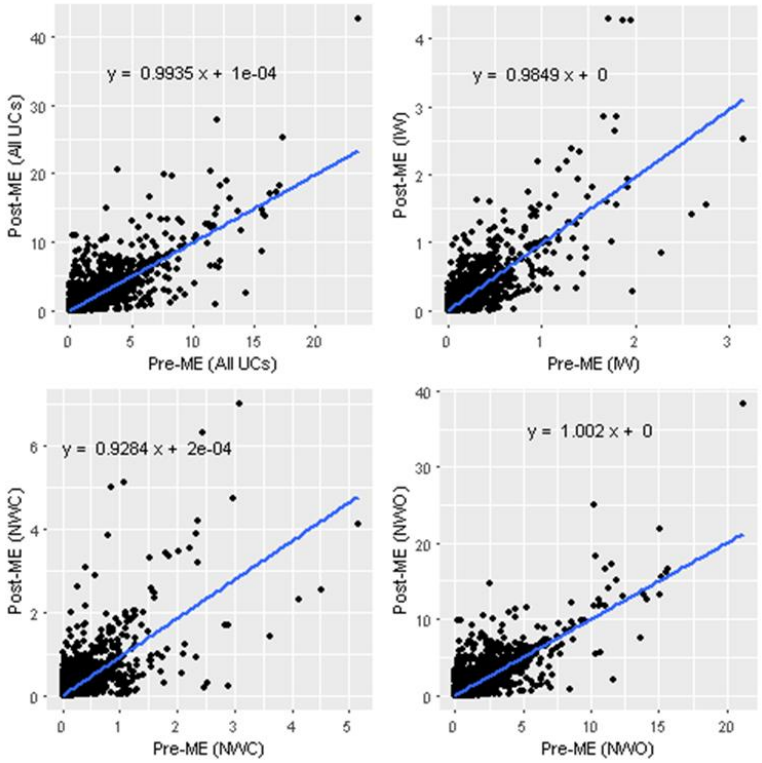



**Figure 11. Pre and Post ME X-Y Scatters: IP**

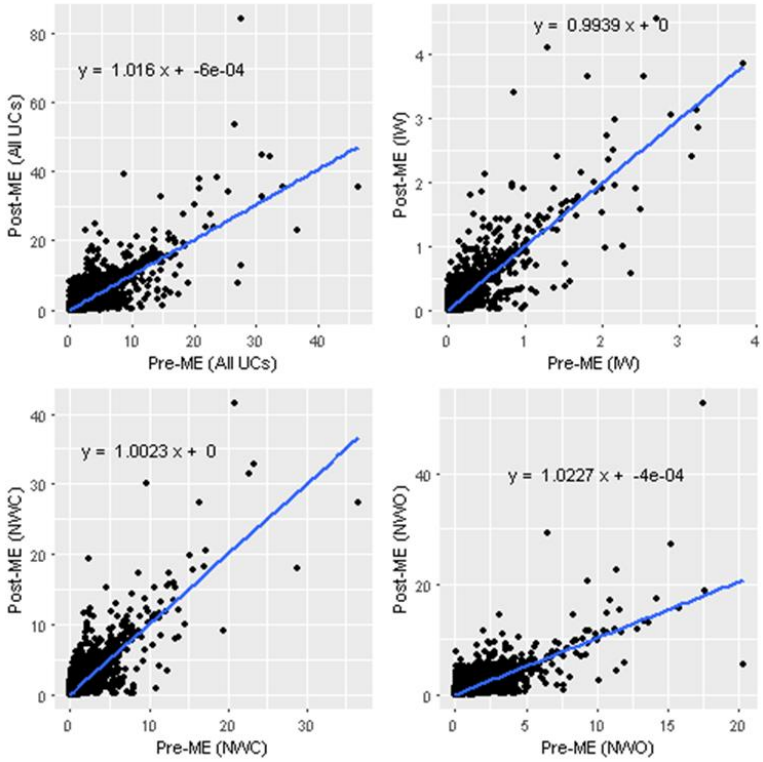



**Figure 12. Pre and Post ME X-Y Scatters: PM**

# 6. MODEL VALIDATION RESULTS

## 6.1 Introduction

6.1.1 This chapter presents the results of the model validation, with the results presented under the following headings:

- Journey time validation;
- Matrix Calibration;
- Assignment validation; and
- Summary of rail station entries and exits.

## 6.2 Journey Time Validation

6.2.1 Bus journey times were extracted from the model assignments and compared against the observed data.

6.2.2 In line with WebTAG, modelled times within ±15% of the timetabled times were considered to show an "OK" representation, while modelled times outside of this range were described as being either "Fast" or "Slow". Speeds applied to bus services within the model have been deduced from the highway network as discussed in Chapter 3.

6.2.3 A summary of the bus journey time validation is presented in Table 15. The results show that in the morning peak, 78% of the bus journey times were within 15% of the observed time, in the inter-peak period 89% of routes considered satisfactory and in the evening peak 72% of the routes were within 15% of the observed time. These figures indicate a good level of bus journey time validation.

6.2.4 Figure 13 to Figure 15 show route-by-route comparisons for each time period.

Table 15. **Bus Journey Time Validation**

| | AM | | IP | | PM | |
|---|---|---|---|---|---|---|
| | No of Lines | % of Lines | No Of Lines | % Of Lines | No of Lines | % Of Lines |
| SLOW | 2 | 11% | 2 | 11% | 2 | 11% |
| OK | 14 | 78% | 16 | 89% | 13 | 72% |
| FAST | 2 | 11% | 0 | 0% | 3 | 17% |

Figure 13. Journey Time Comparison – AM Peak

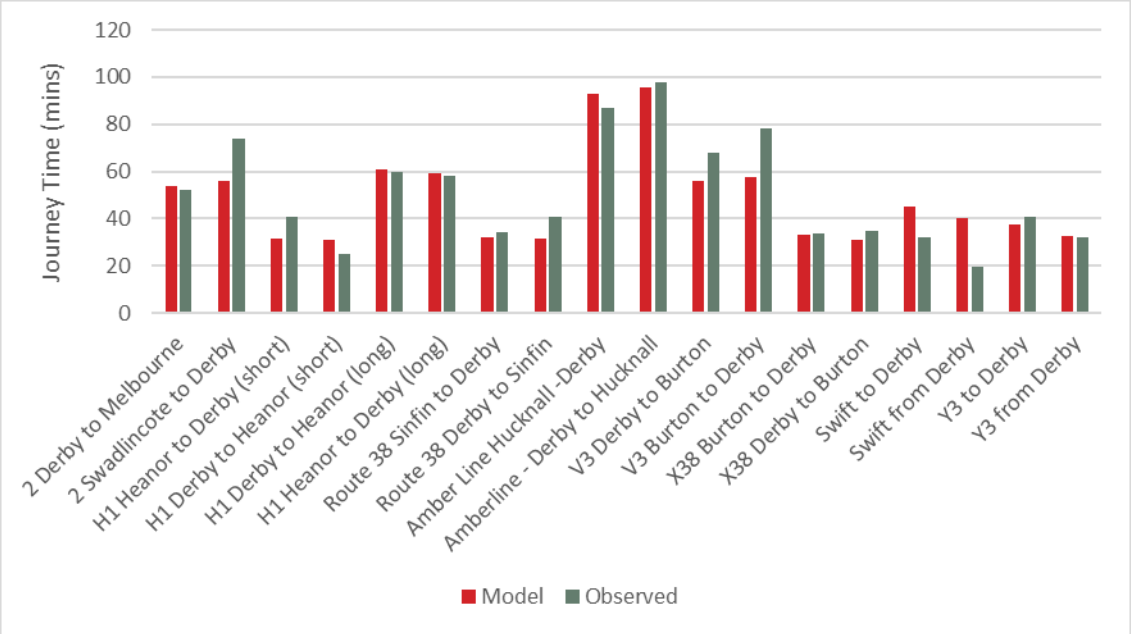



Figure 14. Journey Time Comparison – Inter-Peak

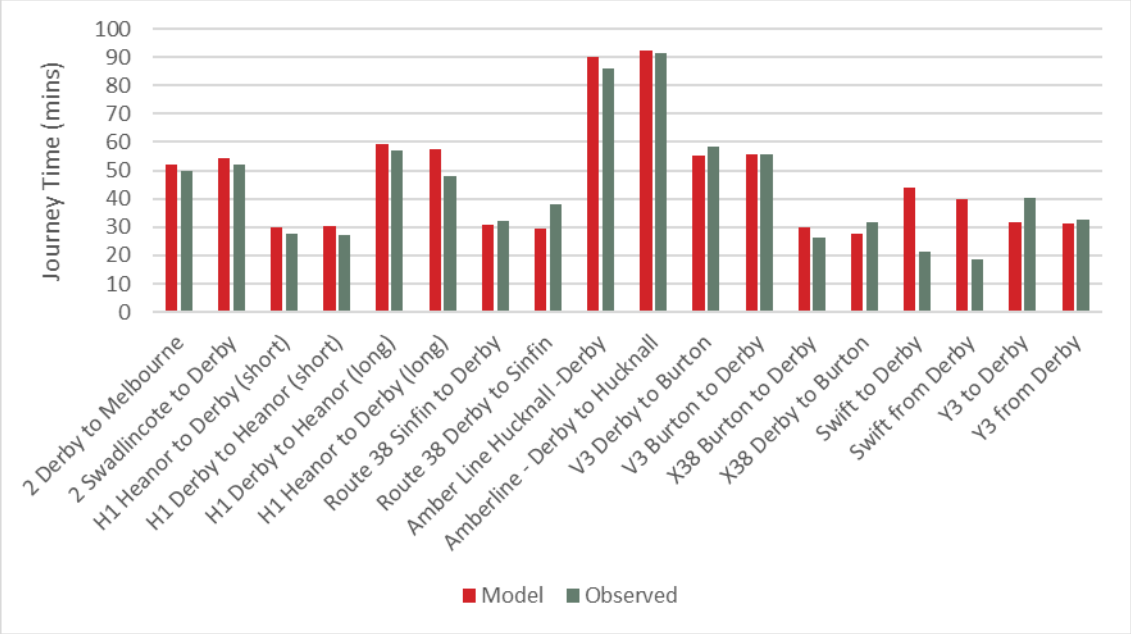
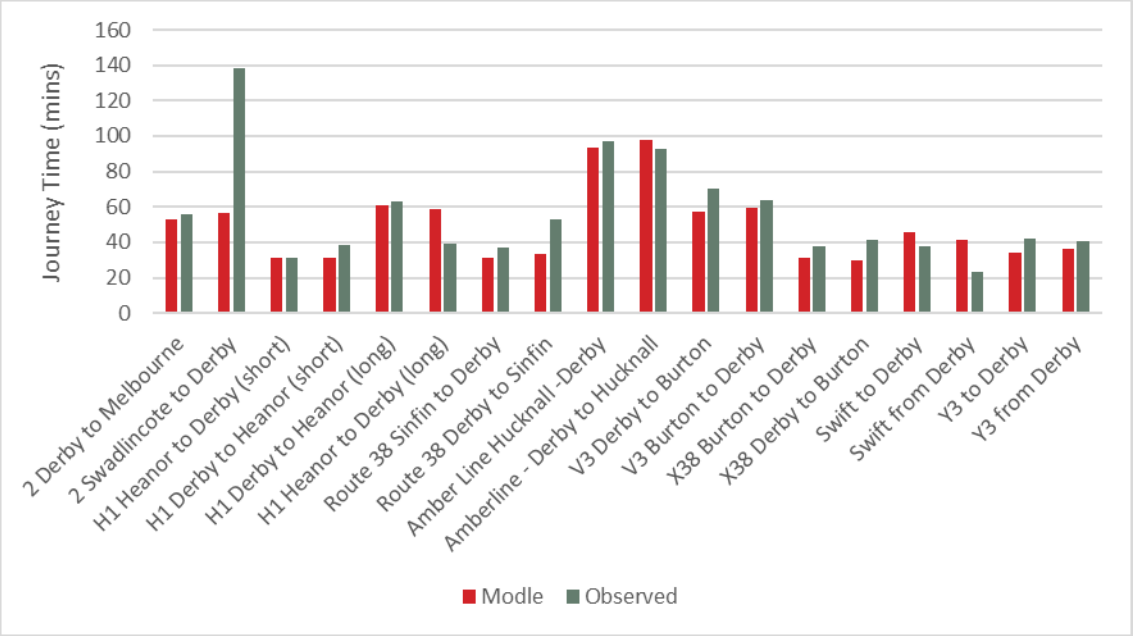


Figure 15. Journey Time Comparison – PM Peak



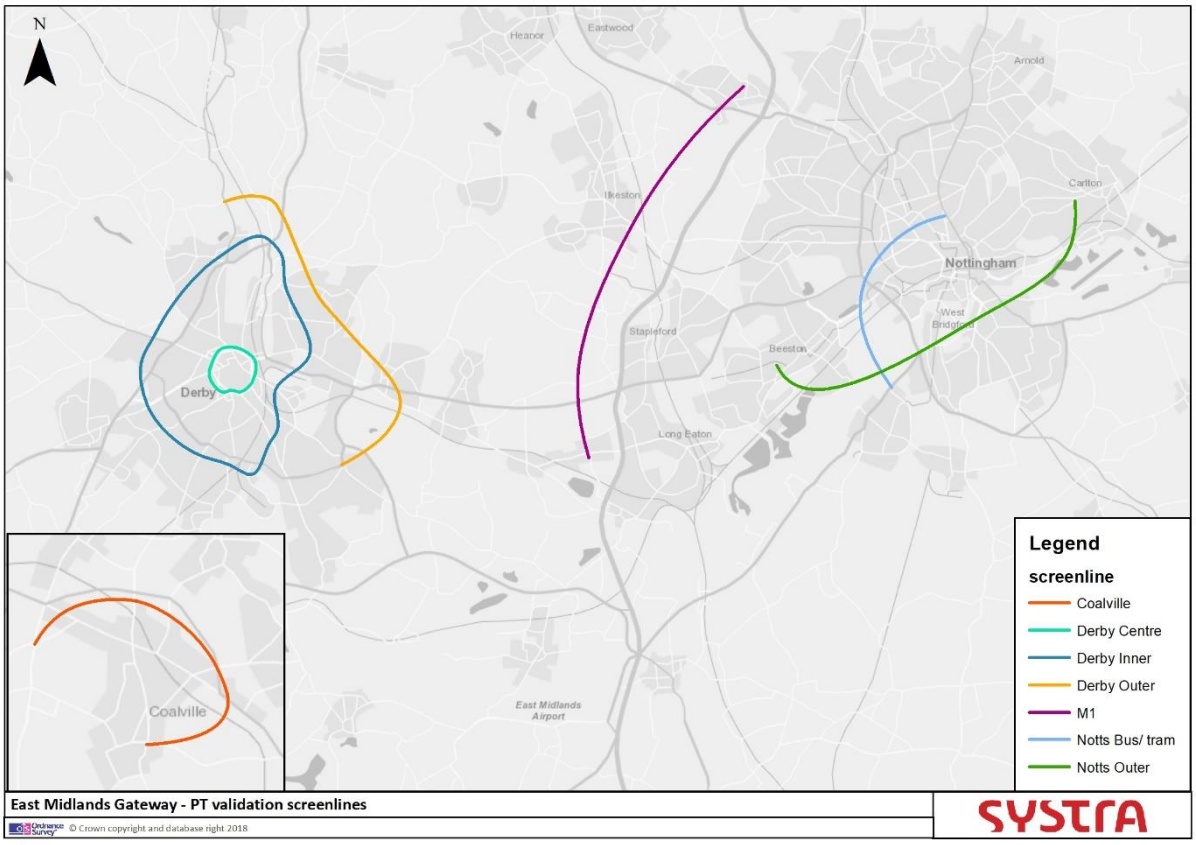

## 6.3 Assignment Validation

6.3.1 This section presents the validation of the public transport assignment model, comparing the model flows with observed counts of vehicle occupancy. TAG Unit M3.2 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.

6.3.2 The locations of the screenlines are shown below in Figure 16.

Figure 16. Public Transport Cordons and Screenlines




6.3.3 The results of the bus and tram screenline validation are presented below, in Table 16 to 0. In the morning peak, 14 out of 16 (88%) screenlines were within 15% of the observed count. In the inter-peak and evening peaks 13 out of 16 (81%) of screenlines were considered satisfactory.

6.3.4 Prior to ME being applied in the AM peak, only 7 out of 16 (44%) screenlines were within 15% of the observed count. In the Interpeak 9 out of 16 (56%) screenlines are within the criteria and 10 out of 16 (63%) in the PM peak.

6.3.5 TAG Unit M3.2 suggests that at a screenline level 95% of the counts should be within 15%. Obviously, all three peaks fall slightly short of that target, though it should be noted that due to the small number of screenlines having only a couple of points outside of the 15% bound has a large impact on the total percentage.

6.3.6 For the AM peak both sceenlines that are outside of the 15% bound are very close (15.6% and 17.2%). Similarly, for the Inter-Peak, two of the three screenlines above 15% are not above by much (15.7%, 17.6% and 27.1%). The cases in the PM are slightly further from the 15% target.

6.3.7 Screenline validation shows high levels of compliance (or near compliance) between the modelled and observed flows within the identified screenlines. This indicates a strong correlation between modelled and observed flows in all peaks and provides confidence that the model replicates flows in to and out of major urban areas.

Table 16. **Morning Peak Bus and Tram Cordon Validation**

| SCREENLINE | DIRECTION | MODELLED | OBSERVED | % DIFFERENCE | MATCH |
|---|---|---|---|---|---|
| Coalville | IB | 224 | 210 | 6.5% | Y |
| Coalville | OB | 184 | 185 | -0.6% | Y |
| Derby Centre | IB | 2014 | 2350 | -14.3% | Y |
| Derby Centre | OB | 1584 | 1370 | 15.6% | N |
| Derby Inner | IB | 2177 | 2340 | -7.0% | Y |
| Derby Inner | OB | 1371 | 1392 | -1.5% | Y |
| Derby Outer | EB | 521 | 460 | 13.2% | Y |
| Derby Outer | WB | 596 | 509 | 17.2% | N |
| M1 | IB | 889 | 969 | -8.3% | Y |
| M1 | OB | 382 | 373 | 2.3% | Y |
| Notts Outer | EB | 1553 | 1639 | -5.3% | Y |
| Notts Outer | WB | 1242 | 1318 | -5.8% | Y |
| Notts Bus/Tram | NB | 2459 | 2365 | 4.0% | Y |
| Notts Bus/Tram | SB | 1421 | 1377 | 3.2% | Y |
| Tram | IB | 3832 | 3802 | 0.8% | Y |
| Tram | OB | 4545 | 4563 | -0.4% | Y |

Table 17. **Inter Peak Bus and Tram Cordon Validation**

| SCREENLINE | DIRECTION | MODELLED | OBSERVED | % DIFFERENCE | MATCH |
|---|---|---|---|---|---|
| Coalville | IB | 90 | 71 | 27.1% | N |
| Coalville | OB | 112 | 111 | 0.8% | Y |
| Derby Centre | IB | 1154 | 1116 | 3.4% | Y |
| Derby Centre | OB | 1230 | 1394 | -11.7% | Y |
| Derby Inner | IB | 1116 | 1188 | -6.1% | Y |
| Derby Inner | OB | 975 | 989 | -1.4% | Y |
| Derby Outer | EB | 328 | 279 | 17.6% | N |
| Derby Outer | WB | 310 | 268 | 15.7% | N |
| M1 | IB | 323 | 312 | 3.3% | Y |
| M1 | OB | 324 | 316 | 2.8% | Y |
| Notts Outer | EB | 794 | 866 | -8.3% | Y |
| Notts Outer | WB | 730 | 824 | -11.3% | Y |
| Notts Bus/Tram | NB | 1603 | 1689 | -5.1% | Y |
| Notts Bus/Tram | SB | 1674 | 1792 | -6.6% | Y |
| Tram | IB | 1834 | 1712 | 7.1% | Y |
| Tram | OB | 4008 | 4028 | -0.5% | Y |

Table 18. **Evening Peak Bus and Tram Cordon Validation**

| SCREENLINE | DIRECTION | MODELLED | OBSERVED | % DIFFERENCE | MATCH |
|---|---|---|---|---|---|
| Coalville | IB | 99 | 69 | 43.6% | N |
| Coalville | OB | 167 | 174 | -4.2% | Y |
| Derby Centre | IB | 1156 | 1103 | 4.8% | Y |
| Derby Centre | OB | 1848 | 2171 | -14.9% | Y |
| Derby Inner | IB | 1280 | 1343 | -4.7% | Y |
| Derby Inner | OB | 1580 | 1625 | -2.8% | Y |
| Derby Outer | EB | 475 | 364 | 30.5% | N |
| Derby Outer | WB | 402 | 388 | 3.6% | Y |
| M1 | IB | 423 | 374 | 13.0% | Y |
| M1 | OB | 704 | 701 | 0.5% | Y |
| Notts Outer | EB | 1082 | 1138 | -4.9% | Y |
| Notts Outer | WB | 1085 | 1358 | -20.1% | N |
| Notts Bus/Tram | NB | 1415 | 1418 | -0.2% | Y |
| Notts Bus/Tram | SB | 2568 | 2554 | 0.5% | Y |
| Tram | IB | 2335 | 2058 | 13.5% | Y |
| Tram | OB | 6928 | 6818 | 1.6% | Y |

## 6.4 Rail station entries and exits

6.4.1 Rail validation was carried out using station entrances and exits. For stations with over 150 entries or exits the level of validation is considered “good” if modelled entries or exits are within 15% of the observed data; the level of validation is considered “adequate” if the modelled entries or exits are within 25% of the observed data.

6.4.2 Table 19 presents a summary of the levels of validation achieved for rail station entries. In the morning peak, 79% of stations match observed entry data. In the inter-peak this figure is 100% and in the evening peak 97% of stations match observed data.

Table 19. **Rail Station Entries**

| | NUMBER OF STATIONS | | | % OF STATIONS | | |
|---|---|---|---|---|---|---|
| | AM | IP | PM | AM | IP | PM |
| Good | 26 | 33 | 32 | 79% | 100% | 97% |
| Adequate | 4 | 0 | 1 | 12% | 0% | 3% |
| Not Validated | 3 | 0 | 0 | 9% | 0% | 0% |
| Total | 33 | 33 | 33 | | | |

6.4.3 This is a marked improvement of the pre-ME values. The number of stations with a good match was 55%, 76% and 67% for the AM peak, Inter Peak and PM Peaks respectively, with the proportion of stations being outside of 25% ("Not Validated) being 36%,m 21% and 27%.

6.4.4 Table 20 presents a summary of levels of validation achieved for rail station exits. In the morning peak, 94% of stations match observed exit data. In the inter-peak this figure is 97% and in the evening peak 73% of stations match observed data.

6.4.5 This indicates a strong correlation between modelled and observed flows in all peaks and provides confidence that the model replicates flows in to and out of key railway stations.

Table 20. **Rail Station Exits**

| | NUMBER OF STATIONS | | | % OF STATIONS | | |
|---|---|---|---|---|---|---|
| | AM | IP | PM | AM | IP | PM |
| Good | 31 | 32 | 24 | 94% | 97% | 73% |
| Adequate | 0 | 1 | 2 | 0% | 3% | 6% |
| Not Validated | 2 | 0 | 7 | 6% | 0% | 21% |
| Total | 33 | 33 | 33 | | | |

6.4.6 Again, this is a marked improvement of the pre-ME values. The number of stations with a good match was 61%, 73% and 58% for the AM peak, Inter Peak and PM Peaks respectively, with the proportion of stations being outside of 25% ("Not Validated) being 36%, 24% and 39%.

# 7. CONCLUSIONS

## 7.1 Use and Development of the Model

7.1.1 The East Midlands Gateway Model (EMGM) has been developed by SYSTRA to appraise a multi-modal access strategy to connect the East Midlands to the proposed HS2 station at Toton between Derby and Nottingham.

7.1.2 EMGM has been developed as a multimodal transport model built following the guidance in WebTAG. The structure of the model is based on the Greater Nottingham Transport Model however it has been developed using information from the existing Greater Nottingham Transport Model, Greater Derby Transport Model and the Leicester and Leicestershire Integrated Transport Model. The model has been fully recalibrated and validated in line with WebTAG guidance.

7.1.3 In addition to being used to assess the HS2 access strategy, the model is likely to be used in the future to assess a wide range of development and highway and public transport scheme applications across the study area.

7.1.4 The model simulation area includes the authorities of Nottingham City, Ashfield, Broxtowe, Erewash, Gedling, Rushcliffe, Derby City, Amber Valley, South Derbyshire, Charnwood and North-West.

7.1.5 The public transport model network and zoning system were both developed to be consistent with the highway model. Key link and node based information attributes such as link distances, congested speeds and coordinates were extracted from the SATURN assignment in an automated process and transformed into a CUBE Voyager EMGM base network.

7.1.6 Bus and NET services were taken from the constituent models and extended to include services accessing Charnwood and North-West Leicester, including routes between these areas and Leicester City Centre. These services were thoroughly reviewed against timetables. Rail services were taken from the Planet Midlands (PfM) Base Model and converted from Emme format to CUBE Voyager.

7.1.7 The majority of the bus matrix is synthetic and was developed using trip end data from the National Trip End Model (NTEM) and supplemented with available ETM data from Trent Barton which gave boardings and alightings by time period for selected services in the Derby and Nottingham area.

7.1.8 Tram demand was derived the Greater Nottingham Transport Model (GNTM), via a select link of movements using the tram network. The select link was undertaken individually for the three user classes and three time periods.

7.1.9 Rail demand was sourced from Planet Midlands (PM) and Planet Long Distance (PLD) models. The PLD data was an extract of demand to and from the EMGTM area.

## 7.2 Validation Performance

### Assignment Validation – Bus and NET

7.2.1 Screenline validation shows high levels of compliance between the modelled and observed flows within the identified screenlines. In the morning peak, 14 out of 16 (88%) screenlines were within 15% of the observed count. In the inter-peak and evening peaks 13 out of 16 (81%) of screenlines were considered satisfactory.

7.2.2 This indicates a strong correlation between modelled and observed flows in all peaks and provides confidence that the model replicates flows in to and out of major urban areas.

### Assignment Validation – Rail

7.2.3 In regards to rail station entries and exits the model shows high levels of compliance between against observed flows.

7.2.4 In the morning peak, 79% of stations match observed entry data and 94% of stations match observed exit data. In the inter-peak this figure is 100% and 97%. In the evening peak 97% of stations match observed entry data and 73% of stations match observed data.

7.2.5 This indicates a strong correlation between modelled and observed flows in all peaks and provides confidence that the model replicates flows in to and out of key railway stations.

### Journey Time Validation

7.2.6 Bus journey times were extracted from the model assignments and compared against the observed data collected for the EMGM study. In the morning peak, 78% of the bus journey times were within 15% of the observed time, in the inter-peak period 89% of routes considered satisfactory and in the evening peak 72% of the routes were within 15% of the observed time. These figures indicate a good level of bus journey time validation.

## 7.3 Overall Conclusion

7.3.1 The EMGM has achieved high levels of validation throughout its simulation area. As a result it is recommended as 'Fit for Purpose' to assess the HS2 multi-modal access strategy and for assessing a wide range of development and scheme applications across the study area.

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