REPORT

STRATHCLYDE REGIONAL TRANSPORT MODEL (SRTM) DEVELOPMENT

ROAD MODEL DEVELOPMENT REPORT

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1. SRTM ROAD MODEL OVERVIEW

1.1 Context

1.1.1 The development of a new regional transport model of Strathclyde (SRTM) was commissioned to provide analysis for the emerging Glasgow City Deal and support additional transport analysis through the regional transport planning process.

1.1.2 The SRTM is a multi-modal 'tour-based' strategic transport model covering the Strathclyde area, including the eight Clydeplan Local Authorities, the three Ayrshire Local Authorities and parts of Argyll and Bute. The model coverage is illustrated in Figure 1. SRTM Geographical Coverage Area

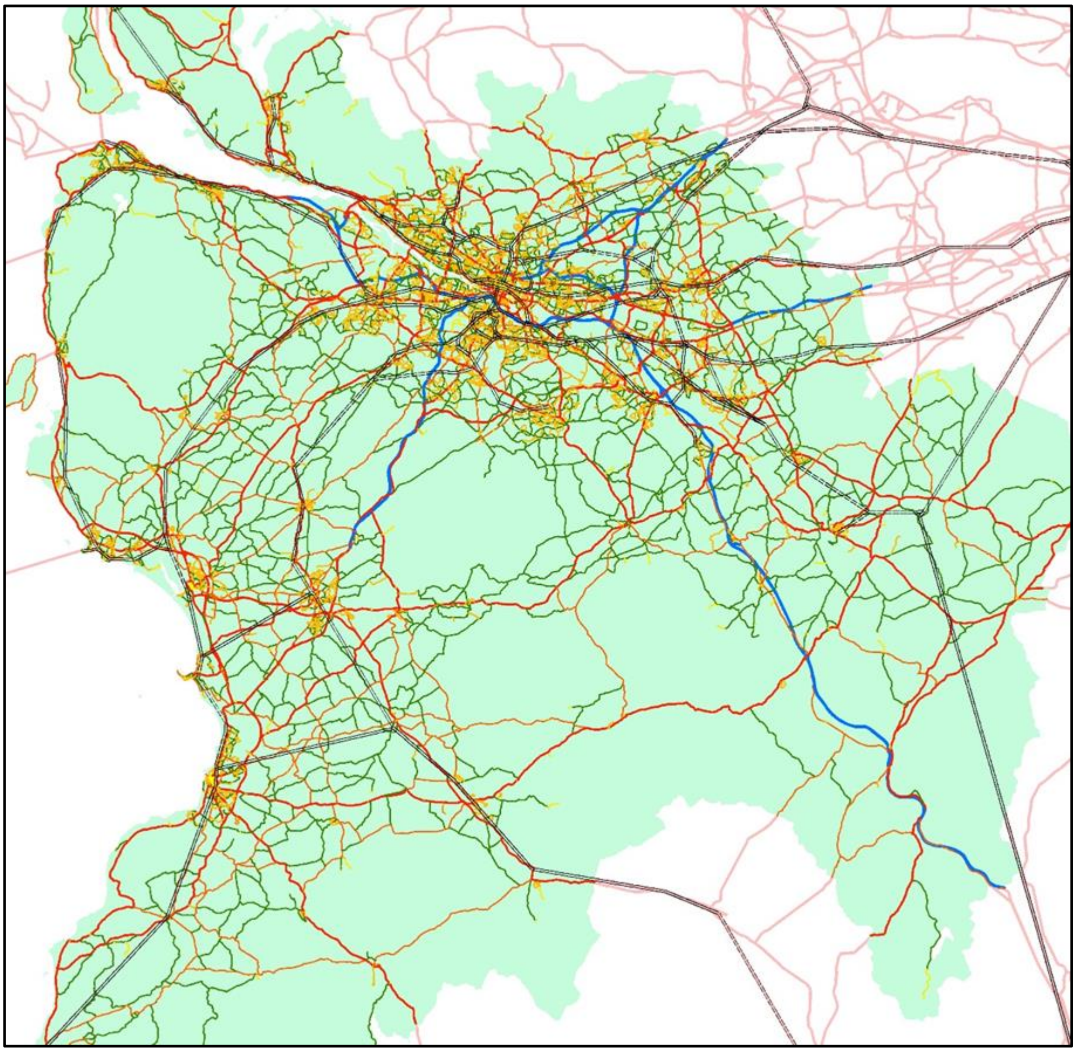

Figure 1. SRTM Geographical Coverage Area

1.1.3 The SRTM interfaces with the TELMoS / TMfS14 (Transport and Economic Model of Scotland / Transport Model for Scotland 2014) national modelling hierarchy to forecast changes in population and jobs, and subsequent changes in levels of traffic and travel over time and represent demand to/from externals areas.

1.1.4 The SRTM incudes trip generation, demand and assignment models covering the main road and public transport modes, including Park and Ride interchange and parking capacity and pricing within Glasgow City Centre. The SRTM is calibrated to reflect 2014 travel conditions.

1.1.5 A key task in the development of the SRTM is the defining of the models' road network that serves as the basis for the detailed SATURN model coding and the roads that the public transport model bus services can operate on. Traffic demand is then assigned to the road network coverage and calibrated and validated against observed traffic counts and journey time data.

1.1.6 The development of the SRTM road model was split into two phases, Phase 1 was created to be used for initial investigations, while Phase 2 represented the full modelling of the wider area.

1.1.7 This report provides commentary on the methodology of the full model, with results for the final Phase 2 road assignment model. No distinct reporting of the Phase 1 results are included, though these are available on request.

1.2 Road Assignment Model

1.2.1 The Road assignment model was developed using SATURN Software (Version 11.3.12f). The Road model consists of:

- SATURN road network coded input '.Dat' files;
- Bus service routing 'Preload' files;
- Road trip matrices;
- Generalised cost parameters;
- Range of assignment procedures, including defining convergence; and
- Output loaded network models by time period.

1.2.2 The road assignment determines the potential routes used by motorists, and calculates the average travel time and costs experienced by users. Base year generalised cost matrices are used to inform the Demand model.

Time Periods

1.2.3 Separate Road assignment models are calibrated to represent the AM Peak, Inter peak and PM Peak hourly time periods (Note that the Inter Peak model is also referred to as 'Lunch Time' (LT)).

1.2.4 The SRTM Road models are calibrated to represent the following time periods:

- AM (07:00 – 10:00);
- Lunchtime (LT, 10:00 – 13:00); and
- PM (16:00 – 19:00);

1.2.5 The School Run (SR, 13:00 – 16:00) and Off-peak (OP, 19:00– 07:00) time periods are not calibrated however assignment matrices are provided by the demand model.

1.2.6 The peak period to peak hour factors are presented in Table 1.

Table 1. Road Peak Period to Peak Hour Factors

	AM	Lunchtime	PM
Peak Period to Peak Hour Factor	0.355	0.333	0.355

User Classes

1.2.7 The Road Model includes the following User Classes:

- Employers Business;
- Commute;
- Others;
- Education;
- Retired;
- Light Goods; and
- Heavy Goods

1.3 Road Network Methodology

1.3.1 The initial methodology for the road network development is described within the SRTM Inception report, with some approaches evolving as development progressed.

1.3.2 The base year road network structure was developed from a GIS database using CUBE Software. Once developed in CUBE, the network was converted to enable the addition of road junction coding in SATURN, and supplemented with additional public transport network and service information.

1.3.3 Bus lane, bus gate and other road space reallocation measures will be coded into the GIS database, prior to conversion into CUBE format

1.3.4 The benefits of this approach are:

- A consistent GIS database to refer to, and between that used in network construction and the SPT bus database;
- The potential to retain / reconstruct the link between the shapefile and the road network, enabling the easier adoption of updates from the GIS in subsequent model development; and
- The potential use of the above shapefile link to considerably improve the quality of the presentation of the road model outputs through GIS.

1.3.5 The principal areas where our methodology has evolved are in the following areas, these are documented in the following chapters:

- Change in source of information for rural / urban definition;
- Introduction of Q nodes for motorway merges; and
- Removal of traffic islands – a specific link classification within the ITN database.

1.3.6 The road network construction processes are outlined in Figure 2. Road Network Build Process – Stage 1 and Figure 3. Road Network Build Process – Stage 2

1.3.7 The proposed road network coverage is illustrated in Figure 4. Road Network Coverage (Fully Modelled Area) and Figure 5. Road Network Coverage (Glasgow Urban Area) Note that Arran although is linked to the mainland via zone centroid connectors and the road network to the north, east and south of the fully modelled area is represented as buffer network.

1.4 Data Sources

1.4.1 The data used in the construction of the SRTM road network was:

- SPT supplied Integrated Transport Network layer data (this is the standard Ordnance Survey ITN layer with additional links for SPT bus services);
- 2011 Census output area population statistics for population density;
- SRTM / TMfS zone system;
- SPT supplied bus route shapefile (January 2016);
- SPT supplied bus stop shapefile (January 2016);
- SATURN manual;
- Google Maps / Earth; and
- Various background mapping layers to aid

1.4.2 The development of the SRTM zone system is detailed in a technical note, Development of Zoning System, SYSTRA, 10/3/2016.

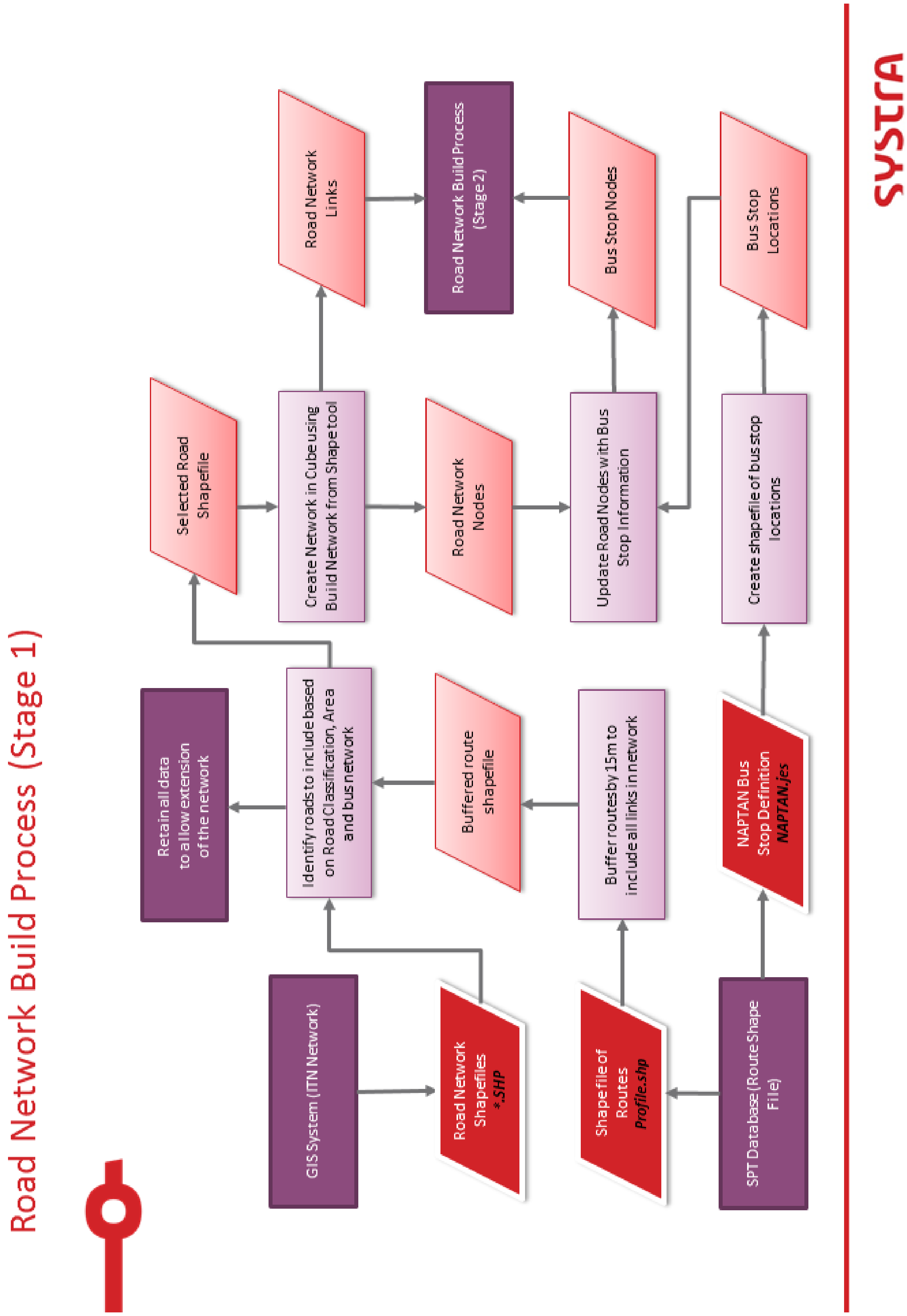

Figure 2. Road Network Build Process – Stage 1

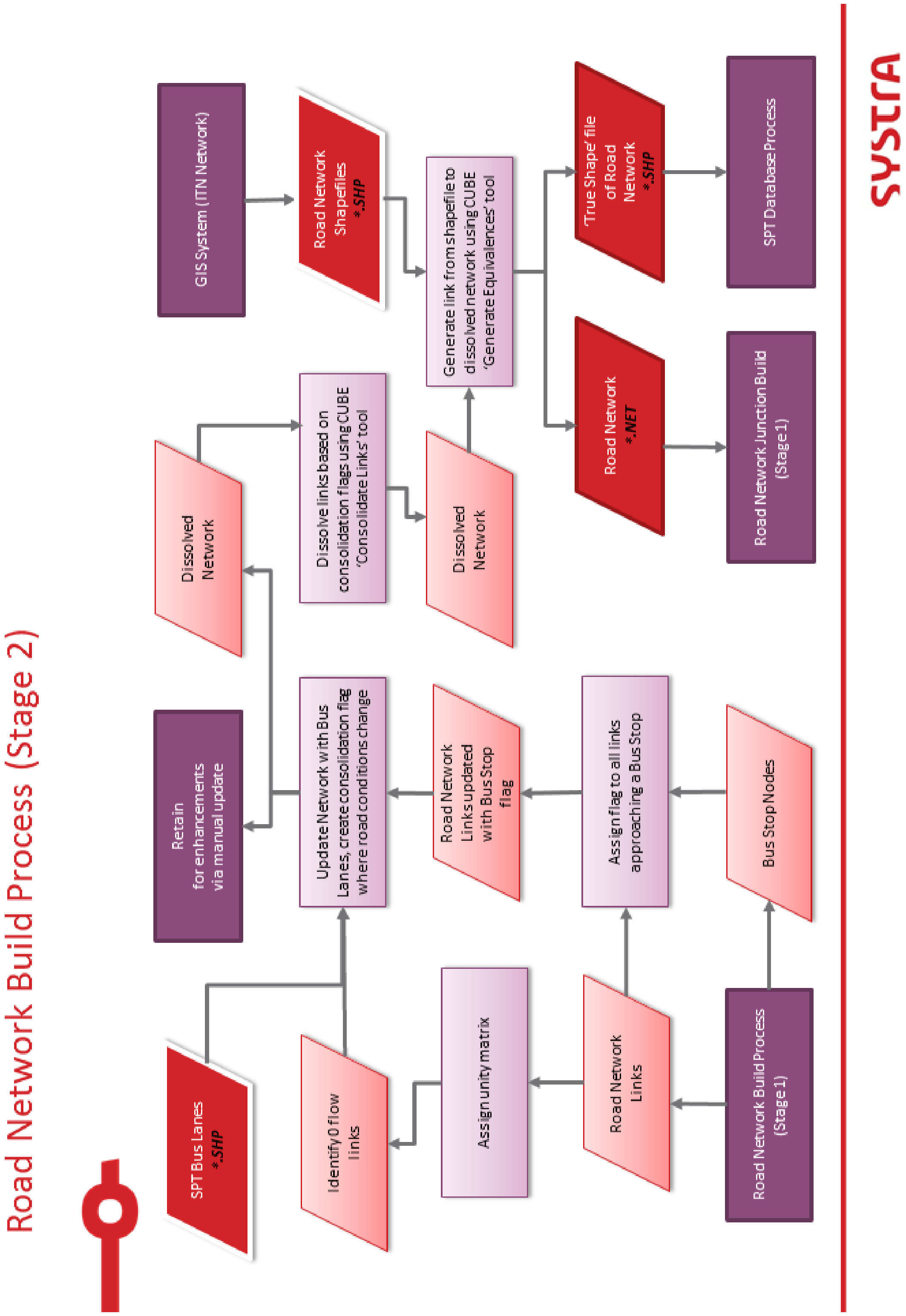

Figure 3. Road Network Build Process – Stage 2

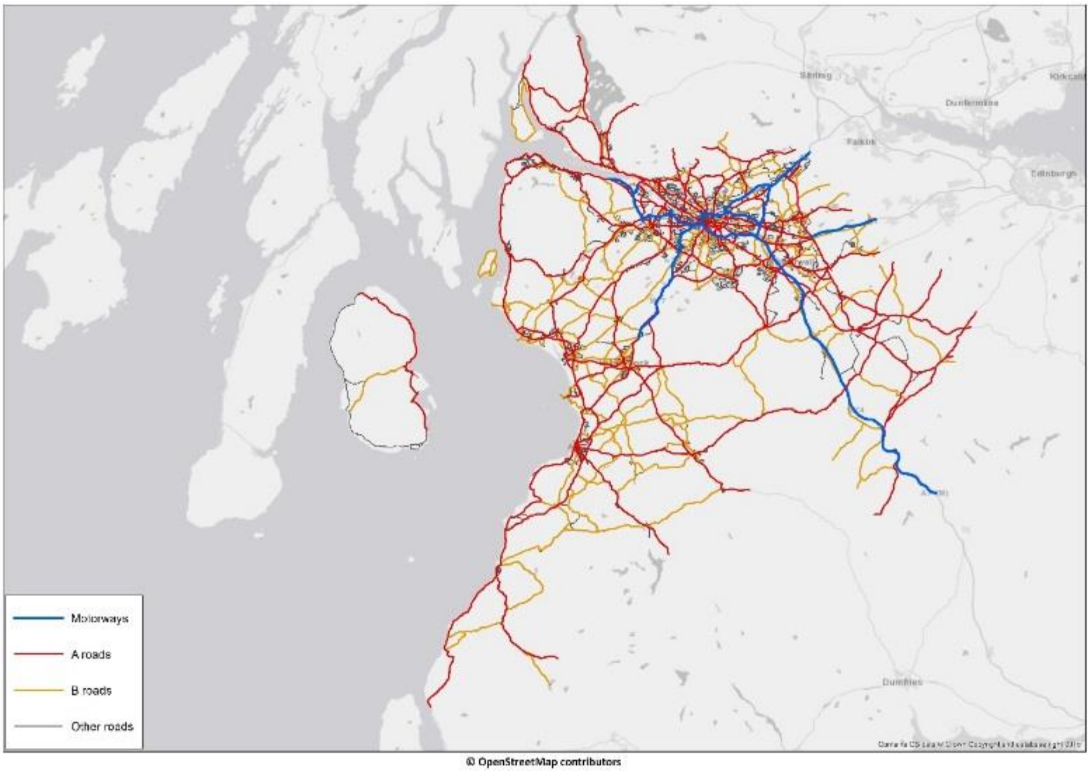

Figure 4. Road Network Coverage (Fully Modelled Area)

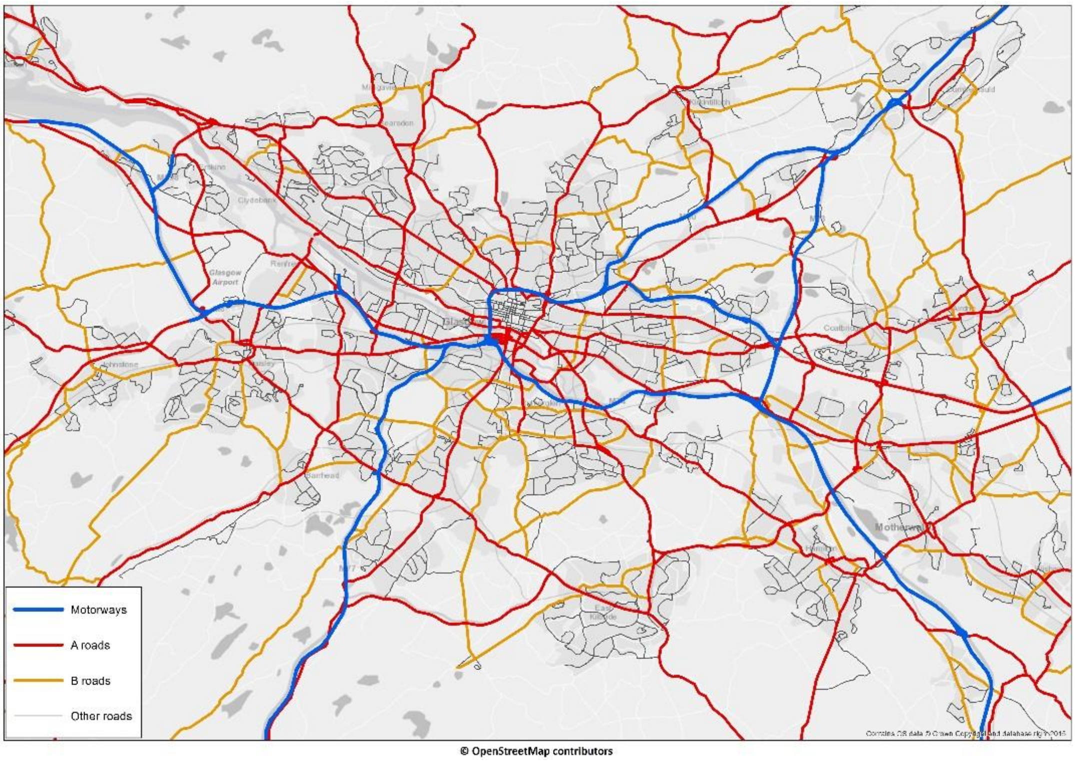

Figure 5. Road Network Coverage (Glasgow Urban Area)

2. ROAD NETWORK DEVELOPMENT

2.1 Network Construction

2.1.1 The SRTM road network has been developed through a multi-stage process from the source ITN road layer supplied by SPT. This road layer shapefile was chosen to maximise consistency between the bus service database and the SRTM road model.

2.1.2 The road network has thus been coded into SATURN format from first principals using the following stages;

- Link distance retained from the ITN shape length;
- The bus routes were identified by the generation of a 10m buffer around the centre of each road link and joining this to the SPT provided bus route profile. This provided a bus route flag on each link to ensure that the link was part of the GIS file sent to CUBE for network building;
- For each link with a bus stop within 10m of the centreline of road, identify and flag the link. This is used to retain the nodes at each end of the link as potential bus stops during the consolidation stage within CUBE;
- Process census population data to obtain an output area based population density value; (section 2.2)
- Add Q nodes by splitting links downstream of dual carriageway / motorway merges; (section 2.3)
- Traffic Island removal – change the link classification of “traffic island” to single carriageway to aid eventual network consolidation; (section 2.4)
- Add link speed and capacity attributes (set section on default link capacity and speed values) to dataset based on link description, nature and urban / rural classification; (section 2.5)
- Build road network within CUBE using “Build Network from Shape tool”;
- Identify zone centres from provisional zoning system and automatically add zone centroid connectors based on shortest link;
- Assign a unity matrix to the road network (using Cube Highway – Best Path generalised cost based on Time + 0.6 x Distance);
- Generate a shapefile from CUBE with link flows from unity assignment;
- Process the updated network in GIS to remove redundant links, based on the following rules:
    - Keep links with flow from unity assignment;
    - Keep all Motorway, A Road and B Roads; and
    - Keep all links with bus route allocated.
- Load trimmed shapefile into CUBE and rebuild network;
- Use CUBE’s network consolidation tool to aggregate links where they have matching adjacent features;
- Export shapefile from CUBE; and
- Use export to build a buffer SATURN road network.

2.1.3 A subsequent stage undertook manual consolidation of links to enable simulation coding of relevant intersections, especially for traffic signal junctions as single nodes.

2.1.4 The automatic buffer network coding of the ITN shapefile was carried out in CUBE, the zone connectors were added at this stage with constraints to avoid dual one-way links. These were then refined as part of the upgrading of the network to simulation. The network was edited using the graphical editor providing default values for the simulation area and in the buffer area.

2.1.5 Throughout the model's development, where large delays were noted these were investigated to determine if the stacking capacity and blocking back was adequately reflected. For example, within city and town centres, signalised roundabouts and 'q' nodes. Similarly based on local knowledge, a review of known hot spots was undertaken to determine whether there was an acceptable level of queuing. In relation to short links, a review of the whole corridor where the short links were located was undertaken. The checks included a review of traffic flows, link times and delays at the nodes.

2.1.6 An additional task was to identify each count site location by the unique ITN layer TOID. This benefits the calibration stage and has no impact on the road network development.

2.2 Use of Census Population Data

2.2.1 Our proposal and inception report identified HERE data as a potential source of information on the number of lanes and rural / urban link classifications. A quote for the supply of the data for the SRTM region was received and it was determined that this cost could not be justified as an additional expense on the project.

2.2.2 Road lane information would be determined by link classification, with suitable manual adjustments for main trunk roads and the local strategic road network reported in section 2.6.

2.2.3 A revised methodology for the urban / rural link classification was sought. A potential source of information on this split was identified through the Scotland Urban Rural Classification work (http://www.gov.scot/resource/0039/00399487.pdf). While we have used this data for the reporting of the zoning system, it proved too coarse to use for road network development, particularly for peri-urban areas.

2.2.4 The selected methodology was to source the 2011 census population data at output area level and calculate a population density values for each output area. A threshold of 100m was then used to create an urban and rural definition.

2.2.5 The population density values were processed to provide a 'fishnet' coverage with the Urban rural flags, this eliminated many of the areas of the model where there were non-residential space in an urban area. Although this approach is more effective than the previous methodology, there was still a residual requirement for manual updating of a number of links as part of the network building/development process.

2.2.6 The resulting shapefile was used to update the road link attribute for urban / rural based on the closest output area to modelled links.

2.3 Addition of Q Nodes

2.3.1 A review of the coding of dual carriageway and motorway merges was carried out, in particular through reference to the SATURN user manual (Appendix Q – Using Q Markers for Motorway Merges).

2.3.2 A link attribute was added into the database to enable all merge locations, links where Q nodes were required, could be identified.

2.3.3 A routine within GIS was developed to split these links if the merge link was more than 175m long. The split created two new links, one representing the 100m (+/- 5m) from the merge point to the "Q" node. The second, representing the remainder of the original link.

2.3.4 These two links were added into the database, with the original link merge location identifier update to be "superseded".

2.3.5 The GIS export for network build did not include the "superseded" links, thus allowing the Q nodes to fall through into the network via the two new links.

2.3.6 For those links less than 175m long, the adjacent node to the merge is used as the Q node.

2.3.7 A list of Q nodes available without splitting links was prepared.

2.4 Traffic Island Removal

2.4.1 An additional stage has been required for the removal of traffic islands within the GIS network data.

2.4.2 These are road links within the ITN layer that have a network attribute entitled traffic island. They are commonly between two identically attributed roads, for example two single carriageway roads.

2.4.3 For the purpose of the SRTM model they do not represent a change in road conditions.

2.4.4 The methodology for their removal has thus been to update the link classification attribute, replacing traffic island with the adjacent value, for example single carriageway. Thus, the subsequent network consolidation stage will group the three links together and in effect remove the traffic island.

2.5 Default Link Capacity and Speed values

2.5.1 In order to perform an initial unity matrix assignment, the network required default speed and link capacity settings to be encoded into the network.

2.5.2 Capacity and speed at free flow values were sourced from COBA, with a subset of six selected for simplicity and applied to the ITN based SRTM link classification as presented in Table 1 below.

Table 2. Default Capacity and Speed Values

ID	DESCRIPTION	FREE FLOW SPEED	LINK CAPACITY
1	Rural – Dual 2 Motorway	112	2,430
2	Rural – Dual 2 All Purpose	104.5	2,180
3	Rural – Single 7m Typical	78	1,380
4	Suburban – Dual (Typical Development)	71	1,270
5	Suburban – Single (Typical Development)	61	1,270
6	Urban – Non central (80% Development)	48.5	780

Source: COBA Speed Flow Curves, Speed is kph, Capacity is pcus/hr/ln

2.5.3 The relationship between ITN classification and COBA classification is provided in Appendix A for each ITN, Rural/Urban combination within the SRTM modelling area.

2.5.4 The selected values represent the default values used for the unity matrix assignment.

2.6 Number of Lanes Check

2.6.1 The ITN layer does not include an attribute documenting the number of lanes on links. Consequently the number of lanes has been coded into the road model to ensure robust representation of link capacity within the model.

2.6.2 Our approach has been to identify all dual carriageways of the ITN layer within the SRTM boundary and create a new flag for number of lanes, provisionally set to zero. We have then through manual inspection of Google maps updated the flag to represent the number of lanes. Table 2 provides a summary of the changes to lane coding within the network.

Table 3. Dual Carriageway Links

NUMBER OF LANES	DUAL CARRIAGEWAY LINKS		DUAL CARRIAGEWAY LINK LENGTH	
	#	%	#	%
1	1,529	17.8%	160,183	12.1%
2	6,043	70.5%	958,554	72.4%
3	871	10.2%	186,901	14.1%
4	120	1.4%	15,326	1.2%
5	12	0.1%	3,330	0.3%
6	1	0.0%	98	0.0%

Note: Link length is in km

2.6.3 At this stage of network development, the junction coding processor was operated to generate template simulation area coding for each node within the SRTM model area. This process is discussed further in the Chapter 4.

2.6.4 Post operation of the junction coding processor, traffic signal junctions have been coded into the model. At many locations, this has required the consolidation of links to enable the junction to be represented as a single node.

2.7 Link Consolidation for Signalised Junctions

2.7.1 Traffic signal junctions within SATURN are represented by single nodes. Link consolidation took place to match the signal specification forms that were provided by Local Authorities covered within the model extent.

2.7.2 There are instances within the ITN layer, principally adjacent to trunk roads, where these layouts have been "exploded" and thus features such as left turn filters are represented as additional links.

2.7.3 This "exploded" representation has been translated into the initial road network through the use of the ITN layer and the processes outlined in Chapter 2.

2.7.4 The approach adopted a manual coding task at each signalised junction, with the existing nodes retained where possible.

2.8 Final Pre-Calibration Road Network

2.8.1 Key statistics regarding the final pre-calibration road network are provided in Table 3. Note there are a handful of differences within the coding of Inter Peak Link Indices. These reflect roads where bus lanes were not identified operating in the Inter Peak, with a higher road capacity assumed (and where this extra capacity does not provide extra parking).

Table 4. Link Type Summary (AM and PM networks)

LINK TYPE	LINK INDEX	NO OF LINKS	DISTANCE (KM)
Urban Central	1	100	14,113
Urban Non Central - Dual	3	3,405	413,974
Suburban - Single	5	30,365	5,298,823
Urban Motorway 70mph	7	28	13,970
Urban Motorway <70mph	8	6	7,018
Ramp at Grade Separation	9	565	99,319
Rural Single Hills L Bends H	16	12	38,724
Rural Single Hills L Bends M	17	5,341	5,647,011
Rural Single Hills H Bends H	19	16	10,781
Rural Dual Hills M Bends H	22	102	36,909
Rural Dual Hills M Bends M	23	2	2,412
Rural Dual Hills M Bends L	24	5	9,505
Rural Dual Hills L Bends H	25	3	93
Rural Dual Hills L Bends L Cap L	27	493	257,627
Motorway D2M Hills L Bends L	36	47	53,786
Motorway D3M Hills L Bends L	37	1	16
Motorway D3M Hills H Bends L	39	1	100
Urban Non Central - Dual	46	26	16,925
Ramp at Grade Separation	50	130	37,534
Motorway 2 Lanes Standard	51	1	74

LINK TYPE	LINK INDEX	NO OF LINKS	DISTANCE (KM)
Rural Dual Dev L 40mph	54	3	630
Rural Dual Dev H 40mph	55	220	49,483
Rural Dual Grade Separated	56	1	480
Rural Dual 50mph	58	4	4,295
Rural 3 lane 50mph	65	6	635
Wide single lane Motorway Merge	76	2	818
Wide single lane Motorway Merge	79	92	92,000
Suburban – Single	99	163	7,565
Renfrew Ferry/Zone Access	101	3	2,615
2 lanes motorway normal 50MPH	102	19	10,585
3 lanes motorway normal 50MPH	103	26	10,639
4 lanes motorway normal 50MPH	104	19	6,761
5 lanes motorway normal 50MPH	105	13	3,810
2 lanes motorway normal 60MPH	106	19	25,148
3 lanes motorway normal 60MPH	107	35	16,889
4 lanes motorway normal 60MPH	108	2	910
2 lanes motorway normal 70MPH	110	111	109,238
3 lanes motorway normal 70MPH	111	89	95,945
4 lanes motorway normal 70MPH	112	18	6,982
2 lanes motorway normal 50MPH	122	33	20,178
3 lanes motorway normal 50MPH	123	5	3,055
4 lanes motorway normal 50MPH	124	5	489
3 lanes motorway low 60MPH	127	2	1,157

LINK TYPE	LINK INDEX	NO OF LINKS	DISTANCE (KM)
4 lanes motorway low 60MPH	128	2	653
Urban Central low	130	2	392
Urban Central 1 lane Roundabout 32kph	131	1,588	26,364
Urban Central 2 lane Roundabout 32kph	132	1,500	29,729
Urban Central 3 lane Roundabout 32kph	133	144	3,312
Urban Central 4 lane Roundabout 32kph	134	19	485
Traffic Calmed	136	383	83,525
Urban Central 1 lane Roundabout 42kph	141	307	6,829
Urban Central 2 lane Roundabout 42kph	142	359	10,139
Urban Central 3 lane Roundabout 42kph	143	36	1,003
Rural Single Hills L Bends M 60MPH	171	6	13,414
Rural Dual Hills L Bends L Cap M	271	35	18,063
Rural Dual Hills L Bends L Cap H	272	13	8,139
Urban Non Central – 3 lanes	333	42	3,343
Urban Non Central – 4 lanes	343	14	698
Zone Centroid	900	5,350	188,133
Zone Centroid Connector (Non-Walking)	901	18	16,012
Zone Centroid Connector (Non-Walking)	902	9	6,062
No Link Index	N/A	115	18,836

3. SIMULATION AREA CODING

3.1 General Approach

3.1.1 The road network coding provides the SATURN buffer network. This buffer network provides a structure to which simulation area coding can be appended. This simulation area coding represents road junctions within the SRTM model, these junctions fall broadly into the following categories:

- Priority Junctions;
- Roundabout junctions;
- Signalised junctions; and
- Motorway merges.

3.1.2 The model was delivered in two phases, with the primary difference in the models being the extent of junction coding within the road assignment model.

3.1.3 The Phase 1 model included simulation coding area as illustrated in Figure 6. Phase 1 Simulation Coding Extent

3.1.4 The subsequent Phase 2 of the model development extended the simulation model area to that illustrated in Figure 7. Full Extent of Simulation Coding

3.1.5 The coding of this number of junctions requires a template approach, as described below.

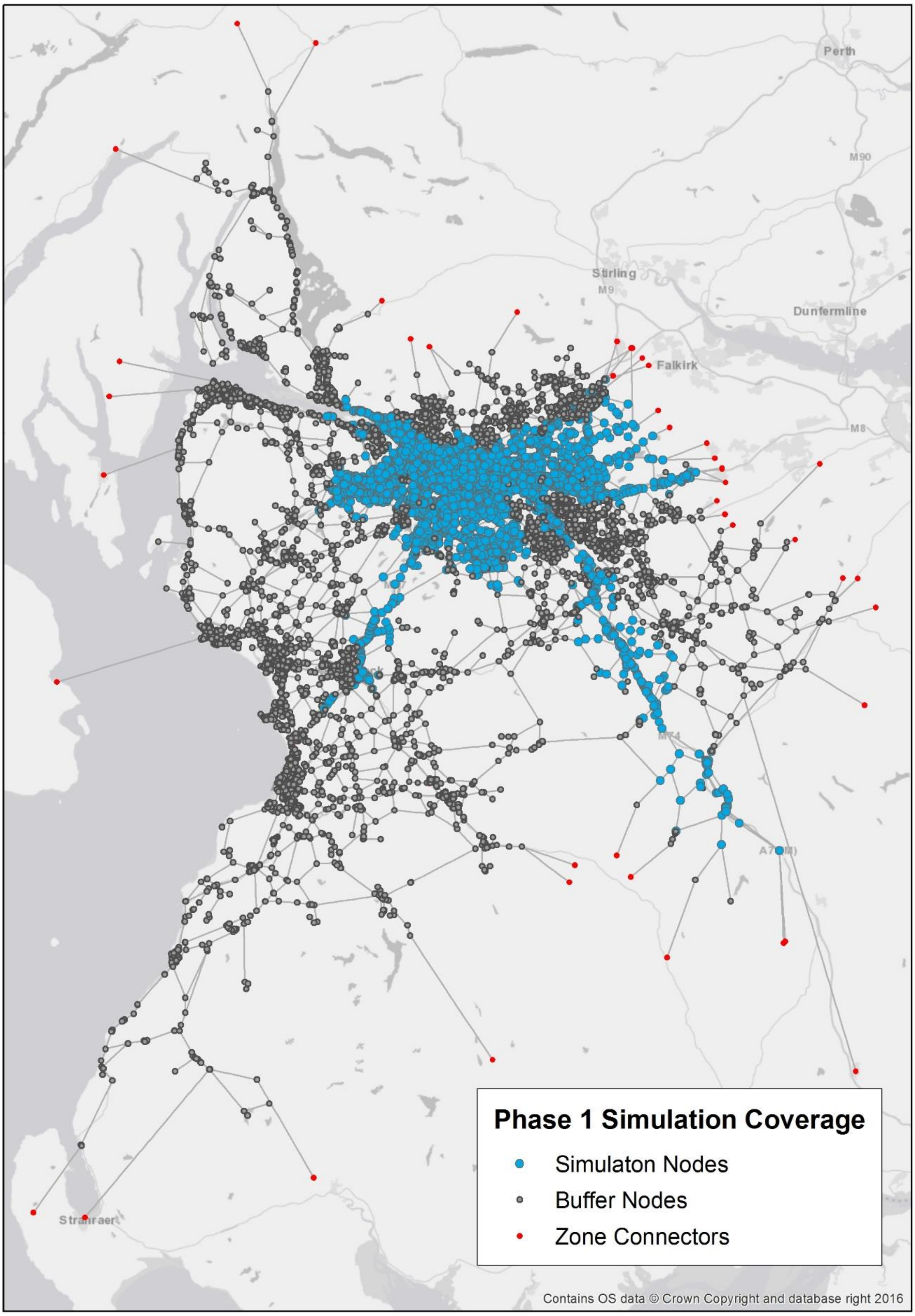

Figure 6. Phase 1 Simulation Coding Extent

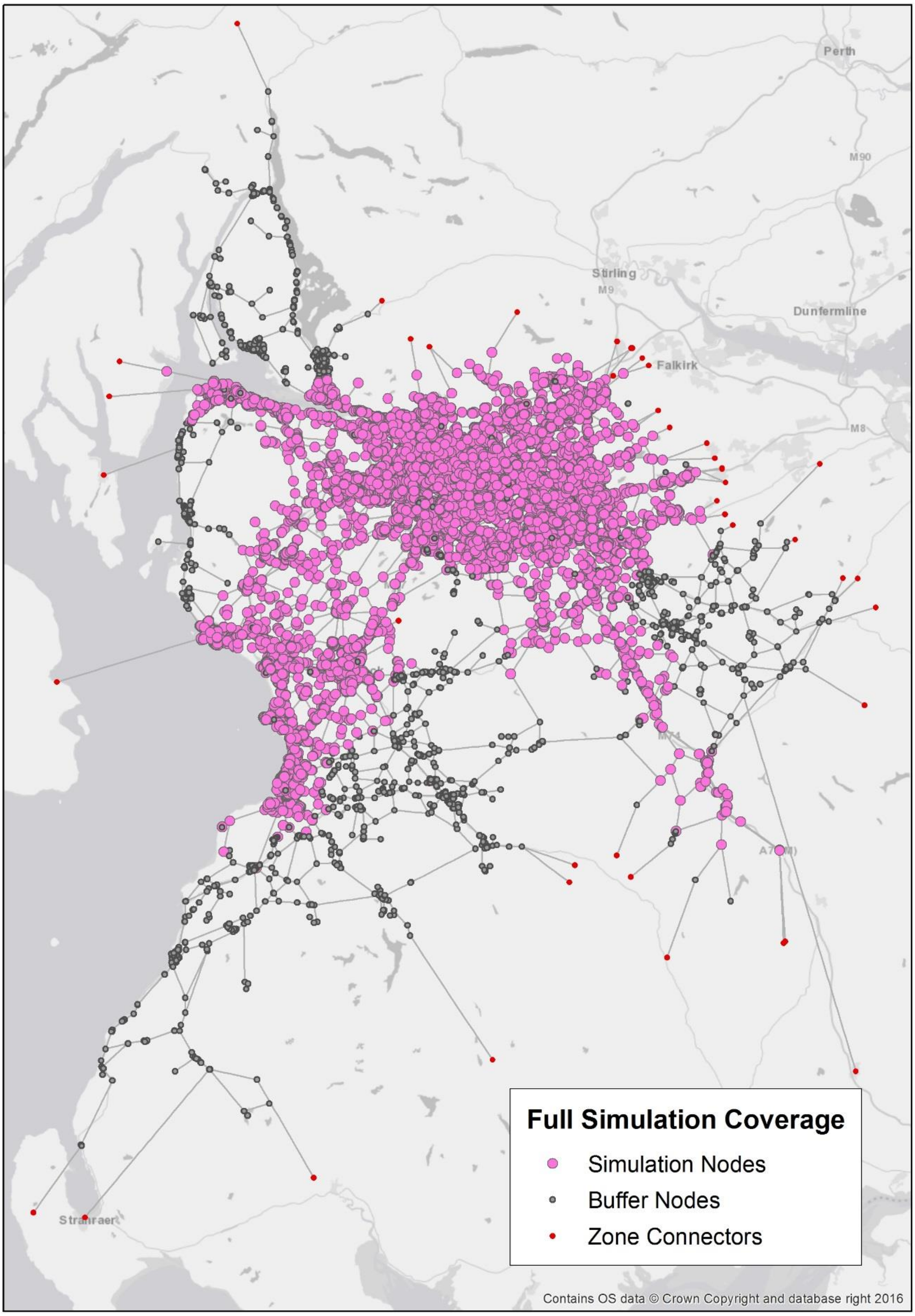

Figure 7. Full Extent of Simulation Coding

3.2 Template Process

3.2.1 The inputs for the template coding process are two files detailing links and nodes respectively. These must be presented in CSV format and should have a header row. It is noted that the header row is not read in and so there is no requirement for the descriptions to match identically.

3.2.2 The link file details all links in the network with sufficient detail to code the arms of each junction. A complete list of attributes is provided in Table 4.

Table 5. Link Input File Description

VARIABLE	TYPE	DESCRIPTION
A Node	Integer	Starting node of the link
B Node	Integer	Terminating node of the link
Lanes	Integer	Number of entry lanes for the link
Freeflow Speed	Integer	The freeflow speed in kph
Distance	Integer	Distance should be provided in (rounded) meters
Speedflow Curve	Integer	The speedflow curve for the link
Priority	Integer	An undefined priority marker which must increase with the importance of the link e.g. motorways should be higher than B roads
Junction Type	Integer	This is currently unused but could potentially be updated to include roundabout coding etc. in a later version. At this point however the field is required but can be left blank.
Banned Link	Boolean	This can be left blank unless travel in that direction along the link is banned in which case a 1 should be used.

3.2.3 The free flow speed coded here, assumes that in the parameter sections of the SATURN network the parameter SPEEDS = T.

3.2.4 The ITN layer provided details of the road classification which determined a hierarchy (combination of a road type and the nature of the junction), using this data, roads were allocated a priority score. When different roads met, the road with the higher score had priority over the other roads, for example 'A' road roundabout had a high priority over a 'B' road roundabout. The priority indicator is used to establish the main carriageway at a junction and evaluate which flows can pass unhindered and where the left and right turns are located, and needs to be generated in ascending order of importance.

3.2.5 The node file provides geographic references for each node in the network, and should account for every node listed at either end of the links. Only three sets of data are required, as shown in Table 6.

Table 6. Node Input File Description

VARIABLE	TYPE	DESCRIPTION
Node	Integer	Node number, must be less than 5 characters long
X coordinate	Integer	Easting
Y coordinate	Integer	Northing

3.2.6 The outputs of the process are two files, the first is the junction coding file with SATURN compatible junction coding and the second is a log file which provides information on potential complications which the process encountered.

3.2.7 The first step in the template process application is to read in files for both links and nodes. Once the full links file has been read in, the reverse links are created where they do not exist (one-way links), and these are given dummy attributes of zero for the majority of fields with the following exceptions:

- A node and B node are taken as the reverse of the known link;
- Distance is inherited from the reverse link; and
- The banned link flag is set to 1.

3.2.8 This also generates a list of junctions by listing all the A nodes and B nodes which it encounters.

3.2.9 The process then loops through the entire list of junctions which were populated and then for each junction, checks all links to establish the number of arms which connect to the junction, regardless of direction.

3.2.10 The bearing of these arms is then established to ensure that the arms are stored in a clockwise direction as required by SATURN, always taken from North as the starting point. At this point, the junction has the basic geometry available with the number of arms, their distances, lanes, and priorities, and their relation to each other. A manual adjustment was made where curving slip roads and over-bridges were not always defined in a strict clockwise order.

3.2.11 An initial junction type can now be established consistent with the SATURN classifications, specifically:

- External nodes (0);
- Priority junctions (1);
- Roundabouts (2);
- Traffic signals (3);
- Dummy nodes (4); and
- Roundabouts with 'U'-turns (5).

3.2.12 Neither roundabouts or signalised junctions are identifiable at this stage so this reduces the practical choices to external nodes, priority junctions, and dummy nodes.

3.2.13 Dummy nodes are easily identifiable as they must have 2 arms while external nodes are identified either by having a junction number less than the user-defined zone limit or only have a single arm (dead-end). All remaining junctions are currently considered to be priority junctions.

3.2.14 Dummy nodes are assumed to be purely an aesthetic node choice in the network used to better reflect the geometric structure of the road network, and are not considered as relevant to capacity impact in this application. In practice this means that an infinite capacity is allowed on the turning movement (if both links are assumed to be two-way), which is coded as 9999. A manual adjustment was made to the capacity if there was a likelihood of blocking back from the downstream node. An example of the coding for a dummy node is shown below.

```
22596     2     4
     22603*   1    48    94 9999  1 1
                                       72
     22595*   1    48   205 9999  1 1
                                       72
```

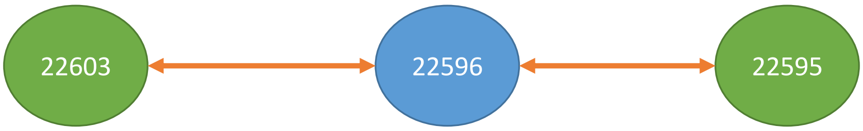

Figure 8. Example Dummy Node Coding

External Nodes

3.2.15 External nodes are only required to have the most basic geometric and link definitions within SATURN, and an example is provided below.

```
22397     1     0
     22314*   2   112   699
                                       75
```

Figure 9. Example External Node Coding

Priority Junctions

3.2.16 Priority junctions are more complex than the previous cases, and begin by establishing the main carriageway of the junction by comparing the maximum priority flag on each arm to find the highest values. A strategic corridor review was undertaken to confirm that priority junctions replicate the on-street conditions.

3.2.17 This comparison must consider both travel entering and leaving the node regardless of whether that is possible (due to a one-way link for instance) in order to get the best estimation of the priorities.

3.2.18 Having established the priority, the turning movements must be coded, which consist of five arguments:

- LSAT, (the saturation flow);
- TPM, (the turn priority marker);
- TPMod, (the turn priority marker modifier);
- Lane 1 (first lane counted from the nearside used by the turn); and
- Lane 2 (last lane used by the turn).

3.2.19 LSAT, the saturation flows are based on previous models such as SEStran Regional Model where a series of default saturation flow (described in Passenger Car Units per Hour (PCU's) were established to represent junction attributes depending on the scale and nature of the intersection and approaches. During the model development, saturation flows (per lane) were reduced where junction geometry appeared constrained due to the nature of the junction layout

3.2.20 TPMod is never used within the template process as they are expected to be used relatively infrequently and are included as required through the manual review of the network.

3.2.21 The remaining arguments follow the definitions provided in Table 7.

Table 7. Priority Junction Turning Movement Template

TURN DESCRIPTION	LSAT	TPM	LANE 1	LANE 2
Main left turn	1200		1	1
Main straight	1800 per lane		1	Last
Main right	875	X	Last	Last
Secondary left	1200	G	1	1
Secondary straight	1800 per lane	G	1	Last
Secondary right	875	G	Last	Last

Merges

3.2.22 Merges are identified in the network by considering priorities of each entry and exit from a junction and comparing the priorities against the user-defined motorway priorities and slip priorities. Merges can be highlighted as any junction which has:

- One motorway priority entering;
- One slip priority entering;
- One motorway priority leaving; and
- No other entries or exits.

3.2.23 In these instances there are only two possible movements in the junction and the coding is as defined in Table 8.

Table 8. Merge Junction Turning Movement Template

TURN DESCRIPTION	LSAT	TPM	LANE 1	LANE 2
Main Carriageway	1800 per lane		1	Last
Join slip	1800 per lane	M	1	Last

3.2.24 A merge scenario automatically takes precedence over the standard priority junction scenario.

3.2.25 The network has been coded with 'Q' nodes in place (as defined in SATURN manual appendix Q), which help to effectively model the merging of traffic on the network. These are identified by checking the immediate upstream node from a merge and checking whether it has 2 arms (is a dummy node). If this condition holds, the upstream node is flagged as a 'Q-marker' and is revisited following the full network conversion.

Q Nodes

3.2.26 Q nodes are used to represent one-way junctions on motorways (or similar class roads) which are initially coded as dummy nodes, but upon completion of the network conversion are revisited and recoded with a Q marker and given a constant definition of turning movement as defined in Table 9.

Table 9. Q Node Junction Turning Movement Template

TURN DESCRIPTION	LSAT	TPM	LANE 1	LANE 2
Main Flow	1800 per lane	Q	1	Last

Motorway Exits

3.2.27 Motorway exits are identified in a similar manner to merges where any junction which fulfils the following requirements is considered a motorway exit:

- One motorway priority entering;
- One slip priority leaving;
- One motorway priority leaving; and
- No other entries or exits.

3.2.28 In these instances there are only two possible movements in the junction and the coding is as defined below in Table 10.

Table 10. Motorway Exit Junction Turning Movement Template

TURN DESCRIPTION	LSAT	TPM	LANE 1	LANE 2
Stay on main Carriageway	2400 per lane		1	Last
Exit slip	2400 per lane		1	1

3.2.29 An exit scenario automatically takes precedence over the standard priority junction scenario.

3.2.30 Note that manual changes to LSAT values were made during the calibration stage to represent specific junction location characteristics.

3.3 SITM4 Simulation Coding

3.3.1 The previous transport model of the Strathclyde area (SITM4) contained a SATURN road assignment model that contained junction simulation coding for the central Glasgow area.

3.3.2 As this coding is based on junction layout surveys, the data contained is likely to be of a higher standard than that of the template approach, where no significant changes to the road layout have taken place since SITM4 calibration.

3.3.3 Therefore, coding from SITM4 has been translated across to the SRTM node numbering system where possible. Junctions with SITM4 coding are identified in Figure 10.

3.3.4 The SITM4 version 11.1.09 allowed coding to be transferred from SITM4 to SRTM which was subjected to a review after the model assignment. It was found that some SITM4 signalised junctions didn’t match the road hierarchy in that some minor roads had excessive green times compared to major roads. This was adjusted accordingly.

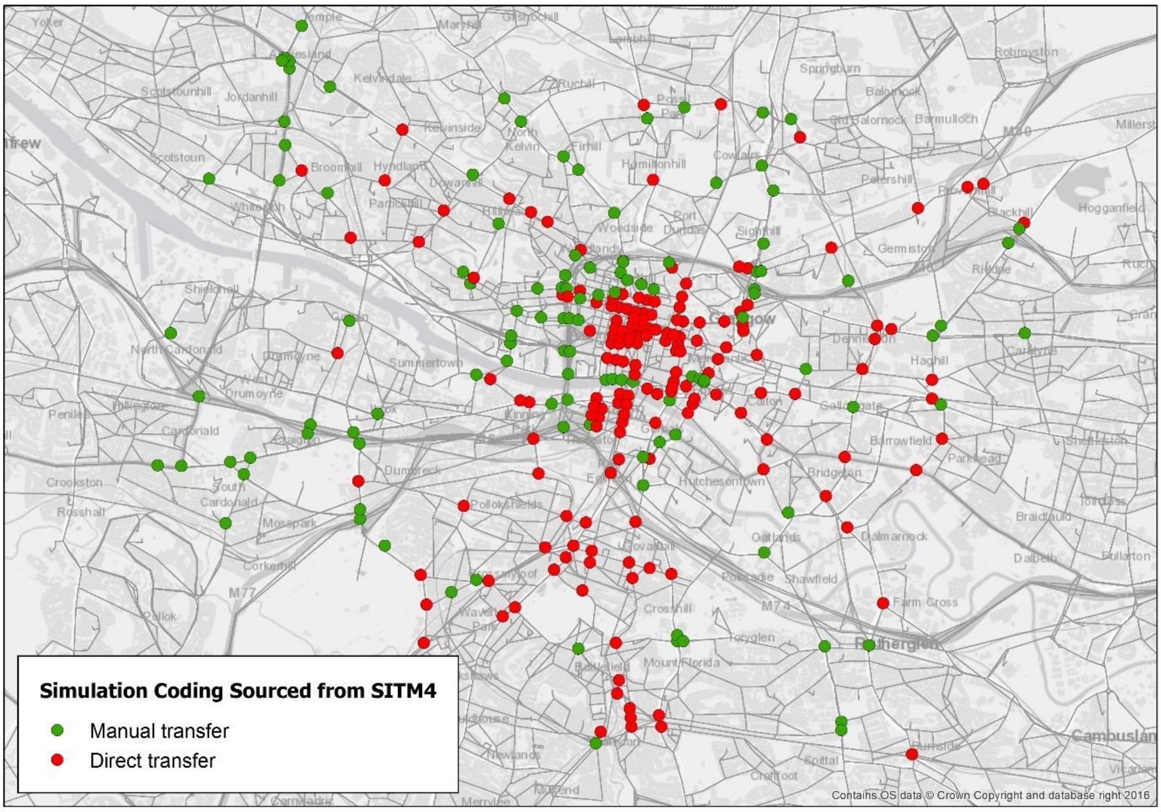

Figure 10. Simulation Coding sourced from SITM4

3.3.5 The red dots illustrate junctions where SITM4 data has been directly transferred, with the green dots illustrating where topographical changes have required manual changes to the SITM4 coding based on Google StreetView / Maps information.

3.4 Manual Junction Update

3.4.1 Following the application of the template coding procedure and the integration of the SITM4 coding, an extensive review of junction coding was undertaken.

3.4.2 SATURN provides a list of speed and distance warnings when the link parameters for one direction do not match the reverse direction. These warnings were reviewed and updates undertaken.

3.4.3 In order to enhance the network building process, sub area cordons were created which focused on specific corridors or areas. These areas were subjected to manual enhancements whereby semi-fatal (NAFF) errors were reviewed for coded priority markings, lane allocations, number of lanes, saturation flow and connectivity with surrounding links.

3.4.4 The process concentrated on the following areas:

- Motorway corridors to ensure correct number of lanes and priorities at merge / diverges;
- Motorway and key arterial corridors, identification of signalised junction locations, consolidation (where required) and coding of template traffic signal junctions; and
- Manual checks were undertaken on non-strategic roads with higher flows

3.4.5 Node consolidation was undertaken where traffic signals were identified. This involved minimising the amount of nodes initially used as part of the 'exploded' signalised location. Figure 11 provides graphical representation, the node structure on the left hand side of the image indicates the network without node consolidation ('exploded'), whereas the image on the right shows same junction after consolidation based on signal information.

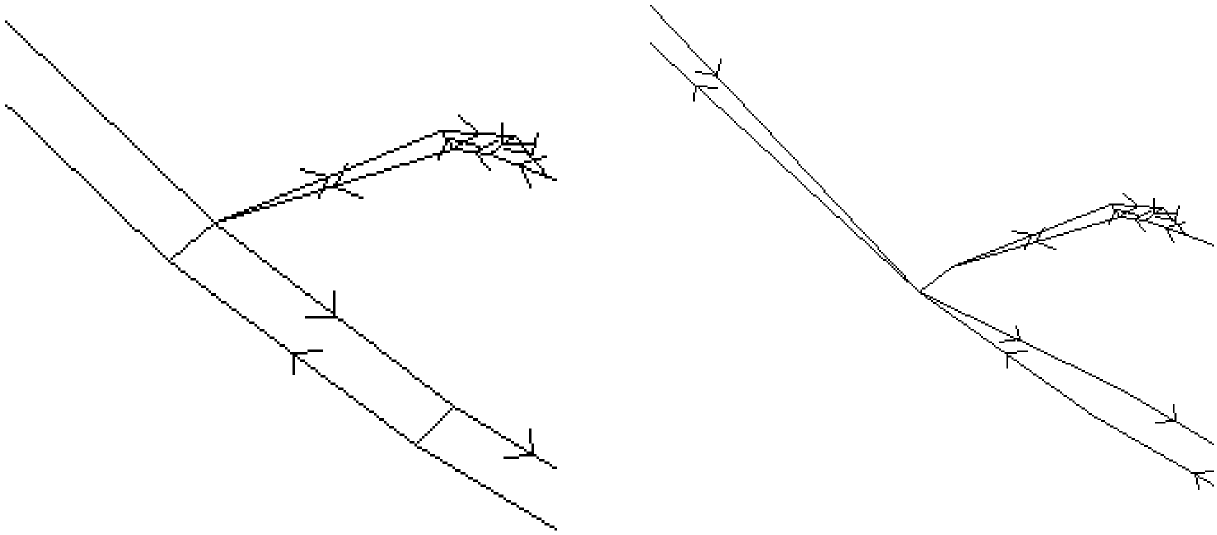

Figure 11. Node Consolidation

3.4.6 Where no SITM4 junction information was made available, a holistic approach to signal timings was undertaken. Using digital mapping, phasing, turning movements, lane allocations and pedestrian facilities were reviewed for input into the road model. Using previous experience, signalised junctions with no forthcoming signal information were modelled as three stages. Within the first stage would be the major roads, the second stage would allow for any major road that contained a right turn movement (effectively acting as a clearout phase) and a third stage for minor roads. Depending on the location of the signalised junction and its perceived use as a pedestrian crossing, an extra ten seconds of intergreen was added to replicate a crossing stage. The signal timings used within the model are listed below in Tables 11 to 14.

Table 11. Signal Timings Template – 2 Stages (no peds)

ARM TYPE	GREEN TIME (S)	INTERGREEN (S)
Major	38	7
Minor	18	7

Total cycle time 70 seconds

Table 12. Signal Timings Template – 2 Stages (with peds)

ARM TYPE	GREEN TIME (S)	INTERGREEN (S)
Major	38	7
Minor	18	17

Total cycle time 80 seconds

Table 13. Signal Timings Template – 3 Stages with filter (no peds)

ARM TYPE	GREEN TIME (S)	INTERGREEN (S)
Major	30	7
Major (filter arm only)	14	7
Minor	15	7

Total cycle time 80 seconds

Table 14. Signal Timings Template – 3 Stages with filter and no peds

ARM TYPE	GREEN TIME (S)	INTERGREEN (S)
Major	30	7
Major (filter arm only)	14	7
Minor	15	17

Total cycle time 90 seconds

3.4.7 The following saturation flows (per lane) were used when signalised junctions were required to be coded:

- Left turn 1,500;
- Straight ahead 1,800; and
- Right turn 1,500.

Note that when the right turn movement was opposed an 'X' was used within the coding.

3.5 Priority Junctions

3.5.1 As part of the strategic and arterial corridor review, numerous priority junctions were reviewed based on digital mapping. The following saturation flows (per lane) were used when priority junctions were required to be coded:

- Left turn 1,200;
- Straight ahead 1,800; and
- Right turn 875.

Give way and opposed turn markers were used within the coding.

4. ROAD NETWORK CALIBRATION ENHANCEMENTS

4.1 Overview

4.1.1 During the calibration of the Phase 1 road model, a number of issues and enhancements were identified. These resulted in changes to the network that are reported through the following three sections.

4.1.2 The final section of this chapter discusses the enhancements and extension to the SATURN junction coding during the Phase 2 road model calibration.

4.2 Zone connectivity

4.2.1 A review of zone connectivity was undertaken to determine the appropriate loading point of trips onto the network. In order to assign trips onto the highway network without significant delay, each node that was responsible for loading trips was given a capacity of 2999 per lane, no give way or opposed markers were used in those junctions. Network wide checks were made to determine if any downstream junctions suffered significant levels of delay because of zones loading points.

4.3 Speed Flow Curve

4.3.1 The road model utilises a range of speed flow curves derived from COBA which allow a representation of a range of typical Scottish roads which have been developed and refined in previous regional and national model updates.

4.3.2 A review provided an opportunity to expand the number of speed flow curves to provide greater flexibility to accurately represent the number of lanes and sign-posted speeds. The motorway network of Glasgow contains a diverse range of road capacity and speed.

4.3.3 The review of speed flow curves used in the model highlighted limitations in accurately modelling roundabouts. Additional speed flow curves were specifically implemented to represent one or two lane circulating roundabouts. Minor enhancements were also made to the speed flow curves used previously.

4.3.4 During the network review, instances of 'rat-running' were noted on residential routes between arterial routes that contained signalised and priority junctions. A new speed flow curve was implemented to represent residential and traffic calmed areas.

4.3.5 A continual review of corridors was undertaken to determine the most appropriate speed flow curve used, this resulted in some links speeds and capacities being reduced where parked cars were evident. Conversely, there was instances where a lower speed was attributed to a link than existed on the ground.

4.3.6 As part of the validation exercise, changes were made to the numerous links not just in terms of speed flow curve but also capacities and speeds. This was undertaken to try to match observed traffic flow, journey times and match the road conditions. As part of this review, perceived urban links have been allocated suburban link types.

4.3.7 Appendix C provides a list of the speed flow curves used in the final SRTM road model.

4.4 Bus Lanes

4.4.1 Bus lanes have been coded into the simulation network to enable the capacity of the road network to be more accurately reflected and to provide an identifier for where the road speeds are to be set to free flow conditions for the public transport model assignment.

4.4.2 The location of bus lanes was provided through a GIS drawing received from Glasgow City Council, as illustrated in Figure 12.

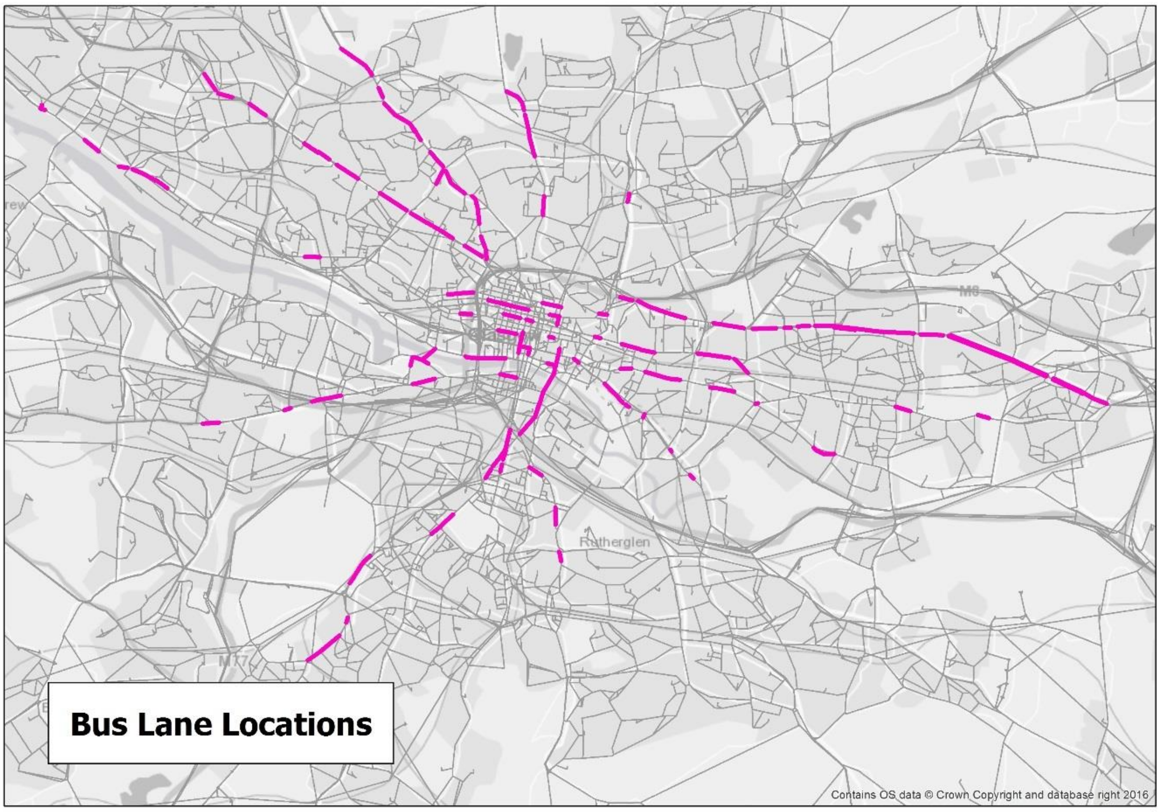

Figure 12. Location of Bus Lanes

4.4.3 These have been coded into the SATURN network, as illustrated by Figure 13:

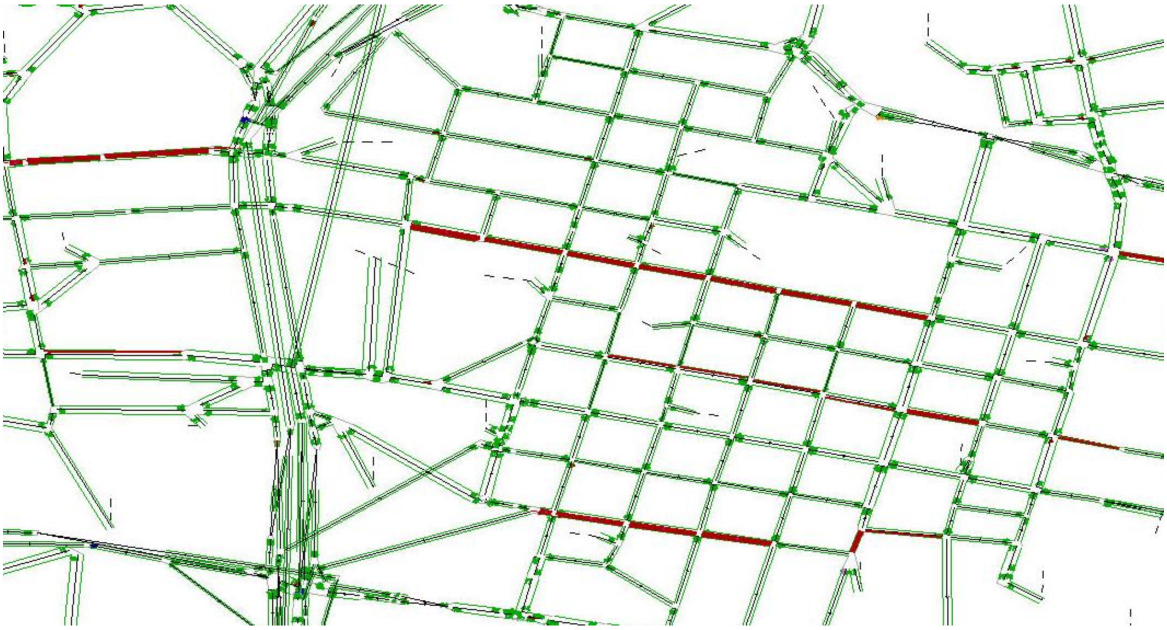

Figure 13. SATURN Representation of Bus Lanes

4.5 Junction Coding Enhancement

4.5.1 Following development of the Phase 1 model, an extension of the SATURN simulation coding was undertaken to encompass the fuller modelled area, as shown in Figure 14.

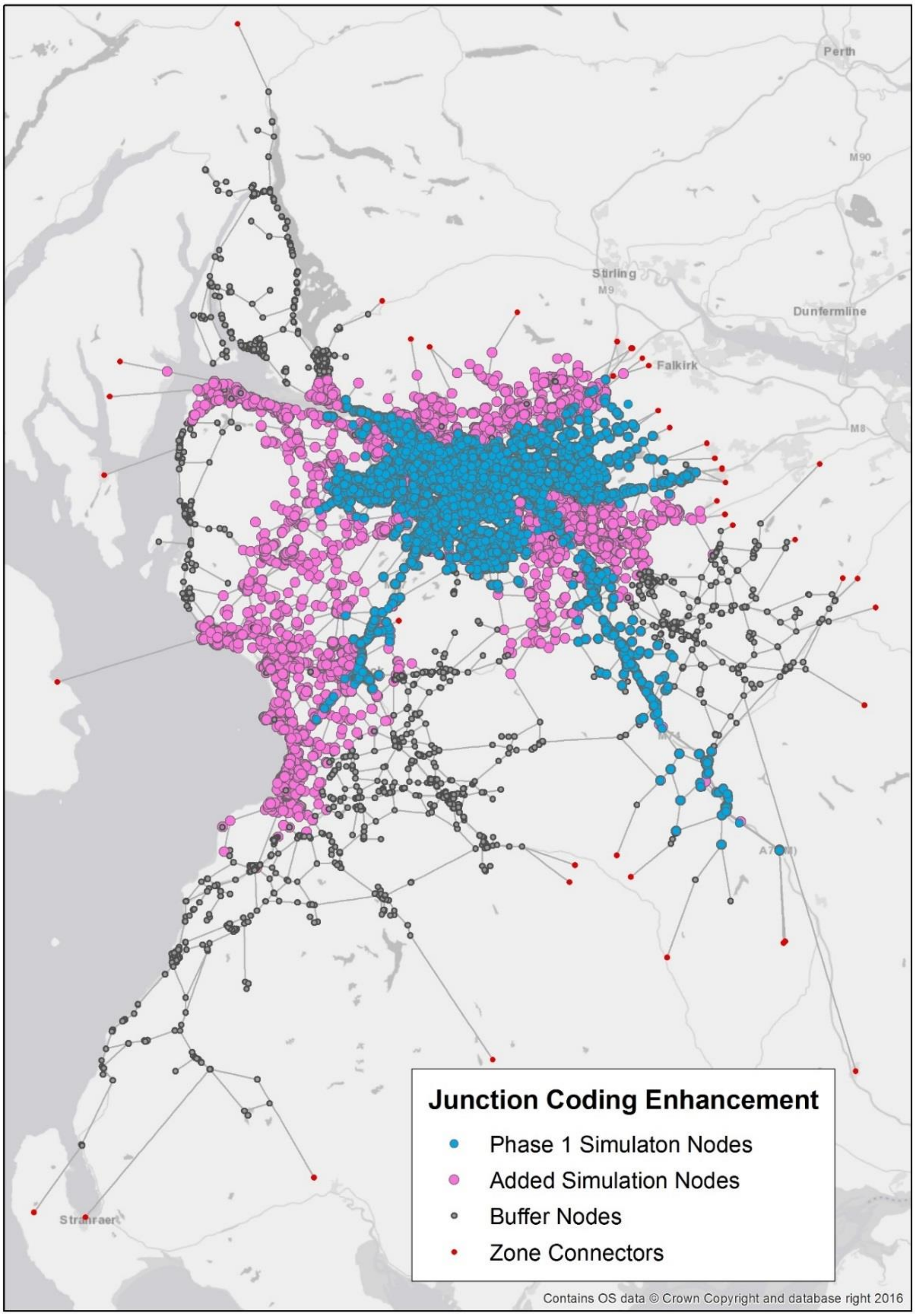

Figure 14. SRTM Junction Coding Extent

4.5.2 Manual checks of the priority variable discussed in Section 3.2.4 were undertaken in arterial corridor reviews. A full corridor review was undertaken where journey time information was known which involved selecting every single node to determine its suitability within the model. It was unrealistic to manually check every single node within the model for priority hierarchy however, all main and arterial 'A' and 'B' roads from strategic settlements have been reviewed.

4.5.3 Further improvements to the Phase 2 model focused on detailed individual turning movements, turning capacities from a major road were increased from 1200 to 1500, whereas right turn movements increased from 875 to 1200. These changes were undertaken to provide a more realistic operation of turning movements based upon early calibration results.

4.5.4 Throughout our node based review, attention was paid to signalised junctions that contained substantial and unrealistic delays. Our review investigated inconsistencies between significant delay on arterial routes. As a result, the use of the signal optimisation process in SATURN was deemed beneficial to improve not only the traffic flows but also the journey time analysis. The optimised signal timings along with the resulting delays were reviewed to ensure that they were realistic.

4.5.5 A review of trip path analysis through Glasgow was undertaken to confirm that despite the models extension, the paths of vehicles through Glasgow City Centre remained consistent.

4.5.6 With the use of 'Q' nodes along motorways and significant 'A' roads, the use of a consistent reduction in capacity would be detrimental as the characteristics of each location can vary. As a result, although a 10% reduction was used in most cases, there was deviation of standard, whereby it was considered to specify specific locations on a case by case situation. These locations are illustrated in Figure 15.

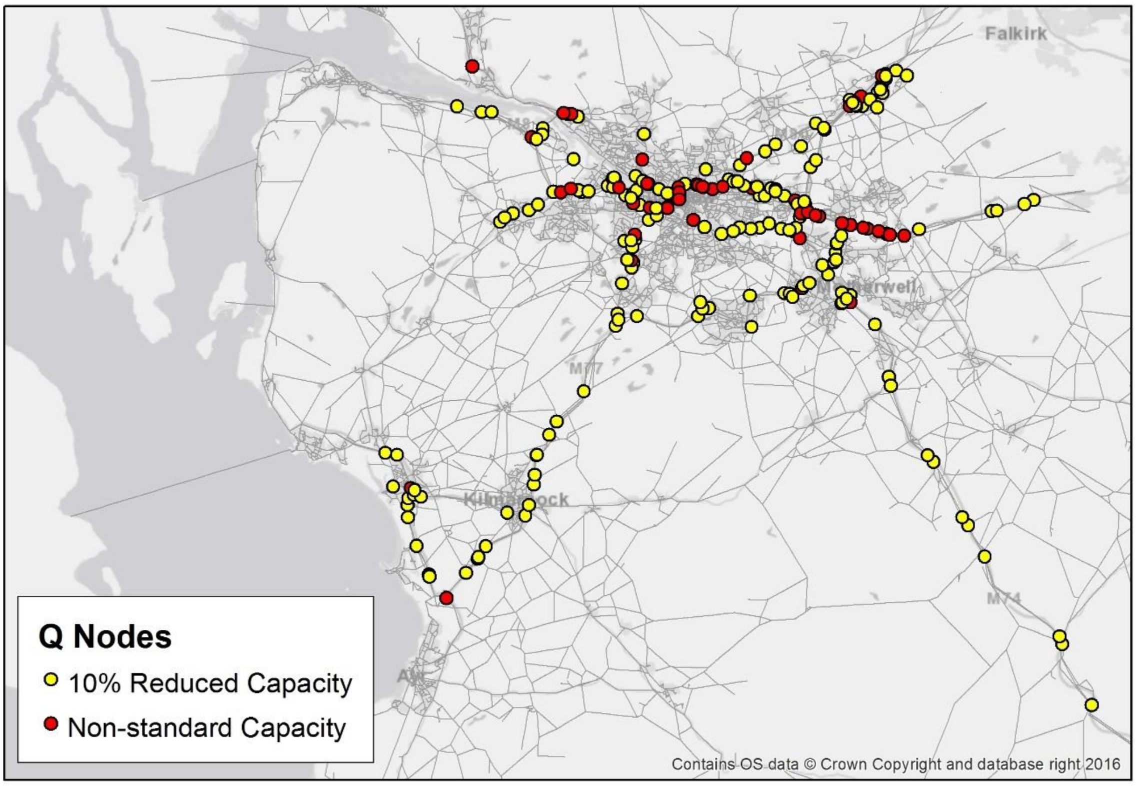

Figure 15. SRTM Phase 2 'Q' Nodes

4.6 Final Road Model Junction Coding Statistics

4.6.1 Table 15 contains information on node types from the final pre-calibration SATURN model coding.

Table 15. SATURN Road Network Node Information (Pre-Calibration)

NODE TYPE	SUB-TYPE	NUMBER
Zone		1,299
Buffer		3,569
Simulation	External	1,305
Simulation	Priority	15,880
Simulation	Roundabout	30
Simulation	Signalised	877
Simulation	Q Node	225
Simulation	Motorway Merge	Coded as Q nodes
Simulation	Dummy	3,106
Simulation	Roundabout with U-Turns	48

5. ROAD MODEL – OTHER INPUTS

5.1 Inputs

5.1.1 This section documents the inputs to the SATURN model that are not contained within the buffer or simulation coding. These inputs include:

- PCU factors;
- Bus Preloads;
- Generalised Cost Equations;
- Assignment Options / Parameters; and
- Zone Areas file.

5.2 PCU Factors

5.2.1 In common with Transport Model for Scotland (TMfS) and other regional transport models, the PCU factors (passenger Car Units) for the SRTM are:

- Car = 1;
- LGV = 1;
- HGV = 1.9; and
- Buses = 2.2

5.3 Bus Preloads

5.3.1 Bus vehicle traffic is represented within the SATURN road assignment model through the coding of bus service route preloads for each time period.

5.3.2 The bus routes and frequency are extracted from the Public Transport model lines files and converted into SATURN format. These are then input into the SATURN model as a set of link based preloaded flows.

5.3.3 The process for creating the bus preload files has been documented within the Public Transport Model Development Report.

5.3.4 The flows are factored by the bus PCU factor of 2.2.

5.4 Generalised Cost Equations

5.4.1 The calculation of generalised cost parameters was based on WebTAG guidance issued in December 2015. The units of the time parameter and the distance based parameter are 'Pence Per Minute' (PPM) and 'Pence Per Kilometre' (PPK) respectively, as required by SATURN. The relevant occupancy values which have been used to derive these values are contained in the SRTM Demand Model Report.

5.4.2 Table 16 lists the relevant values and describes the parameters calculated for each User Class along with their associated value of time coefficients. Generalised Cost has been calculated by using the formula below:

Generalised Cost (minutes) = Time + (Distance * PPK / PPM)

Table 16. Road Assignment Coefficients for 2014 Base Year

USER CLASS	PPM	PPK
Car – Employers Business	44.60	13.42
Car – Commute	12.95	6.86
Car – Education	17.06	6.86
Car – Retired	26.21	6.86
Car – Others	17.06	6.86
LGV	20.97	15.54
HGV	42.38	45.58

5.4.3 The above PPM and PPK values have been input into the 88888 records within the SATURN data files.

5.5 Assignment Options / Parameters

5.5.1 The SATURN model parameters applied in the final calibrated road model include:

- ISTOP = 95
- KOB = 0
- KOMBI = 0
- KONSTP = 5
- KORN = 0
- LRTP = 60
- MASL = 200
- MAXDTP = 10
- MAXQCT = 60
- MODET = 1
- NISTOP = 4
- NITA = 70
- NITS = 50
- NFT = 113
- NOPD = 0
- NOTUK = 1
- NITA_C = 256
- NITA_F = 0
- NITA_M = 6
- NITA_S = 150
- NITS_M = 10
- MET = 0
- NIPS = 0
- KLUNK = 0
- MASL_M = 0
- ALEX = 5.75
- CAPMIN = 30.
- GONZO = 1.000
- SUET = 0.20
- TAX = 2.00
- TDEL = 3.00
- AFTERS = 0.50
- WLMIN = 300
- WLMAX = 2000.
- APRESV = 1.00
- AK_MIN =0.000
- TIJMIN = 0.1000E-03
- RSTOP =97.50
- SAVEIT = T
- SPIDER = T
- UFC109 = T
- UFC111 = T
- XFSTOP = 0.050
- FISTOP = 0.050
- UNCRTS = 0.050
- PCNEAR = 2.000
- STPGAP = 0.200
- STPCPU = 1000.0
- MULTIC = T: OPTION TO USE SATURN MULTI-CORE (IF AVAILABLE)

5.5.2 The road assignment model procedure adopted for the SATURN model is an Equilibrium Assignment. The Frank-Wolfe Algorithm is used to identify the equilibrium solution. The SATURN model combines the assignment stage with a junction simulation stage. The traffic delay information from the simulation is passed back to the assignment stage where a new trip pattern is derived. The process is iterated until convergence is achieved.

5.6 Zone Areas Input File

5.6.1 The zone areas input file is used within the Cube scripts to identify the modelled zones during the process to build the road network within Cube format.

5.6.2 The file is in dbf format and contains the following fields / information:

- ZONE – Zone Number
- FIRST_COUN – Council Area name
- FIRST_NAME - Zone Name
- FIRST_LA – Local Authority code
- SUM_HHLDS – Total number of households per zone – base year
- SUM_POP – Total population per zone – base year
- SUM_HHLD_P – Total household population per zone – base year
- SUM_EMP – Total number of employees per zone – base year
- SECTOR – Sector number for local authority sector system
- AREA – Area of zone in sq km

5.6.3 While the road assignment model does not make extensive use of the data fields within the dbf file above, the file is primarily intended to be used within post model analysis.

6. CALIBRATION AND VALIDATION DATA

6.1 Approach

6.1.1 Calibration and validation of the road model makes use of a variety of data to undergo a process of, firstly, attempting to achieve a 'best fit' against observed data and then, secondly, validating the robustness of the model against other independent observed data. The road model calibration process included the following steps:

- Collation of traffic count data;
- Formation of traffic count screenlines;
- Matrix estimation (based on the 'prior matrices');
- Iterations of model refinement; and
- Calibration analysis.

6.1.2 The model calibration approach uses groups of traffic counts to form screenlines, which are used to compare modelled traffic volumes. Initial comparisons are based on the Prior road model matrices (described further in Chapter 7), which are used as a starting point for matrix calibration. Using an iterative process, the screenline comparisons are then used to review and refine the model network and matrices, and subsequently undertake matrix estimation to adjust traffic movements to better match observed traffic volumes.

6.1.3 The calibration is compared in terms of overall matrix adjustments, trip length distribution analysis and screenline flow comparisons.

6.1.4 These steps and resultant calibration analysis are described within the following sections.

6.2 Collation of Traffic Data

6.2.1 A variety of observed traffic count data sources were collated to inform the calibration and validation processes, including:

- The Scottish Roads Traffic Database (SRTDb) – 2014 data covering neutral months, and averaged to cover weekday time period data;
- 2014 DfT traffic count data for major roads forming analysed ATC data;
- East Kilbride manual turning counts from 2015;
- 2014/2015 Glasgow City inner and outer boundary and river crossing counts supplied by Glasgow City Council;
- Renfrewshire turning counts from 2015;
- Traffic counts commissioned for the project in May 2016 – covering routes North of Airdrie, within the Hamilton area, North of the GSO and in Dunbartonshire;
- A814 manual turning counts from March 2015, provided by West Dunbartonshire Council;
- Clyde Gateway manual turning counts from March 2014; and
- Cathkin and Rutherglen turning counts from November 2014, provided by South Lanarkshire Council.

6.2.2 Average AM peak hour, LT hour and PM peak hour traffic count data was derived from each of these data sources.

6.2.3 Factoring traffic data to a common year was not deemed necessary as traffic growth after 2012 was regarded as remaining relatively static. No factors were applied to account for seasonality and where data was sourced from a single day survey during a neutral month, the data was taken as per source. The impact of any roadworks was not considered in the data processing.

6.2.4 A neutral month was considered as a month with no major holiday period. We therefore excluded June, July and August, and for winter December, January and February. No manual amendments were made to take into account of Easter holidays, however, the use of Tuesday, Wednesday, and Thursday data minimised the impact of any Monday or Friday holidays.

6.2.5 Any long term data e.g. SRTDb processed excluded any partial data (e.g. less than 24 hours)and weekday averages were calculated using the remaining data.

6.3 Traffic Count Screenlines

6.3.1 A total of 41 Screenlines were used to inform the calibration comparisons and undertake matrix estimation. These Screenlines were chosen to represent the major movements across the key network corridors and focused primarily on the motorway network and salient arterial routes.

6.3.2 Further groups of traffic counts were developed using data that was not used within the calibration analysis to inform the road model validation comparisons. Table 17 provides a more detailed breakdown of the traffic counts used in both calibration and validation.

Table 17. Summary of Traffic Counts Types

CALIBRATION/VALIDATION	NO. COUNT SITES	SITE LOCATIONS
Calibration/Matrix Estimation	65	Motorway only
Calibration/Matrix Estimation	294	'A' Main road
Calibration/Matrix Estimation	6	Other
Validation Links Counts	292	Motorway/'A' Main road only
Validation Links Counts	30	Other
Validation (Turning Counts)	432	Various

6.3.3 Calibration Screenlines and individual calibration points are illustrated in Figures 16 and 17 and described overleaf.

- 1 South of Cumnock
- 2 East Kilbride North
- 3 East Kilbride South West
- 4 East of Larkhall
- 5 South of Hamilton
- 6 Hamilton Centre
- 7 A8 M74 east of M73
- 8 M8 M74 West of M73
- 9 M74 A74 east of A763
- 10 M74 Dalmarnock
- 11 M74 Clyde crossing
- 12 G'gow Green river crossing
- 13 RiverCrossing central G'gow
- 14 M74 east of M8
- 15 M8 East of A737 Airport Junction
- 16 M898 north of M8
- 17 M8 A8 B'head (Jnc25-25a)
- 18 North of M'hill (A81, A879)
- 19 M8 A8 west of M80
- 20 M80 A80 North Hoganfield
- 21 Cumbernauld East
- 22 M8 A8 Cranhill
- 23 City Southern Boundary
- 24 North of Airdrie
- 25 North of GSO
- 26 Yoker GWR
- 27 West of Dalmuir Clydebank
- 28 West of Bishopton: M8/A82
- 29 Renfrew
- 30 East Kilbride West
- 31* Inner Glasgow E
- 32 Renfrew Area
- 33 Clyde Gateway
- 34 Cathkin Area
- 35 Cambuslang South of M74
- 36 Clyde Crossings West
- 37 Clydebank A82
- 38 South of Braehead
- 39 South of Ayr
- 40 North of Ayr
- 41 South of Kilmarnock
- 42 South of Kilwinning

6.3.4 * Screenline 31 was not included within the calibration / matrix estimation process due to a lack of relevant count data but was included in the screenline comparison summary in Section 8.

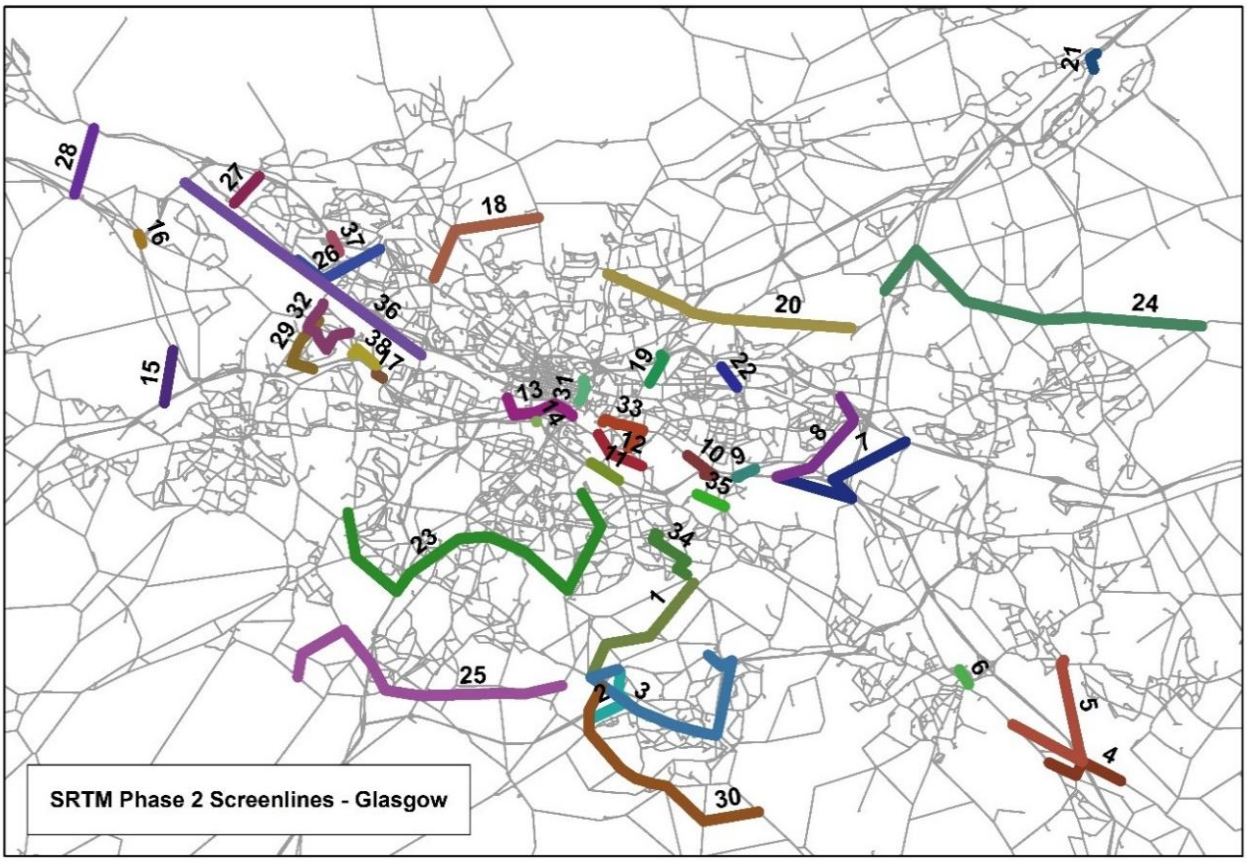

Figure 16. Glasgow Traffic Count Screenlines

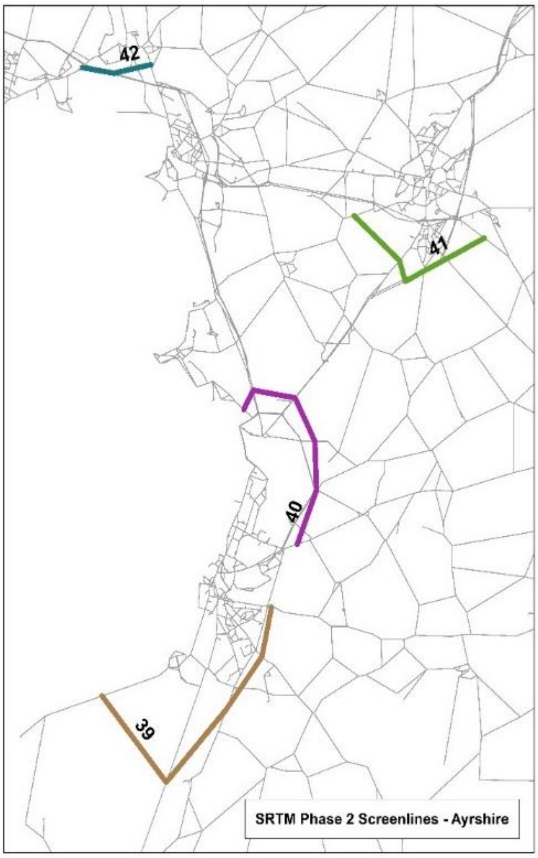

Figure 17. Ayrshire Traffic Count Screenlines

Traffic Count Screenline Analysis

6.3.5 Modelled traffic volumes for each time period were measured against observed traffic count Screenlines (including some single calibration points) and cross referenced using DMRB guidance. Two levels of Screenline analysis were undertaken, the first comparing the total traffic flow across all Screenline, and the second comparing all individual data points included within the Screenlines.

GEH Statistic

6.3.6 When comparing observed and modelled counts, focusing on either absolute differences or percentage differences alone can be misleading when there is a wide range of observed flows. For example, a difference of 50 vehicles is more significant on a link with an observed flow of 100 vehicles than on one with 1,000 vehicles, while a 10% discrepancy on an observed flow of 100 vehicles is less important than a 10% discrepancy on an observed flow of 1,000 vehicles.

6.3.7 To avoid these comparison difficulties, a standard summary statistic known as the GEH score is used. This statistic is designed to focus attention on significant absolute differences at low flows and significant percentage differences at high flows.

6.3.8 The GEH statistic is defined as:

$$GEH = \sqrt{\frac{(M - C)^2}{(M + C) \div 2}}$$

6.3.9 Where, *GEH* is the statistic, *M* is the modelled flow and *C* is the observed count.

Total Screenline Calibration Criteria

6.3.10 WebTAG guidance relating to total screenlines comparisons are as follows:

- Total screenline flows (normally > 5 links) to be within 5% for all (or nearly all) screenlines; and
- GEH statistic: screenline totals GEH < 4 for all (or nearly all) screenlines.

6.3.11 It should be noted that WebTAG guidance refers to comparisons based on vehicles, however, in the calibration and validation of the SRTM12 model, PCUs are used for assignment and matrix estimation purposes. These flows have been used for comparison with WebTAG criteria, and all traffic volumes are reported in PCUs for this section.

6.4 Road Journey Time Routes

6.4.1 The SRTM road journey time validation involved comparing modelled traffic journey times with observed travel time data sets for a selection of routes.

6.4.2 TomTom satellite navigation speed/time data covering the period 2nd February 2015 to 30th November 2015 was commissioned and supplied from Streetwise Services. This data excluded Easter and various other public holidays. This 'Area-based' data represented the average time for all recorded vehicles travelling along a link/road segment and covered the modelled AM, LT and PM peak time periods.

6.4.3 The TomTom data was used to validate the modelled road travel times, and was also used to feedback into the calibration process to allow refinements to be made to the model.

6.4.4 TomTom journey route distances were extracted and compared to modelled distances to validate the network building processes.

6.4.5 Observed journey time data was extracted from the TomTom dataset to construct a total of 100 routes to be used during validation (50 routes in each direction).

6.4.6 Figure 18 provides an illustration of the routes and route descriptions are described below. Appendix E provides more detailed illustrations of the journey time route locations.

TomTom Data

6.4.7 The TomTom data sets described here represent the **mean** journey time along a given route. These routes have been developed from a GIS by combining links to form journey time segments or routes.

6.4.8 The average TomTom times represent average travel speeds / times across the network during the AM, Inter (LT) and PM peak average hours, and are likely to include periods of disruption caused by roadworks and potentially accidents. These times of incidents are not captured within the base year model congested speeds, so the model will be unlikely to represent the full average time recorded by TomTom.

6.4.9 From reviewing the data and experience from using this type of data in other models, it was felt that an appropriate level of journey time validation would be achieved if the modelled journey times fell just below the time recorded by TomTom data. There may be a tendency for the 'mean' TomTom speeds to capture network incidents such as roadworks and accidents, whereas although the 'median' speed would be less likely to capture high variances / incidents, it may also not capture some legitimate high congestion periods. On balance, it was felt reasonable if the modelled speeds were slightly higher (and Journey times lower by a few percent) on average across the journey time routes compared to the mean TomTom statistics.

Route Descriptions

- Route 1 Eastbound: A8 East of Baillieston Jct to West of Newhouse Jct
- Route 1 Westbound: A8 West of Newhouse Jct to East of Baillieston Jct
- Route 2 Northbound: M74 East of J4 to M8 West of Baillieston Jct (M73)
- Route 2 Southbound: M8 West of Baillieston Jct to M74 East of J4 (M73)
- Route 3 Northbound: M74 J6 (Hamilton) to J4 (M73)
- Route 3 Southbound: M74 J4 (M73) to J6 (Hamilton)
- Route 4 Northbound: M74 J3A to J1 (M8)
- Route 4 Southbound: M74 J1 (M8) to J3A
- Route 5 Northbound: M77 J5 to M8 J25
- Route 5 Southbound: M8 J25 To M77 J5
- Route 6 Eastbound: M8 Erskine Bridge To North of Kingston Bridge
- Route 6 Westbound: M8 North of Kingston Bridge to Erskine Bridge
- Route 7 Eastbound: M8 North of Kingston Bridge to East of Ballieston Jct
- Route 7 Westbound: M8 East of Ballieston Jct to North of Kingston Bridge
- Route 8 Eastbound: M80 J1 (M8) to J6
- Route 8 Westbound: M80 J6 to J1 (M8)
- Route 9 Northbound: A737 East of Dalry (at B707) to Beith (Manrahead Rdbt)
- Route 9 Southbound: A737 Beith (Manrahead Rdbt) to East of Dalry (at B707)
- Route 10 Eastbound: B766 Carmunnock Bypass / A727 to A726 Greenhills Rdbt
- Route 10 Westbound: A726 Greenhills Rdbt to B766 Carmunnock Bypass / A727
- Route 11 Eastbound: A8/A78 Bullring Rdbt to M8 Erskine Bridge
- Route 11 Westbound: M8 at Erskine Bridge To A8/A78 Bullring Rdbt
- Route 12 Eastbound: A82 at Stoneymollan Rdbt to Erskine Bridge

- Route 12 Westbound: A82 at Erskine Bridge to Stoneymollan Rdbt
- Route 13 Eastbound: A82 Great Western Rd at Erskine Bridge to West of M8
- Route 13 Westbound: A82 Great Western Rd West of M8 to Erskine Bridge
- Route 14 Northbound: A725 East Kilbride Expressway from A726 Rdbt to M74 J5
- Route 14 Southbound: A725 East Kilbride Expressway from M74 J5 to A726 Rdbt
- Route 15 Eastbound: A726 from M77 J5 to A727 Rdbt
- Route 15 Westbound: A726 from A727 Rdbt to M77 J5
- Route 16 Eastbound: M8 J29 (Airport) to B766 Carmunnock Bypass / A727 Rdbt
- Route 16 Westbound: B766 Carmunnock Bypass / A727 Rdbt to M8 J29 (Airport)
- Route 17 Northbound: A737 from Beith (Manrahead Rdbt) to M8 J29 (Airport)
- Route 17 Southbound: A737 from M8 J29 (Airport) to Beith (Manrahead Rdbt)
- Route 18 Eastbound: A814 Dumbarton Road (Old Kilpatrick) to Clydeside Expressway / M8 Off Ramp
- Route 18 Westbound: A814 Clydeside Expressway / M8 Off Ramp to Dumbarton Road (Old Kilpatrick)
- Route 19 Northbound: M74 J8 (Larkhall) to J6 (Hamilton)
- Route 19 Southbound: M74 J6 (Hamilton) to J8 (Larkhall)
- Route 20 Northbound: M73 Ballieston Jct (M8) to M80 Jct
- Route 20 Southbound: M73 M80 Jct to Ballieston Jct (M8)
- Route 21 Northbound: A723 East of M74 J6 to B799 South of M8
- Route 21 Southbound: B799 South of M8 to A723 East of M74 J6
- Route 22 Northbound: A725 from M74 J5 to A8
- Route 22 Southbound: A725 from A8 to M74 J5
- Route 23 Northbound: B766 Carmunnock Bypass / A727 Rdbt to A8 Castle St at Royal Infirmary
- Route 23 Southbound: A8 Castle St at Royal Infirmary to B766 Carmunnock Bypass / A727 Rdbt
- Route 24 Northbound: A73 from M8 Newhouse Jct to M80 J5
- Route 24 Southbound: A73 from M80 J5 to M8 Newhouse Jct
- Route 25 Eastbound: A749 London Road / Moir St to A74 at A721 Rdbt
- Route 25 Westbound: A74 at A721 Rdbt to A749 London Road / James Morrison St
- Route 26 Eastbound: A8 at Castle St (Royal Infirmary) to A8/A89 Jct
- Route 26 Westbound: A8/A89 Jct to A8 at Castle St (Royal Infirmary)
- Route 27 Eastbound: A80 Cumbernauld Rd from A8 to M73
- Route 27 Westbound: A80 Cumbernauld Rd from M73 to A8
- Route 28 Northbound: A803 at A804 to A891 at B822 (Lennoxtown)
- Route 28 Southbound: A891 at B822 (Lennoxtown) to A803 at A804
- Route 29 Eastbound: A89 at Glasgow Cross to A8/A89 Jct
- Route 29 Westbound: A8/A89 Jct to A89 at Moir St
- Route 30 Northbound: A879 at Speirs Wharf to A807 Auchenhowie Rd at Dowan Rd
- Route 30 Southbound: A807 Auchenhowie Rd at Dowan Rd to A879 at Speirs Wharf
- Route 31 Eastbound: M8 J29 (Airport) to J13 (M80)
- Route 31 Westbound: M8 J13 (M80) to J29 (Airport)
- Route 32 Northbound: A72 at B7078 to A74 at B7001
- Route 32 Southbound: A721 at A74 Rdbt to A72 at B7078
- Route 33 Northbound: A723 at B754 Airbles Rd to A749 at B763 (Dunn St)
- Route 33 Southbound: A749 at B763 (Dunn St) to A723 at B754 Airbles Rd
- Route 34 Northbound: A749/A725 (East Kilbride Expressway) to A730/A728 (New Gorbals)
- Route 34 Southbound: A730/A728 (New Gorbals) to A749/A725 (East Kilbride Expressway)
- Route 35 Northbound: B767/B764 (Eaglesham) to A730/B8762 (Kings Park)
- Route 35 Southbound: A730/B8762 (Kings Park) to B767/B764 (Eaglesham)
- Route 36 Northbound: A77 from M77 J5 to Broomielaw

- Route 36 Southbound: A77 from Broomielaw to M77 J5
- Route 37 Northbound: B787 Macdowall St (Johnstone) to A877 High St (Renfrew)
- Route 37 Southbound: A877 High St (Renfrew) to B787 Macdowall St (Johnstone)
- Route 38 Eastbound: Paisley (Horseshoe) to A77 Commerce St
- Route 38 Westbound: A77 Commerce St to Paisley (Horseshoe)
- Route 39 Northbound: A804 Phoenix Road to A808 Hillfoot
- Route 39 Southbound: A808 Hillfoot to A804 Phoenix Road
- Route 40 Northbound: A761 Paisley Rd W (Cardonald) to A810 Duntocher Road
- Route 40 Southbound: A810 Duntocher Road to A761 Paisley Rd W (Cardonald)
- Route 41 Eastbound: Renfrew (Abbotsinch Rd) to Ibrox (Midlock St)
- Route 41 Westbound: Ibrox (Midlock St) to Renfrew (Abbotsinch Rd)
- Route 42 Northbound: Busby Station to Cranhill (A8 Edinburgh Rd)
- Route 42 Southbound: Cranhill (A8 Edinburgh Rd) to Busby Station
- Route 43 Northbound: A77 Dutch House Rdbt to M77 J5
- Route 43 Southbound: M77 J5 to A77 Dutch House Rdbt
- Route 44 Eastbound: Kilwinning (Byres Rd) to A71/A719 Galston Rdbt
- Route 44 Westbound: A71/A719 Galston Rdbt to Kilwinning (Byres Rd)
- Route 45 Northbound: A78 Monktonhead Rdbt to A78 between Sharphill and Pennyburn Rdbts
- Route 45 Southbound: A78 between Sharphill and Pennyburn Rdbts to Monktonhead Rdbt
- Route 46 Northbound: Bankfield Rdbt to Monktonhead Rdbt via Ayr
- Route 46 Southbound: Monktonhead Rdbt to Bankfield Rdbt via Ayr
- Route 47 Northbound: A77 at B7034 to Monktonhead Rdbt
- Route 47 Southbound: Monktonhead Rdbt to A77 at B7034
- Route 48 Northbound: A719 Doonfoot (West) to Whitletts Rdbt (East)
- Route 48 Southbound: Whitletts Rdbt (East) to A719 Doonfoot (West)
- Route 49 Northbound: A738 Stevenston (Hayocks Rd) to A737 Dalry (at B780)
- Route 49 Southbound: A737 Dalry (at B780) to A738 Stevenston (Hayocks Rd)
- Route 50 Eastbound: Troon Cross to B7038/A77 Jct North of Kilmarnock
- Route 50 Westbound: B7038/A77 Jct North of Kilmarnock to Troon Cross

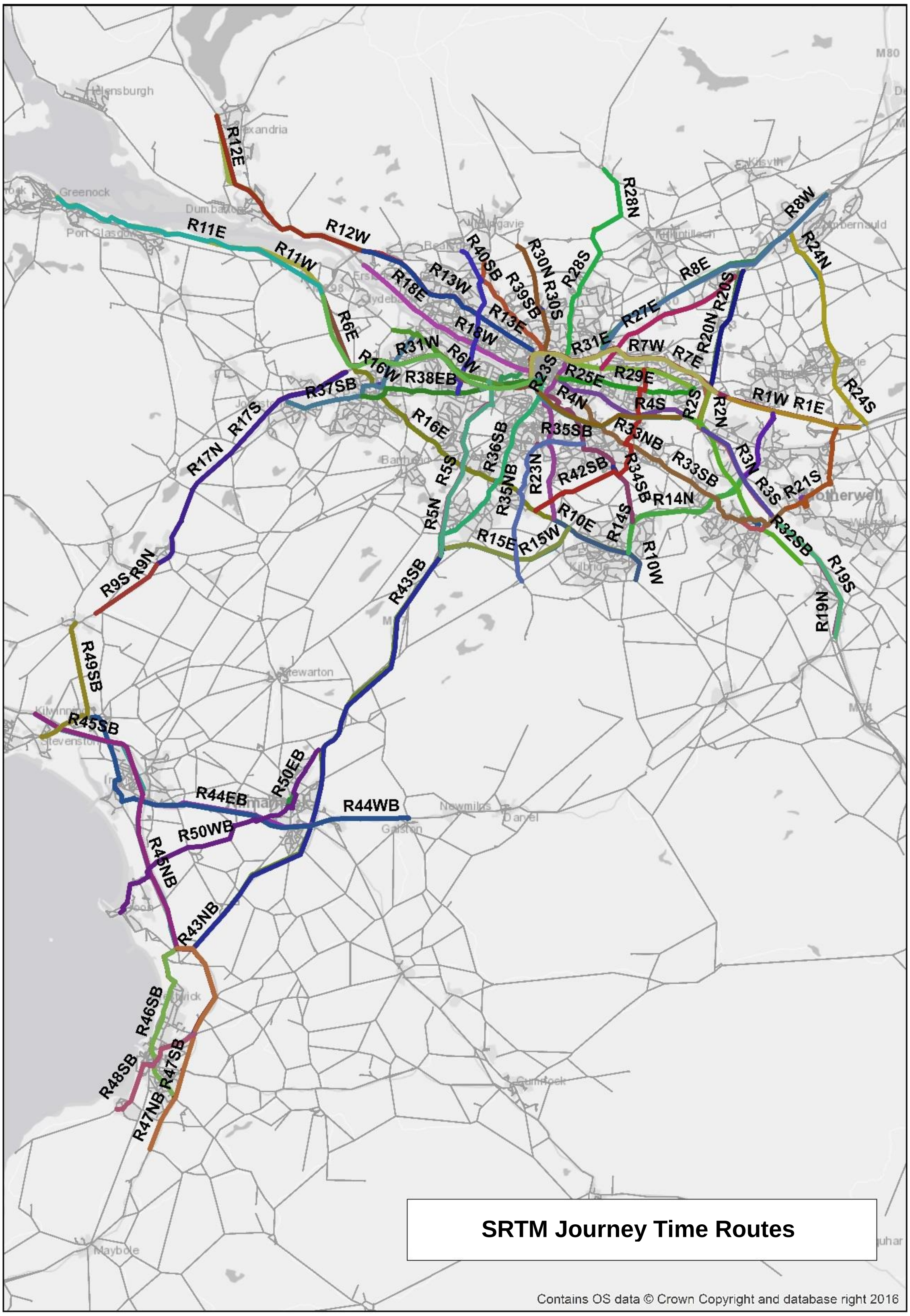

Figure 18. Road Journey Time Routes

7. MATRIX DEVELOPMENT

7.1 Matrix Development

Initial TMfS14 'Prior' Travel Demand

7.1.1 The initial prior matrix was developed from the application of the SRTM demand model using travel costs from an assignment of the prevailing networks using travel demands disaggregated from the existing TMfS14 base year model.

7.1.2 The TMfS14 purposes are as follows:

- In Work (IW) which is our Employer's Business
- Non Work Commute (NWC) which is SRTM Commute
- Non Work Other (NWO)

7.1.3 These purposes have been disaggregated based on factors obtained from the Scottish Household Survey into Other, Education & Retired, as shown in the Table 18 below.

Table 18. TMfS Purpose Disaggregation

Time Period	Other	Education	Retired
AM	0.72	0	0.28
IP	0.635	0	0.365
PM	0.75	0	0.25

7.1.4 These matrices had been expanded into SRTM zones using the same Census based proportions as was used within the SRTM trip end model.

7.1.5 These initial runs provided travel cost matrices that were used to check the road network for any major issues, such as delays greater than 300 seconds. Once updates and refinements were undertaken to resolve these issues, the networks were reassigned with the TMfS derived matrices to generate updated costs.

SRTM Demand Model 'Prior' Matrices

7.1.6 These new costs were then input into the demand model and a partial calibration to mode shares was performed. The matrices output by the demand model were then used as the prior road matrices for internal car trips.

7.1.7 External trips for representing movements out with the demand model coverage area were sourced from the trip end model via a subarea of the TMfS14 model, followed by disaggregation into the SRTM zoning system. Further information regarding the external trip processing is described within the SRTM trip end model technical note.

7.1.8 Following completion of Phase 1 of the road model, the coverage of simulation modelling was increased to form the Phase 2 Road network. The process above was repeated, though this time using the Phase 1 travel matrices (post estimation) assigned to the phase 2 network (referred to as SRTM Version 1.5). The travel cost matrices were used to start the Phase 2 demand modelling processes.

7.1.9 The SATURN Road model matrix user classes are listed below:

- UC1 – Employers Business
- UC2 – Commute
- UC3 – Others
- UC4 - Education
- UC5 - Retired
- UC6 – Light Goods
- UC7 – Heavy Goods

7.2 Goods Vehicle matrices

Light Goods Vehicle Matrices

7.2.1 The light goods vehicle matrices have been sourced direct from the TMfS14 light goods matrices, with expansion to the SRTM zoning system based on the census jobs proportion of SRTM to TMfS14 zones for both origin and destination trip ends.

Heavy Goods Vehicle Matrices

7.2.2 Initial heavy goods vehicle matrices were soured directly from TMfS14, including internal and external movements. During the Phase 2 development internal heavy goods vehicle trips were updated to incorporate information from the trip matrices supplied through the mobile phone data collection.

7.2.3 Comparisons of the heavy goods vehicle mobile phone data based trip matrices was undertaken against HGV traffic counts from the Scottish Road Traffic Database (SRTDb). These comparisons were undertaken by assigning the TMfS zoned-based mobile phone data onto the paths used in the 2014 base year TMfS14 assignment.

7.2.4 Two comparisons were undertaken, one for MPD data alone, and another for MPD data with the addition of external to external matrices sourced from TMfS14. Table 19 provides the overall performance against counts by each time period. Further details of the analysis undertaken are reported via the mobile phone data analysis note.

Table 19. MPD & TMfS – GEH Analysis

TEST	TIME PERIOD	GEH SCORE ANALYSIS			
		0 - 5	5 - 7	7 - 10	10 +
HGV Count data vs MPD Data	AM	60%	8%	15%	17%
	LT	37%	15%	14%	34%
	PM	37%	22%	12%	29%
HGV Count Data vs Sum of internal MPD and TMfS External	AM	58%	15%	11%	15%
	LT	46%	17%	17%	20%
	PM	55%	20%	5%	20%

7.2.5 The analysis indicated a relatively poor comparison, particularly for the LT and PM peak time periods, and that some further manipulation of the mobile phone data matrices would be beneficial to enable input to the prior matrix process. A factoring process was therefore developed to uplift the MPD data to best match the GEH scores.

7.2.6 Figures 19 to 21 illustrate the GEH scores post factoring, through a cumulative plot of GEH scores with analysis segmented by HGV vehicle flow.

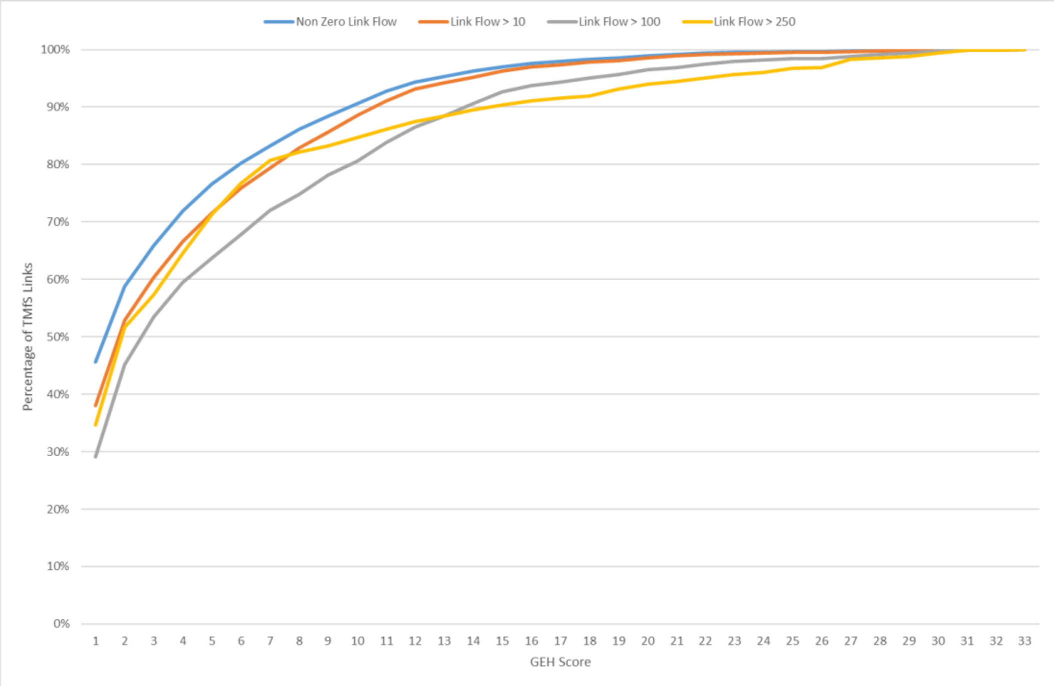

Figure 19. Factored HGV Mobile Phone Data– AM GEH Analysis

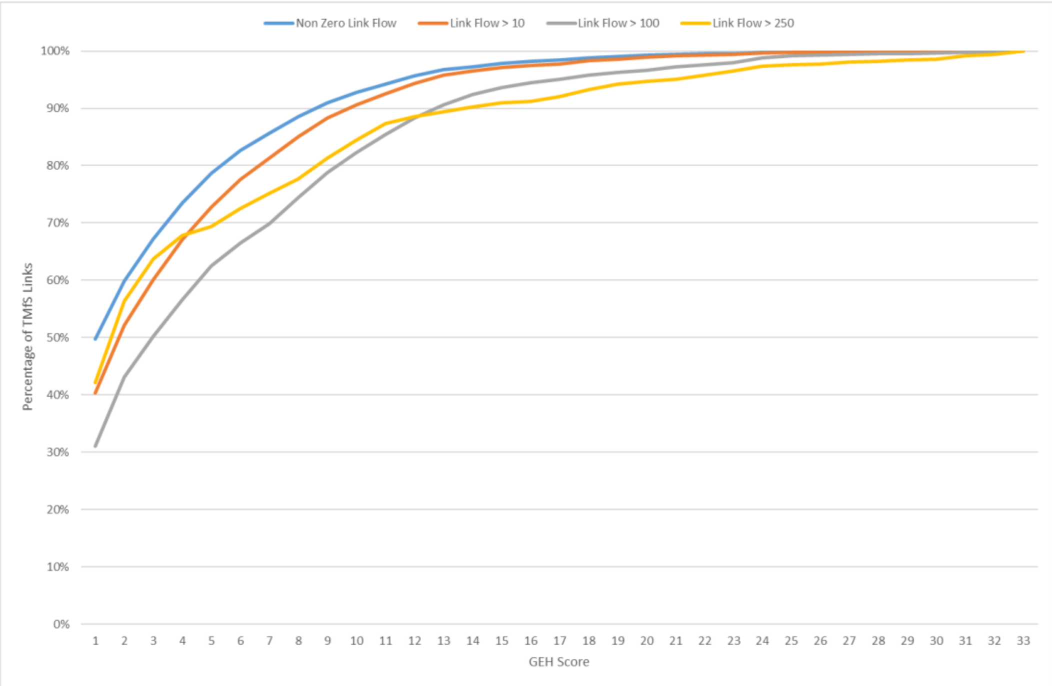

Figure 20. Factored HGV Mobile Phone Data– LT GEH Analysis

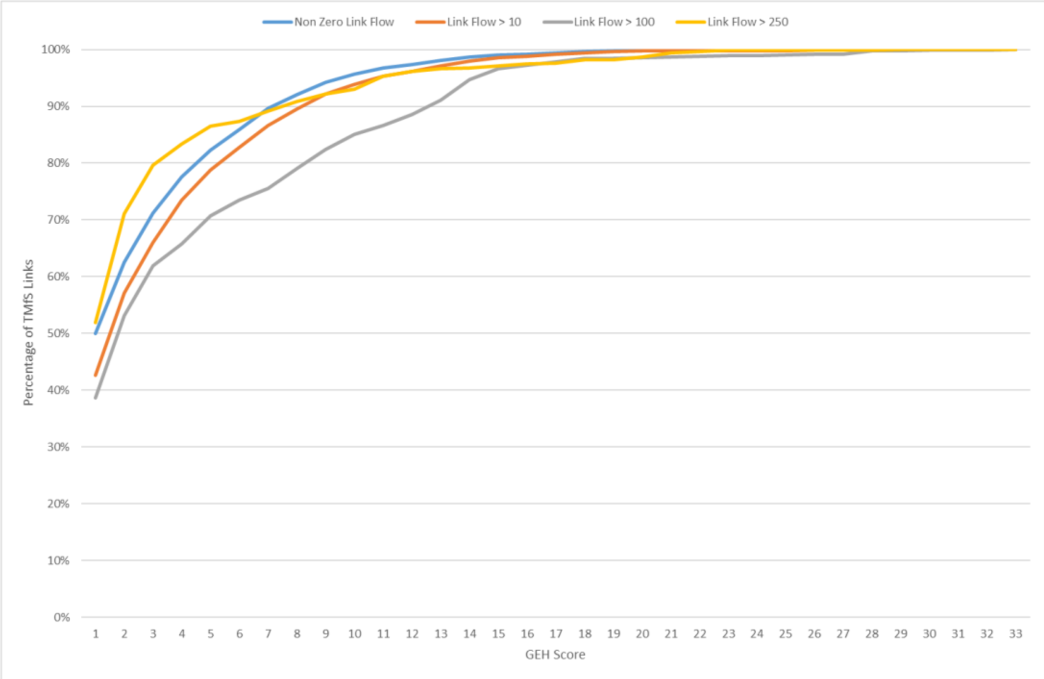

Figure 21. Factored HGV Mobile Phone Data– PM GEH Analysis

7.2.7 These HGV matrices were then converted into the SRTM zoning system by disaggregating using the TMfS14-SRTM base year Census jobs proportion for origins and destinations.

7.2.8 Internal to internal only trip movements from the factored MPD matrices were then integrated with the external trips from TMfS14, with the resulting matrices passed to the SATURN road model as the prior HGV matrix.

7.3 Matrix Estimation

7.3.1 The matrix estimation process is a mechanism employed in the creation of the base year matrices. The goal of the process is to modify the prior trip matrices to better match a range of observed data, which was undertaken for lights (Car/LGV) and heavies (LGV).

7.3.2 Matrix estimation procedures were undertaken using the SATURN SATME2 and SATPIJA processes. The inputs were AM, LT (Lunchtime time period) and PM peak hourly prior matrices, and traffic count Screenlines. Trip movements between Park and Ride sites, were kept constant during matrix estimation as these are controlled by another development process. External trips derived from TMfS14 were also fixed.

7.3.3 The following constraints were applied during the matrix estimation process:

- Trip ends +- 15%
- Cell +- 5 pcus
- PnR trip ends constrained
- Motorways and strategic routes given a higher weighting

7.3.4 A SATURN road assignment was carried out using the base year road network containing Screenline locations and the prior demand matrix. To reach a balance between accuracy and runtime required, the procedure was configured to loop through three matrix estimation iterations, producing intermediate files after each iteration, with a final set of estimated matrices at the end of the procedure.

7.3.5 The above procedure was carried out for all three time periods, over a number of iterations, with investigation and refinement of the road modelling undertaken to improve the comparison in specific areas and for specific purposes. The process was judged to be successful when comparisons of model outputs were favourable when compared to observed data sets and calibration criteria.

7.3.6 350 traffic count locations across 41 Screenlines (as described in Chapter 6) were used as inputs. Counts included within Screenlines across the Clyde, along motorway corridors, new Screenlines in Ayrshire and routes with high traffic counts were prioritised.

7.3.7 Tables 20 to 22 summarise the Prior, Post Estimation and difference matrix totals.

Table 20. Road Assignment 'Prior' Matrix totals (PCUs per hour)

USER CLASS	AM PEAK	LT PEAK	PM PEAK
Employers Business	19,748	7,299	11,943
Commute	94,950	17,847	80,983
Others	88,394	87,387	114,227
Education	11,179	-	637
Retired	14,404	24,575	17,982
Light Goods	14,420	15,226	15,589
Heavy Goods	11,801	12,246	8,883
Total	**254,896**	**164,580**	**250,243**

Table 21. Road Assignment 'Post' Matrix totals (PCUs per hour)

USER CLASS	AM PEAK	LT PEAK	PM PEAK
Employers Business	19,921	7,565	12,650
Commute	94,192	18,449	84,318
Others	82,678	86,394	105,942
Education	8,930	-	637
Retired	13,427	24,304	17,026
Light Goods	18,199	18,554	20,977
Heavy Goods	13,398	13,695	10,214
Total	**250,744**	**168,962**	**251,763**

Table 22. Change (%) Between Prior & Post Estimation Road Assignment Matrices

USER CLASS	AM PEAK	LT PEAK	PM PEAK
Employers Business	+1%	+4%	+6%
Commute	-1%	+3%	+4%
Others	-6%	-1%	-7%
Education	-20%	-	0%
Retired	-7%	-1%	-5%
Light Goods	+26%	+22%	+35%
Heavy Goods	+14%	+12%	+15%
Total	**-2%**	**+3%**	**+1%**

7.4 Trip Length Distribution Analysis

7.4.1 Trip length distribution is used in matrix estimation to understand the level of trips travelling at a range of distances across the modelled area. This analysis is used to ascertain whether the estimation process has impacted the overall distribution of trips and distances travelled while attempting to match observed flows across the Screenlines.

7.4.2 Figures 22 to 24 illustrate the Prior and Post estimation trip distributions for the AM, Lunchtime and PM peak time periods respectively for all trip lengths. The analysis shows little change in the distribution of post 30km trip lengths, which confirms that the matrix estimation process has restrained changes to the longer distance and external trips.

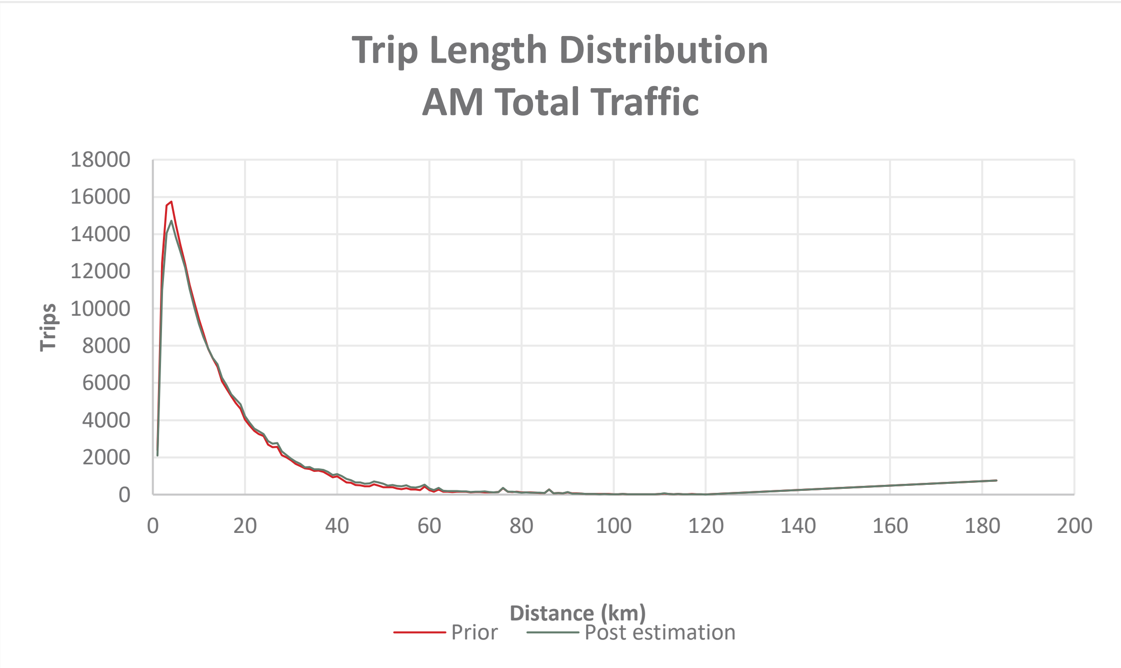

Figure 22. AM Trip Length Distribution for Prior and Post-Matrix Estimation

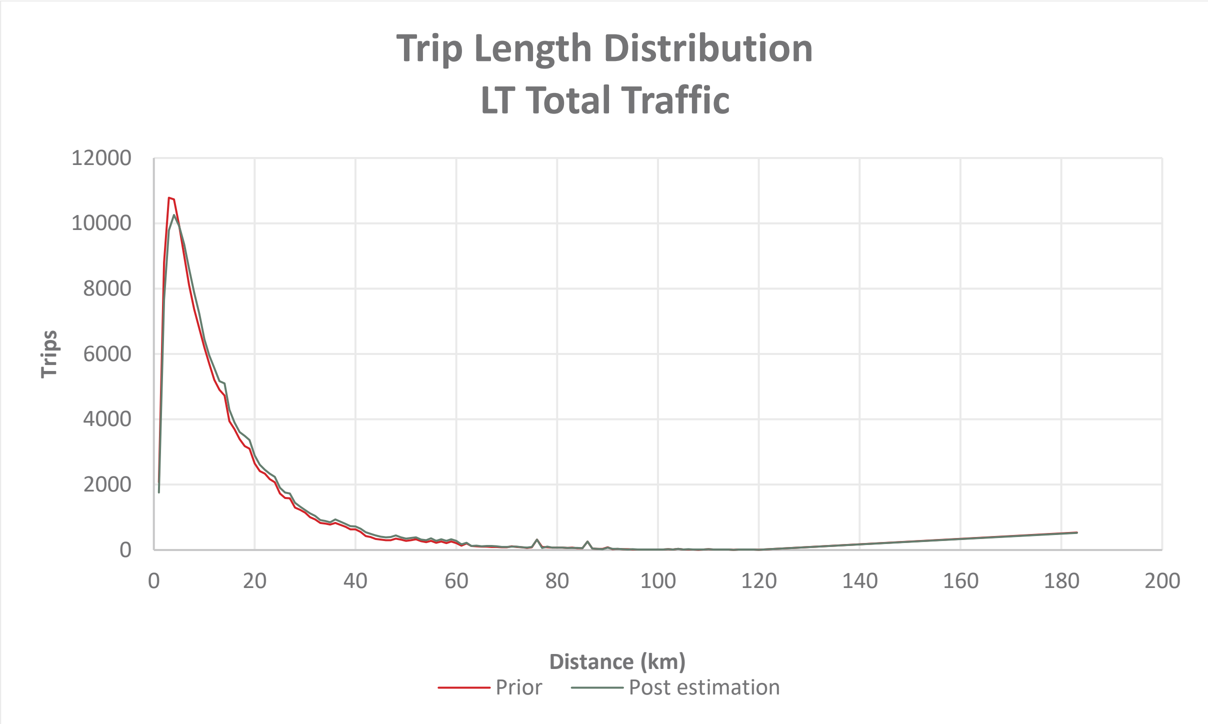

Figure 23. LT Trip Length Distribution for Prior and Post-Matrix Estimation

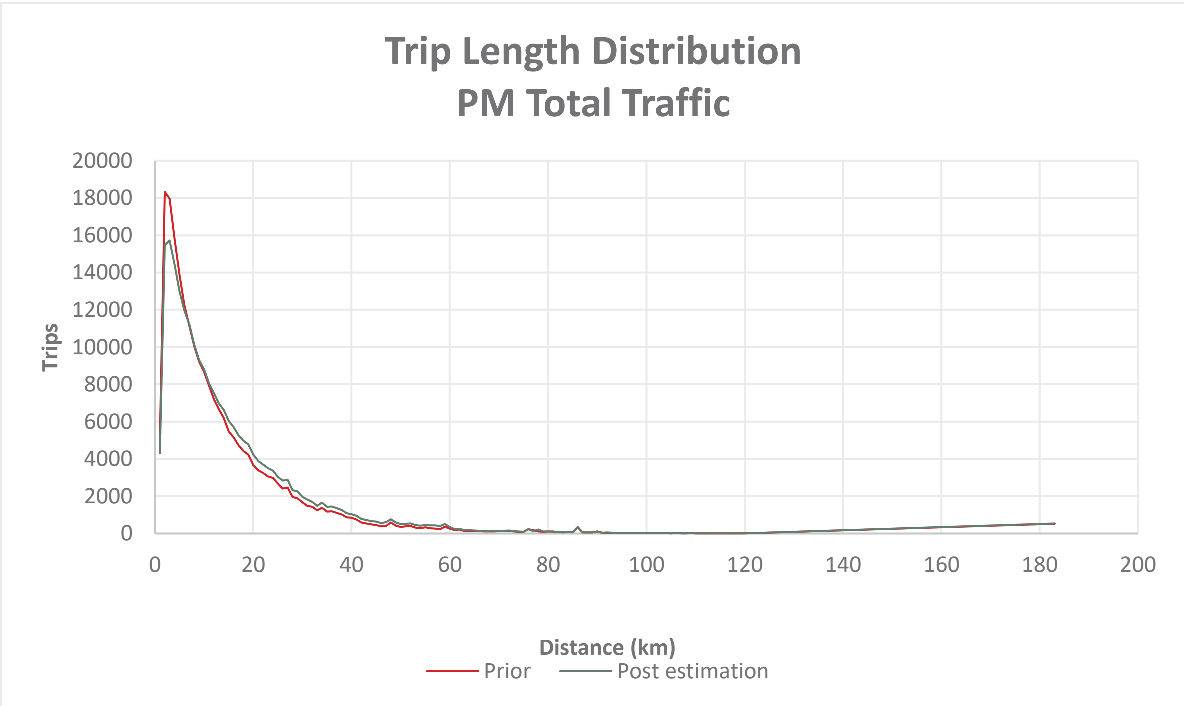

Figure 24. PM Trip Length Distribution for Prior and Post-Matrix Estimation

7.4.3 Figures 25 to 27 illustrate the Prior and Post estimation trip distributions for trips shorter than 30km for the AM, Lunchtime and PM peak time periods respectively.

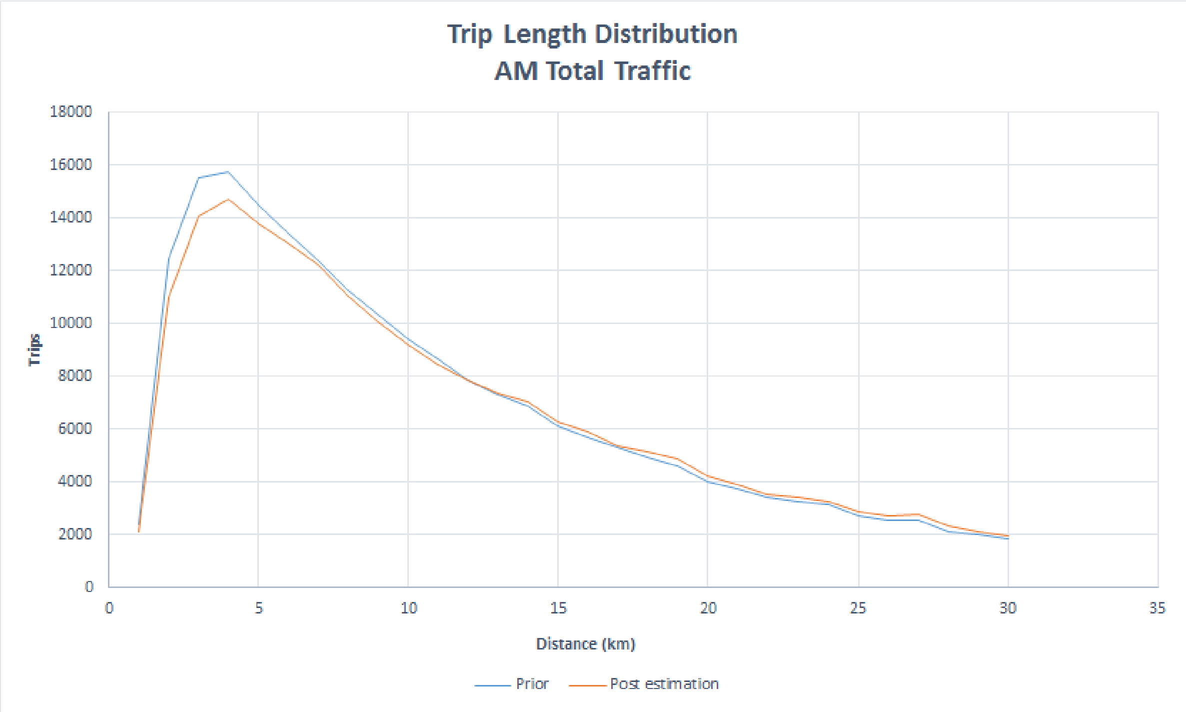

Figure 25. AM Trip Length Distribution for Prior and Post-Matrix Estimation (<30km)

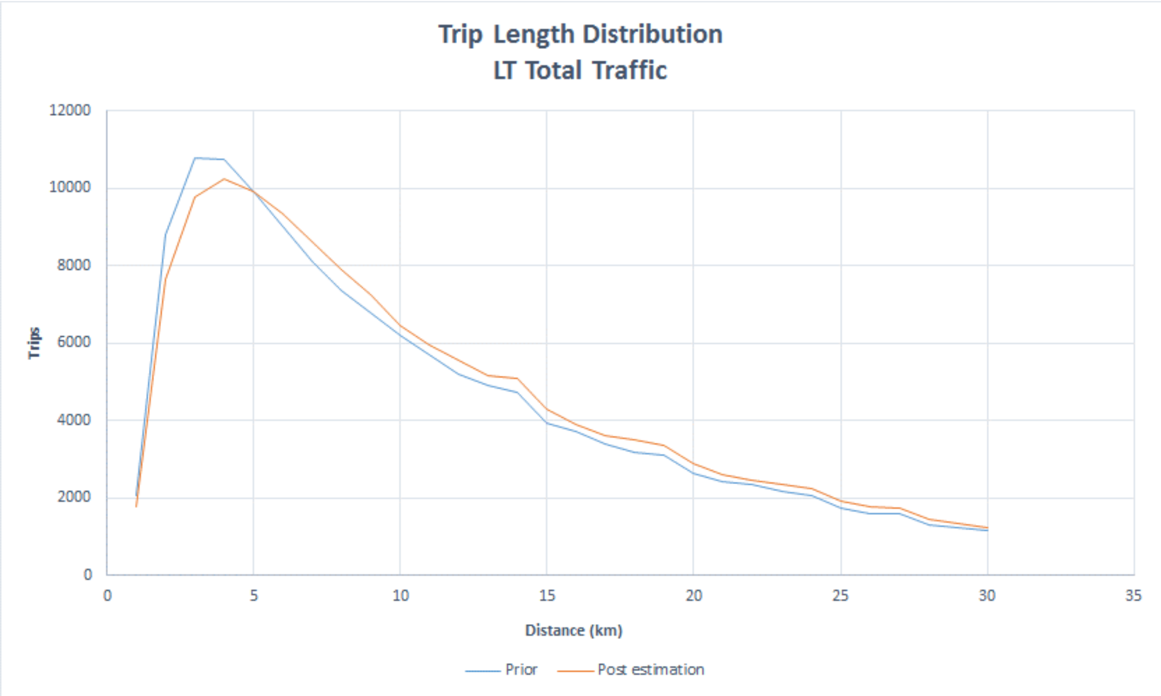

Figure 26. LT Trip Length Distribution for Prior and Post-Matrix Estimation (<30km)

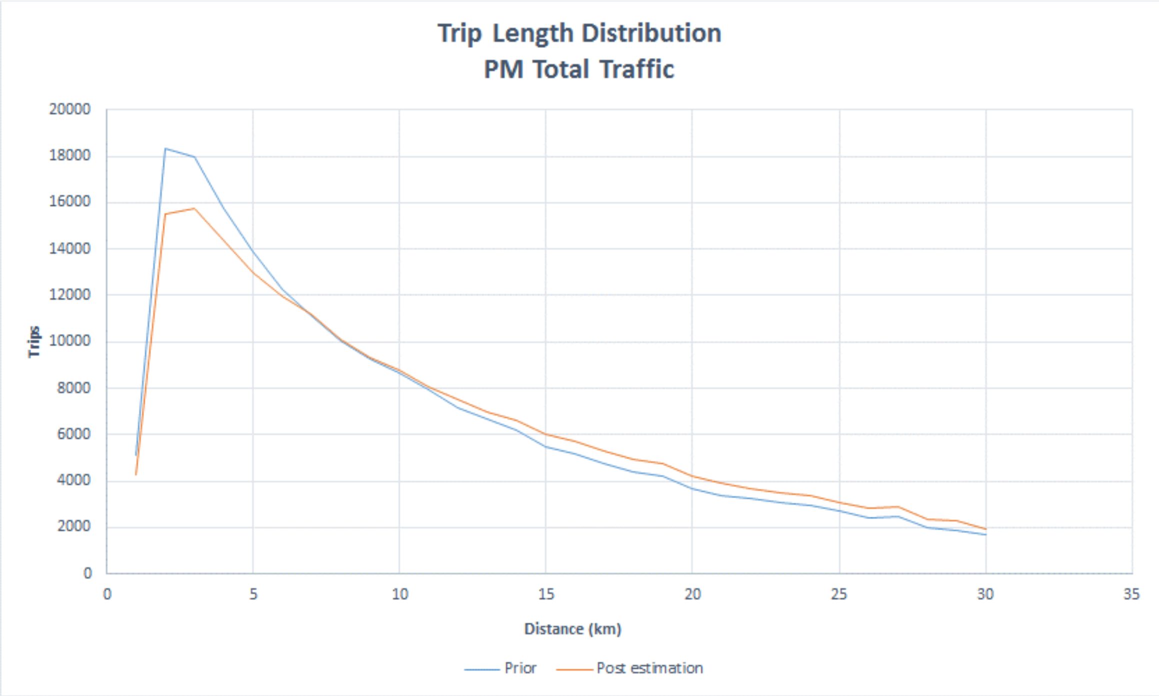

Figure 27. PM Trip Length Distribution for Prior and Post-Matrix Estimation (<30km)

7.4.1 The analysis shows that the estimation has reduced the number of shorter distance trips (lower than 3 km) and redistributed these relatively consistently across other movements.

7.4.2 This change is to be expected given the synthetic modelling source of the prior matrices.

7.5 Matrix Sector Comparison with Census and Mobile Phone Data

7.5.1 A comparison between the modelled matrices and the census and Mobile Phone data has been undertaken at a 4 sector and a 33 sector level. Further details of this analysis is contained in the SRTM Demand Model Report, SYSTRA, August 2019.

8. TRAFFIC FLOW CALIBRATION RESULTS

8.1.1 This section presents results of the road traffic volume calibration, comparing modelled traffic flows (from the estimated matrix assignment) against observed data, including:

- Total Screenline traffic flow comparisons;
- Individual Screenline point traffic flow comparisons; and
- Individual Screenline point comparisons for motorway locations.

8.1.2 Further more detailed information for Screenline and traffic count comparisons is provided within Appendix D.

8.2 Total Screenline Traffic Flow Comparison

8.2.1 This section presents results of the total Screenline modelled traffic flow compared against total observed traffic counts for each Screenline.

8.2.2 DRRB provides the following criteria for calibrating total Screenline flows:

- *Differences between modelled flows and counts should be less than 5% of the counts for 'All or nearly all screenlines'.*

8.2.3 Table 23 provides a summary of the proportion of Screenlines that fall within various percentage difference bands compared to observed traffic counts for each time period.

Table 23. Summary of Total Screenline Traffic Flows Percentage Differences

% RANGES	AM PEAK SCREENLINE	% OF TOTAL	LT PEAK SCREENLINE	% OF TOTAL	PM PEAK SCREENLINE	% OF TOTAL
+/- 5%	54	64%	56	67%	49	58%
+/- 10%	69	82%	69	82%	66	79%
+/- 15%	75	89%	74	88%	73	87%
> +/-15 %	9	11%	10	12%	11	13%

8.2.4 The total Screenline percentage flow difference analysis demonstrates that 64% of total Screenline comparisons fall within 5% of the total observed flow in the AM peak time period, 67% in the LT peak period and 58% for the PM Peak time period.

8.2.5 Model calibration comparisons improve considerably when compared against the 10% threshold with around 80% of Screenline flows falling within this criteria across all modelled time periods.

8.2.6 The comparisons show that only around ten Screenlines (around 12% of comparisons) do not fall within the 15% threshold. The most significant outlier here relates to Screenline 31 - this Screenline was not technically used in the calibration process (see Chapter 6). The next largest flow differences relate to Screenline 30 – East Kilbride West, with a 15% to 27% variation.

8.2.7 Other significant flow differences include Screenline 32 – Renfrew area in the Inter Peak and PM time periods (18-28% difference); on Screenline 23 - City Southern Outbound (12-16% difference); on Screenline 16 - M898 North of M8 in the AM time period (15-19% difference); and on Screenline 3 - East Kilbride South West Southbound in the AM time period (16% difference). See Appendix D for further comparison data.

8.2.8 Table 24 describes the proportion of Screenline comparisons that fall within the various GEH statistic bands.

Table 24. Summary of Total Screenline Traffic Flows GEH Statistic

GEH RANGES	AM PEAK SCREENLINE	% OF TOTAL	LT PEAK SCREENLINE	% OF TOTAL	PM PEAK SCREENLINE	% OF TOTAL
0 – 4	58	69%	67	80%	56	67%
<7	72	86%	71	85%	66	79%
>7	12	14%	13	15%	18	21%

8.2.9 The GEH statistical analysis indicates that 69% of Screenlines fall within a GEH of four in the AM time period, 80% within the LT peak period and 67% in the PM time period. The comparisons improve to around 85% when set against a GEH of 7 for the AM and LT time periods, with a slightly lower level of calibration achieved during the PM peak.

8.2.10 Table 25 summarises the difference between modelled and observed flows for the 84 by-direction calibration Screenlines. This shows that 80% of calibration Screenlines are within relevant criteria for the AM peak, increasing to 86% for the LT peak, and falling to 74% for the PM peak.

Table 25. Calibration Screenline Flow Comparisons

FLOW RANGES	AM PEAK SCREENLINE	% WITHIN CRITERIA	LT SCREENLINE	% WITHIN CRITERIA	PM PEAK SCREENLINE	% WITHIN CRITERIA
<700	0	0%	0	0%	0	0%
700 – 2,700	24	92%	31	89%	19	86%
>2,700	43	77%	41	87%	43	72%
All Ranges	**67**	**80%**	**72**	**86%**	**62**	**74%**

8.2.1 Overall, the total Screenline traffic flow analysis demonstrates that the SRTM road assignment model provides an appropriate calibration comparison for a model of this scale and nature.

8.3 Individual Link Traffic Flow Comparison

DMRB Individual Link Count Calibration

8.3.1 For individual link flow comparisons, DMRB criteria are as follows;

- *Individual flows within 15% for flows 700 – 2,700 vph (>85% of cases);*
- *Individual flows within 100 vph for flows < 700 vph (>85% of all cases);*
- *Individual flows within 400 vph for flows > 2,700 vph (>85% of all cases); and*
- Individual flows: GEH < 5 (>85% of all cases).

8.3.2 Table 26 provides analysis of the individual calibration count locations. The results show that within all the flow ranges, all time periods produced comparisons above 75%, but with some time periods falling below the 85% threshold. Comparisons for the larger Flows over 2,700 vehicles are all above the 85% threshold.

Table 26. Individual Link Flow Calibration Comparisons

FLOW RANGES	AM PEAK NO. OF LINKS	% WITHIN CRITERIA	LT PEAK NO. LINKS	% WITHIN CRITERIA	PM PEAK NO. OF LINKS	% WITHIN CRITERIA
<700	168	79%	213	84%	163	77%
700 – 2,700	89	75%	84	91%	91	76%
>2,700	30	86%	19	100%	30	88%
All Ranges	**287**	**79%**	**316**	**87%**	**284**	**78%**

8.3.3 Tables 27 summarises the GEH statistics for modelled and observed flows for all 365 individual calibration count locations (all counts forming the Screenlines).

Table 27. Summary of Individual Link Calibration GEH statistic

GEH RANGES	AM PEAK NO. OF LINKS	% OF TOTAL	LT PEAK NO. LINKS	% OF TOTAL	PM PEAK NO. OF LINKS	% OF TOTAL
< 5	276	76%	295	81%	271	74%
< 7	300	82%	314	86%	297	81%
< 10	324	89%	333	91%	324	89%

8.3.1 Analysis shows that 76% of these counts fall within a GEH of five in the AM time period, 81% the LT peak period and 74% in the PM time period. The comparisons indicate that the 85% criteria is close to being achieved when a GEH threshold of seven is applied, and that the model passes the 85% criteria when a GEH threshold of ten is applied.

Motorway Locations

8.3.2 Table 28 provides analysis of the calibration counts that relate to motorway locations. The results show that for the larger flow ranges, all time periods are generally around the 85% criteria, with some cases exceeding this value. There are instances where the flow range criteria is below 85% particularly where the flow is less than 700 vehicles.

Table 28. Motorway Flow Calibration Comparisons

FLOW RANGES	AM PEAK NO. OF LINKS	% WITHIN CRITERIA	LT PEAK NO. LINKS	% WITHIN CRITERIA	PM PEAK NO. OF LINKS	% WITHIN CRITERIA
<700	6	75%	9	75%	5	56%
700 – 2,700	22	85%	35	97%	23	88%
>2,700	26	84%	17	100%	26	87%
All Ranges	**54**	**83%**	**61**	**94%**	**54**	**93%**

8.3.1 Some notable variations include: the M74 On Slip at Junction 2 Southbound, which does not match across all 3 time periods, having significantly higher modelled flows than observed flows; the M80 Northbound calibration point at Junction 6 (Old Inns) also falls outside the recommended criteria within the AM and PM time periods.

8.3.2 Table 29 presents a summary of the GEH statistics for the 65 motorway links used in calibration. It shows that for the AM Peak period, 82% of motorway links are within the <5 GEH score. The LT Peak period indicates a higher number of links (88%), meeting the GEH score, with the PM also providing a good level of GEH score at 82%. Higher percentages are noted at the next grading of GEH score.

Table 29. Summary of Motorway GEH statistic

GEH RANGES	AM PEAK NO. OF LINKS	% OF TOTAL	LT PEAK NO. LINKS	% OF TOTAL	PM PEAK NO. OF LINKS	% OF TOTAL
< 5	53	82%	57	88%	53	82%
< 7	57	88%	62	95%	58	89%
< 10	60	92%	63	97%	64	98%

8.3.3 Reviewing the calibration statistics as a whole, it is considered that an appropriate level of calibration is achieved given the scale and nature of this large strategic regional model. The variations recorded between modelled and observed traffic counts for specific Screenlines should be borne in mind during model application.

8.3.4 The full list of traffic count calibration comparisons for individual sites is described within Appendix D.

9. ROAD MODEL VALIDATION RESULTS

9.1 Approach & Data Sets

9.1.1 This chapter analyses the level of validation of the road model. This involves a comparison of the model to observed data that were set aside during the calibration process. Validation analysis includes comparisons with independent traffic count data, and road journey time analysis.

9.1.2 Chapter 6 describes and illustrates the number and locations of journey time routes that have been compared.

Validation Data

9.1.3 This validation process made use of the following data sources to determine the overall level of validation of the road model:

- Independent validation traffic counts covering;
    - All Count Locations;
    - Strategic Roads;
    - Local
- TomTom satellite navigation journey time data (2015);
- ANPR Motorway corridor journey time data derived from ANPR analysis; and
- Checks of road model convergence.

9.1.4 Validation analysis has been described separately to provide a distinction between link flow and turning counts which were translated into link flows.

9.2 Traffic Flow Validation

Link Flow Validation Criteria

9.2.1 Individual link criteria used for validation are consistent with the individual link criteria used in calibration, which are as follows:

- Individual flows within 15% for flows 700 – 2,700 vph (>85% of cases);
- Individual flows within 100 vph for flows < 700 vph (>85% of all cases);
- Individual flows within 400 vph for flows > 2,700 vph (>85% of all cases); and
- Individual flows: GEH < 5 (>85% of all cases).

9.2.2 The locations of the traffic count validation points are illustrated in Figure 28.

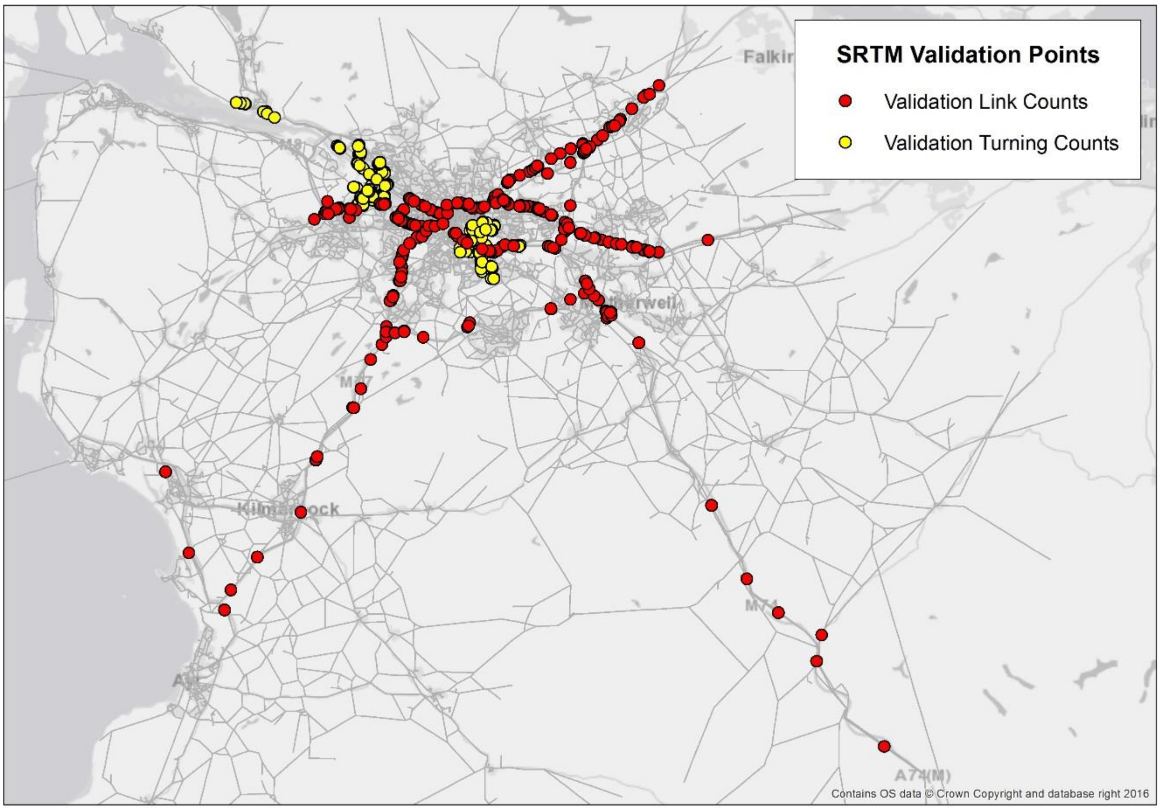

Figure 28. Individual Traffic Count Validation Locations

9.2.3 Tables 30 summarises the individual link flow comparisons between the total modelled flows and the observed traffic data for each validation criteria. There are a total of 296 link flows that have been used in the comparison process.

Table 30. Individual Link Flow Validation

FLOW RANGES	AM PEAK NO. OF LINKS	% WITHIN CRITERIA	LT PEAK NO. LINKS	% WITHIN CRITERIA	PM PEAK NO. OF LINKS	% WITHIN CRITERIA
<700	37	46%	65	56%	35	42%
700 – 2,700	36	33%	49	47%	50	43%
>2,700	62	58%	45	61%	51	53%
All Ranges	**135**	**46%**	**159**	**54%**	**136**	**46%**

9.2.4 The analysis suggests a relatively low level of validation when comparing with observed data, although comparisons appear more favourable for the higher trafficked routes.

9.2.5 Tables 31 summarises the individual link validation analysis against GEH criteria. The analysis is based on 296 individual links that are a combination of motorway/'a' roads and other roads. The results show that in all cases where the GEH range is <10, we have at least 70% of the links within the criteria, with the LT peak indicating 78%.

Table 31. Individual Link Validation GEH Criteria

GEH RANGES	AM NO. OF LINKS	% OF TOTAL	LT NO. LINKS	% OF TOTAL	PM NO. OF LINKS	% OF TOTAL
< 5	125	42%	150	51%	129	44%
< 7	162	55%	185	63%	167	56%
< 10	208	70%	230	78%	216	73%

9.2.6 In general, the independent flow validation results appear relatively low. It should be borne in mind that there can be some inconsistencies within the observed flow data, whereas the modelled flows can appear relatively consistent and intuitive (ie the modelled inbound and outbound flows match up for the relevant time periods but the observed data does not, or neighbouring observed flows can vary considerably – indicating more uncertainty).

Overall, the level of flow validation is broadly in line with expectations given the level of flow calibration and the size and nature of this type of model. The general variation within these flow comparisons should be borne in mind during model application.

Local Road Flows (Turning Counts)

9.2.7 Traffic turning count data sets were converted into link flows. Table 32 summarises the individual link flow comparisons between the total modelled flows and the observed traffic data for each validation criteria. As the turning counts are primarily focused on non-motorway links, observed traffic counts did not exceed 2,700, therefore there are no comparisons at this flow range.

Table 32. Individual Link Flow Validation

FLOW RANGES	AM PEAK NO. OF LINKS	% WITHIN CRITERIA	LT PEAK NO. LINKS	% WITHIN CRITERIA	PM PEAK NO. OF LINKS	% WITHIN CRITERIA
<700	178	49%	212	57%	170	48%
700 – 2,700	44	63%	1	8%	25	33%
>2,700	0	0%	0	0%	0	0%
All Ranges	**248**	**51%**	**231**	**55%**	**216**	**45%**

9.2.8 Table 33 provides analysis of the 432 turning counts that have been turned into link flows. Analysis shows that in the AM and LT peaks, over 75% of links are with a GEH score of 10. The PM peak has 67% of the links within that range.

Table 33. Individual Link Validation GEH Criteria

GEH RANGES	AM NO. OF LINKS	% OF TOTAL	LT NO. LINKS	% OF TOTAL	PM NO. OF LINKS	% OF TOTAL
<5	192	44%	185	48%	178	41%
< 7	261	60%	228	60%	224	52%
< 10	325	75%	294	77%	290	67%

9.2.1 In summary, the analysis indicates a reasonable level of validation given the scale and nature of this large regional model, and the differences in some of the age of the validation data sets. The full range of validation comparisons are described within Appendix E, and these can be used to review model representation in areas of interest prior to model application.

9.3 Network Distance Comparison

TomTom vs SRTM network

9.3.1 Network distances within the SRTM were developed from an Integrated Transport Network (ITN) as supplied by Ordnance Survey. TomTom data also provides a data set containing network distances, which can be used as a check against model coding.

9.3.2 The TomTom data set contains salient node locations, where possible these are aligned to reflect node locations on the SRTM network, however there are slight inconsistencies in the start and end locations. Distance route checks are described in Appendix E.

9.3.3 Table 34 provides a comparison of the distances calculated from TomTom data and the respective SRTM modelled distances. Analysis shows an excellent match, with 99% of the SRTM journey time routes falling within 5% of the distances measured by TomTom data.

9.3.4 The largest difference in metres is 467m short for route R20 northbound - from M73/Ballieston to the intersection with the M80. This is a consequence of the subsequent link in the SRTM network being >1km in length and thus to match this link would require splitting. This route is also the route above that is greater than 5% out.

Table 34. Journey Time Route – Distance Comparison TomTom vs SRTM network

DIFFERENCE (%)	NUMBER IN RANGE	CUMULATIVE %AGE
<1%	50	50%
>1% to <2%	24	74%
>2% to <3%	17	91%
>3% to <4%	5	96%
>4% to <5%	3	99%

9.4 Journey Time Validation

DMRB Journey Time criteria

9.4.1 For road journey time validation, the following DMRB criteria is advised:

- Modelled journey times to be within 15% (or 1 minute if higher) for greater than 85% of routes.

TomTom Journey Time Comparison

9.4.2 Table 35 summarises the overall operational performance of the road model against the observed journey times developed from TomTom data. The validation analysis demonstrates that in all time periods, at least 85% of all routes meet the journey time validation criteria.

Table 35. Summary of Overall Journey Time Performance

WITHIN DMRB	AM PEAK	% WITHIN 15%	LT PEAK	% WITHIN 15%	PM PEAK	% WITHIN 15%
Yes	85	85%	90	90%	86	86%
No	15	15%	10	10%	14	14%

9.4.3 Appendix E provides more detailed information on the journey time comparison against the TomTom data set for the 50 routes.

9.4.4 Some notable variations include: Journey Time Route 38, between A77 Commerce Street and the Horseshoe Junction in Paisley, is faster in the model than what the observed data suggests across all three time periods and for both directions, by up to 30%. Routes 20 and 22 Southbound are also faster by up to 37% and 41% respectively; while Route 8, the M80 between Junctions 1 and 6, is significantly slower in the PM time period (by 41-42%).

9.4.5 When taking an average comparison across all journey time routes (in both directions), the modelled times are 0.4% higher than the observed times in the AM Peak, 2.7% lower in the Inter Peak and 2.2% lower in the PM Peak. This suggests a balanced journey time within the AM Peak, with the Road model running slightly faster vehicle speeds (on average) during the Inter and PM peak time periods.

Automatic Number Plate Recognition (ANPR) Comparisons

9.4.6 Automatic Number Plate Recognition (ANPR) data collected for March 2016 was provided by Transport Scotland to verify journey times along the key M8 corridor through Glasgow. This analysis was focused on the journey times between the M8/A80 and M8/Helen Street intersection. Average duration was derived for the three time periods and compared with modelled journey times.

9.4.7 Tables 36 to 38 compare the observed ANPR timing with model output. The analysis shows that in the westbound direction, the comparison matches DMRB guidelines. Overall in the eastbound direction, the model is generally slower than ANPR data suggests.

9.4.8 Further analysis was undertaken to determine which section of the route was causing the relevant delay, therefore two sections were disaggregated from overall journey route - eastbound from M8/Helen Street to Junction 19 and M8/Helen Street to Junction 15.

9.4.9 In all time periods, the model matches the DMRB guidelines for observed data, therefore as the table indicates the section of delay is between junction 15 to junction 13 (A80)

Table 36. M8 Corridor ANPR Journey Time Performance AM Peak

SECTION	OBSERVED (TT_SECS)	MODELLED (SRTM_SECS)	DIFF IN SEC	%DIFF	WITHIN 15% (OR 60 SECS IF HIGHER)
M8 Eb ANPR Helen Street to A80	636	795	159	25%	☒
M8 Eb ANPR to North of J19	365	396	30	8%	✓
M8 Eb ANPR to West of J15	568	620	52	9%	✓
M8 Eb ANPR West of J15 to A80	68	175	107	157%	☒
M8 Wb ANPR A80 to Helen Street	901	901	0	0%	✓

Table 37. M8 Corridor ANPR Journey Time Performance LT Peak

SECTION	OBSERVED (TT_SECS)	MODELLED (SRTM_SECS)	DIFF IN SEC	%DIFF	WITHIN 15% (OR 60 SECS IF HIGHER)
M8 Eb ANPR Helen Street to A80	455	547	92	20%	☒
M8 Eb ANPR to North of J19	174	215	41	24%	✓
M8 Eb ANPR to West of J15	356	375	19	5%	✓
M8 Eb ANPR West of J15 to A80	99	172	73	73%	☒
M8 Wb ANPR A80 to Helen Street	497	552	55	11%	✓

Table 38. M8 Corridor ANPR Journey Time Performance PM Peak

SECTION	OBSERVED (TT_SECS)	MODELLED (SRTM_SECS)	DIFF IN SEC	%DIFF	WITHIN 15% (OR 60 SECS IF HIGHER)
M8 Eb ANPR Helen Street to A80	714	844	129	18%	☒

SECTION	OBSERVED (TT_SECS)	MODELLED (SRTM_SECS)	DIFF IN SEC	%DIFF	WITHIN 15% (OR 60 SECS IF HIGHER)
M8 Eb ANPR to North of J19	292	300	8	3%	✓
M8 Eb ANPR to West of J15	607	621	14	2%	✓
M8 Eb ANPR West of J15 to A80	108	223	115	107%	☒
M8 Wb ANPR A80 to Helen Street	700	687	-12	-2%	✓

9.5 Road Model Convergence Statistics

9.5.1 WebTAG guidance requires specific criteria to be met on Convergence Statistics by Sub-Model and Loops Road Model. Table 39 below summarises the convergence statistics output from the SATURN road assignment model.

Table 39. Convergence Statistics

MEASURE OF CONVERGENCE	BASE MODEL ACCEPTABLE VALUES	AM PEAK	LT PEAK	PM PEAK
Delta and %GAP	Less than 0.1% or at least stable with convergence fully documented and all other criteria met	YES	YES	YES
Percentage of links with flow change (P)<1%	Four consecutive iterations greater than 98%	YES	YES	YES
Percentage of links with cost change (P2)<1%	Four consecutive iterations greater than 98%	YES	YES	YES
Percentage change in total user costs (V)	Four consecutive iterations less than 0.1% (SUE only)	N/A	N/A	N/A

9.5.2 As can be seen from the table above, the road assignment model meets the convergence criteria. Appendix F provides further information on the convergence statistic.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

Strathclyde Regional Transport Model Capability

10.1.1 The Strathclyde Regional Transport Model (SRTM) is a multi-modal ‘tour-based’ strategic transport model covering the Strathclyde area, interfacing with the TELMoS / TMfS14 national modelling hierarchy to forecast changes in levels of traffic and travel over time.

10.1.2 The SRTM is calibrated to reflect 2014 travel conditions and incudes trip generation, demand and assignment models covering the main road and public transport modes, including Park and Ride interchange and parking capacity.

Road Model Development

10.1.3 The SRTM Road model has been extensively developed using SATURN Software to provide a road network and junction simulation covering the Strathclyde area. The Road network has been built from a detailed ITN GIS layer to generate network connectivity, link distances and speed / capacity attributes.

10.1.4 Simulation junction coding has been imported from the previous Strathclyde Integrated Saturn Model (SITM), using traffic signal profiles received from Local Authorities and Template junction coding with estimated signal timings applied to fill junction data gaps.

10.1.5 The network is connected to a detailed zone system to link to the road assignment matrices and demand modelling.

10.1.6 Road traffic matrices are developed from the SRTM Demand Model and are disaggregated for road user classes and for each of the AM, Inter and PM Peak time periods. Road matrices are informed by the interrogation of Mobile Phone Movement Data sets, and are estimated to match observed traffic volumes.

Calibration and Validation

10.1.7 The SRTM Road model is calibrated to reflect road traffic volume Screenlines and validated against independent road traffic count and journey time validation data sets.

10.1.8 Road traffic flow calibration is reasonably representative when compared to observed traffic flows, and although falls short of some model development guidance thresholds, provides an appropriate level of calibration for a model of this scale and nature.

10.1.9 Modelled road traffic flow comparisons against independent validation traffic counts results appear less favourable, falling short of model development criteria. These variations should be borne in mind during model application.

10.1.10 Operational performance of the Road model was validated against observed journey times developed from TomTom satellite navigation data, producing observed vehicle time data for 50 routes. The journey time comparisons demonstrate a good level of validation in all modelled time periods, with at least 85% of routes meeting the journey time validation criteria.

Overall, given the scale and nature of this large, complex strategic model, the calibration and validation comparisons are generally appropriate. The validation against a wide range of vehicle speed/time data provides confidence in the overall development of each time period model, with a reasonable level of calibration when comparing traffic Screenline flows. Independent validation flow comparisons are more varied, with some considerable variations recognised for some locations.

10.2 Recommendations

10.2.1 The SRTM is a complex and wide ranging strategic model covering an extensive geography. Calibration and validation comparisons vary throughout the model extents, with sizeable data sets prepared to report the models performance.

10.2.2 It is recommended that potential model users interrogate these data sets and other model outputs to review areas of interest prior to model application. Reviews could consider network detail, signal phasing/timings, traffic counts and journey time comparisons.

10.2.3 The journey time comparison charts are especially useful in understanding how and where the modelling fluctuates from the observed TomTom journey time data.

10.2.4 It some instances the road modelling would benefit from additional traffic count comparisons within areas where data was unavailable. If required these could be made to form further screenlines to adjust traffic flows in some areas.

APPROVAL

Version	Name		Position	Date	Modifications
1.4	Author	Paul Gray Archie Burns Marton Juhasz	Associate Director Principal Consultant Analyst	08/05/2017	Draft for comment
	Checked by	Jeff Davidson	Project Manager	08/05/2017	
	Approved by	David Connolly	Project Director	08/05/2017	
1.6b	Author	Archie Burns Malcolm Neil Marton Juhasz	Principal Consultant Associate Director Consultant	05/08/2019	Response to Draft Audit Report
	Checked by	Daniel Ruscoe	Senior Consultant	05/08/2019	
	Approved by	Malcolm Neil	Associate Director	06/08/2019	